



MEMORANDUM

Comfort Lake-Forest Lake Watershed District

Date: April 03, 2023
To: CLFLWD Board of Managers
From: Mike Kinney, District Administrator
Subject: 2022 Draft Water Quality Monitoring Report



District Wide

Background/Discussion

The purpose of this agenda item is to provide the Board with the Draft 2022 Water Monitoring Report for consideration. Emmons & Olivier Resources (EOR) will give a brief presentation of the findings from the 2022 monitoring efforts and be available to answer any questions.

The report will be brought back at the **April 27th** Board Meeting for acceptance. Comments or other feedback on the report are requested to be provided back to staff by April 19th so that staff may collaborate with EOR to finalize the report prior to the 27th.

Attached

2022 Draft Water Quality Monitoring Report

Prepared by: EOR

For the Comfort Lake-Forest Lake Watershed District

2022 Comfort Lake-Forest Lake Water Monitoring Report



Cover Image

Lake Keewahtin, May 16, 2009

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EXECUTIVE SUMMARY

Climate Conditions

In 2022, the dry conditions from 2021 were carried over, impacting water levels and stream flows throughout the season. In terms of total precipitation, 2022 was a normal year. However, the precipitation and snowmelt in the spring (March and April) and a series of intense rain events in August, were the reasons why 2022 is considered an average precipitation year.

Most of the monitoring season had lower than normal precipitation, causing drought conditions that resulted in limitations in data collection. This was particularly noticeable in the District's streams which showed no flow for most of the season.

Regarding annual average temperatures, 2022 was a cooler than average year. This is mostly due to the low temperatures early in the season. Growing season (June-September) temperatures were slightly higher than average contributing to the drought conditions and associated lower flows.

Lake Monitoring

Fifteen lakes were monitored in 2022 for surface water quality (Total Phosphorus, Chlorophyll-a, and Secchi depth) and lake levels. Six of these lakes were also monitored for oxygen/temperature profiles and bottom ortho-phosphate to assess internal loading. Chloride profiles were also monitored.

Most lakes showed good water quality (close to or slightly exceeding State's water quality standards) at the beginning of the monitoring season. The likely cause for this good water quality was snow melt from late February through April, combined with above normal precipitation for that period. Flow records from the Sunrise River DNR/MPCA stream gage support this conclusion.

Additionally, drier than normal conditions in June and July resulted in less external Phosphorous load than expected. This was an important factor (although not the only one) that contributed to the very good overall water quality in the District's lakes. In 2022, lakes met or excided State's water quality standards.

Furthermore, using the Metropolitan Council Lake Grading System most lakes in the District received an A or B rating. The 2022 and 5-year average lake grades are shown in the table below.

CLFLWD Lake Water Quality Grades for 2022 and most recent 5-year average (2018-2022)

Lake	DNR ID	Lake size (acres)	TP		Chl.-a		Secchi		Overall	
			2022	5-yr Avg	2022	5-yr Avg	2022	5-yr Avg	2022	5-yr Avg
Birch	13-0042-00	33	--	C-	--	B	--	C-	--	C
Bone	82-0054-00	221	B	B	B	B+	C	C	B	B
Comfort	13-0053-00	218	B	B+	B	B+	C	C+	B	B+
Elwell	82-0079-00	16	C	C	B	B	--	--	--	--
Forest (West)	82-0156-00	1,086	A	B+	A	A-	B	B-	A	B+
Forest (Middle)	82-0156-00	364	B	B-	B	B	C	B-	B	B-
Forest (East)	82-0156-00	790	C	B-	B	B	C	B-	C	C+
<i>Forest (All Basins)</i>	<i>82-0156-00</i>	<i>2,240</i>	B	B-	B+	B+	C+	B-	B	B-
Fourth Lake	13-0022-00	8	--	D	--	B	--	--	--	--
Heims	13-0056-00	90	--	--	--	--	--	--	--	--
Keewahtin	82-0080-00	75	A	A	A	A	A	A	A	A
Lendt Lake	13-0103-00	42	A	A	A	A	--	--	--	--
Little Comfort	13-0054-00	36	B	C+	A	B	B	C+	B	C+
Moody	13-0023-00	45	C	C-	C	C+	C	C-	C	C
Nielson	82-0055-00	37	--	D	--	F	--	F	--	F
School	13-0057-00	47	B	C+	B	B-	C	C-	B	C+
Sea	82-0053-00	50	--	--	--	--	--	--	--	--
Second	13-0025-00	75	--	B	--	A-	--	B-	--	B
Shields	82-0162-00	30	B	C-	A	B-	C	C-	B	C
Third Lake	13-0024-00	42	A	A	A	A	--	--	--	--
Twin Lake	82-0157-00	19	--	B	--	A	--	--	--	--

A: No impairment blue, **B:** Some impairment green, **C:** Is impaired yellow, **D:** Severely impaired orange; **F:**Total impairment rating red

2022 monitoring showed that continued effort to improve water quality is needed for the lakes close to meeting or exceeding State’s water quality standards. These lakes include Forest Lake’s middle and east basins, and Moody Lake. The upcoming alum treatment in Forest Lake - Middle is expected to substantially improve water quality in Forest Lake - Middle and have a beneficial impact in Forest Lake – East.

Key results from the 2022 assessment of other District's lakes include:

- Shields lake's and Moody Lake's alum treatment is still effectively reducing internal loading.
- Internal loading in Comfort Lake and Little Comfort Lake were not shown to be a major contributor to lake water quality.
- Possible reverse flow from Comfort Lake to Little Comfort Lake was shown by comparing lake water levels. This reverse flow may be common in early spring because the Sunrise River inlet has larger drainage area with more impervious land use and more significant ditching compared to the Little Comfort Lake inlet.
- Bone Lake water quality continued to be below state standards and should be considered for impairment delisting.
- Keewahtin Lake continued to have exceptional water quality
- Chloride concentrations are below state standards for the six lakes that were monitored

Stream Monitoring (Long-term and Diagnostic)

2022 stream monitoring was exceptionally difficult. Significantly drier than normal conditions in June and July were key factors for the lack of stream monitoring data. Most of the streams showed no to little flow in June and July and did not recover for the remainder of the season. Therefore, the precise determination of pollutant loads and year average concentrations was particularly challenging.

Key findings from the 2022 stream monitoring include:

- Chloride concentrations remained below state standards with the highest observed concentration at Greenway Ave on 8/19/2022.
- The wetland complex between County Line Ditch and 256th St. removes a large volume of water due to evapotranspiration.
- During dry years, JD2 likely contributes a larger percentage of runoff (and potentially pollutant loads) due to the higher percentage of impervious area compared to other drainage areas.
- Heims Lake's outlet does not discharge often and, therefore, its annual runoff volume contributions downstream are limited. On the other hand, when there is discharge, pollutant concentrations are very high.
- The extraordinarily flat District's topography makes flow monitoring very challenging (as it was the case this year at the Little Comfort Lake inlet), especially during dry years. Blockages and obstructions are common (e.g., beaver dams) and because of the system's flatness, a small obstruction can potentially backup water in large upstream areas. Developing an accurate flow rating curve under this type of backwater conditions is sometimes very difficult.
- The low runoff depth at all three Heims drainage ditch monitoring sites suggests a significant runoff retention capacity in the Heims Lake watershed. This is consistent with the high percentage of wetlands and landlocked areas within the watershed.
- Higher pollutants' concentrations are more likely to occur later in the summer as shown throughout many stream monitoring sites. These higher concentrations are likely caused by wetlands' pollutants release under stagnant flow conditions.

Stream Monitoring Recommendations

Due to the many challenges present in collecting, interpreting, and analyzing data from the long-term stream monitoring sites, especially during periods of drought, it is recommended to develop a thorough statistical model. Data from previous years can be used to develop daily estimates that can then be verified with annual data. This approach would also allow for more targeted sampling and data collection, focused on filling key data gaps.

Effectiveness Monitoring

Two water quality management projects were monitored for effectiveness in 2022; the Castlewood Agricultural BMP project, which drains to Forest Lake, and the Broadway Avenue Iron Enhanced Sand Filter (IESF), which ultimately drains to Comfort Lake.

Key findings from the 2022 effectiveness monitoring include:

- The Castlewood Agricultural BMP project exhibited much higher annual TSS, Orthophosphate, and TP concentrations at the outlet in 2022 than in 2021. When 2021 and 2022 concentrations are analyzed for the common months, concentrations are very similar.
- The Broadway Avenue IESF had limited water quality data due to the drought conditions, which impacted the degree of certainty in the overall assessment. However, TP concentrations decreased, and Orthophosphate concentrations increased. TSS concentration reduction in the facility is significant. This seems to indicate that the filtration component of the IESF works well.

Effectiveness Recommendations

For the Castlewood Agricultural BMP project, it is recommended to conduct a site visit during the growing season and July/August to determine if the perennial vegetation has established itself and look for signs of active erosion.

For the Broadway Avenue IESF project, it is recommended that the entire filter bed be replaced in conjunction with future work done on this facility. The iron sand filter bed should be redesigned to current standards.

1. OVERVIEW / BACKGROUND

The Comfort Lake-Forest Lake Watershed District has a robust water quality monitoring program. Each year, surface water data (both quality and quantity) is collected throughout the District, with the intent of understanding how much progress has been made in meeting water quality goals, and to guide short-term and long-term projects' implementation. This monitoring program is fundamental to the District's Adaptive Management approach to watershed management.

This report summarizes the lake monitoring, long-term stream monitoring, diagnostic monitoring, and effectiveness monitoring data that was collected in 2022. It also provides an update on lake and stream water quality trends, lake progress towards meeting State's standards and District's water quality goals, and overall observations of the District's surface water system. This report also includes one-page lake factsheet (Appendix A), highlighting lake characteristics, current conditions, and long-term trends.

1.1. 2022 climate conditions

Climate conditions are important to fully understand and put monitoring results and analysis in perspective. For instance, wet years may show low pollutant concentrations in the runoff, but because it is a wet year with higher runoff volumes, total pollutant loads may be higher than average. On the flip side, dry years may show high pollutant concentrations, but lower runoff volumes may result in lower total pollutant loads.

Overall, 2022 exhibited drought-like conditions, despite being a normal year for precipitation. This is likely due to the dry conditions from 2021 being carried over, along with the lower-than-average precipitation throughout most of the monitoring season.

1.1.1. State-wide climate trends

State-wide temperatures in 2022 were colder than average and total 2022 precipitation was average. The data developed by the PRISM Climate Group shows that the average annual temperature and precipitation have shifted to a much warmer and wetter conditions in the last 30 years (1993-2022) compared to the years prior (1895-1992). This trend is shown in Figure 1. Annual precipitation is displayed in inches on the Y-axis and annual average temperature is shown in Fahrenheit on the X-axis. The four quadrants represent the following conditions:

- Upper left quadrant: lower temperatures, higher precipitation
- Lower left quadrant: lower temperatures, lower precipitation
- Lower right quadrant: higher temperatures, lower precipitation
- Upper right quadrant: higher temperatures, higher precipitation

The **grey dots** represent the conditions between 1895 and 1992, while the **golden dots** represent the conditions between 1993 and 2022. As shown in the figure, there is a shift in the later years into the upper right quadrant, representing higher temperatures and more annual precipitation. This is consistent with climate change predictions.

Regarding Minnesota, there are two key trends that have been observed by State's climatologists:

1. Wetterter conditions due to more precipitation, more snow, and more frequent and larger storm events.
2. Increasing temperatures especially at night and during winter. In general, cold days are becoming less cold.

Regarding droughts and high temperatures, the State Climatologist has not observed heat extremes or droughts getting worse in Minnesota, but these are projected to get worse by mid-century.

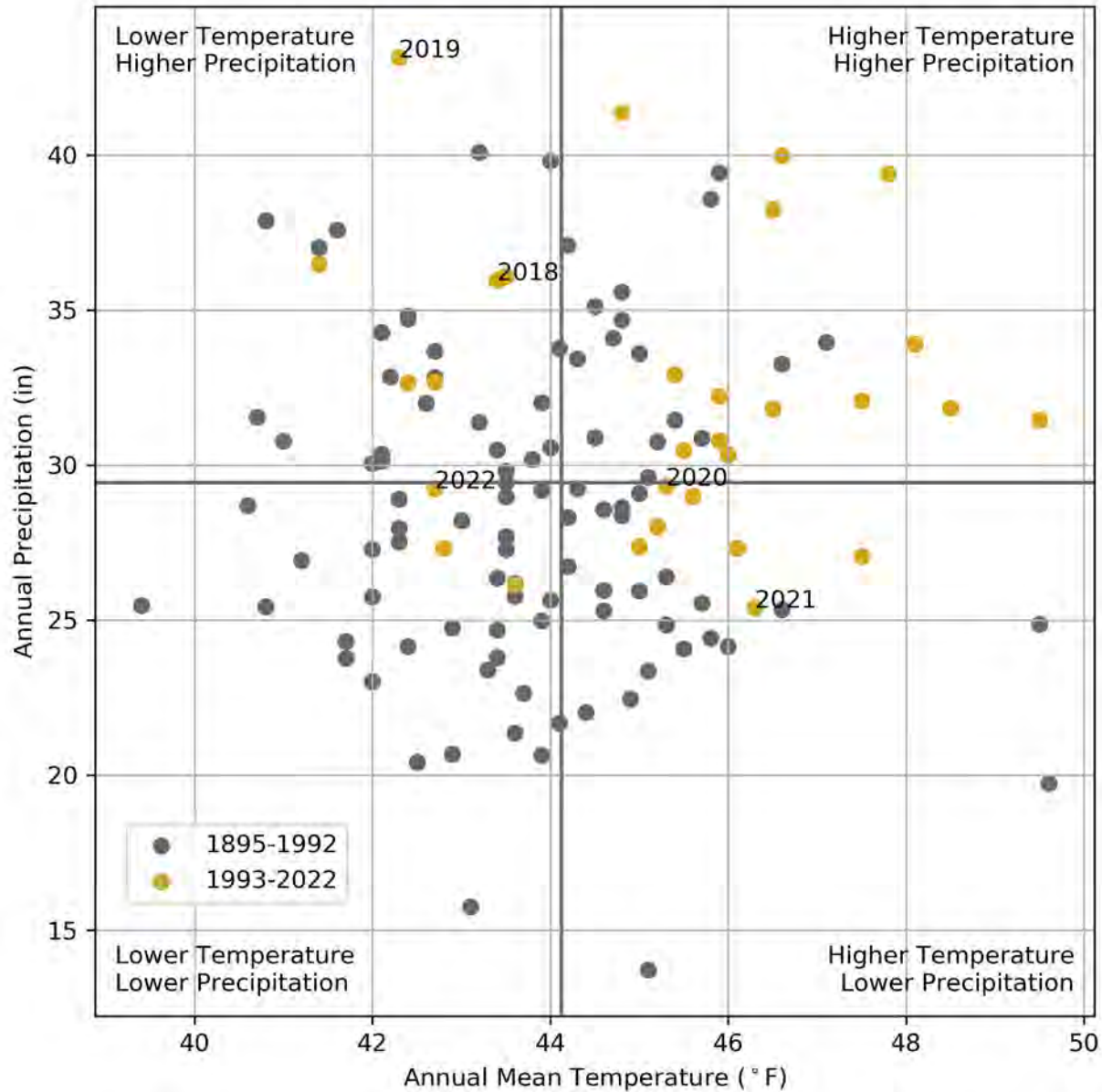


Figure 1. The shifting climate quadrants, comparing precipitation and temperature in 1895-1992 to 1993-2022 (PRISM Climate Group 2022)

1.1.2. Annual precipitation

Annual precipitation for 2004-2022 is summarized in

Figure 2 based on precipitation data retrieved from the Minnesota State Climatology Office for Forest Lake, MN (at T32N, R21W, S13). The 2022 annual precipitation in Forest Lake was approximately 29 inches, which is within the normal range. The average total annual precipitation between 1981 and 2010 was 29.5 inches per year. The Minnesota State Climatology Office defines wet years as years with total annual precipitation greater than the 70th percentile for the period of record (or 32.3 inches) and dry years as years with total annual precipitation less than the 30th percentile for the period of record (or 26.1 inches). Normal precipitation years are defined as years with a total precipitation between the 30th and 70th percentile for the period of record (or between 26.1 and 32.3 inches). In

Figure 2, the normal precipitation range is indicated by the area between the two black lines. Wet precipitation years since 2004 include 2010, 2013, 2014, 2015, 2016, 2018, and 2019. Dry precipitation years since 2004 include 2009 and 2021. Due to 2021 being a dry year, the tributaries monitored in 2022 were still exhibiting drought-like conditions even though 2022 was an average year.

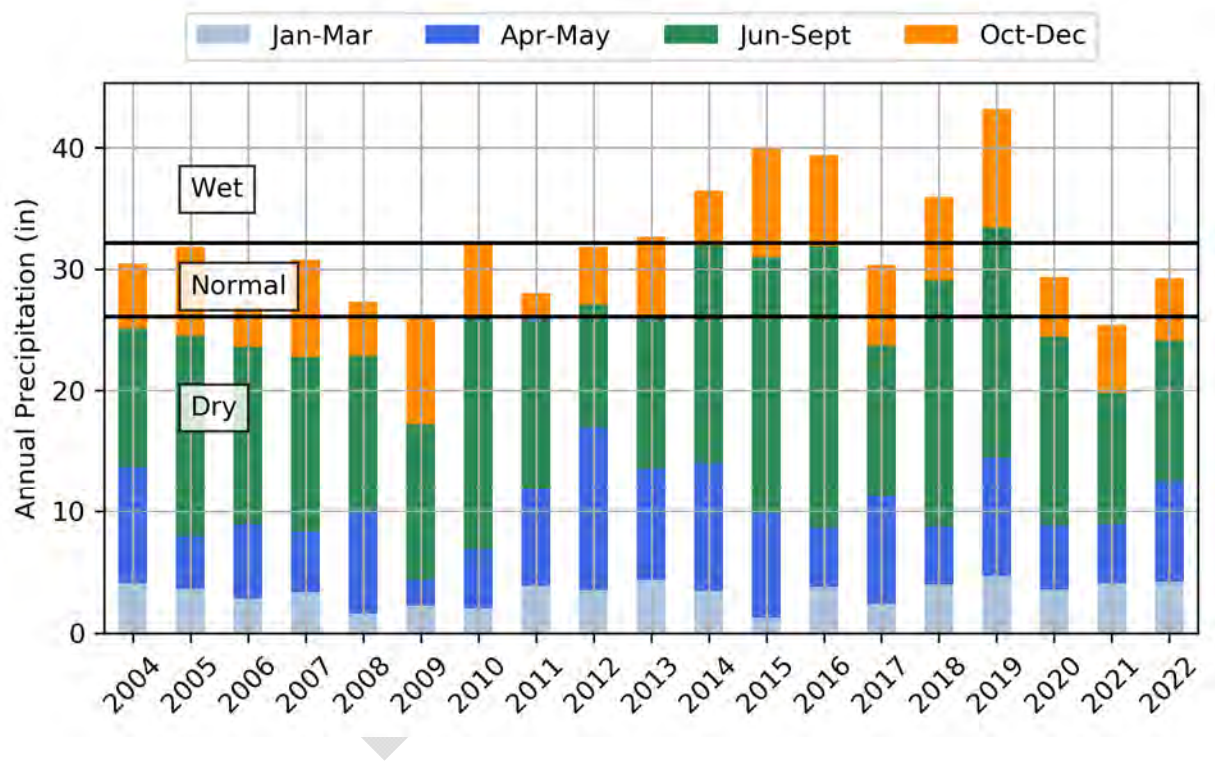


Figure 2. 2004-2022 Annual Gridded Precipitation for Forest Lake at Township 32N, Range 21W, Section 13

1.1.3. Monthly precipitation and temperatures

Monthly precipitation in 2022 is summarized in Figure 3 and compared to the 1991-2020 normal monthly precipitation based on precipitation data retrieved from the Minnesota State Climatology Office for Forest Lake, MN (at T32N, R21W, S13). In 2022, the months of March, April, and August all exhibited precipitation levels higher than the 1991-2010 precipitation averages. The months of May, June, July, September, and October were all dryer than normal, contributing to drought-like conditions (and the perception of 2022

being a dry year even though it was average) within the tributaries that were being monitored. Temperatures were also colder than average in March and April, which led to some challenges with installing the equipment early in the season. Therefore, some sites were installed later in the season due to ice blockage.

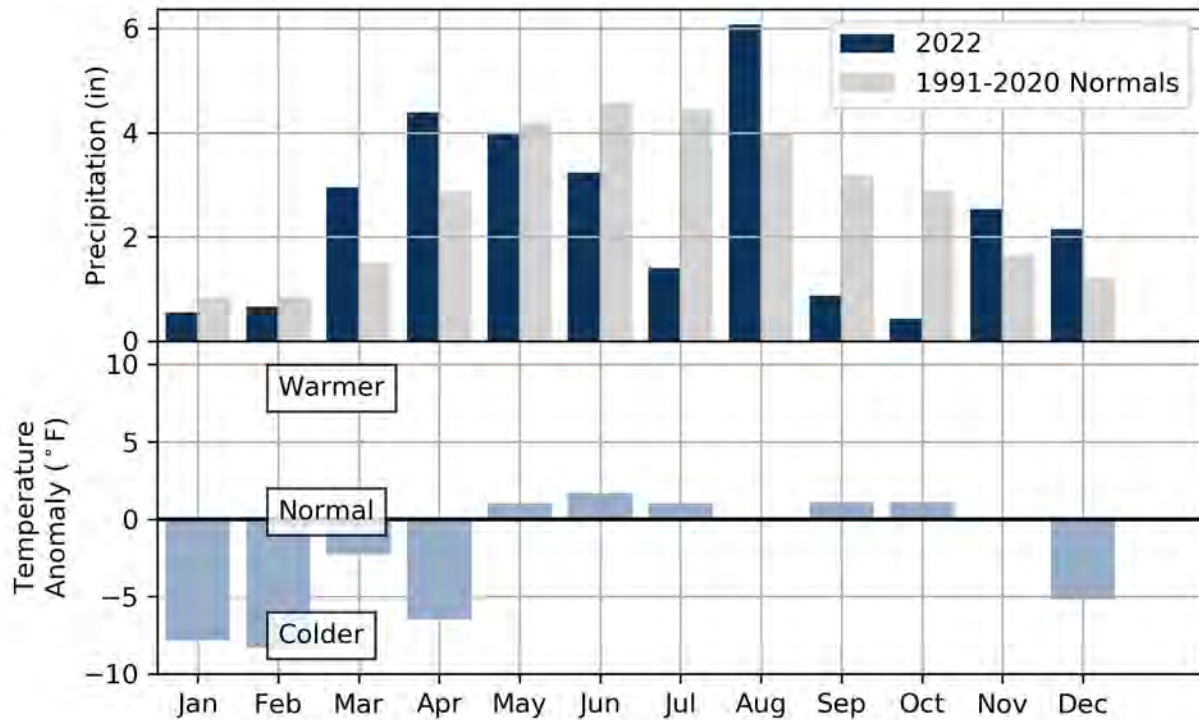


Figure 3. 2022 Monthly Precipitation and temperature for Forest Lake at Township 32N, Range 21W, Section 13

1.2. Data collected in 2022

There were four different types of monitoring conducted in the 2022 monitoring season (Lake Monitoring, Long-term Stream Monitoring, Diagnostic Monitoring, and Effectiveness Monitoring), which are described in Table 1. Table 2 also includes the type of data that was collected and its purpose. Figure 4 shows the monitoring locations by monitoring type.

Table 1. Monitoring types for 2022

Monitoring Type	Types of data collected	Purpose
Lake Monitoring (shown in purple in Figure 4)	<ul style="list-style-type: none"> • Lake water elevations • Surface water quality • Dissolved Oxygen concentrations and Temperature profiles • Bottom water phosphorus concentration • Chloride 	To assess progress in meeting State’s standards and District’s goals in lakes across the District shown in Figure 4.
Long-term creek & stream Monitoring (shown in green in Figure 4, also called Legacy sites).	<ul style="list-style-type: none"> • Creek/stream and culverts’ inlets/outlets survey elevations • Continuous water stage (water levels in the creek/stream) • Rating curves to estimate water flow rates at different water levels) • Water quality samples to determine pollutants’ concentrations and loads. • Field observations about site conditions and other factors potentially affecting monitoring results. 	To understand the annual loads and flows discharged from the lake management districts (LMDs) for the purpose of tracking large-scale pollutant reductions within the District.
Diagnostic Monitoring (shown orange in Figure 4)	<ul style="list-style-type: none"> • Creek/stream and culverts’ inlets/outlets survey elevations • Continuous water stage (water levels in the creek/stream) • Rating curves to estimate water flow rates at different water levels) • Water quality samples to determine pollutants’ concentrations and loads. • Field observations about site conditions and other factors potentially affecting monitoring results. 	To routinely re-evaluate which tributary sites continue to be most dominant pollutants’ contributors to District’s lakes. The 2022 diagnostic monitoring data collection was performed for Comfort Lake Management District (LMD)
Effectiveness Monitoring (shown in blue in Figure 4)	<ul style="list-style-type: none"> • Survey elevations at the inlet and outlet of the project or practice • Continuous water stage at the inlet and outlet of the project or practice • Rating curves to estimate water flow rates in and out the project or practice. • Water quality samples to determine pollutants’ concentrations and loads in and out the project or practice. • Field observations about site conditions and other factors potentially affecting monitoring 	Assess effectiveness of projects & practices implemented by the District.

1.3. Data collection purpose

There are numerous applications for surface water monitoring data, such as calibration of hydrologic and hydraulic (H&H) models, estimation of pollutant loads to key water resources, assessment of the effectiveness of projects/practices implemented by the District, and evaluation of long-term trends in water

quality (Table 2). The type, amount, and precision of data needed for each of these efforts may vary based on how it will be used to inform assessment and decision making. Therefore, to use District’s resources efficiently, it is important to determine beforehand what monitoring data is needed and how the data will be used.

Table 2. Uses of monitoring data

Decision tool	Description/Use
H&H Modeling	Characterizing rate and volume of runoff in a drainage to determine where flooding issues may occur across a landscape.
Pollutant loading	Characterizing pollutants discharged from a drainage area during a specific time interval to determine the impact of a particular drainage area on downstream water resources.
Project effectiveness	Measuring flows and concentrations of pollutants at the inlet and outlet of built practices to assess the effectiveness of projects in achieving the water quality/quantity benefits for which they were designed.
Water Quality Trends	Evaluating progress in achieving State standards and District's water quality goals.

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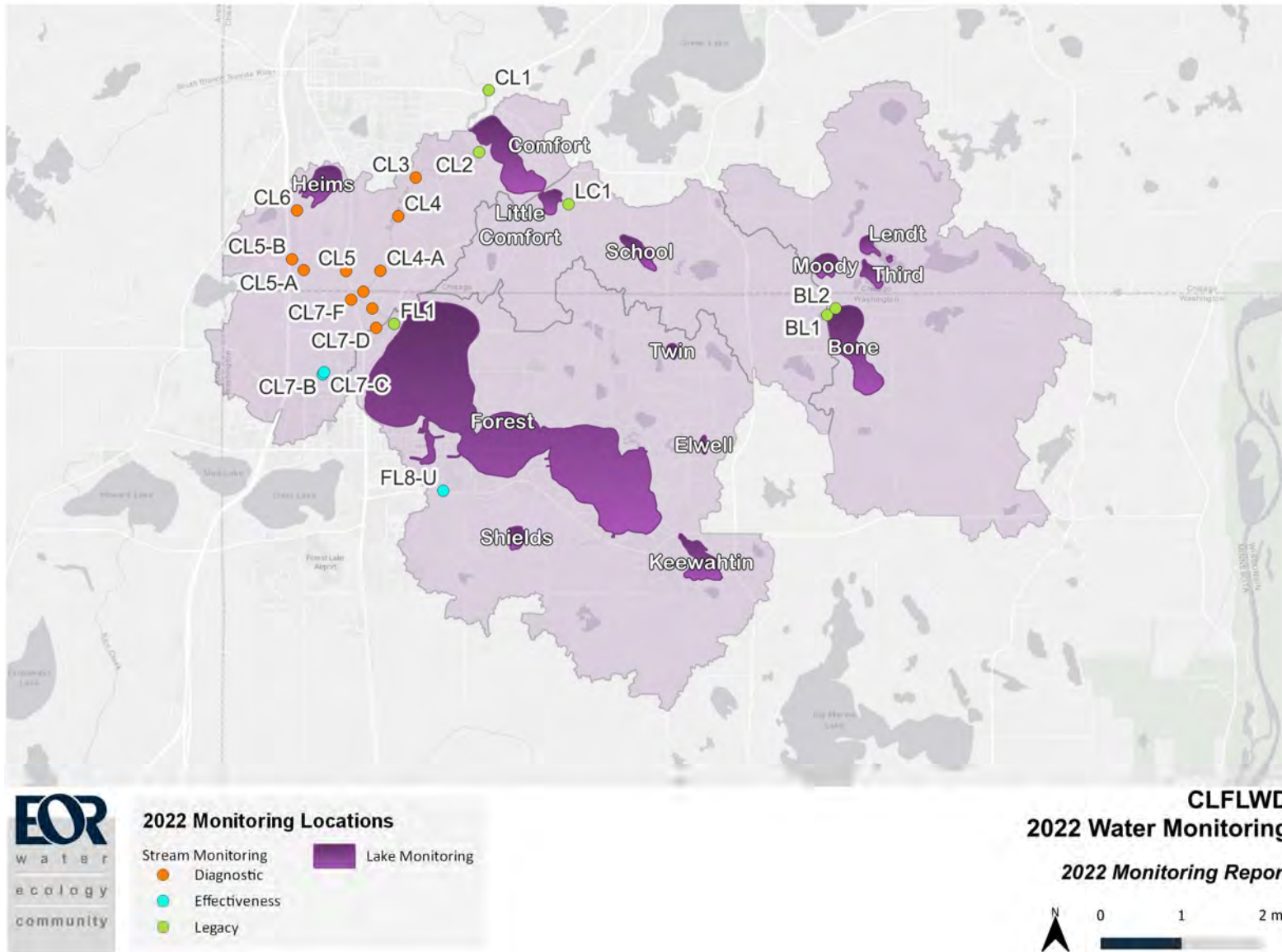


Figure 4. 2022 Water Monitoring Locations and monitoring types in Comfort Lake Forest Lake Watershed District

2. LAKE MONITORING

The District’s Lake monitoring program is broken down into five primary categories that include sentinel monitoring, routine monitoring, rotational monitoring, limited monitoring, and internal load monitoring. A description of these is shown in Table 3 below.

Table 3. 2022-2031 Lake Monitoring Recommendations (Lake and Stream Monitoring Program Recommendations Memo, EOR, 2020)

Monitoring Type	Description	Applicable District lakes
Sentinel monitoring	Surface water monitoring (total phosphorus, chlorophyl-a, Secchi Depth) fourteen times a year, every year. Using the CAMP protocol and volunteers in some instances.	Moody, Bone, Forest, and Keewahatin, Shields, Little Comfort, and Comfort
Routine monitoring	Surface water monitoring fourteen times a year, for two consecutive years every five years	Birch, School
Rotational Monitoring	Surface water monitoring fourteen times a year, for two consecutive years every ten years	Sea, Lendt, First, Second, Third, Twin, Clear, Elwell, Heims
Limited monitoring	No specified parameters or frequency of collection	Cranberry (limited access), Fourth (wetland)
Internal loading monitoring	Dissolved oxygen and temperature profiles, and fourteen bottom water phosphorus measurements for two consecutive years every five years	Lakes with completed or planned alum treatments

2.1. Lake Monitoring Summary

In 2022, fifteen lakes were monitored for surface water quality and lake levels. Of those lakes, six of them were also monitored (lake depth profiles, bottom TP) to assess internal P loading and chloride pollution. The lakes and the respective parameters that were collected for each are shown in Table 4.

Table 4. Lakes monitored in the 2022 monitoring season and the respective parameters collected

Lake	DNR ID	Monitoring type	Surface WQ (CAMP)	Lake Levels	Dissolved Oxygen and Temp Profiles	Bottom TP	Chloride
Bone	82005400	Sentinel	X				
Comfort	13005300	Sentinel, internal loading	X	X	X	X	X
Forest (West)	82015900	Sentinel	X	X			
Forest (Middle)	82015900	Sentinel, internal loading	X	X	X	X	X
Forest (East)	82015900	Sentinel, internal loading	X	X	X	X	X

Lake	DNR ID	Monitoring type	Surface WQ (CAMP)	Lake Levels	Dissolved Oxygen and Temp Profiles	Bottom TP	Chloride
Moody	13002300	Sentinel, internal loading	X	X	X	X	X
Little Comfort	13005400	Sentinel, internal loading	X	X	X	X	X
Shields	82016200	Sentinel, internal loading	X	X	X	X	X
Keewahtin	82008000	Semi-Sentinel	X	X			
School		Routine	X	X			
Third Lake	13002400	Rotational	X	X			
Twin Lake	82015700	Rotational	X	X			
Elwell	82007900	Rotational	X	X			
Heims	13005600	Rotational	X	X			
Lendt Lake	13010300	Rotational	X	X			

The main takeaways for the 2022 lake monitoring season include:

- Overall, 2022 average lake water quality was excellent with all the lakes in the District meeting or exceeding State standards for either TP and chlorophyll-a or Secchi depth criteria.
Most of the lakes started the monitoring season with good water quality close to or slightly exceeding State water quality standards. The likely cause was snow melt (late February through April) combined with above normal precipitation for that period. Flow records from the Sunrise River DNR/MPCA stream gage support this conclusion.
- Drier than normal conditions in June and July resulted in less external Phosphorous load than expected. This was an important factor (although not the only one) that contributed to the very good overall water quality in the District's lakes. In 2022, lakes met or exceeded State's water quality standards.
- Two high wind events, August 3rd and August 27th, observed at the MSP International Airport are potential factors contributing to mixing in Little Comfort Lake, Comfort Lake, Forest Lake – Middle and Forest Lake – East.
 - Little Comfort Lake and Comfort Lake Bottom P concentrations showed evidence of slight mixing after the August 27th high wind event. Bottom P concentrations decreased slightly in early September.
 - Forest Lake – Middle temperature and dissolved oxygen profiles showed evidence of complete turnover in early September.
 - Forest Lake – East showed evidence of at least slight mixing after the August 3rd high wind event. Bottom P concentrations decreased during August.
- Continued monitoring is needed for the lakes close to meeting or exceeding State water standards:
 - Forest Lake – Middle and Forest Lake – East

- Alum Treatment planned for Forest Lake – Middle is expected to appreciably improve water quality in the middle basin and have a beneficial impact in Forest Lake – East.
 - Moody Lake
 - The alum treatment is still effective in reducing internal loading in the lake.
 - Proposed Moody Lake Capstone BMPs will likely have a positive impact on long-term water quality.
- Shields Lake Alum treatment is still effectively reducing internal loading.

2.2. Data Collected

A description of the types of data collected, the purpose of collecting this data, and the entity collecting the data are described in Table 5.

Table 5. Data types collected for the lake monitoring effort

Data type	Purpose	Who collects?
Surface water quality	To determine how each lake is performing in relation to state water quality standards, and to determine if a lake should be removed or added to the impaired waters list.	CAMP, Analyzed by Met Council Labs
Lake Levels	To assess the association between lake levels and water quality concentrations, pollutant loading from tributaries, and weather conditions.	CLFLWD Staff, CAMP
Dissolved oxygen and temperature	To see how strongly the lake stratifies or separates into a distinct warm surface layer and a cool bottom layer. The lake temperature at the interface between these two layers is characterized by a very rapid change from warm to cooler temperatures. This can often be felt when swimming in a lake in the summer where the surface water feels warm, but your toes feel cool when sticking them straight down into the water. The dissolved oxygen profile is used to show the amount of oxygen depletion of the bottom waters	CLFLWD Staff
Bottom Water Phosphorus	Bottom water phosphorus represents the amount of phosphorus released from lake sediments when the lake water is stratified. This is used to assess internal loading.	CLFLWD Staff, analyzed by Instrumental Research Labs
Chloride	To assess potential impacts to the growth and reproduction of aquatic species, their food sources, and critical biological functions in amphibians, or a change to the density of the water entering a waterbody, preventing the natural exchange of gases from the bottom of a lake to the top.	CLFLWD Staff

2.2.1. Surface Water Quality

Lake surface water quality is typically sampled for total phosphorus, chlorophyll-a and Secchi depth transparency using the CAMP protocol.

Total phosphorus represents the amount of nutrients in a lake that fuel algae growth. Phosphorus sources include soil erosion, stormwater runoff, leaf litter and other organic materials, manure runoff and wastewater (including septic tanks).

Chlorophyll-a represents the number of algae in the surface water. Algae blooms reduce water clarity (as measured by Secchi depth) and can cause unpleasant odors. They can also use dissolved oxygen in the lake critical for fish and reduced aquatic plant growth that supports important habitat for fish and aquatic invertebrates.

Secchi transparency depth is a measure of water clarity and is measured by lowering a Secchi disk in the lake. The depth at which the Secchi disk is still visible is the Secchi depth. More algae in the water results in more turbidity or cloudiness of the water and lower (shallower) Secchi depth; less algae in the water results in clearer water and higher (deeper) Secchi depth as shown in Figure 5.

Surface water quality generally varies seasonally for Minnesota lakes, with lower phosphorus and chlorophyll-a and deeper Secchi depth in spring and fall, with peak concentrations and lowest water clarity typically in July and August.

More Phosphorus = More Algae = Less Clarity

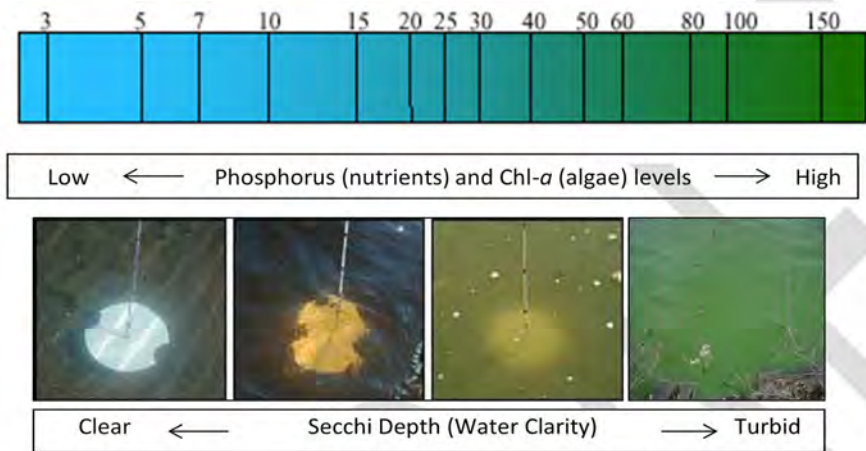


Figure 5. Relationships between lake phosphorus and algae levels with water clarity (WCD)

Lake grades were assigned to each lake in 2022 and for the average of the last five years (2018-2022) for total phosphorus, chlorophyll-a, Secchi depth, and overall lake water quality (the average of the TP, Chl.-a and Secchi grades). Lake grades followed the Met Council water quality grading system developed in 1989 (Table 6):

Table 6. Metropolitan Council Lake Water Quality Grading System

Grade	Total phosphorus (TP), $\mu\text{g/L}$	Chlorophyll-a (Chl.-a), $\mu\text{g/L}$	Secchi depth (ft)
A	<23	<10	>9.8
B	23-32	10-20	7.2-9.8
C	32-68	20-48	3.9-7.2
D	68-152	48-77	2.3-3.9
F	>152	>77	<2.3

2.2.2. Lake Levels

The surface water elevation of the lakes is recorded during monitoring events and reported to DNR. These lake levels can be used to calibrate hydraulic and hydrologic (H&H) models used to identify and design best management practices.

2.2.3. Internal Loading

It is common for a lake to show some temperature stratification (see Appendix A) during the summer months, when the temperature at the lake surface is higher and decreases abruptly with depth. Water temperature at the lower layers in the lake is cooler and pretty much constant. Water (and associated pollutants) vertical movement between layers is mostly the result of temperature differential (temperature gradient). Since at lower layers the temperature gradient is low, not a lot of vertical movement takes place during lake stratification.

Stratification also prevents the exchange of oxygenated water from the surface to the lower layers. With time, the layers at the bottom of the lake become anoxic (no oxygen). In an anoxic situation, phosphorus that is bound to iron (and other metals) in the sediments is released and stays at the lower layers of the lake over the summer. Phosphorus accumulation at the bottom waters is called "internal loading".

When internal loading is sufficiently high, phosphorus can diffuse up into the surface waters and decrease surface water quality. The release of phosphorus from the bottom layers to the lake's surface is most notable after severe storm events and winds that mix the lake waters. In the Fall, when lake temperature stratification weakens due to reduced ambient temperatures, the surface and bottom waters mix (the lake "turns"). If a significant accumulation of phosphorus in the lower layers exist when the lake turns, it will be transferred to the surface waters with the consequent impact on water quality.

Alum treatment is one commonly used management practice for reducing this source of phosphorus. The alum (aluminum sulfate) binds with the phosphorus, a process known as flocculation, and traps the phosphorus in the sediment so it cannot migrate and be dissolved into the water column. Typically, Lakes that have completed or are planning alum treatments are monitored for internal loading. This is to assess whether an alum treatment is needed or, if already completed, how effective it was in binding phosphorus.

Monitoring for internal loading assessment includes collecting dissolved oxygen and temperature profiles to determine the length of summer stratification and collecting bottom water phosphorus concentrations to determine if phosphorus is accumulating in bottom waters over time.

2.2.4. Chloride

Every winter, roads and other paved surfaces require a significant amount of de-icing material to prevent unsafe conditions. The most common deicer by far is salt. The main component in salt is sodium-chloride. Salt helps prevent ice buildup and melts ice from paved surfaces. However, salt dissolves into the melted ice water and it breaks down leaving the Chloride in the runoff. This runoff eventually reaches water resources like rivers and lakes. Because deicing with salt is so common, it is one of the biggest contributors of excess chloride in our groundwater and drinking water sources.

Another major source of chloride in the environment is water softeners. Home water softener systems often use chloride to react with the sources of water hardness (calcium and magnesium). If your home has softened water, you may have noticed that it tastes a little salty. However, just as overly salty food is bad for your health, overly salty water acts in the same way. Unfortunately, chloride is very difficult to remove and as a result, the softened water

that leaves houses often ends up letting chloride into the environment too. There are not many natural processes that can remove chloride and reduce harmful levels in the environment, and our water treatment plants do not have technologies to remove chloride except through one costly, energy-intensive process.

Although chloride exists naturally in the environment at low levels, it is toxic to aquatic life at high levels. In low concentrations, chloride supports key biological functions; at toxic levels, chloride impacts the growth and reproduction of aquatic species, their food sources, and critical biological functions in amphibians. This is largely because chloride disrupts the natural process of molecules flowing in and out of cells. In high environmental concentrations, chloride can force water to leak out of cells while preventing other critical molecules from entering—a necessary biological function for aquatic and amphibious species.

If aquatic life is exposed to such excessive concentrations of chlorides for too long, their cells get stressed and can even die. Another issue is the link between low dissolved oxygen and high chloride levels, which is another reason high chloride levels are harmful for aquatic life. Chloride can change the density of the water entering a waterbody and prevent the natural exchange of gases from the bottom of a lake to the top. Chloride measurements were collected in the lakes using a probe for the first time in 2021, but due to possible calibration issues, the concentrations could not be verified as accurate and therefore were not reported.

2.3. Results

To view the full results of the lake monitoring effort by lake for 2022, see Appendix A. Please note, chloride data and the additional metalimnion data collected for Little Comfort Lake are not included in those lake sheets.

2.3.1. Surface Water Quality

State Water Quality Standards

Table 7 shows the standards and the level of compliance of all District's lakes. Lakes meeting all State Lake Water Quality Standards are: Keewahtin Lake, Comfort Lake, Third Lake, Second Lake, Heims Lake and Sea Lake. Lakes meeting two of the three State Lake Water Quality Standards are: Bone Lake, Forest Lake, School Lake, and Birch Lake. Finally, Lakes meeting one of the three State Lake Water Quality Standards are: Little Comfort Lake and Fourth Lake. Moody Lake is the only lake not meeting any of the lake water quality standards.

Table 7. Progress towards State Water Quality Standards

Lakes (In order of increasing TP)	Total Phosphorus (µg/L)			Chlorophyll-a (µg/L)			Secchi Depth (ft)		
	2013 - 2022 Average	Years of Data (N)	Standard	2013 - 2022 Average	Years of Data (N)	Standard	2013 - 2022 Average	Years of Data (N)	Standard
GENERAL LAKES									
Keewahtin	13.9	10	40 ✓	2.7	10	14 ✓	14.3	10	4.6 ✓
Comfort *	30.2	10	40 ✓	13.8	10	14 ✓	5.7	10	4.6 ✓
Bone *	32.1	10	40 ✓	17.2	10	14	4.9	10	4.6 ✓
Forest	33.0	10	40 ✓	15.4	10	14	6.0	10	4.6 ✓
Little Comfort *	48.3	10	40	19.4	10	14	5.3	10	4.6 ✓
Moody *	81.6	10	40	43.2	10	14	3.0	10	4.6
SHALLOW LAKES									
Lendt	14.8	4	n/a	5.7	4	n/a	4.1	4	n/a
Third	19.3	4	60 ✓	4.5	4	20 ✓	4.5	9	3.3 ✓
Second **	27.5	4	60 ✓	8.9	4	20 ✓	7.6	4	3.3 ✓
Twin	27.8	1	n/a	5.6	1	n/a	4.2	1	n/a
Heims	42.2	3	60 ✓	11.8	3	20 ✓	3.3	3	3.3 ✓
Elwell	43.1	2	n/a	11.3	2	n/a	2.5	2	n/a
School *	45.2	5	60 ✓	26.5	5	20	4.1	5	3.3 ✓
Sea	49.5	2	60 ✓	9.2	2	20 ✓	4.5	2	3.3 ✓
Nielson	64.2	2	n/a	37.8	2	n/a	4.8	2	n/a
Birch	80.8	4	60	13.2	4	20 ✓	5.0	4	3.3 ✓
Fourth	89.7	3	60	18.9	3	20 ✓	2.1	3	3.3
Shields *	160.9	10	60	41.6	10	20	3.7	10	3.3 ✓

N = number of years data has been collected within the 2013-2022 period.

* = Impaired, included in the 2010 Six Lakes TMDL Study

** = Impaired, included in the 2014 Sunrise River Watershed TMDL Study but no data collected within the last 10-years

Lake names in bold = Lakes that have been assigned goals different from State Water Quality Standards

✓ = meets Standard; ## = does not meet Standard; n/a = insufficient data

Secchi disk District goals

Lakes meeting the 2040 District Secchi Depth goals (last column in Table 8) include Keewahtin Lake, Third Lake, Lendt Lake, Second Lake, Twin Lake, Forest Lake – East, School Lake, Birch Lake, and Shields Lake.

Lakes not meeting 2040 District Secchi Depth goals include Sea Lake, Fourth Lake, Nielson Lake, Moody Lake, Elwell Lake, Little Comfort Lake, Heims Lake, Forest Lake-Middle, Comfort Lake, Forest Lake-West, and Bone Lake (see Table 8).

Table 8. Secchi Depth 5-Year Average and progress to 2040 goals in all District Lakes

Lakes (in order of increasing TP)	Existing 5-year Average Secchi Depth (2018-2022) [ft]	Years of Data	2040 District Secchi Depth Goal
Keewahtin Lake	12.9	5	10.0 ✓
Third Lake	4.9	4	3.3 ✓
Lendt Lake	4.2	2	3.3 ✓
Bone Lake	5.9	5	7.0
Forest Lake (West)	6.4	5	7.0
Comfort Lake	6.6	5	7.0
Second Lake	7.6	4	3.3 ✓
Twin Lake	4.2	1	3.3 ✓
Forest Lake	6.7	5	7.0
Forest Lake (East)	7.2	5	7.0 ✓
Forest Lake (Middle)	6.6	5	7.0
Heims Lake	2.6	1	3.3
Little Comfort Lake	5.9	5	7.0
School Lake	4.5	4	3.3 ✓
Elwell Lake	2.5	2	3.3
Moody Lake	3.8	5	4.6
Birch Lake	5.0	3	3.3 ✓
Shields Lake	4.7	5	4.3 ✓
Nielson Lake	0.9	1	3.3
Fourth Lake	2.3	1	3.3
Sea Lake	n/a	0	3.3

Total Phosphorus District goals

Lakes meeting the 2040 District TP goals include Keewahtin Lake, Third Lake, Lendt Lake, Bone Lake, Forest Lake-West basin, Comfort Lake, Second Lake, Twin Lake, Heims Lake, School Lake, and Elwell Lake (Table 9).

Lakes not meeting 2040 District TP goals include Forest Lake-East, Forest Lake-Middle, Little Comfort Lake, Moody Lake, Birch Lake, Shields Lake, Nielson Lake, Fourth Lake, and Sea Lake (Table 9)

Table 9. Total Phosphorus 5-Year Average and progress to 2040 goals in all District Lakes

Lakes (in order of increasing TP)	Existing 5-year Average TP (2018-2022) [$\mu\text{g/L}$]	Years of Data	2040 District TP Goal
Keewahtin Lake	15.3	5	20 ✓
Third Lake	15.5	2	60 ✓
Lendt Lake	15.6	2	60 ✓
Bone Lake	24.9	5	30 ✓
Forest Lake (West)	26.3	5	30 ✓
Comfort Lake	27.0	5	30 ✓
Second Lake	27.5	4	60 ✓
Twin Lake	27.8	1	60 ✓
Forest Lake	32.7	5	30
Forest Lake (East)	33.1	5	30
Forest Lake (Middle)	38.7	5	30
Heims Lake	39.0	1	60 ✓
Little Comfort Lake	42.2	5	30
School Lake	43.1	4	60 ✓
Elwell Lake	43.1	2	60 ✓
Moody Lake	55.9	5	40
Birch Lake	83.8	3	60
Shields Lake	84.4	5	60
Nielson Lake	86.9	1	60
Fourth Lake	87.4	1	60
Sea Lake	n/a	0	60

Lake Grades

The majority of the lakes monitored in 2022 in the District received A/B grades using Met Council’s Lake Grading System (Table 10). The Met Council’s Lake Grading System is as follows:

- A = No impairment,
- B = Some impairment,
- C = Impaired,
- D = Severely impaired,
- F = Total impairment

Forest Lake – West and Keewahtin Lake had the best water quality with A grades. Forest Lake – East and Moody Lake had the worst water quality with C grades.

Table 10. CLFLWD Lake Water Quality Grades for 2022 and most recent 5-year average (2018-2022)

Lake	DNR ID	Acres	TP		Chl.-a		Secchi		Overall	
			2022	5-yr Avg	2022	5-yr Avg	2022	5-yr Avg	2022	5-yr Avg
Birch	13-0042-00	33	--	C-	--	B	--	C-	--	C
Bone	82-0054-00	221	B	B	B	B+	C	C	B	B
Comfort	13-0053-00	218	B	B+	B	B+	C	C+	B	B+
Elwell	82-0079-00	16	C	C	B	B	--	--	--	--

Lake	DNR ID	Acres	TP		Chl.-a		Secchi		Overall	
			2022	5-yr Avg	2022	5-yr Avg	2022	5-yr Avg	2022	5-yr Avg
Forest (West)	82-0156-00	1,086	A	B+	A	A-	B	B-	A	B+
Forest (Middle)	82-0156-00	364	B	B-	B	B	C	B-	B	B-
Forest (East)	82-0156-00	790	C	B-	B	B	C	B-	C	C+
<i>Forest (All Basins)</i>	<i>82-0156-00</i>	<i>2,240</i>	B	B-	B+	B+	C+	B-	B	B-
Fourth Lake	13-0022-00	8	--	D	--	B	--	--	--	--
Heims	13-0056-00	90	--	--	--	--	--	--	--	--
Keewahtin	82-0080-00	75	A	A	A	A	A	A	A	A
Lendt Lake	13-0103-00	42	A	A	A	A	--	--	--	--
Little Comfort	13-0054-00	36	B	C+	A	B	B	C+	B	C+
Moody	13-0023-00	45	C	C-	C	C+	C	C-	C	C
Nielson	82-0055-00	37	--	D	--	F	--	F	--	F
School	13-0057-00	47	B	C+	B	B-	C	C-	B	C+
Sea	82-0053-00	50	--	--	--	--	--	--	--	--
Second	13-0025-00	75	--	B	--	A-	--	B-	--	B
Shields	82-0162-00	30	B	C-	A	B-	C	C-	B	C
Third Lake	13-0024-00	42	A	A	A	A	--	--	--	--
Twin Lake	82-0157-00	19	--	B	--	A	--	--	--	--

A: No impairment blue, **B:** Some impairment green, **C:** Is impaired yellow, **D:** Severely impaired orange, **F:** Total impairment red

Lake Water Quality Trends

Long-term lake water quality trends were calculated using the Kendall's Tau statistical analysis which essentially reports how consistently a water quality parameter (such as TP or Secchi) increases or decreases over time. Kendall's Tau for short-term period (since 2013) and long-term period (for the entire monitoring period, beginning with the earliest available year) were determined for each lake. Monitoring data available from the MPCA EDA Surface Water Database was used in the analysis. Many lakes had large gaps in their monitoring records and therefore, only short-term trends could be determined, as noted in Table 11 below.

- **No trend** indicates that the water quality parameter is not consistently increasing or decreasing from year to year over the time-period AND that this is a statistically significant "no change".
- **Improving** or **declining** trends means that the water quality parameter is consistently increasing or decreasing from year to year over the time-period but NOT in a statistically significant way.
- **Significantly improving** or **significantly declining** means that the water quality parameter is consistently increasing or decreasing from year to year over the time-period AND does that in a statistically significant way. The percent change in the parameter over the entire time-period is reported for statistically significant trends.

- **NA** means that there was insufficient data to determine a statistical trend. At least 4 samples must be collected per year to be included in the trend analysis, and at least 75% of all years in the total period of record have at least 4 samples collected per year. Ten lakes do not have enough monitoring data to determine long-term trends in water quality.

Lake water quality trends are shown in Table 11 for those lakes with sufficient data to calculate trends. Overall, most District lakes have improving trends in lake water quality. Forest Lake-Middle and Forest Lake-East are both exhibiting declining water quality trends. The first alum treatment for Forest Lake - Middle is planned for 2023.

Table 11. Lake Water Quality Trends

Lake	Total Phosphorus Trend	Chlorophyll-a Trend	Secchi Disk Trend
Bone	Significantly Improving since 2013 (-39%)	Improving since 2001 Significantly Improving since 2013 (-44%)	Improving since 1984 Significantly Improving since 2013 (85%)
Comfort	Improving since 1994	Improving since 1994 Significantly Improving since 2013 (-46%)	Improving since 1987 Significantly Improving since 2013 (52%)
Forest – West	Significantly Improving since 1984 (-29%) Significantly Improving since 2013 (-38%)	Significantly Improving since 2001 (-60%) Significantly Improving since 2013 (-69%)	Improving since 1984 Significantly Improving since 2013 (116%)
Forest – Middle	Declining since 2013	Declining since 2013	Declining since 2013
Forest – East	Declining since 2013	Declining since 2013	Improving since 2013
Keewahtin	Improving since 2013	Improving since 2013	Improving since 1974 Declining since 2013
Little Comfort	Significantly Improving Since 2013 (-48%)	Improving since 2013	Improving since 2013
Moody	Significantly Improving since 2005 (-79%) Significantly Improving since 2013 (-73%)	Improving since 2005	Improving since 2005
Shields	Significantly Improving since 2013 (-33%) Significantly Improving since 2013 (-92%)	Improving since 2001 Significantly Improving since 2013 (-57%)	Improving since 2013

Short-term trends are noted for the most-recent 10-years (since 2013)

Long-term trends are noted for the period of record for each lake, with the earliest year noted

2.3.2. Lake Levels

One important fact to note is that the Little Comfort Lake received flow from Comfort Lake throughout April and May according to the lake water levels, meaning Comfort Lake had higher water levels than Little Comfort Lake (Figure 6). This behavior was observed in 2021 as well and could be a common phenomenon that needs to be investigated further. Section 4.2.2 provides more detail on this finding and includes some recommendations on how to further evaluate it.

One possible explanation for the elevation discrepancy between Little Comfort Lake and Comfort Lake has to do with the timing and magnitude of the snowmelt early in the season. The Sunrise River drainage area to Comfort Lake is larger with a 13,625-acre drainage area, with more impervious land use, and more channelized than the Little

Comfort Lake’s drainage area (10,563-acre drainage area). Therefore, earlier in the season and during snowmelt, the volume of water entering Comfort Lake from the Sunrise River is significantly larger, causing Comfort Lake’s levels to temporarily rise above those in Little Comfort. The time it takes for Comfort and Little Comfort Lakes to equalize can vary from year to year, depending on multiple conditions.

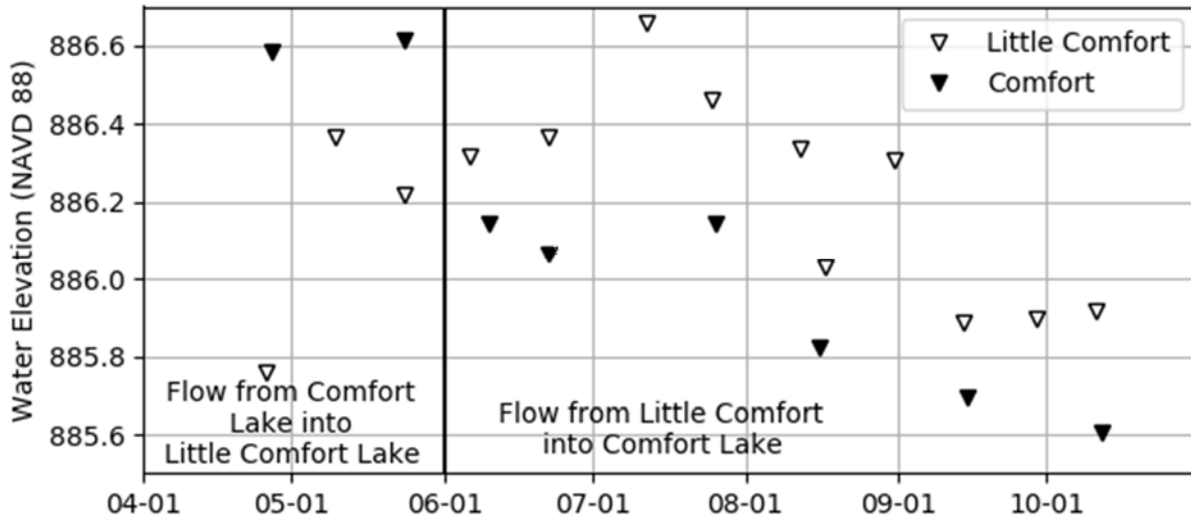


Figure 6. Little Comfort Lake and Comfort Lake 2022 water elevations (NAVD 88)

2.3.3. Internal Loading

Some important general observations regarding internal loading include:

- The ratio of Maximum Growing Season Bottom P to Mean Growing Season TP is an important factor to determine how much influence (risk) Bottom P concentration has on Surface P concentration.
- Based on the data collected, Forest Lake-Middle and East have the highest risk for internal loading.
- The lake’s physical characteristics and morphology are also important factors (e.g., Little Comfort has a lower risk for internal loading because it is deep and lake stratification is maintained year-around not allowing Bottom P to migrate upwards).

Internal loading conclusions (summarized in Table 12):

1. Shields Lake and Moody Lake Alum treatments continue to work. According to MPCA Alum treatments last 4-21 years.
2. Mixing events in August helped prevent extremely high bottom P concentrations in the other lakes monitored besides Forest Lake - Middle
3. Forest Lake – Middle still had extremely high bottom P concentrations by the end of August.
4. Comfort Lake and Little Comfort Lake showed signs of increasing bottom P concentrations, but it was not evident that this increase P concentration impacted surface water quality at this point.
5. Additional Metalimnion (lake’s middle layer) samples collected in Little Comfort Lake confirmed that bottom P concentrations had little impact on surface water quality in 2022. The only metalimnion concentration higher than the surface TP was in October.

Table 12. Internal Loading Results

Lake	Alum Treatment	Seasonal Increase**	Max Growing Season Bottom P : Mean Growing Season TP	Mixing Influence***	Diffusion Influence****
Comfort Lake	Potential	Yes	12	No	No
Forest Lake - Middle	Planned for 2023	Yes	44	Maybe	No
Forest Lake -East	Potential	Yes	14	Maybe	No
Little Comfort Lake*	Not recommended at this point still potential	Yes	18	No	No
Moody Lake	2018/2019	No	2	No	No
Shields Lake	2019/2020	No	1	No	No

* Metalimnion samples did not suggest bottom P concentrations contributed to surface water TP concentrations (Figure 7)

** Seasonal increase is another risk factor, but is also a natural part of stratified lakes

*** Mixing Influence is identified as a noticeable increase in surface TP after fall turnover or another mixing event

**** Diffusion Influence is identified as any correlations in the bottom and surface TP at the time the lake was stratified

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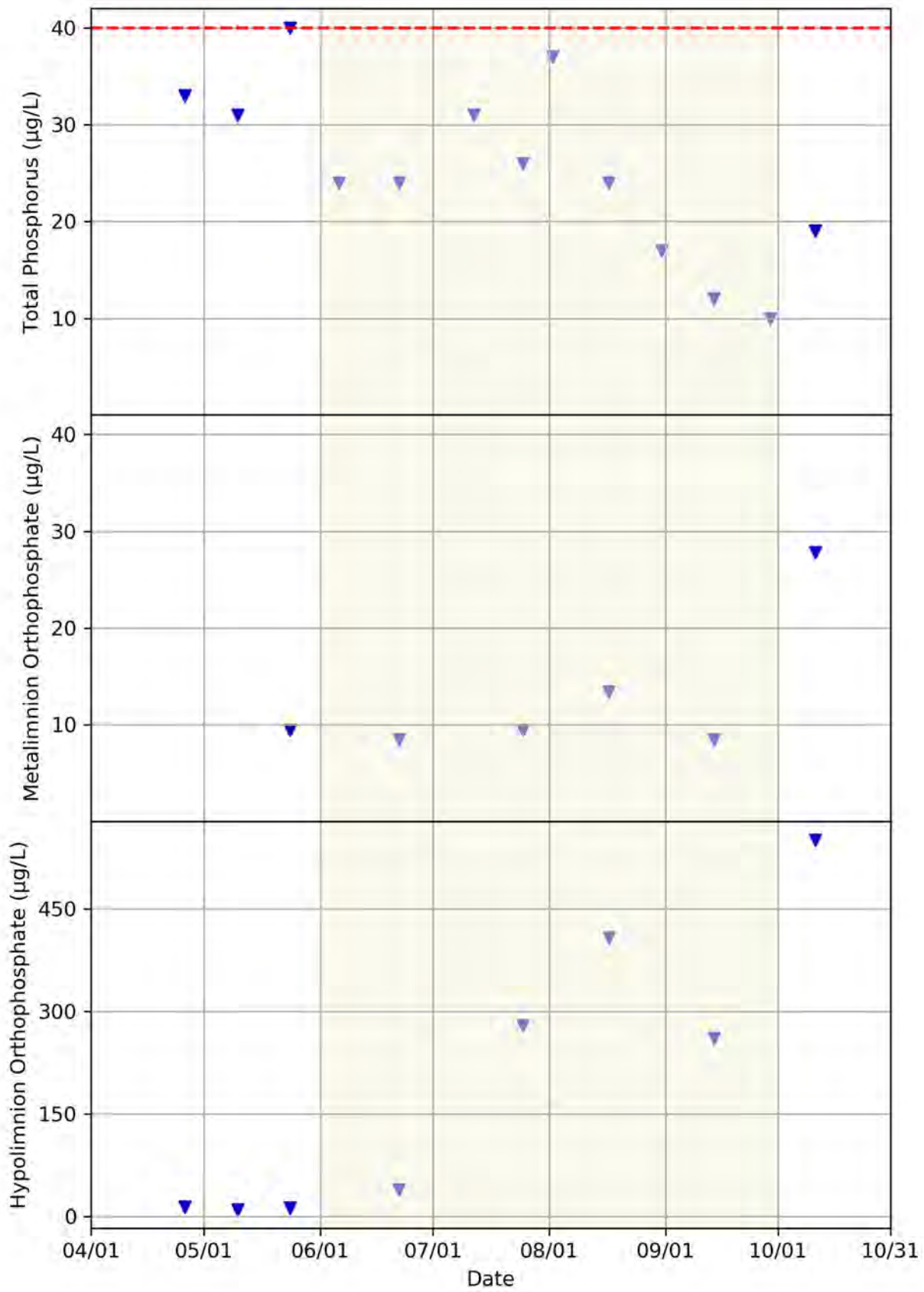


Figure 7. Little Comfort Lake phosphorus profile (epilimnion/metalimnion/hypolimnion) monitoring

2.3.4. Chloride

The 2022 chloride profiles are shown in Figure 8 through Figure 13. Chloride Impairment is defined as Chloride concentrations above the State Standard of 230 mg/L for four days or 860 mg/L for one measurement. None of the lakes that were monitored exhibited chloride levels above 230 mg/L. Chloride monitoring should continue in the lakes because it is an emerging pollutant of concern in the Metro Area ([MPCA 2016](#)).

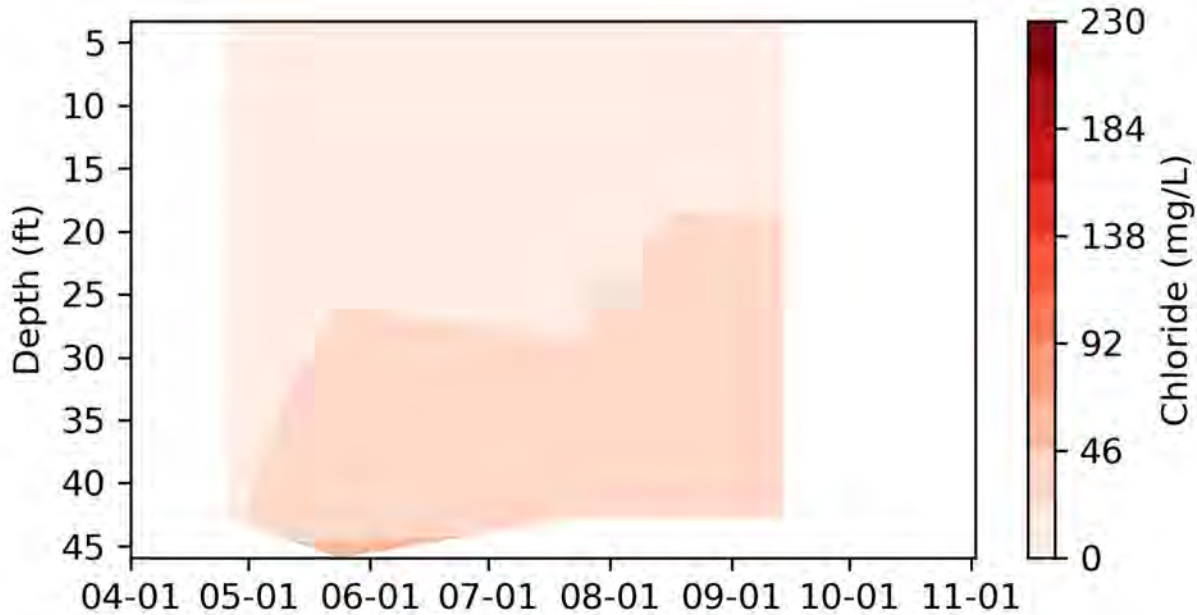


Figure 8. 2022 Moody Lake chloride profiles

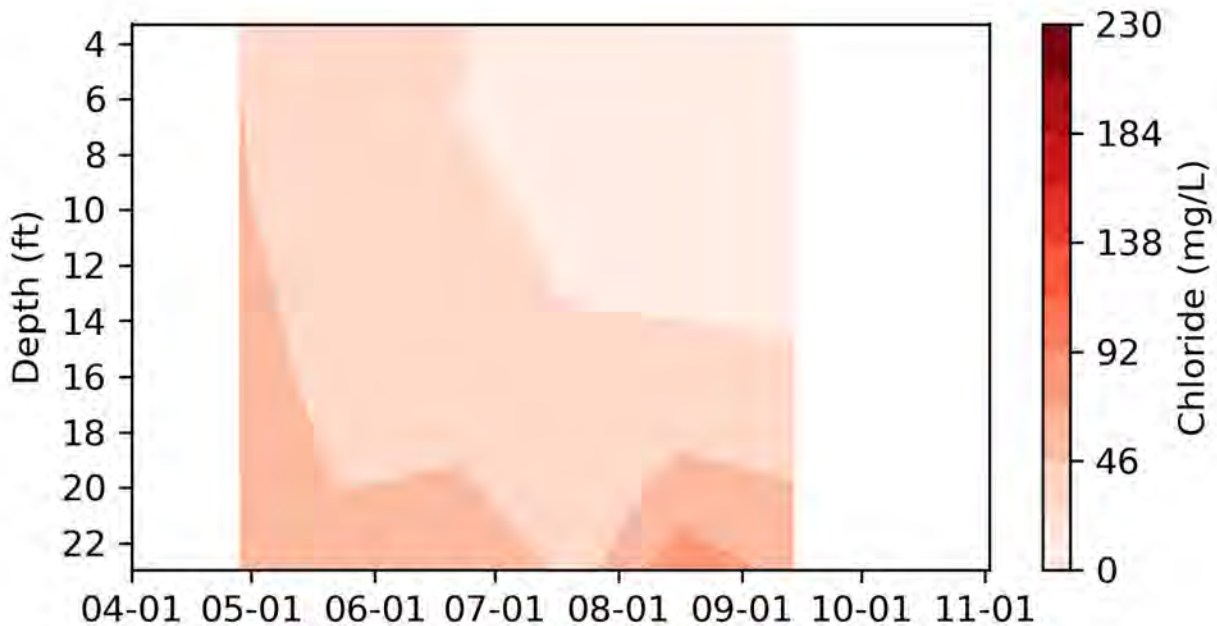


Figure 9. 2022 Shields Lake chloride profiles

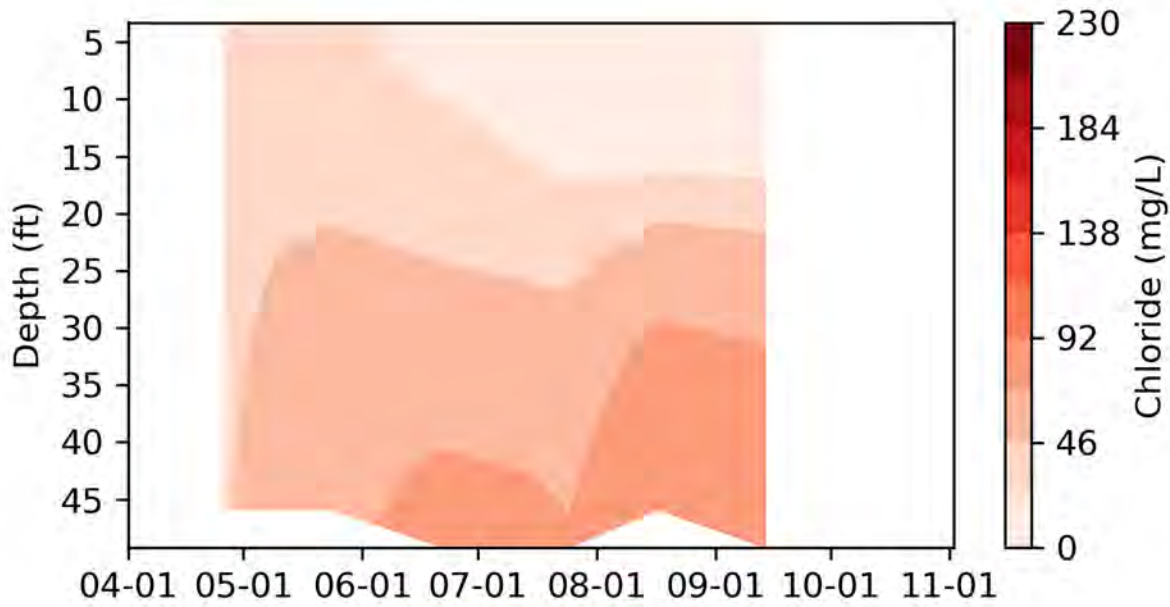


Figure 10. 2022 Little Comfort Lake chloride profiles

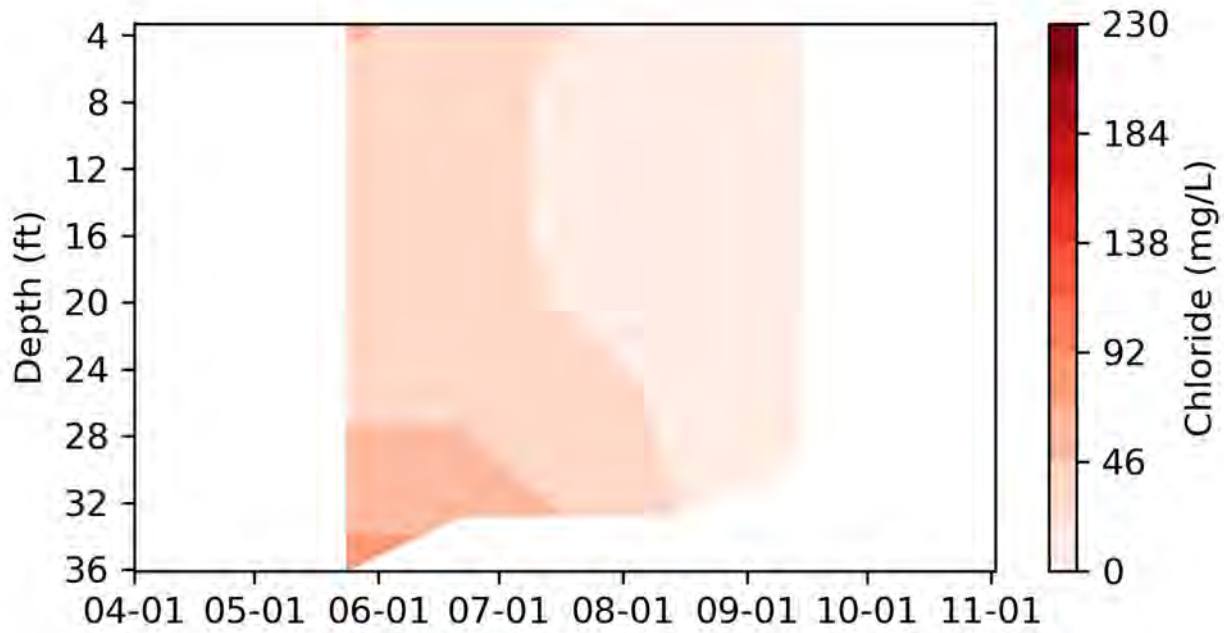


Figure 11. 202 Forest Lake - Middle basin chloride profiles

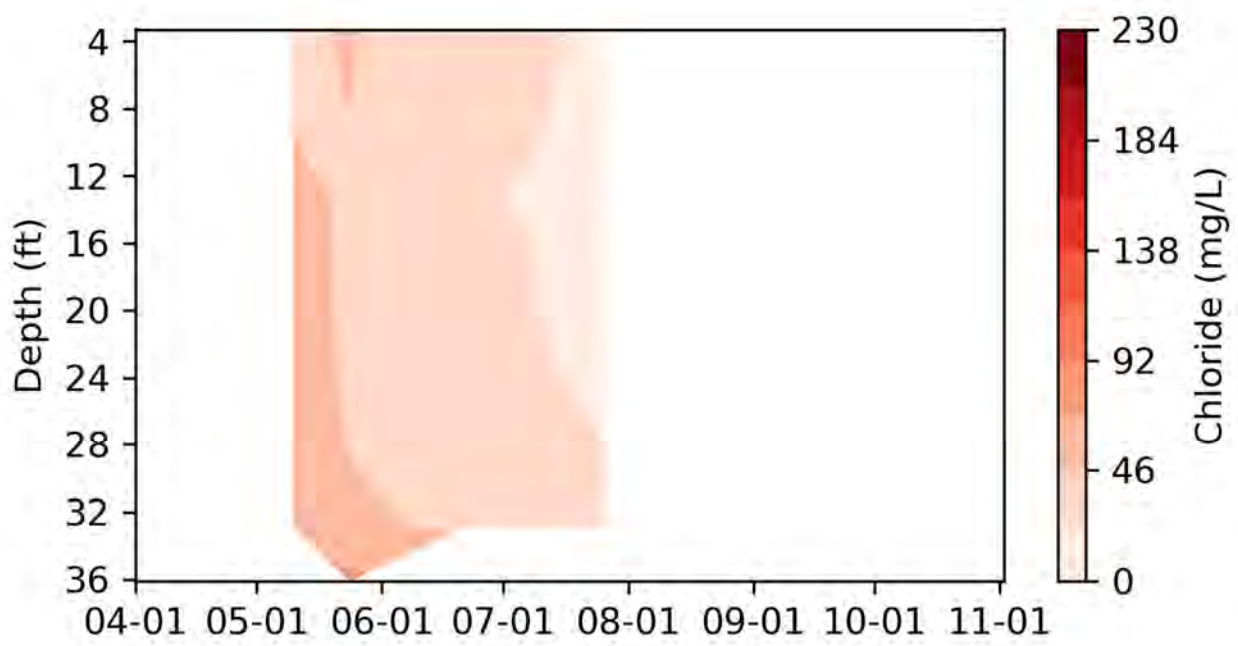


Figure 12. 2022 Forest Lake – East basin chloride Profiles

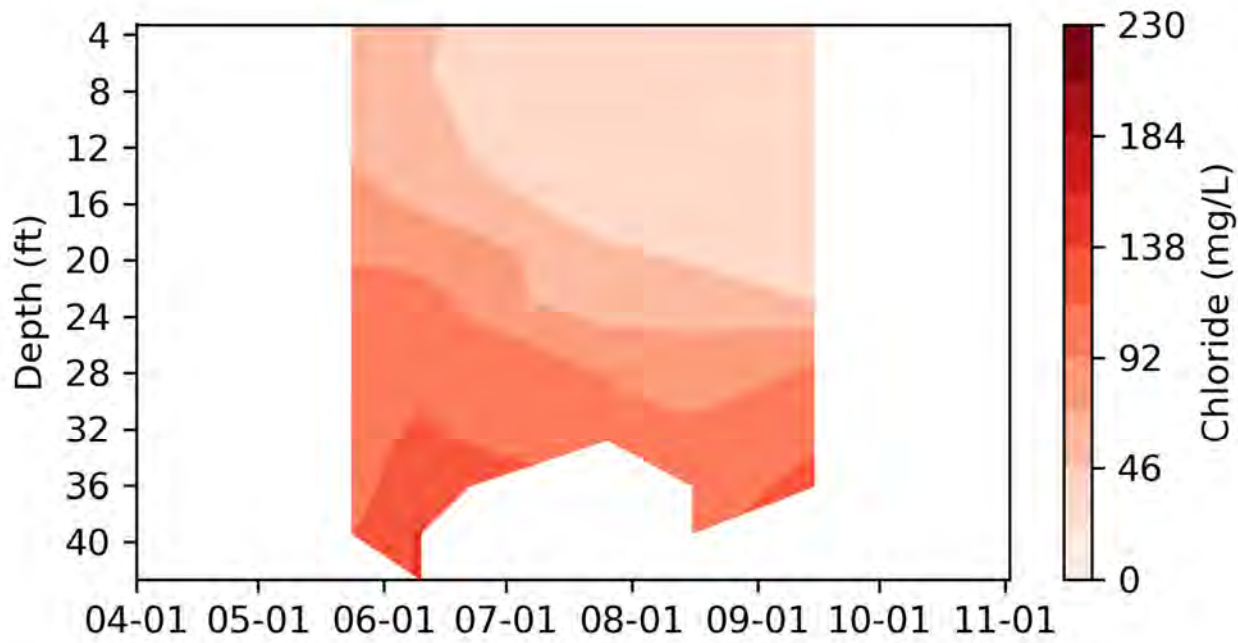


Figure 13. 2022 Comfort Lake Chloride Profiles

3. STREAM MONITORING

Streams are assessed by the Minnesota Pollution Control Agency (MPCA) for their ability to support aquatic life and aquatic recreation designated uses. Those designated uses are:

- Protection of “aquatic life” means protection of the aquatic community from the direct harmful effects of toxic substances, and protection of human and wildlife consumers of fish or other aquatic organisms.
- Protection of “aquatic recreation” means protection of the ability to recreate on and in Minnesota’s waters.

CLFLWD streams are Class 2B Waters, according to MPCA standards (Minn. R. 7050.0222). These types of streams are described as cool- and warm-water fisheries (not protected for drinking water). Class 2B Water Quality Standards are shown in Table 13.

Table 13. MPCA Class 2B Water Quality Standards

Parameter	Class 2B Waters Standard
Chloride (Chronic)	< 230 mg/L
Low Dissolved Oxygen (DO)	> 5 mg/L as daily minimum
pH	> 6.5 or < 8.5
Total Suspended Solids (TSS)	< 30 mg/L*
Total Phosphorus (TP)	< 100 µg/L**

* May be exceeded no more than 10% of the time (Apr. 1-Sept. 30)

** June-September 10-year average

In addition to Table 13 standards, the Escherichia (E.) coli standard requires not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, or more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31.

3.1. Purpose of collecting stream data

It is important to track these water quality standards at each stream monitoring site to determine if the waters are meeting State goals and whether they are impaired. For the purposes of identifying instances in which the MPCA 2B standards are not met, only discrete (grab) samples taken manually are considered in this report.

Multiple water quality parameters were monitored and analyzed at each stream site in 2022. The purpose of this monitoring was to assess and document the current water quality conditions of the streams, identify problem resources or areas, and to continue a long-term baseline monitoring program which will enable the District to identify trends.

3.1.1. Location

Long-term stream

The purpose of long-term stream monitoring is to understand the status of District resources, identify changes over time, and define problems at the watershed or subwatershed level.

There are 3 lake outlet sites with long-term records in CLFLWD: Bone Lake, Forest Lake, and Comfort Lake. Data from these sites are useful for calibrating H&H models and tracking total flow and loads discharged from the lakes over time to downstream waters. However, data from these sites is greatly influenced by the water quality of the lake itself and does not provide direct information on how landscape changes influence water quality over time.

There are 3 lake inlet sites with long-term records in CLFLWD: Bone Lake North Inlet, Comfort Lake Inlet, and Little Comfort Lake Inlet at Itasca Avenue. Data from these sites are useful for calibrating H&H models, tracking total flow and loads discharged to lakes over time, and can provide some information on how climate and landscape changes influence water quality over time.

Diagnostic

The purpose of diagnostic monitoring is to determine the specific causes of impairments to surface water and to quantify inputs/loads of contaminants to a water body from various sources. It is also used to determine the actions needed to return a resource to a condition that meets standards or goals. The findings from specific investigations can be used to refine/improve water quality modeling tools.

Project effectiveness

The purpose of effectiveness monitoring is to determine the effectiveness of a specific regulatory or management action taken to improve water quality. Examples of effectiveness monitoring include monitoring conducted following installation of a BMP or site-specific monitoring that is done to assess compliance with a permit or rule.

3.1.2. Physical Parameters

Temperature

Water temperature affects the oxygen content of the water (oxygen levels become lower as temperature increases), the rate of photosynthesis by aquatic plants, the metabolic rates of aquatic organisms, and the sensitivity of organisms to toxic wastes, parasites, and diseases. Aquatic organisms from microbes to fish are dependent on certain temperature ranges for their optimal health. Optimal temperatures for fish depend on the species. Some species survive best in colder water, whereas others prefer warmer water. Benthic macroinvertebrates are also sensitive to temperature changes and will move in the stream to find their optimal temperature range. If

temperatures are outside this optimal range for a prolonged period, organisms are stressed and can die. Warm temperatures (typically above 20 degrees Celsius, or 68 degrees Fahrenheit) can stress or cause mortality in cold water fish species. At this point, there are no known stream cold water fish species in the District.

Dissolved oxygen

The amount of dissolved oxygen (DO) available in the water is key to support aquatic life. A stream system both produces and consumes oxygen. It gains oxygen from the atmosphere and from plants because of photosynthesis. Running water, because of its churning, dissolves more oxygen than still water, such as that in a reservoir behind a dam.

Respiration by aquatic animals, decomposition, and various chemical reactions consume oxygen. If more oxygen is consumed than is produced, dissolved oxygen levels decline and some sensitive animals may move away, weaken, or die. DO levels fluctuate seasonally and over a 24-hour period. They vary with water temperature and altitude. Cold water holds more oxygen than warm water and water holds less oxygen at higher altitudes. Thermal discharges, such as water used to cool machinery in a manufacturing plant or a power plant, raise the temperature of water and lower its oxygen content.

Aquatic animals are most vulnerable to lowered DO levels in the early morning on hot summer days when stream flows are low, water temperatures are high, and aquatic plants have not been producing oxygen since sunset. DO levels below 5 mg/L can cause stress or mortality in fish and macroinvertebrates.

Water acidity

pH is a measure of the acidity of the water. pH affects many chemical and biological processes. Different organisms flourish within different pH ranges. The largest variety of aquatic animals prefer a range of 6.5-8.0. pHs outside this range reduces the diversity in the stream. Low pH can also allow toxic elements and compounds to become mobile and "available" for uptake by aquatic plants and animals. This can produce conditions that are toxic to aquatic life.

Specific conductance

Specific conductance is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge).

Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well and therefore lower the water. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported as conductivity at 25 degrees Celsius. Distilled water has a conductivity in the range of 0.5 to 3 $\mu\text{mhos/cm}$. The conductivity of rivers in the United States generally ranges from 50 to 1500 $\mu\text{mhos/cm}$. Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 $\mu\text{mhos/cm}$. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macroinvertebrates.

Turbidity

Turbidity is a measure of water clarity or how much the material suspended in water decreases the passage of light through the water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances. These materials are typically in the size range of 0.004 mm (clay) to 1.0 mm (sand). Turbidity can affect the color of the water. Higher turbidity increases water temperatures because suspended particles absorb

more heat. This, in turn, reduces the dissolved oxygen concentration. Higher turbidity also reduces the amount of light penetrating the water, which reduces photosynthesis and the production of DO. Suspended materials can clog fish gills, reducing resistance to disease in fish, lowering growth rates, and affecting egg and larval development. As the particles settle, they can blanket the stream bottom, especially in slower waters, and smother fish eggs and benthic macroinvertebrates. The Minnesota Class 2B water quality standard for TSS is 30 mg/L.

3.1.3. Nutrients

Phosphorous

Both phosphorus and nitrogen are essential nutrients for the plants and animals that make up the aquatic food web. Since phosphorus is the nutrient in short supply in most fresh waters, even a modest increase in phosphorus can, under the right conditions, set off a whole chain of undesirable events in a stream including accelerated plant growth, algae blooms, low dissolved oxygen, and the death of certain fish, invertebrates, and other aquatic animals.

There are many sources of phosphorus, both natural and human. These include soil and rocks, wastewater treatment plants, runoff from fertilized lawns and cropland, failing septic systems, runoff from animal manure storage areas, disturbed land areas, drained wetlands, water treatment, and commercial cleaning preparations.

Phosphorus has a complicated story. Pure, "elemental" phosphorus (P) is rare. In nature, phosphorus usually exists as part of a phosphate molecule (PO₄). Phosphorus in aquatic systems occurs as organic phosphate and inorganic phosphate. Organic phosphate consists of a phosphate molecule associated with a carbon-based molecule, as in plant or animal tissue. Phosphate that is not associated with organic material is inorganic. Inorganic phosphorus is the form required by plants. Animals can use either organic or inorganic phosphate. Both organic and inorganic phosphorus can either be dissolved in the water or suspended (attached to particles in the water column).

Nitrogen

Forms of nitrogen include ammonia (NH₃), nitrates (NO₃), and nitrites (NO₂). Nitrates are essential plant nutrients, but in excessive amounts can cause significant water quality problems. Together with phosphorus, nitrates can accelerate lake eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream. This, in turn, affects dissolved oxygen, temperature, and other indicators. Excess nitrates can cause hypoxia (low levels of dissolved oxygen) and can become toxic to warm-blooded animals at higher concentrations (10 mg/L or higher) under certain conditions.

The natural level of ammonia or nitrate in surface water is typically low (less than 1 mg/L). In the effluent of wastewater treatment plants, it can range up to 30 mg/L. Sources of nitrates include wastewater treatment plants, runoff from fertilized lawns and cropland, failing on-site septic systems, runoff from animal manure storage areas, and industrial discharges that contain corrosion inhibitors.

Nitrates from land sources end up in rivers and streams more quickly than other nutrients like phosphorus. This is because they dissolve in water more readily than phosphates, which have an attraction for soil particles. As a result, nitrates serve as a better indicator of the possibility of a source of sewage or manure pollution during dry weather. Water that is polluted with nitrogen-rich organic matter might show low nitrates. Decomposition of the organic matter lowers the dissolved oxygen level, which in turn slows the rate at which ammonia is oxidized to nitrite (NO₂) and then to nitrate (NO₃). Under such circumstances, it might be necessary to also monitor for nitrites or ammonia, which are considerably more toxic to aquatic life than nitrate. There is currently no nitrate standard to protect aquatic life in Minnesota; nitrate levels must be below 10 mg/L in drinking water sources.

3.1.4. Bacteria

Escherichia coli

Members of two bacteria groups, coliforms and fecal streptococci, are used as indicators of possible sewage contamination because they are commonly found in human and animal feces. Although they are generally not harmful themselves, they indicate the possible presence of pathogenic (disease-causing) bacteria, viruses, and protozoans that also live in human and animal digestive systems. Therefore, their presence in streams suggests that pathogenic microorganisms might also be present and that swimming and eating shellfish might be a health risk.

Since it is difficult, time-consuming, and expensive to test directly for the presence of a large variety of pathogens, water is usually tested for coliforms and fecal streptococci instead. Sources of fecal contamination to surface waters include wastewater treatment plants, on-site septic systems, domestic and wild animal manure, and storm runoff. *E. coli* is a species of fecal coliform bacteria that is specific to human fecal material and other warm-blooded animals.

3.1.5. Flow

Stream flow is the total volume of water going past a point. Higher stream flows may represent more precipitation or more runoff generated by precipitation due to greater imperviousness (such as in developed landscapes) or drainage (such as ditched landscapes) in a watershed.

3.1.6. Runoff Depth

Runoff depth is the depth of the total volume of water going past a point if it were evenly distributed across the monitoring site drainage area. Runoff depth normalizes stream flow to annual precipitation. Higher runoff depth may represent more runoff generated by precipitation due to greater imperviousness or drainage in a watershed.

3.1.7. Pollutant Load

The District measures continuous stream flow and collects water quality concentration samples to model the total pollutant load discharged to and from District lakes. Load can be thought as the total amount of phosphorus or other pollutants moving past a point in the stream and is equal to the amount of pollutant per volume of water times the total volume of water going past a point (Figure 14). Higher loads may represent more precipitation or more phosphorus concentration sources compared to lower loads.

$$\text{Concentration} \times \text{Flow} = \text{Load}$$

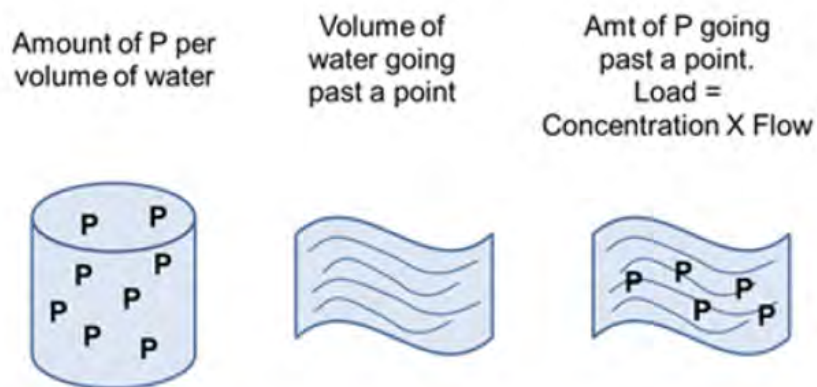


Figure 14. Relationship between stream flow and pollutant concentrations and loads

Flow-weighted Mean Concentration

The flow-weighted mean concentration (FWMC) is calculated as the total annual load divided by the total annual flow. The FWMC indicates how much pollutant is discharged relative to the flow. The phosphorus FWMC tends to have a greater impact on lake water quality than the total phosphorus load. The state lake water quality standards for deep lakes in the North Central Hardwood Forests region of 40 µg/L can typically be met when watershed runoff TP FWMC are less than 100 µg/L. For example, if the TP load and flow both increase to a lake, resulting in a similar TP FWMC, the higher TP load will have less impact on lake water quality because the time the load spends in the lake decreases under higher flows (water flows in and out of the lake faster).

Total flow and pollutant loads are most influenced by the amount and timing of precipitation, in addition to changes in land use, and implementation of BMPs. During wet years, pollutant loads may be higher due to overall higher watershed runoff and flows, even without any significant changes in land use or BMP implementation that influence the amount of pollutant loads. In this way, flow weighted mean pollutant concentrations are better indicators of watershed changes, such as land use changes or implementation of BMPs, than total phosphorus loads.

4. LONG-TERM MONITORING (LEGACY)

Six long-term monitoring sites (Figure 4) are monitored each year to track large-scale pollutant load reduction trends within each of the four Lake Management Districts (LMDs): Comfort LMD, Little Comfort LMD, Forest LMD, and Bone LMD. All these sites have ISCO units, which collect stage data (water levels) to measure flow at the sites. Flow levels trigger the collection of samples for water quality analysis. The samples are collected over a 24-hour period and composited into one sample that would be representative of the concentration of pollutants during the event. This composited sampling reduces the lab analysis cost and provides more accurate results that represent an entire event, rather than just a point in time.

4.1. Long-term Monitoring Summary

As shown in Table 14, very few water quality samples were composited during 2022 due to low rain conditions during the first part of summer and early Fall. No samples were collected in BL1, and the maximum number of samples collected for one of these sites was three, which was achieved for FL1 and BL2. Due to a power outage, there was also a significant data gap for station FL1 and CL2. Pollutant loads cannot be accurately calculated when large gaps in data are present. Additionally, for statistical validity, sites with less than five samples are considered insufficient by the FLUX32 program for load calculations. No long-term monitoring sites meet this requirement. Therefore, for the two sites with the three samples load estimates are provided but, the uncertainty of these loads is unknown and should be used with caution.

Table 14. Long-term monitoring sites

Lake Management District	Site Description	Site code	# of water quality samples (2022)
Comfort Lake	Comfort Lake Outlet	CL1	1
	Comfort Lake Inlet	CL2	1
Little Comfort Lake	Little Comfort Lake Inlet	LC1	2
Forest Lake	Forest Lake Outlet	FL1	3
Bone Lake	Bone Lake North Inlet	BL1	0
	Bone Lake Outlet	BL2	3

4.2. Results

Stream water chemistry grab sample results for total suspended solids, phosphorus, nitrogen, iron, and chloride are reported for five of the six long-term stream monitoring sites in Appendix B:

- Comfort Lake Outlet and Inlet (Table 23 and Table 24)
- Little Comfort Inlet (Table 25)
- Forest Lake Outlet (Table 26)
- Bone Lake Outlet (Table 27)

Most of the time stream water quality is generally good throughout the District as observed by stream chemistry concentrations that are low and generally below state standards for all sites except occasional exceedances of total phosphorus and total suspended solids stream standards. Notably nitrogen levels are very low, and no chloride readings exceeded State standards District-wide.

Total runoff volume, TP and TSS loads, and FWMC were determined using FLUX32. Table 15 summarizes the long-term monitoring site results. The results are discussed by LMD in the following sections.

Table 15. 2022 Long-term Stream Monitoring Site Concentrations and Loads.

Monitoring Site		MPCA Station ID	Drainage Area (acres)	Days of Flow	Number of Sample Events	Flow			Total Phosphorus			Total Suspended Solids		
						Daily Mean (cfs)	Volume (ac-ft)	Runoff depth (in)	FWMC (µg/L)	Load (lbs.)	CV	FWMC (mg/L)	Load (lbs.)	CV
Central Region Reference FWMC									<100			< 30		
Long-term Sites														
Bone Lake North Inlet	BL1	S004-471	2,479	146	0	0.5	157	0.8	*	*	*	*	*	*
Bone Lake Outlet	BL2	S004-463	5,495	135	3	5.0	1328	2.9	170	615	*	51	182,765	*
Forest Lake Outlet	FL1	S004-466	8,719	189**	3	6.9	2588	3.6	111	782	*	60	422,106	*
Little Comfort Inlet	LC1	S001-232	10,513	196	2	5.4	2081	2.4	*	*	*	*	*	*
Big Comfort Inlet	CL2	S001-223	13,625	203**	1	8.4	3390	3.0	*	*	*	*	*	*
Big Comfort Outlet	CL1	S004-468	24,558	181	1	17.5	6273	3.1	*	*	*	*	*	*

* Not enough samples to calculate FWMC and loads.

** Gaps in the flow hydrograph were filled in using area or flow-weighting with nearby monitoring sites.

Bolded values have very high coefficient of variation (i.e., high uncertainty > 0.5) and should be used with caution.

Shaded FWMC values exceed the Central Region Reference values

4.2.1. Comfort Lake Management District

In 2022, diagnostic monitoring was conducted for Comfort LMD. There are two long-term monitoring sites within the Comfort LMD, Comfort Lake inlet (CL2) and Comfort Lake outlet (CL1). Sampling site's locations are shown in Figure 4.

At CL1, flows peaked at 66 cfs in May and then decreased to completely dry conditions in September (Figure 18 and Figure 19 in Appendix B.1).

At CL2, flows peaked at 44 cfs also in May and significantly decreased by late summer (Figure 20 and Figure 21 in Appendix B.1).

CL1 showed evidence of a possible obstruction towards the end of July with predicted flows elevated above reasonable values for the hydrologic conditions and compared to flows at upstream monitoring sites. Only one sample (May/2/2022) could be taken throughout the season for both CL2 and CL1. Both TSS and TP concentrations met District's water quality goals and MN Class 2B Standards (Table 23 and Table 24 in Appendix B.1).

4.2.2. Little Comfort Lake Management District

There is one long-term monitoring site in the Little Comfort LMD, which is the inlet into Little Comfort from the School Lake tributary (LC1). The location of this sampling site is shown in Figure 4.

Flows were present throughout the entire season and varied between 0.6 cfs and 23 cfs. After August 1 the flow hydrograph is considered provisional due to blockages in the stream (Figure 22 and Figure 23 in Appendix B.2).

Of the two samples collected, one high TSS and TP concentration sample was collected during a blockage in early August (Table 25 in Appendix B.2). Blockage produces stagnant water and stagnant water in streams routinely leads to very high pollutants' concentrations. This may be part of the cause for past high water quality concentrations measured at this site.

Blockage and backup situations

Each year, the Little Comfort Inlet (LC1) exhibits blockages (beaver action at the culvert crossing underneath Itasca Avenue) and backups from Comfort and Little Comfort Lakes water elevations. These dual situation makes measuring water flows, determining water volumes, and calculating pollutant loads very difficult. The random nature of these blockages and backups also makes them difficult to predict and act proactively.

In 2022, three blockages were removed on three separate occasions: June 15th, August 25th, and September 26th. There was a significant increase in the water's stage in August and September when these blockages were preventing water from traveling downstream and entering Little Comfort Lake. When the obstructions were removed, the water level at the upstream of the channel dropped approximately 1.5 feet, resulting in a large and sudden flush of water downstream.

Developing an accurate stage/discharge rating curve to calculate flows at LC1 was problematic. When there is a blockage, flow rates do not increase as stage (water level on the upstream side) increases, as it is the case in standard flow rating curve development. In a blockage situation, the water level in the upstream side could be high, indicating that more flow is passing by, but in reality, there is less flow because free flow is prevented.

Regarding backups from Comfort and Little Comfort Lakes water elevations, Figure 15 shows that the invert of the Little Comfort Lake Inlet (LC1) has consistently been below the elevation of Comfort Lake, indicating almost constant tailwater (backup) impacts at LC1. This adds to the challenge of using the standard stage/discharge flow rating curve

approach. Overcoming these blockage/backup impacts will require a more sophisticated approach involving evaluation of the unique system dynamics at the site.

Due to the ecological significance of this site's surroundings, as well as the long history of data available, several recommendations are provided in the next section. The challenge is how to monitor Little Comfort LMD more holistically to better understand the impact of this system on the overall Comfort Lake-Forest Lake Watershed.

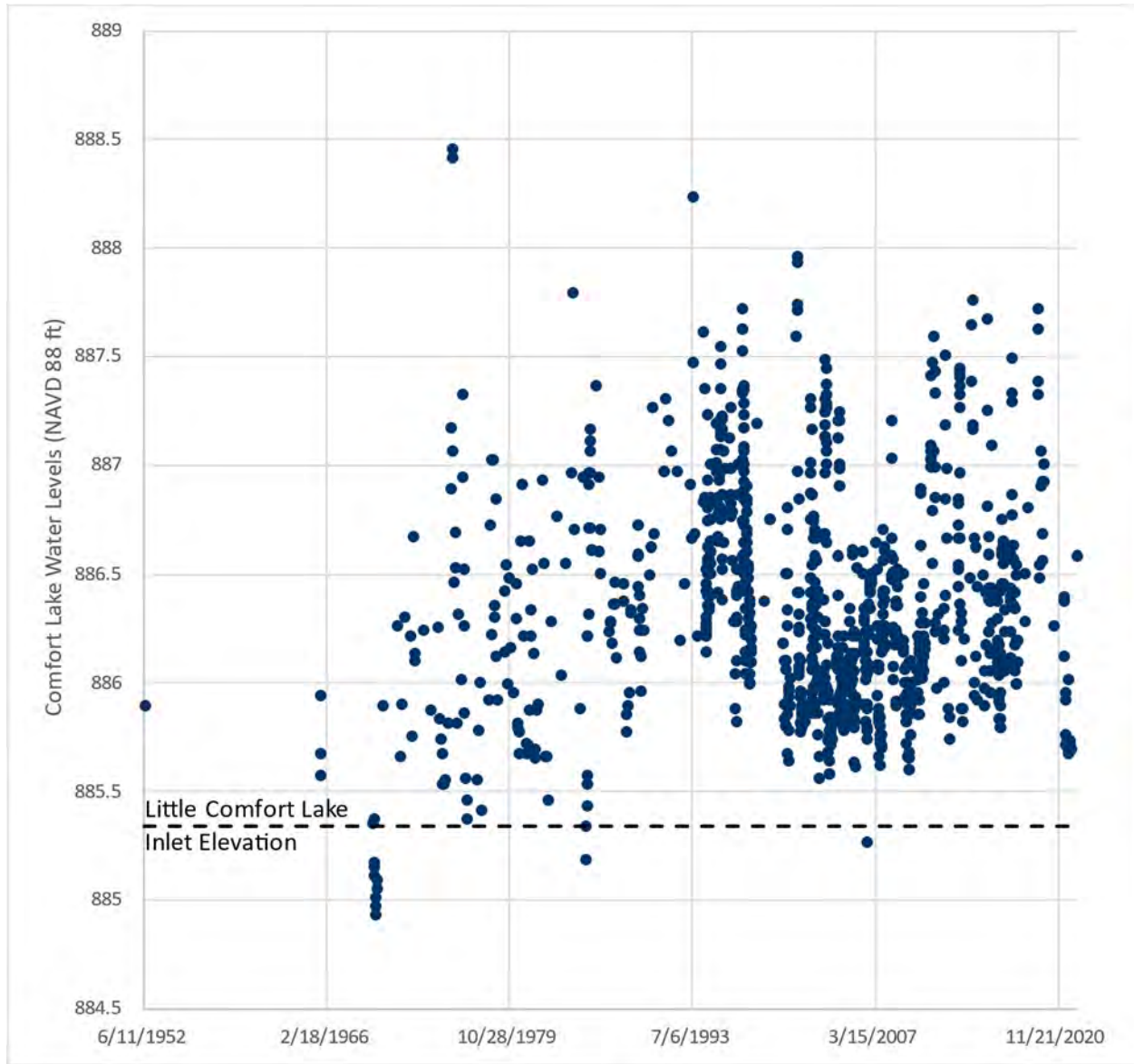


Figure 15. Historical Comfort Lake water levels compared to the LC1 inlet elevation

Little Comfort LMD Recommendations

- Short-term – Manage site conditions to get more usable data next year.
 - Continued water quality, stage, and flow monitoring.

- Continued internal loading monitoring at the bottom (hypolimnion) and where lake stratification takes place (metalimnion)
- Consider beaver deceiver device, blocking the culvert from beaver activity while other approaches to managing this are explored.
- Include additional lab analysis of TSS data to differentiate volatile suspended solids (VSS) to provide insight into whether TSS at this location is related to upland erosion or organic material from adjacent wetlands.
- Long-term - Comprehensive analysis and assessment of the complex Little Comfort Lake system
 - Monitor beaver activity and identify strategies for management, especially downstream of Itasca Avenue North. It is recommended that this assessment is conducted in partnership with someone who has expertise and knowledge in beaver management, particularly within ecosystems such as this one.
 - Evaluate the extent of tailwater impacts to water elevations by looking at stage data in Little Comfort Lake and Comfort Lake, and comparing water elevations to what is being seen at the LC1 monitoring site. These lake elevations should be measured on the same day to make it easier to compare water levels.
 - Modeling - To better understand the impact of LC1 on the Little Comfort Lake system, it is recommended that this data be evaluated using the District's H&H model. This would allow for a more accurate and robust understanding of how such damming activities are influencing an accurate calculation of Little Comfort Lake's pollutant loads.

4.2.3. Forest Lake Management District

FL1 is the one long-term monitoring site in the Forest LMD, which is the outlet from Forest Lake into the Sunrise River. The location of this sampling site is shown in Figure 4.

Flows peaked at 29 cfs in May and were significantly reduced by mid-July (Figure 24 and Figure 25 in Appendix B.3). Stage data was lost between early May and late June due to a power failure. Flows during this period were approximated using the downstream monitoring site (CL7-E) and flow weighting for days where both sites had observed flows. Very low flows were present from early summer until the end of the season.

All three water quality samples had elevated total phosphorus and total suspended solids concentrations (Table 26 in Appendix B.3). Two of the three samples, however, were during very low flows which can produce abnormally high concentrations.

4.2.4. Bone Lake Management District

There are two long-term monitoring sites within the Bone LMD, the north inlet into Bone Lake (BL1) and the Bone Lake outlet (BL2). The location of these sampling sites is shown in Figure 4. No samples were collected at BL1 due to no flow conditions.

Flows at the Bone Lake North inlet (BL1) peaked at 6 cfs, but eventually the site dried out completely by early July (Figure 26 in Appendix B.4). Flows at the Bone Lake Outlet (BL2) are moderated by the lake and are mostly maintained above 6 cfs until July (Figure 27 and Figure 28 in Appendix B.4). The outlet stopped flowing in early August.

Concentrations of the three TSS samples at BL2 were relatively low while the three TP concentration samples were above the recommended 100 µg/L (Table 27 in Appendix B.4). Two of the three samples (8/8/2022 and 8/19/2022) were collected during very low flows.

4.3. Long-term Monitoring Recommendations

Due to the many challenges present in collecting, interpreting, and analyzing data from the long-term stream monitoring sites, especially during periods of drought, EOR recommends a more comprehensive approach to measuring loads within these sites. This can be accomplished by developing a thorough statistical model.

Currently, data is summarized each year, without using past data to help fill key gaps in stage, discharge, and water quality. In developing a customized statistical model, data from previous years can be used to develop daily estimates that can then be verified with annual data and discrete water quality sampling points. This would also allow for more targeted sampling and data collection, focused on filling key data gaps. The ultimate goal, as it has been the case in past monitoring efforts, is to keep improving methods that would result in a better and more accurate assessment of water quality trends across the District and a better understanding of the dynamic nature of these systems.

DRAFT

5. DIAGNOSTIC MONITORING

Diagnostic monitoring is conducted on a rotating basis for the four LMDs within the District. This year, diagnostic monitoring was conducted in the Comfort LMD. Several drainageways were monitored to identify any pollutant hotspots that need more attention.

5.1. Diagnostic Monitoring Summary

Eleven sites were included in the diagnostic monitoring effort for 2022 (Table 16). The location of these sampling sites is shown in Figure 4.

Table 16. Comfort Lake Diagnostic site descriptions and associated number of grab samples

Site Description	Site Code	Site type	# of Water Quality samples
Heims outlet	CL6	Pollutant Load	3
Downstream 35	CL5-B	Water quality	0
Fallbrook Ave	CL5-A	Pollutant Load	4
Highway 61	CL5	Pollutant Load	6
Sunrise @ Tax Forfeit	CL4-A	Water quality	0
County Line Ditch	CL7-G	Pollutant Load	8
JD2 @ Forest Road N	CL7-F	Pollutant Load	8
City Wetland	CL7-E	Pollutant Load	3
City Pipe @ Wetland	CL7-D	Pollutant Load	5
Sunrise @ 256th	CL3	Pollutant Load (ISCO)	0
Sunrise @ Greenway Ave	CL4	Pollutant Load (ISCO)	2

5.1.1. Data gaps

Due to access and field conditions issues, it was not possible to monitor CL5-B and CL4-A this year. Also, the level logger CL7-G data presented some problems being downloaded at the end of the season. The level logger was sent back to the manufacturer, but in the end the data could not be recovered. Finally, due to the unsafe conditions within the drainageway, a flow rating curve could not be fully developed for site CL7-F. The discharge calculation was further complicated by a potential obstruction in the channel which may have increased the predicted flows at the site. Alternatively, higher volumes at this site may be due to the significantly higher impervious area within the watershed which may have continued to deliver flow to the stream during the very dry months of June and July.

5.1.2. Results

Table 17 summarizes the diagnostic stream monitoring site concentrations and loads. Flow hydrographs paired with TSS and TP are shown in Appendix C. As discussed previously the significant dry conditions in June and July dried up most of the streams in the District. Monitoring data available to estimate flow weighted mean concentrations and loads was limited.

To minimize the impact of the missing concentration data and augment the data base, concentrations observed during the May 2nd event (one of the largest in 2022) were included in the analysis. The May 2nd event is an example of a runoff-driven event at high flows, and it does not capture wetland release which is more important in the watershed later in the summer during July and August.

Data is summarized in Table 17 by tributary within the Comfort LMD starting at the upstream end and moving downstream. Key findings from the diagnostic monitoring include:

- Most of the water quality concentrations during the May 2nd event were well below State standards
- The wetland complex between County Line Ditch and 256th St. removes a large volume of water due to evapotranspiration.
- JD2 likely contributes a larger percentage of runoff during dry years because of the high impervious area.
- When Heims outlet contributes runoff downstream, which isn't often, the concentrations are high.
- The extraordinarily flat drainage area in the District makes monitoring difficult as blockages and obstructions can potentially influence large areas.
- The low runoff depth at all three Heims drainage ditch monitoring sites suggests a large potential in the watershed to absorb runoff due to wetland landcover and potentially closed basins within the watershed.
- Higher water quality concentrations are more likely later in the summer as shown throughout many stream sites (Appendix C) and is likely caused by wetland release and stagnant flow conditions.

5.2. Recommendation

Like in the long-term stream monitoring sites, it is recommended that a statistical model is developed for the diagnostic sites to better track and estimate conditions within these systems as rotational monitoring is conducted.

Table 17. 2022 Diagnostic Stream Monitoring Site Concentrations and Loads.

Monitoring Site		MPCA Station ID	Drainage Area (ac)	Days of Flow	Number of Sample Events	Flow			Total Phosphorus				Total Suspended Solids			
						Daily Mean (cfs)	Volume (ac-ft)	Runoff Depth (in)	May 2 nd Concentration (µg/L)	FWMC (µg/L)	Load (lbs)	CV	May 2 nd Concentration (mg/L)	FWMC (mg/L)	Load (lbs)	CV
Central Region Reference FWMC									<100	<100			<30	<30		
Comfort LMD																
Sunrise River																
Forest Lake Outlet	FL1	S001-234	8,719	189	3	7	2,588	3.6**	110	111	782	*	60	60.0	422,105.6	*
City Wetland	CL7-E		8,831	184	2	8	2,956	4.0	15				3.2			
County Line Ditch	CL7-G		10,563	162	7	13	4,184	4.8*	31	74	842	0.31	3.8	7.4	841,74.6	0.26
Sunrise River at Greenway Ave.	CL4		12,954	203	2	9	3,449	3.2	90				16			
Sunrise River at 256th St.	CL3		13,311	155	0	12	3,599	3.2								
Big Comfort Inlet	CL2		13,625	203	1	8	3,390	3.0**	53				8			
Big Comfort Outlet	CL1		24,558	181	1	17	6,273	3.1*	45				7			
Heims Drainage Ditch																
Heims Outlet	CL6		668	184	2	0	17	0.3	161							
Fall Brook Ave.	CL5-A		1,359	184	2	0	19	0.2	79				3.2			
Heims Drainage Ditch	CL5		1,561	184	5	0	92	0.7	64	109	27	0.35	2	9.4	2,334.1	0.69
Other Tributaries																
City Pipe at Wetland	CL7-D		80	184	5	0	31	4.6	70	181	15	0.17	3	5.1	422.2	0.04
JD2	CL7-F		1,675	NA	NA	NA	1,228***	8.8	63				2.2			

* Possible Obstruction elevated predicted flows using rating curve

** Provisional flow data used to fill data gaps

*** Calculated using mass balance assumptions

Bolded values have very high coefficient of variation (i.e., high uncertainty > 0.5) and should be used with caution.

Shaded FWMC values exceed the Central Region Reference values

6. EFFECTIVENESS MONITORING

Castlewood Agricultural BMPs and Broadway Avenue Iron Enhanced Sand filter (IESF) were the two projects assessed for performance effectiveness (Table 18). The location of these sampling sites is shown in Figure 4.

Table 18. Sites assessed for effectiveness and number of stormwater grab samples

Site Description	Site Code	# of Water Quality samples
Castlewood Agricultural BMPs - Outlet	FL8-U	8
Broadway Avenue IESF - Outlet	CL7-C	1
Broadway Avenue IESF - Inlet	CL7-B	5

6.1. Castlewood Agricultural BMPs

This site is an agricultural field located in the Forest Lake drainage area west of Forest Lake – Middle (see Figure 4). This field was actively row cropped and showed erosion coming from the field into the adjacent drainageway. The site is currently being rented by the CLFLWD and has been revegetated with perennial cover with goal of reducing sediment and nutrient runoff.

6.1.1. Results

The effectiveness of this revegetation was measured by collecting samples at the downstream end of the adjacent drainageway throughout the season. The water quality samples for 2022 are shown in Table 19, and for comparison, the samples collected in 2021 are shown in Table 20.

Table 19. Stormwater Grab Samples for FL8-U in 2022

Date	Time	TP (mg/L)	OPO4 (mg/L)	TSS (mg/L)
3/21/2022	11:15	0.475	0.400	3.73
4/7/2022	15:30	0.171	0.112	2.00
5/2/2022	16:40	0.097	0.054	1.40
5/12/2022	13:40	0.306	0.204	6.00
March – May Average (2022)		0.26	0.19	3.3
7/15/2022	16:30	1.489	0.525	792
8/8/2022	9:50	1.547	0.590	285
8/17/2022	17:00	0.459	0.371	37.2
8/19/2022	15:15	0.198	0.135	5.00
Total Average (2022)		0.59	0.29	141.58

Table 20. Stormwater Grab Samples for FL8-U in 2021

Date	Time	TP (mg/L)	OPO4 (mg/L)	TSS (mg/L)
3/11/2021	12:30	0.27	0.22	3.87
3/24/2021	17:40	0.19	0.13	5.80
4/7/2021	8:05	0.08	0.06	1.60
5/20/2021	15:00	0.29	0.22	4.50
5/27/2021	16:01	0.23	0.19	4.00
Total Average (2021)		0.21	0.17	3.80

Total averages in Table 19 and Table 20 show that concentrations were higher in 2022 than in 2021. Nevertheless, there are specific considerations that need to be factored in these results:

- The samples in 2022 were collected throughout the entire season. July - August is the time of the year when we can expect the highest TP, Orthophosphate, and TSS concentrations. 2021 sampling did not include July and August.
- As shown in Figure 16 and Figure 17, the high concentrations in 2022 occurred during periods of very low flow (close to zero).
- Field notes indicate that the water was “stagnant and mucky” when these samples were collected in July and August 2022. It is very possible that the two orders of magnitude difference between 2021 and 2022 TSS is due some bottom sediments in the samples.

If we compare 2021 and 2022 averages only for the common months (March to May) the results are very close (March - May average Table 19 and Total average in Table 20). TP and Orthophosphate concentrations slightly higher in 2022, and TSS slightly higher in 2021. Based on this analysis, we can conclude that from March to May the site is providing very similar treatment in 2022 and 2021.

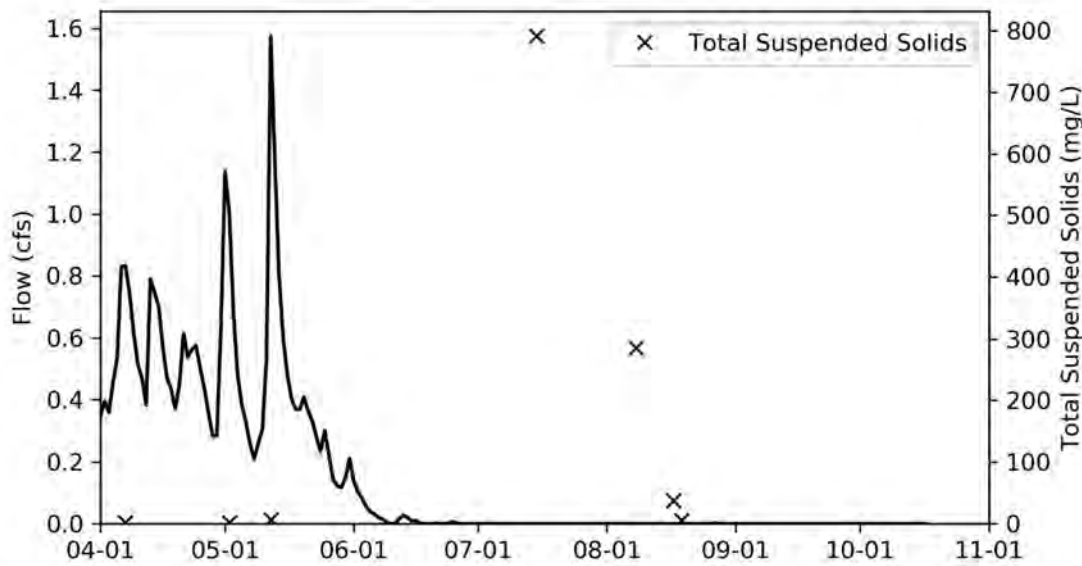


Figure 16. FL8-U 2022 flowrates and associated TSS concentrations

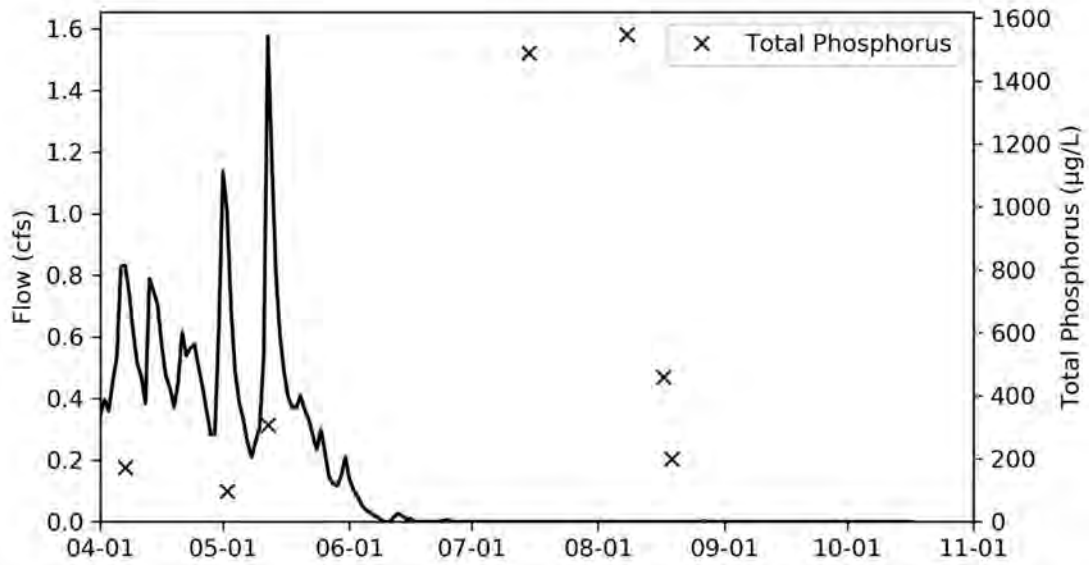


Figure 17. FL8-U 2022 flowrates and associated TP concentrations

6.1.2. Recommendations

Due to the high concentrations of TSS, Orthophosphate, and TP in July and August, EOR recommends conducting a site visit during the growing season and July/August to determine if the perennial vegetation has established itself and look for signs of active erosion. Additionally, it is recommended that this site is monitored again in future years. Weather permitting, additional samples in the months of July and August during storm events would be useful. If high concentrations continue, additional BMPs may be needed in the fields or in line with the drainageway.

6.2. Broadway Avenue IESF

The Broadway Avenue IESF is in the upstream section of the Comfort Lake drainage area (see Figure 4). The facility was designed to capture and treat runoff from Broadway Avenue along with existing impervious areas tributary to the roadway. This was a 2011 County's project implemented in partnership with the landowner (City of Forest Lake) and CLFLWD.

6.2.1. Results

Effectiveness of IESF projects can be assessed by collecting TP, Orthophosphate, and TSS concentrations at inlet and outlet simultaneously. In 2022, only one sample (May 12th) was collected at CL7-C (outlet). The reasons for this lack of data at the outlet were:

- The low precipitation in June through September (excluding August) shown in Figure 3
- The storage capacity of the sand bed itself that can capture a significant volume of runoff after a storm event. The outlet was dry most of the time in 2022.

Table 21 and Table 22 show TP, Orthophosphate, and TSS concentrations for the 6 samples collected.

May 12th, 2022, is the only common sample collected at both inlet and outlet. The samples were taken within 10 minutes from each other, first the inlet and 10 minutes later the outlet. Keeping in mind that no definitive assessment or conclusions can be derived from only one sample, we could make some general preliminary evaluation of the results that will have to be corroborated with more data in the future:

- The overall effluent concentrations patterns of the May 12th, 2022 sample are consistent with other sporadic samples collected at the site in past years.
- TP concentrations decreased and Orthophosphate concentrations increased. Since the TP concentration is reduced, this would point to a potential Orthophosphate leaching from the EISF facility since compost was added to the filter bed at the time of design and construction. This potential Orthophosphate leaching was also pointed out in the past.
- TSS concentration reduction in the facility is significant. This seems to indicate that the filtration component of the EISF works well.

Due to the facility's high capacity for runoff storage (sand bed interstitial volume, infiltration, and evapotranspiration), a very high percentage of runoff volume gets retained in the facility. Therefore, reducing TP, Orthophosphate, and TSS concentrations may not be as critical to achieve significant load reductions as it would be maintaining the retention capacity of the practice.

Table 21. Stormwater grab sample for CL7-C (outlet effluent) in 2022

EOR Site	Date	Time	TP (mg/L)	OPO4 (mg/L)	TSS (mg/L)
CL7-C	5/12/2022	11:30	0.139	0.088	3.20

Table 22. Stormwater grab samples for CL7-B (inlet) in 2022

EOR Site	Date	Time	TP (mg/L)	OPO4 (mg/L)	TSS (mg/L)
CL7-B	5/12/2022	11:20	0.221	0.062	46.80
CL7-B	7/15/2022	10:55	0.257	0.046	184
CL7-B	8/8/2022	10:20	0.351	0.024	23.4
CL7-B	8/17/2022	16:30	0.102	0.020	12.7
CL7-B	8/19/2022	14:55	0.102	0.021	16.0

6.2.2. Recommendations

As part of the recent regional treatment study completed by the City of Forest Lake, the City is considering to expand this IESF facility to provide treatment for future redevelopment. It is recommended that the entire filter bed be replaced in conjunction with future work done on this facility. The iron sand filter bed should be redesigned to current standards, compost should not be incorporated in the soil mix, a prairie mix should not be planted within the filter, and the outlet structure should be reconfigured to ensure the drain tiles in the filter can completely drain and the filter remains aerobic.

If further documentation is required to justify the filter bed replacement, it is recommended to take soil samples to verify the TP to Iron ratio in the facility. A TP to Iron (Fe) Ratio greater than or equal to five (TP:Fe >= 5) indicates that the sand bed needs to be replaced.

APPENDIX A. LAKE MONITORING SHEETS

Information on how to read the information provided in the individual lake summaries is provided in the Bone Lake example. Individual lake summaries were developed for the lakes with District goals that were monitored in 2022:

1. Bone
2. Comfort
3. Elwell
4. Forest Lake – West Basin
5. Forest Lake – Middle Basin
6. Forest Lake – East Basin
7. Heims
8. Keewahtin
9. Little Comfort
10. Lendt
11. Moody
12. School
13. Shields
14. Third
15. Twin

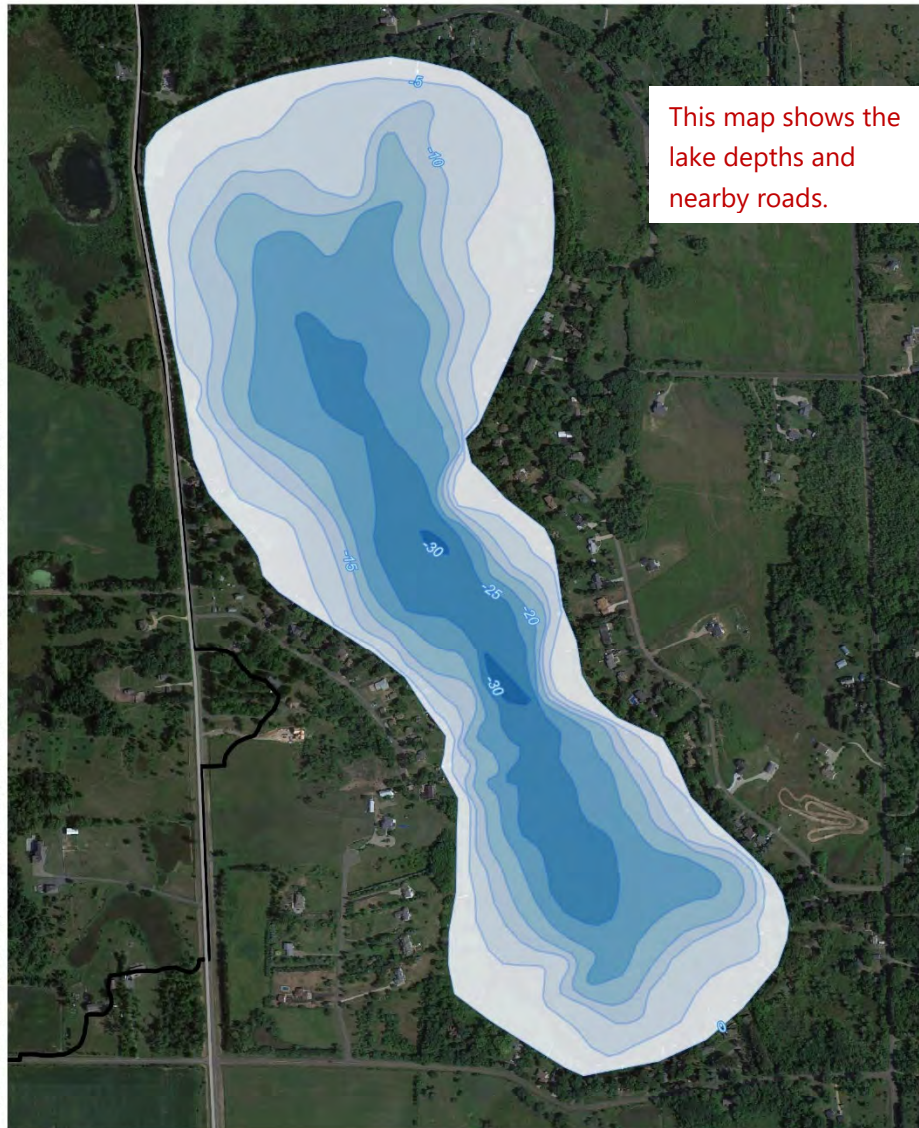
DRAFT

Example Lake Summary (BONE LAKE)

Fast Facts:

DNR Lake ID: 82-0054-00
County: Washington
Surface Area: 221 acres
Littoral Area (depths less than 15 feet): 124 acres
Maximum Depth: 30 feet
Shore Length: 3.01 miles

Some basic information about the lake, such as how big it is and where it is.



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— Lake Depth (ft)



0 500 1,000 ft

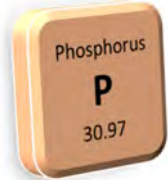
CLFLWD
Bone Lake
Bathymetry

Example Lake Summary (BONE LAKE)

2022 Surface Water Quality Summary

Nutrients:

June-Sept. Average Total Phosphorus (TP, $\mu\text{g/L}$)



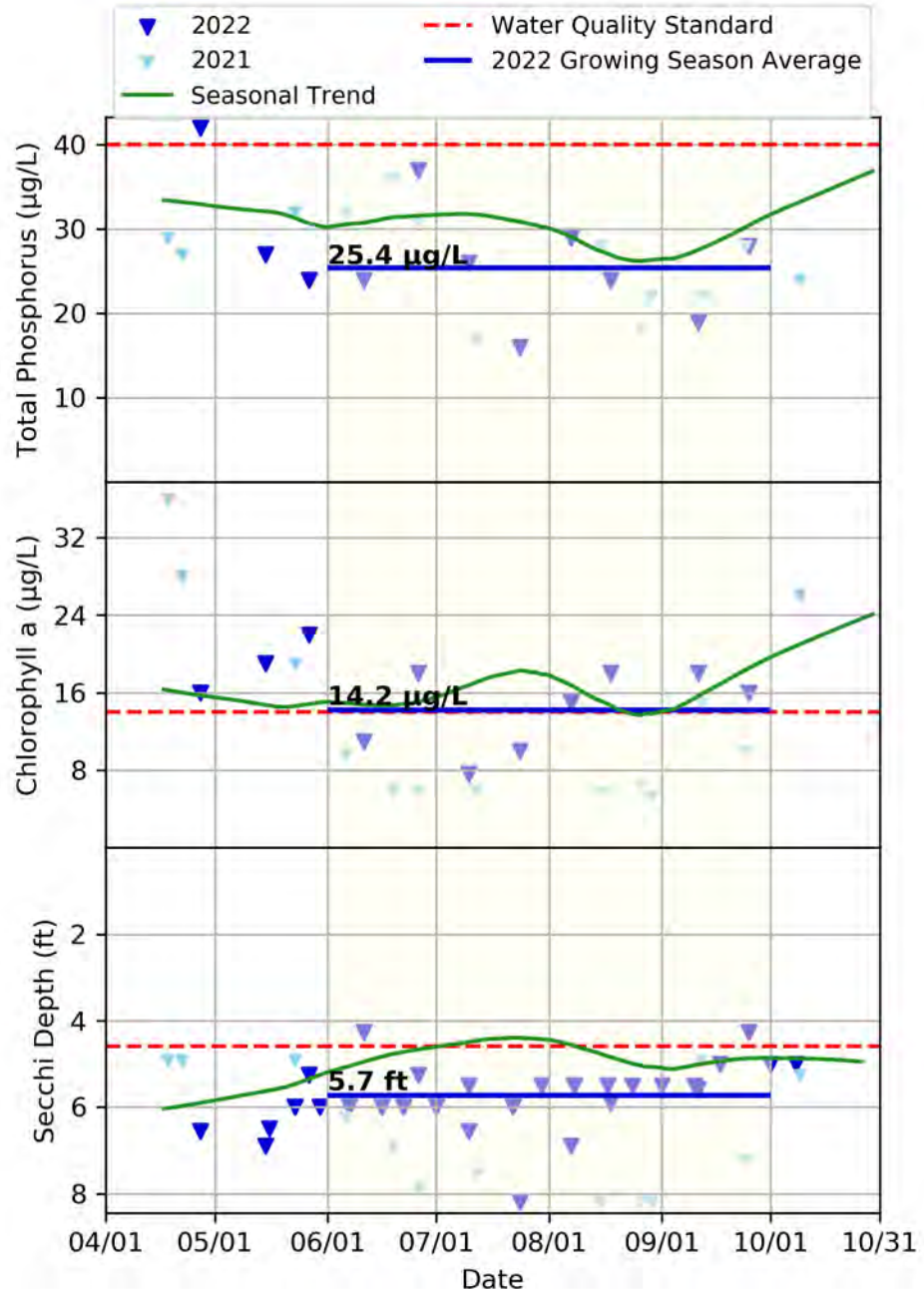
Algae:

June-Sept. Average Chlorophyll-a (Chl-a, $\mu\text{g/L}$)



Clarity:

June-Sept. Average Secchi Depth (Secchi, ft)



This figure shows all the water quality samples collected in 2022. Navy blue triangles represent 2022 data, light blue triangles represent 2021 data, and the green line represents the 10-year seasonal average. The top figure shows the phosphorus concentrations. The growing season (June-September) is shaded in tan. These samples were used to calculate a growing season average that is presented in the blue line in the center. The red line represents the State water quality standard for each parameter. Points above the line do not meet the water quality sample. However, lakes are only considered impaired if the average of all samples collected during the growing season do not meet the water quality standard.

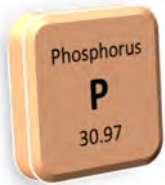
Example Lake Summary (BONE LAKE)

Historical Water Quality Summary

	Phosphorus ($\mu\text{g/L}$)	Chl-a ($\mu\text{g/L}$)	Secchi (feet)
State Standard	<40	<14	>4.6
10-year Average (2013-2022)	32.1	17.2	4.9
2040 District Goal	<30	n/a	>7.0
5-year Average (2018-2022)	24.9	12.7	5.9

Nutrients:

June-Sept. Average
Total Phosphorus
(TP, $\mu\text{g/L}$)



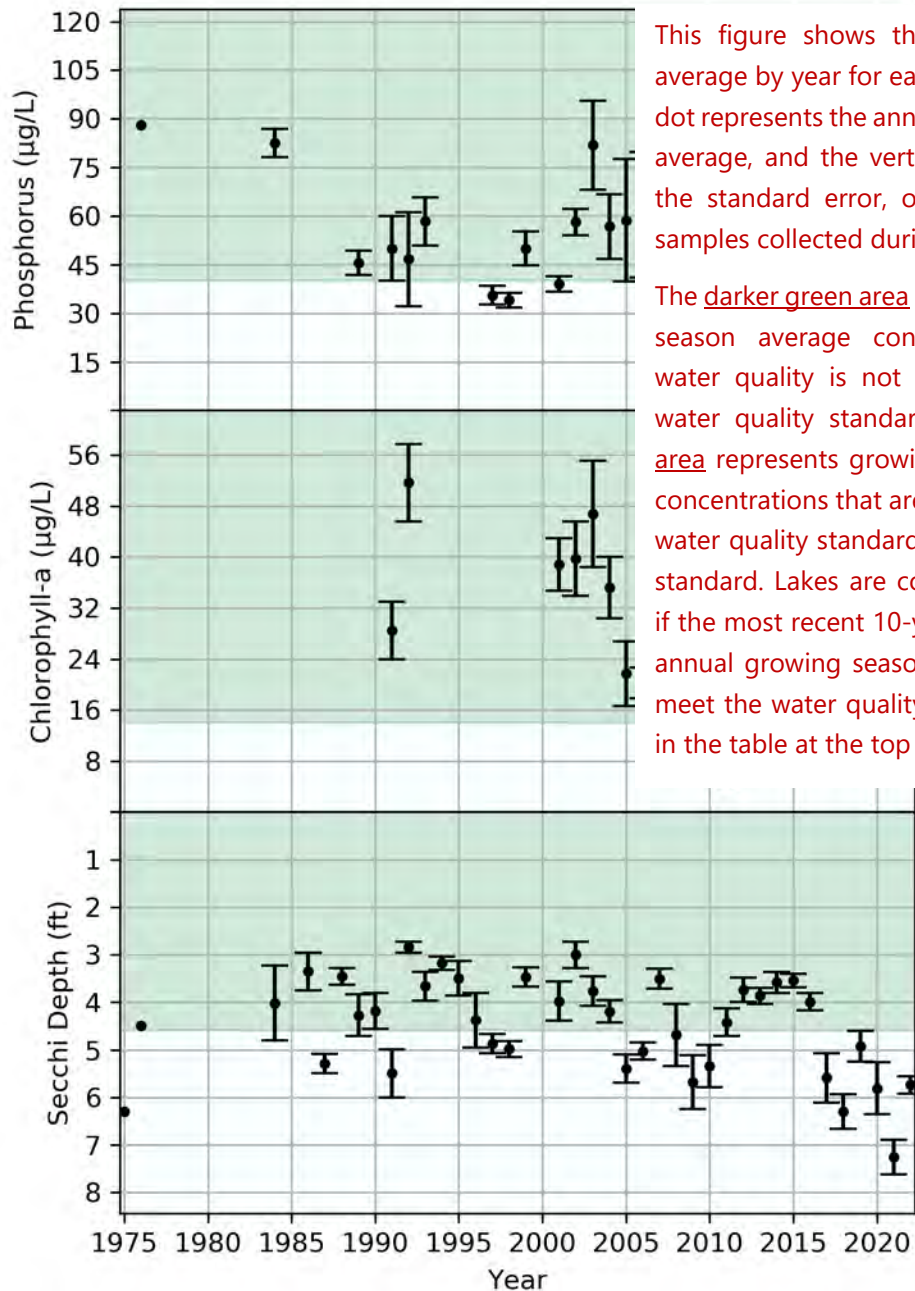
Algae:

June-Sept. Average
Chlorophyll-a
(Chl-a, $\mu\text{g/L}$)



Clarity:

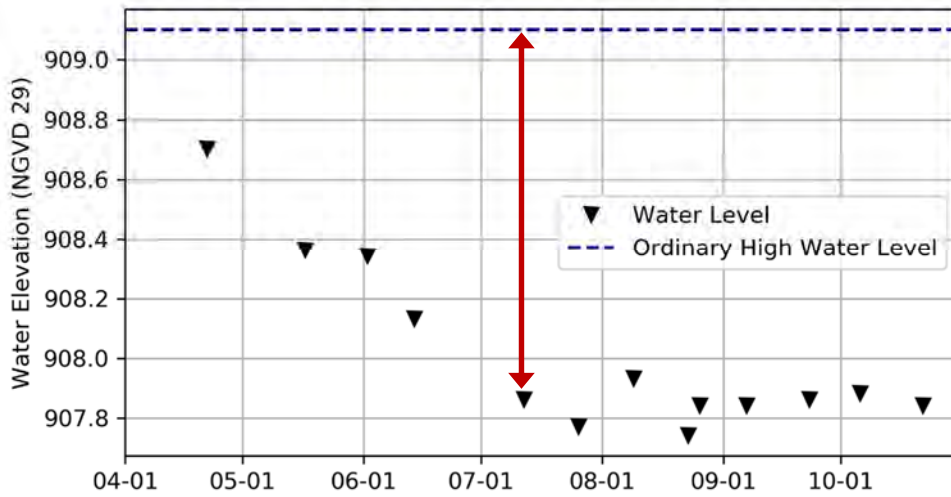
June-Sept. Average
Secchi Depth
(Secchi, ft)



This figure shows the growing season average by year for each parameter. Each dot represents the annual growing season average, and the vertical line represents the standard error, or the variability in samples collected during that year.

The darker green area represents growing season average concentrations where water quality is not meeting the State water quality standards. The light blue area represents growing season average concentrations that are meeting the State water quality standards. Lakes are considered impaired if the most recent 10-year average of the annual growing season averages do not meet the water quality standards, shown in the table at the top of the page.

Example Lake Summary (BONE LAKE)



2022 Lake Levels

Lake levels ranged over a total of 1.6 feet; from a minimum of 908.71 feet on September 9, 2020 to a maximum of 910.31 feet on October 25, 2020.

This figure shows the lake level measurements for 2022. Each triangle represents one measurement. The date is shown along the bottom of the figure as MM-DD. The dashed blue line shows the Ordinary High Water level.

DRAFT

BONE LAKE

Fast Facts:

DNR Lake ID: 82-0054-00

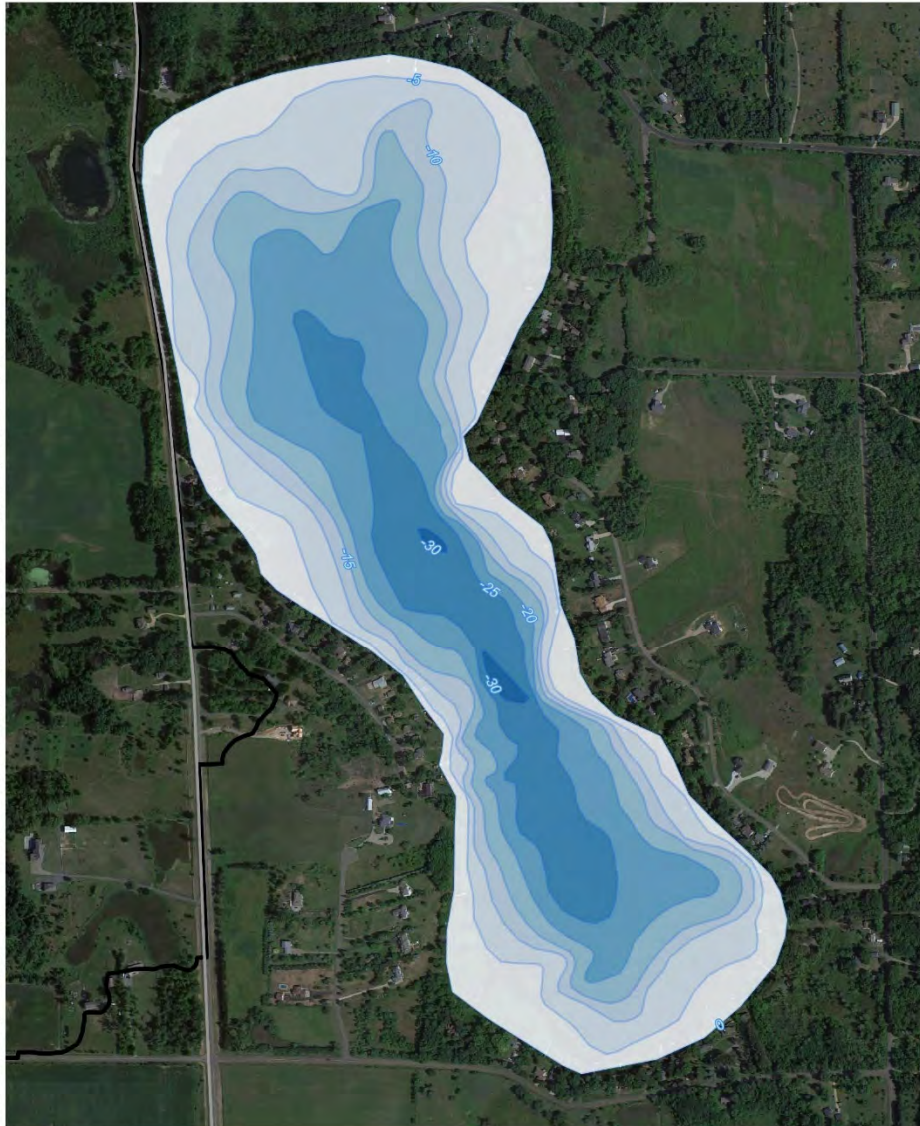
County: Washington

Surface Area: 221 acres

Littoral Area (depths less than 15 feet): 124 acres

Maximum Depth: 30 feet

Shore Length: 3.01 miles



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— Lake Depth (ft)



CLFLWD
Bone Lake

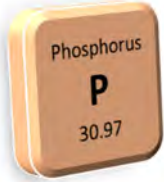
Bathymetry

BONE LAKE

2022 Surface Water Quality Summary

Nutrients:

June-Sept. Average Total Phosphorus (TP, $\mu\text{g/L}$)



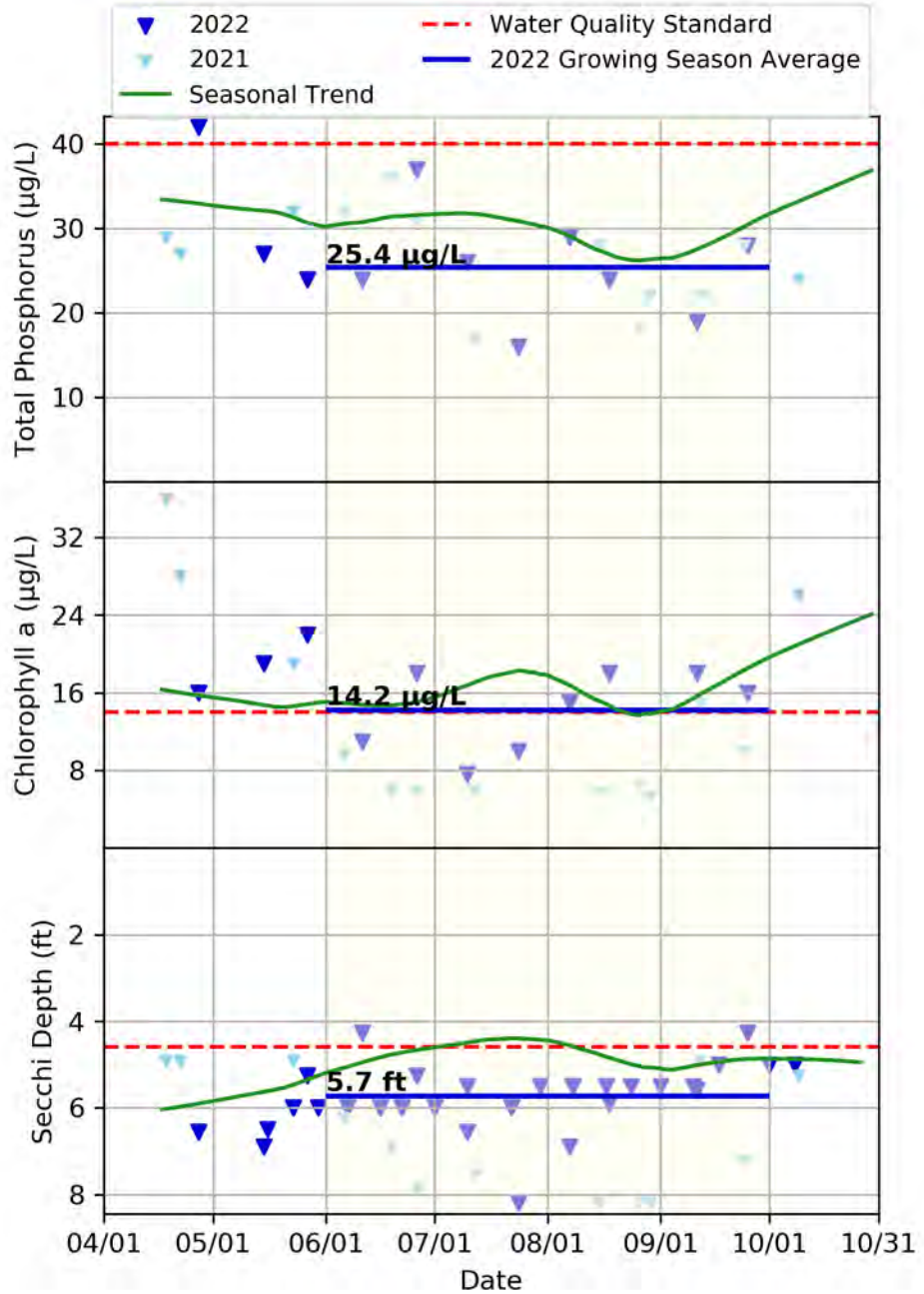
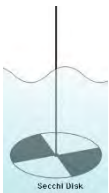
Algae:

June-Sept. Average Chlorophyll-a (Chl-a, $\mu\text{g/L}$)



Clarity:

June-Sept. Average Secchi Depth (Secchi, ft)



State standards are shown with a dashed red line. Phosphorus = $40 \mu\text{g/L}$, Chlorophyll-a = $14 \mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

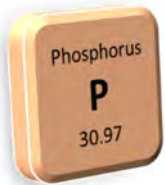
BONE LAKE

Historical Water Quality Summary

	Phosphorus ($\mu\text{g/L}$)	Chl-a ($\mu\text{g/L}$)	Secchi (feet)
State Standard	<40	<14	>4.6
10-year Average (2013-2022)	32.1	17.2	4.9
2040 District Goal	<30	n/a	>7.0
5-year Average (2018-2022)	24.9	12.7	5.9

Nutrients:

June-Sept. Average
Total Phosphorus
(TP, $\mu\text{g/L}$)



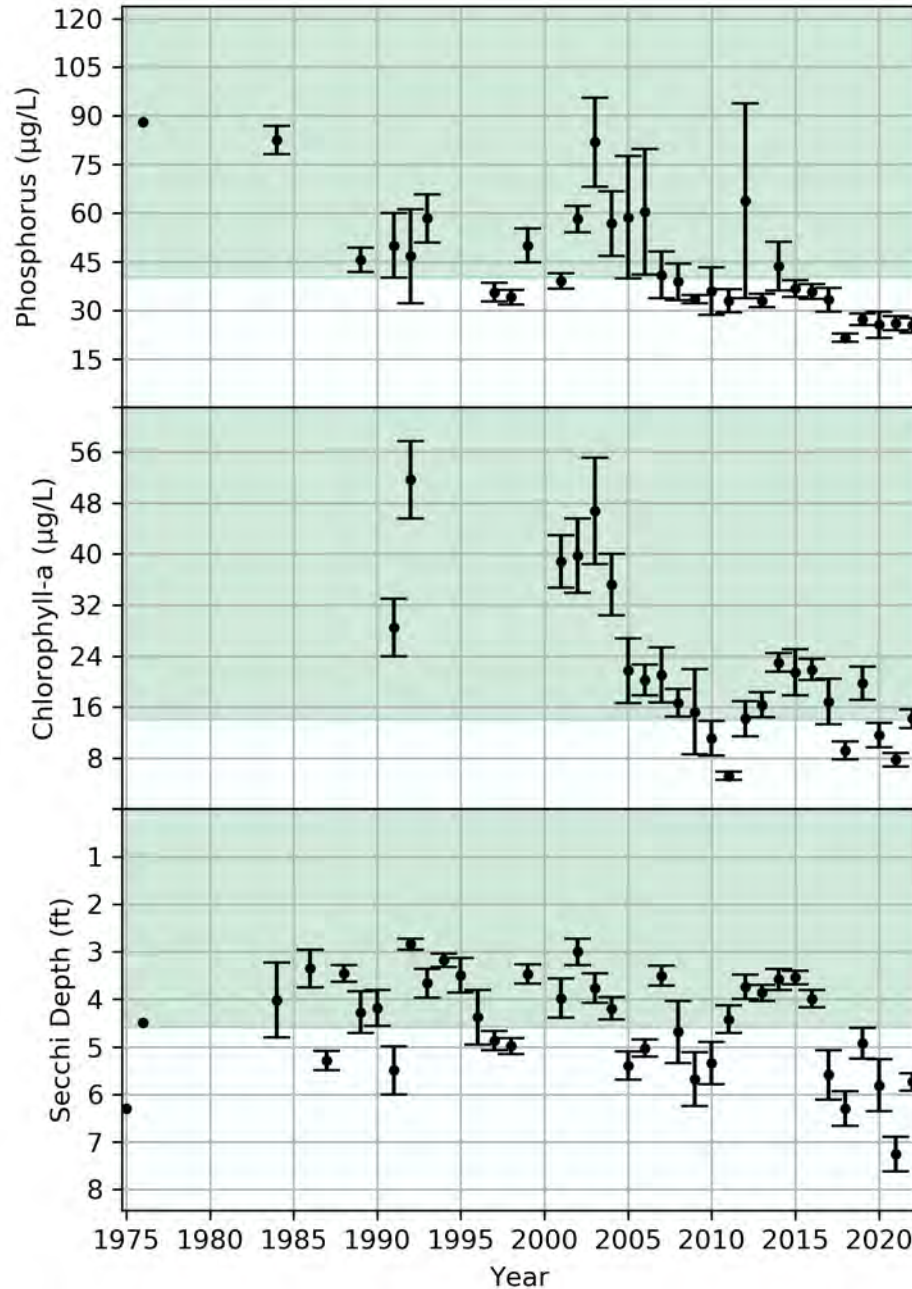
Algae:

June-Sept. Average
Chlorophyll-a
(Chl-a, $\mu\text{g/L}$)



Clarity:

June-Sept. Average
Secchi Depth
(Secchi, ft)



State standards are shown as the boundary between green and light blue. (Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Growing season averages are shown as black points. Points in the green area are above the state standard. Points in the light blue area are better than the State standard.

COMFORT LAKE

Fast Facts:

DNR Lake ID: 13-0053-00

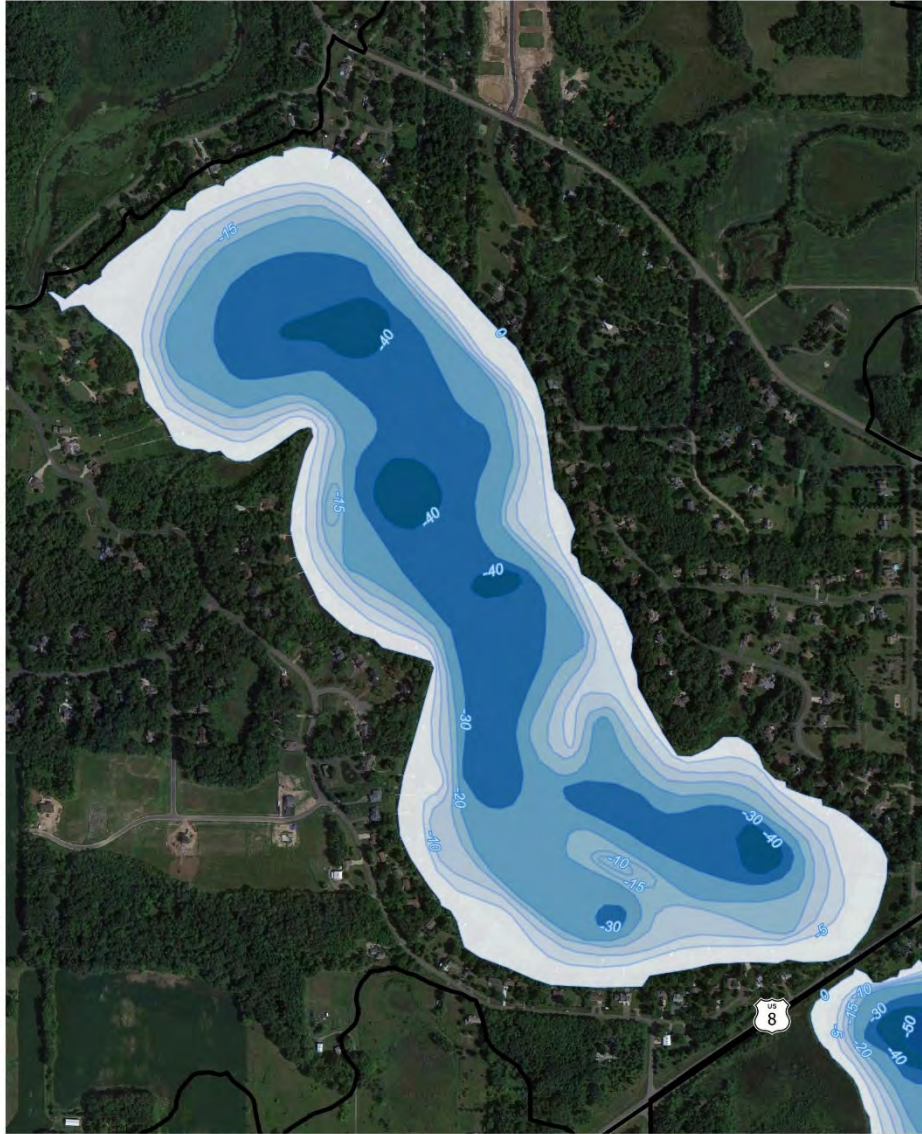
County: Chisago

Surface Area: 218 acres

Littoral Area (depths less than 15 feet): 90 acres

Maximum Depth: 47 feet

Shore Length: 3.24 miles



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— Lake Depth (ft)



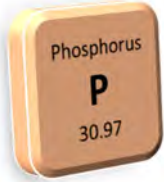
CLFLWD
Comfort Lake
Bathymetry

COMFORT LAKE

2022 Surface Water Quality Summary

Nutrients:

June-Sept. Average Total Phosphorus (TP, $\mu\text{g/L}$)



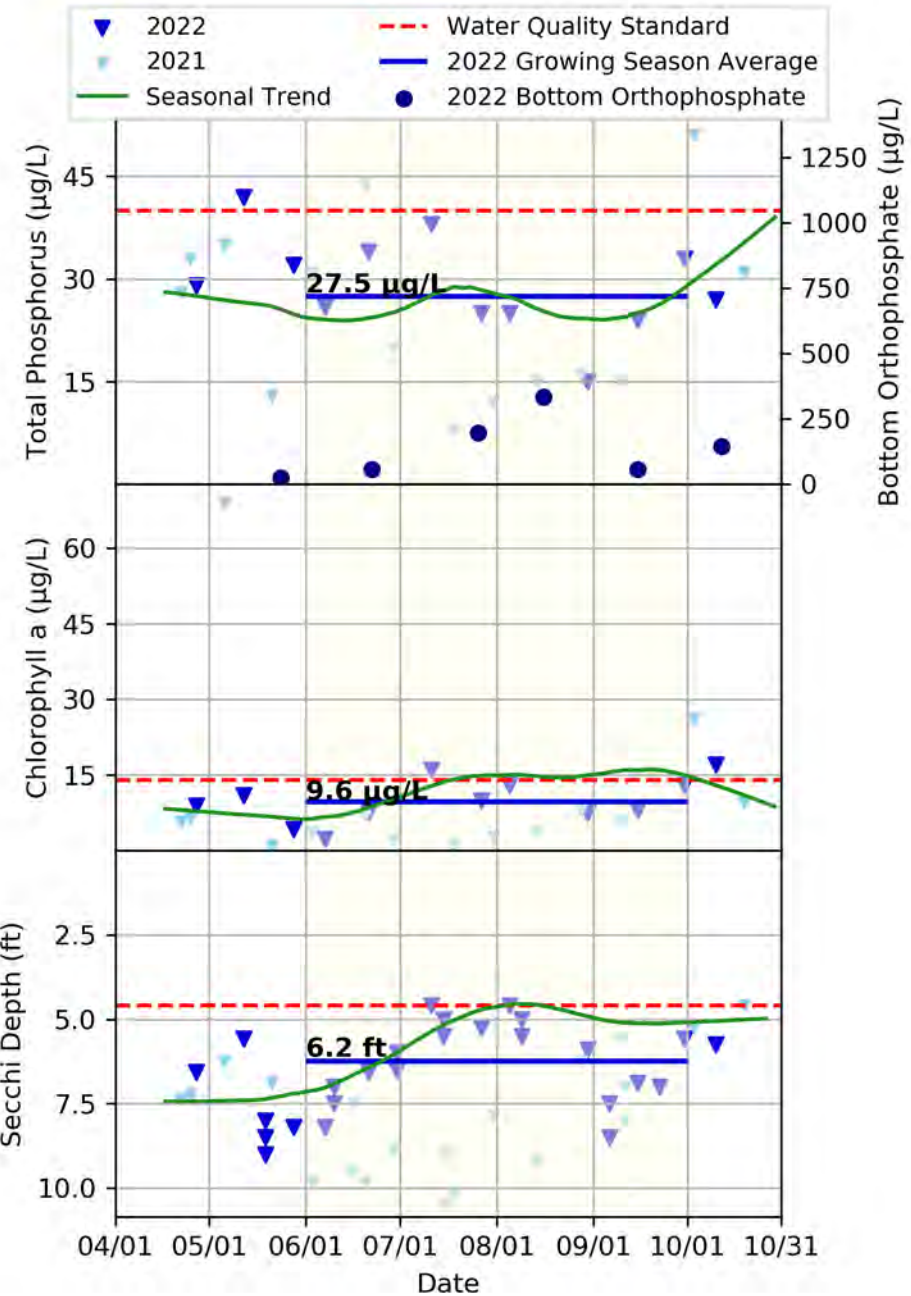
Algae:

June-Sept. Average Chlorophyll-a (Chl-a, $\mu\text{g/L}$)



Clarity:

June-Sept. Average Secchi Depth (Secchi, ft)



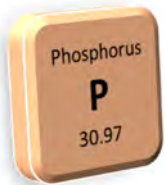
State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

COMFORT LAKE

Historical Water Quality Summary

	Phosphorus ($\mu\text{g/L}$)	Chl-a ($\mu\text{g/L}$)	Secchi (feet)
State Standard	<40	<14	>4.6
10-year Average (2013-2022)	30.2	13.8	5.7
2040 District Goal	<30	n/a	>7.0
5-year Average (2018-2022)	27.0	11.6	6.6

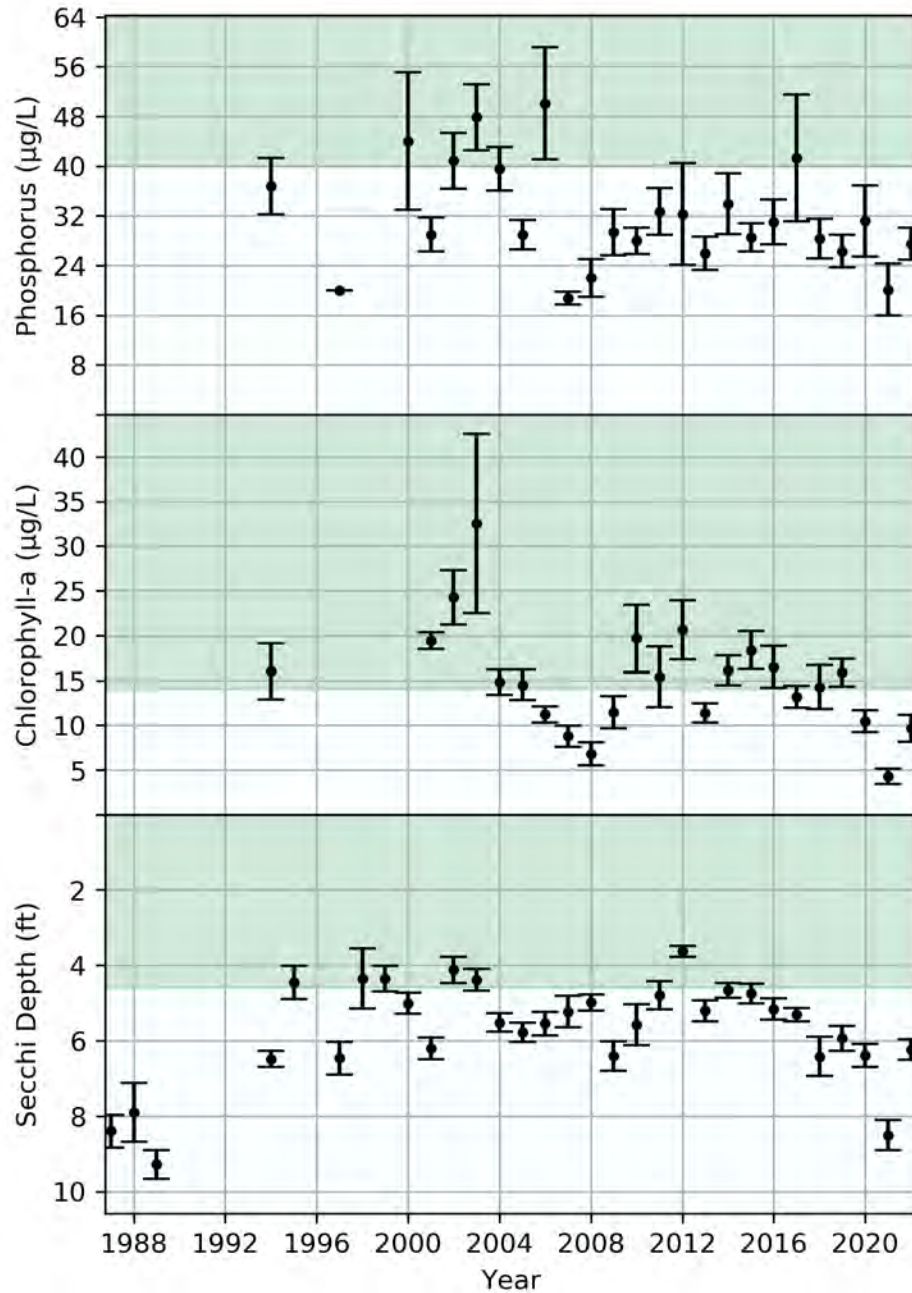
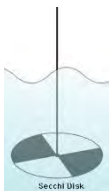
Nutrients:
June-Sept. Average
Total Phosphorus
(TP, $\mu\text{g/L}$)



Algae:
June-Sept. Average
Chlorophyll-a
(Chl-a, $\mu\text{g/L}$)

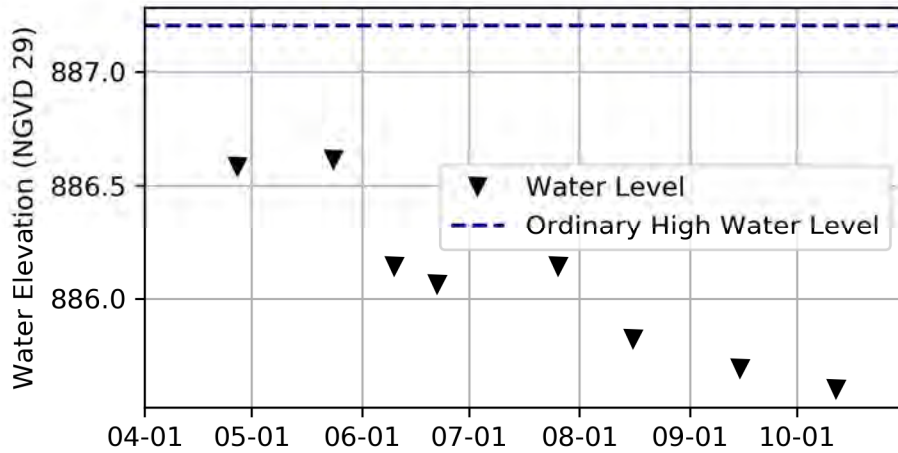


Clarity:
June-Sept. Average
Secchi Depth
(Secchi, ft)



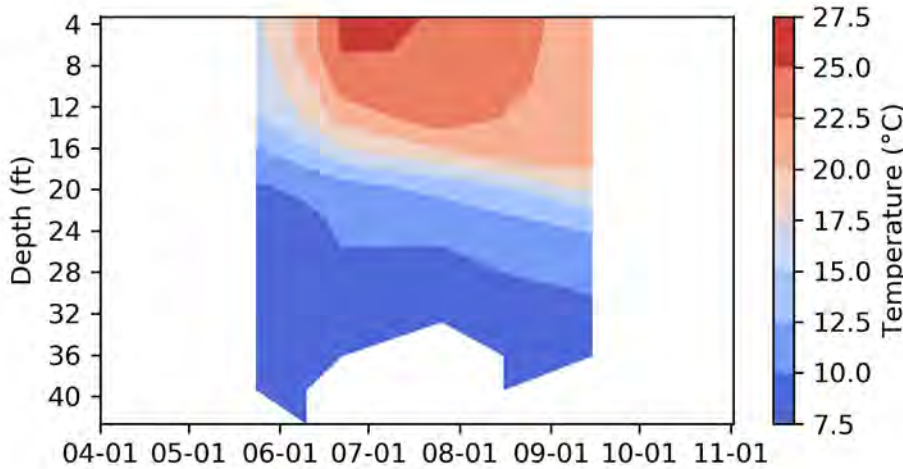
State standards are shown as the boundary between green and light blue. (Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Growing season averages are shown as black points. Points in the green area are above the state standard. Points in the light blue area are better than

COMFORT LAKE



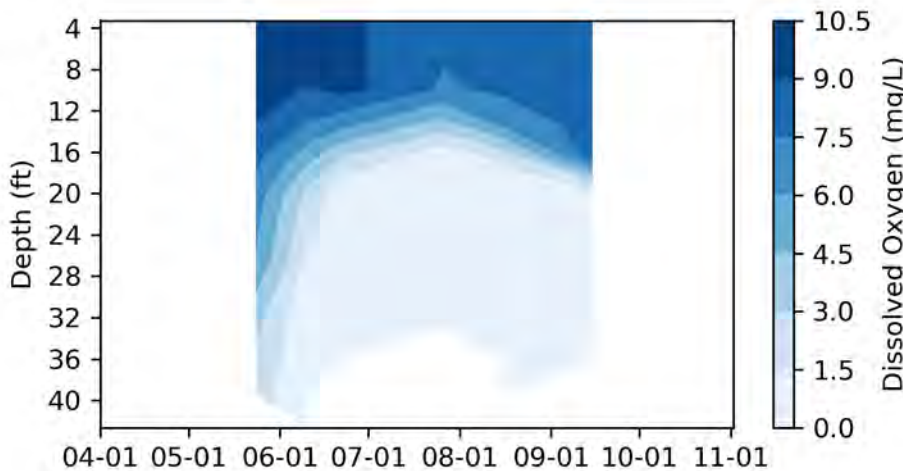
2022 Lake Levels

Lake levels ranged over a total of 1.0 feet; between a minimum of 885.6 feet on October 12, 2022 and a maximum of 886.6 feet on May 24, 2022.



2022 Temperature Profiles

The lake was stratified from early May through at least mid-September



2022 Dissolved Oxygen Profiles

The lightest blue represents the duration and depths where no oxygen is present and sediment phosphorus can be released and contribute to internal loading.

Internal loading was possible starting in June. Bottom P increased after this time. A high wind event on Aug 27th likely contributed to a slight mixing and bottom P decreased slightly in early September

ELWELL LAKE

Fast Facts:

DNR Lake ID: 82-0079-00

County: Washington

Surface Area: 16 acres

Littoral Area (depths less than 15 feet): NA acres



Maximum Depth: NA feet

Shore Length: NA miles



Date: 2023-02-24T13:14:55.160 Author: Eljensen, Layout: RM, CLFLWD_Lake
Document Path: X:\Clients_WD\00376_CLFLWD\0010_General_Watershed_Eng\3000_Program\3003A_monitoring\07_GIS\lake_aerials\022.jpg



-  Lake Management District Boundary
-  Lake



CLFLWD
Elwell Lake

Lake Map

0 100 200 ft

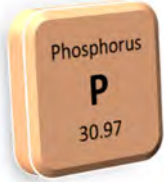


ELWELL LAKE

2022 Surface Water Quality Summary

Nutrients:

June-Sept. Average Total Phosphorus (TP, $\mu\text{g/L}$)



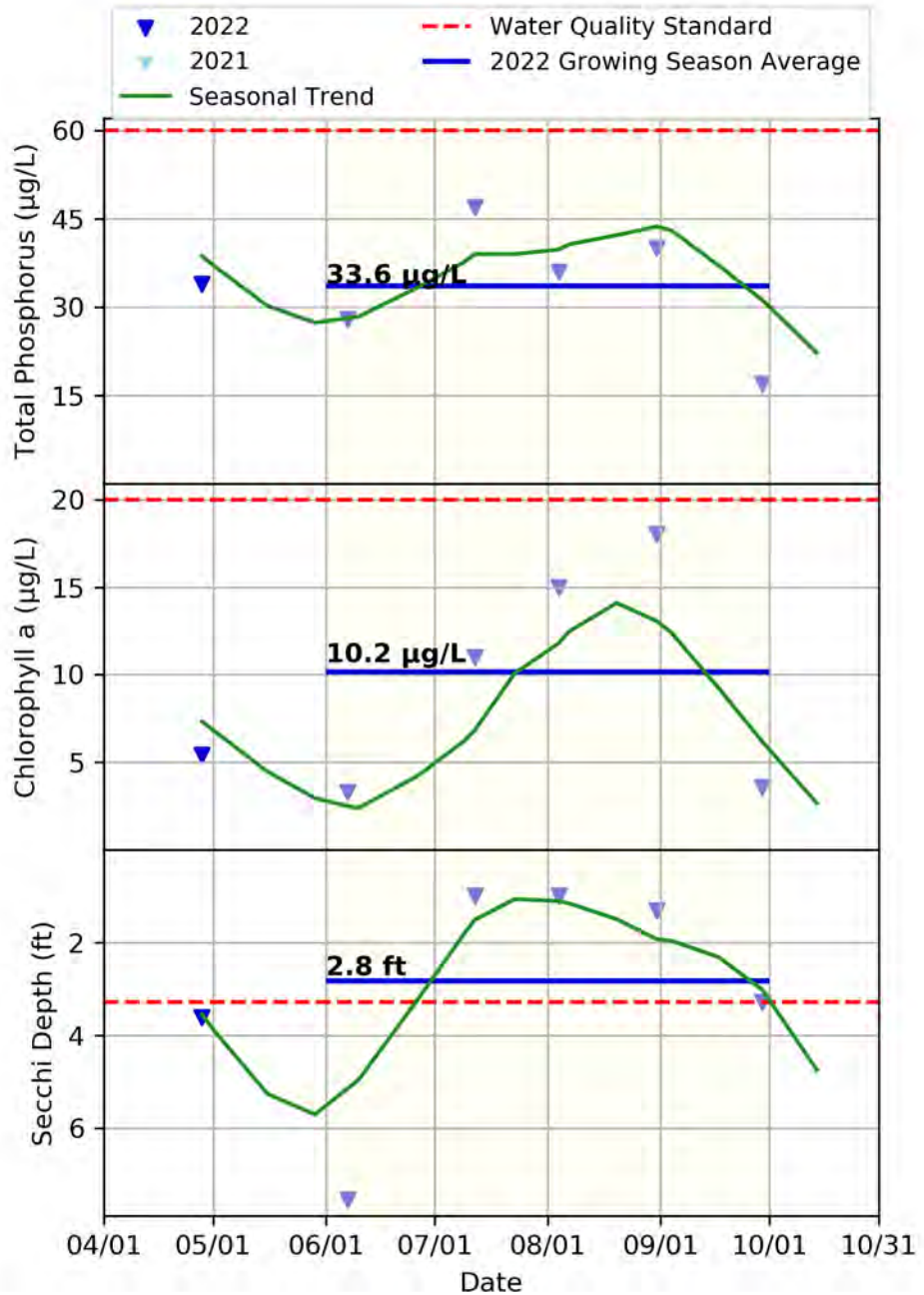
Algae:

June-Sept. Average Chlorophyll-a (Chl-a, $\mu\text{g/L}$)



Clarity:

June-Sept. Average Secchi Depth (Secchi, ft)



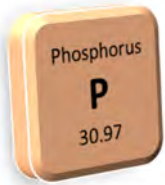
State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

ELWELL LAKE

Historical Water Quality Summary

	Phosphorus ($\mu\text{g/L}$)	Chl-a ($\mu\text{g/L}$)	Secchi (feet)
State Standard	<60	<20	>3.3
10-year Average (2013-2022)	43.1	11.3	2.5
2040 District Goal	<60	n/a	>3.3
5-year Average (2018-2022)	43.1	11.3	2.5

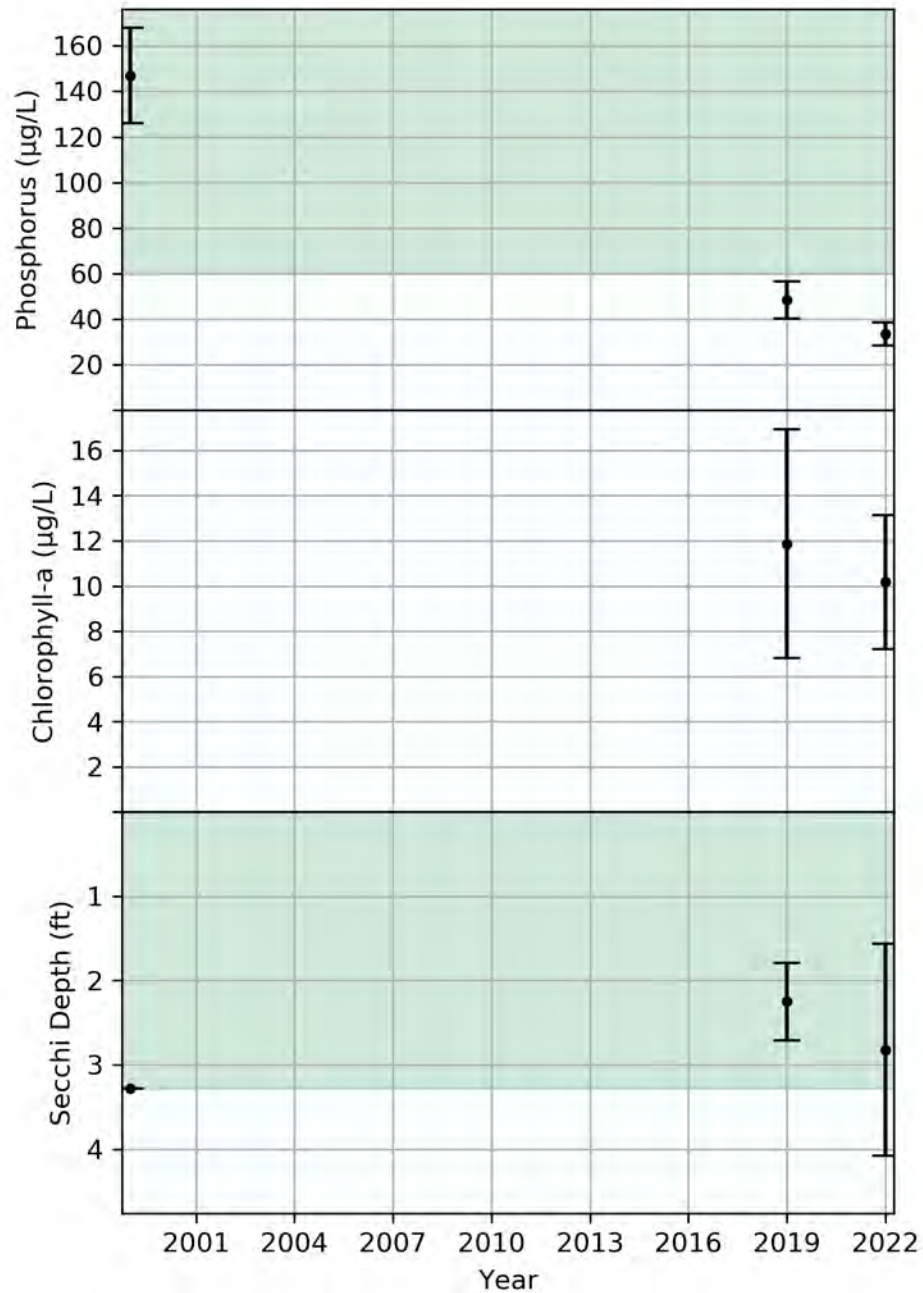
Nutrients:
June-Sept. Average
Total Phosphorus
(TP, $\mu\text{g/L}$)



Algae:
June-Sept. Average
Chlorophyll-a
(Chl-a, $\mu\text{g/L}$)



Clarity:
June-Sept. Average
Secchi Depth
(Secchi, ft)



State standards are shown as the boundary between green and light blue. (Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Growing season averages are shown as black points. Points in the green area are above the state standard. Points in the light blue area are better than

FOREST LAKE

Fast Facts:

DNR Lake ID: 82-0159-00

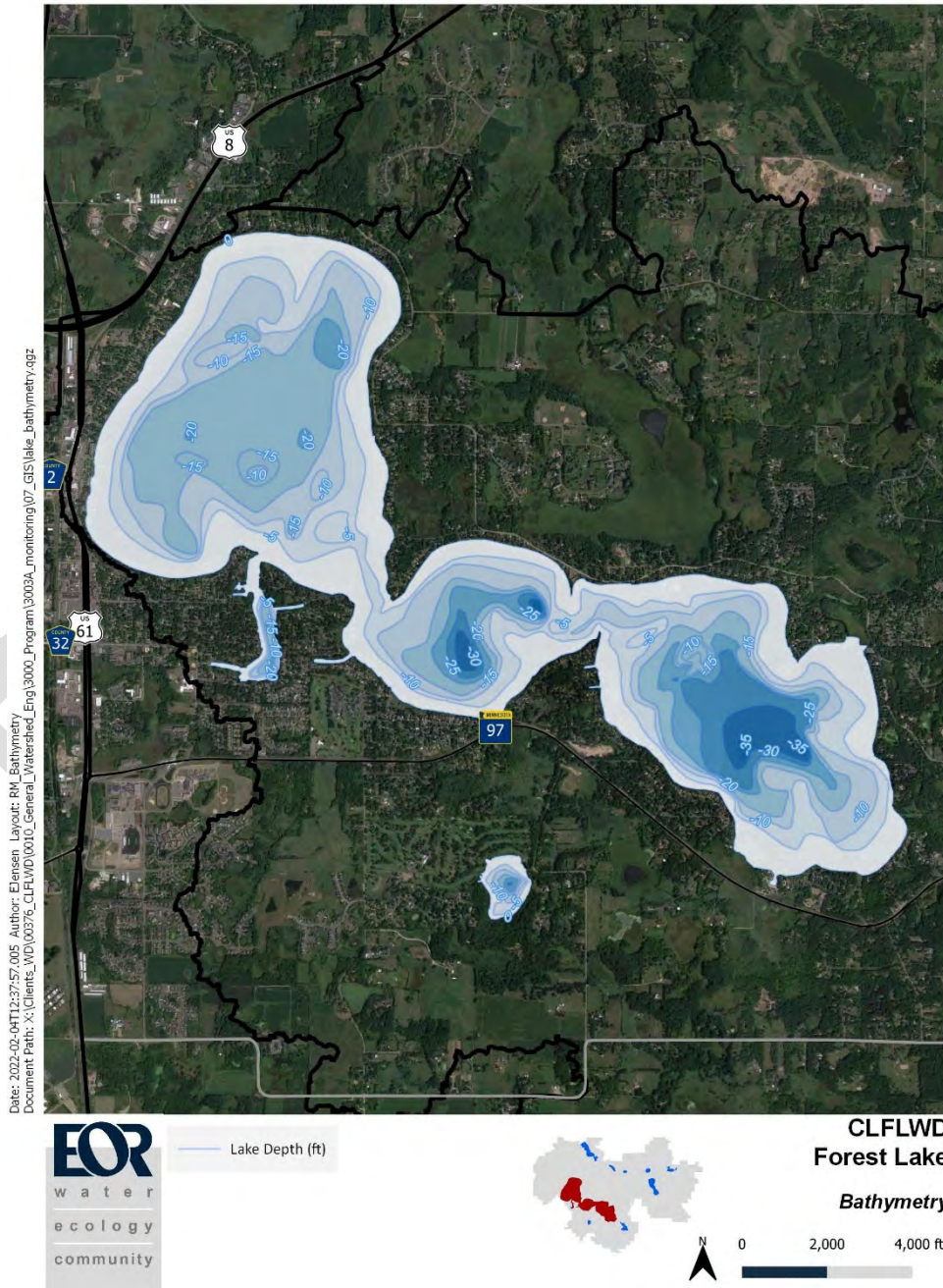
County: Washington

Surface Area: 2,271 acres

Littoral Area (depths less than 15 feet): 1,531 acres

Maximum Depth: 37 feet

Shore Length: 15.71 miles

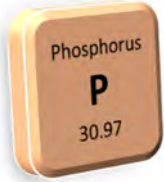


FOREST LAKE – WEST BASIN

2022 Surface Water Quality Summary

Nutrients:

June-Sept. Average Total Phosphorus (TP, $\mu\text{g/L}$)



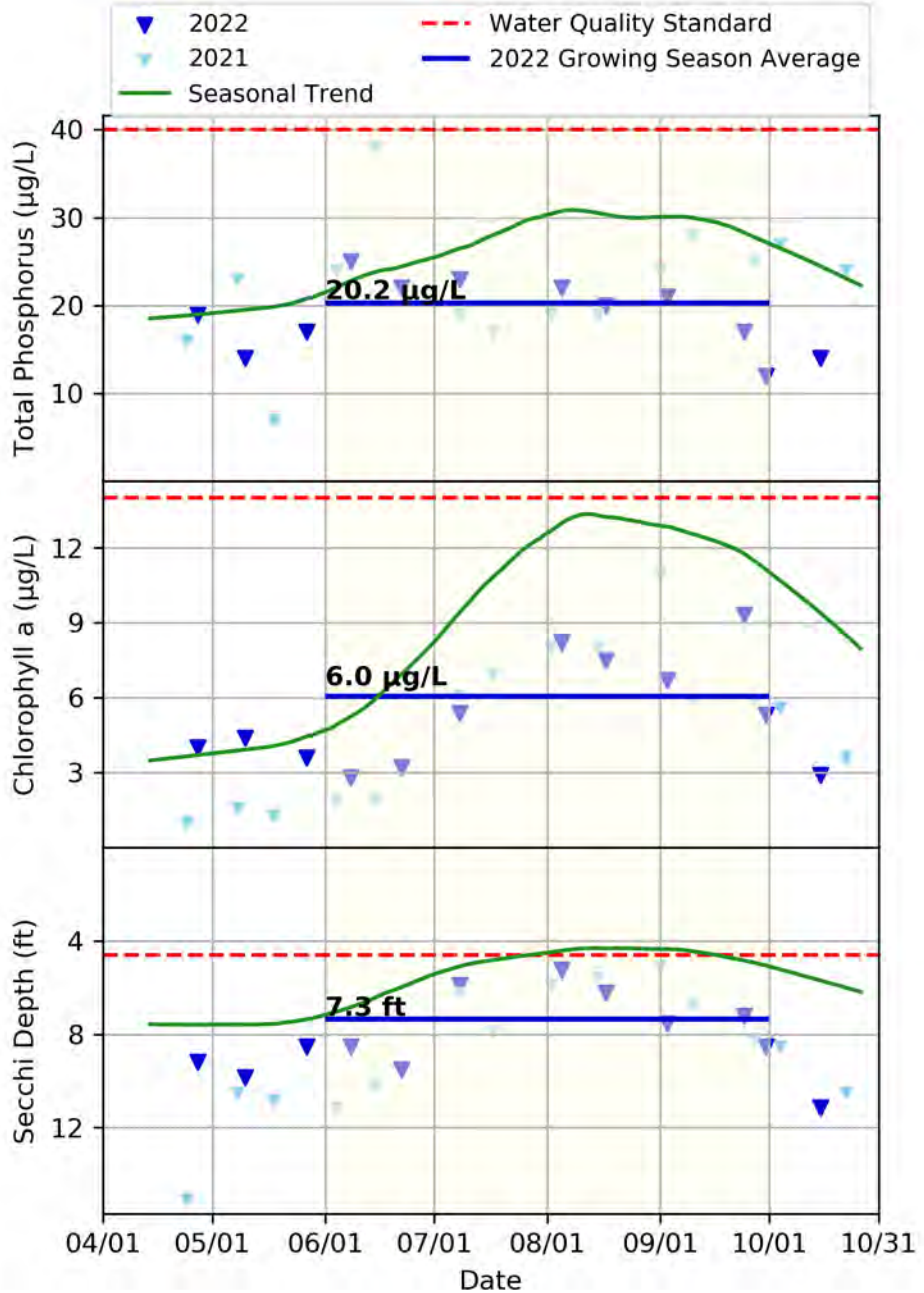
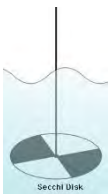
Algae:

June-Sept. Average Chlorophyll-a (Chl-a, $\mu\text{g/L}$)



Clarity:

June-Sept. Average Secchi Depth (Secchi, ft)



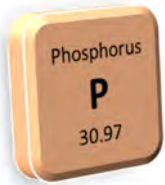
State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

FOREST LAKE – WEST BASIN

Historical Water Quality Summary

	Phosphorus ($\mu\text{g/L}$)	Chl-a ($\mu\text{g/L}$)	Secchi (feet)
State Standard	<40	<14	>4.6
10-year Average (2013-2022)	29.6	11.8	5.1
2040 District Goal	<30	n/a	>7.0
5-year Average (2018-2022)	26.3	8.2	6.4

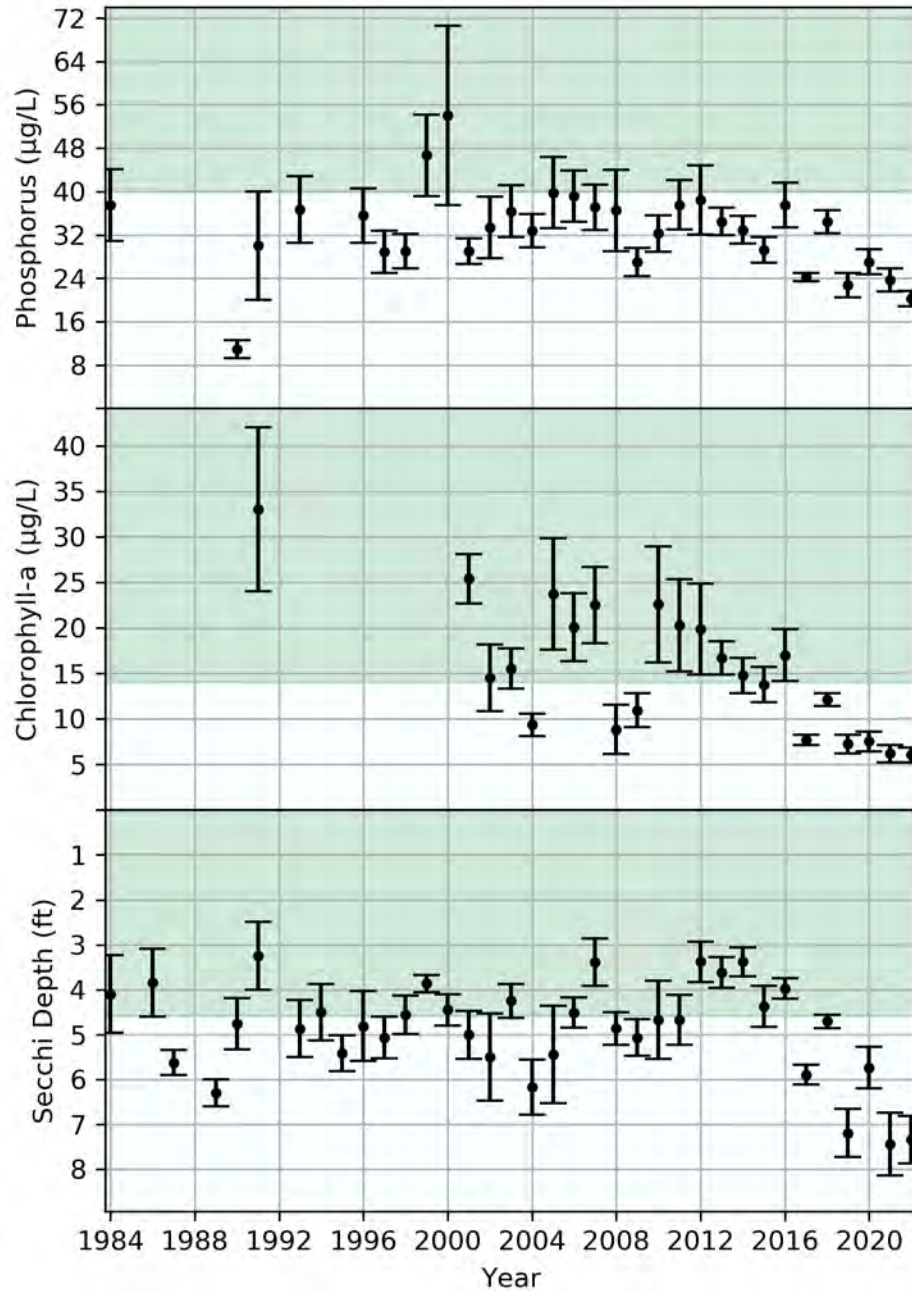
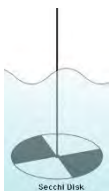
Nutrients:
June-Sept. Average
Total Phosphorus
(TP, $\mu\text{g/L}$)



Algae:
June-Sept. Average
Chlorophyll-a
(Chl-a, $\mu\text{g/L}$)



Clarity:
June-Sept. Average
Secchi Depth
(Secchi, ft)



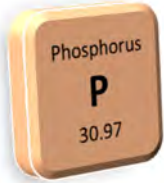
State standards are shown as the boundary between green and light blue. (Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Growing season averages are shown as black points. Points in the green area are above the state standard. Points in the light blue area are better than the State standard.

FOREST LAKE – MIDDLE BASIN

2022 Surface Water Quality Summary

Nutrients:

June-Sept. Average Total Phosphorus (TP, $\mu\text{g/L}$)



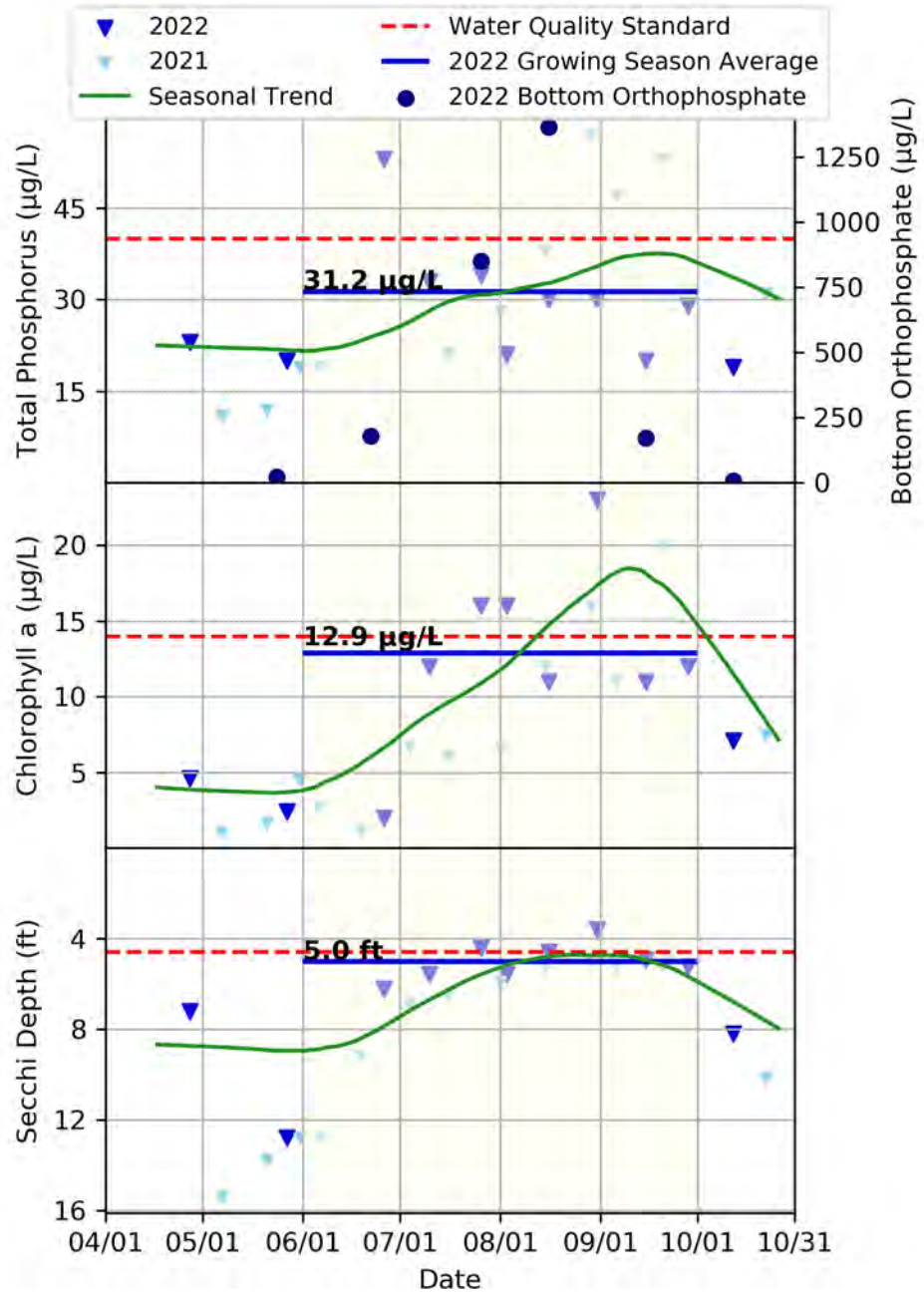
Algae:

June-Sept. Average Chlorophyll-a (Chl-a, $\mu\text{g/L}$)



Clarity:

June-Sept. Average Secchi Depth (Secchi, ft)



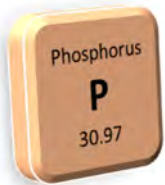
State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

FOREST LAKE – MIDDLE BASIN

Historical Water Quality Summary

	Phosphorus (µg/L)	Chl-a (µg/L)	Secchi (feet)
State Standard	<40	<14	>4.6
10-year Average (2013-2022)	34.8	14.6	6.3
2040 District Goal	<30	n/a	>7.0
5-year Average (2018-2022)	38.7	15.4	6.6

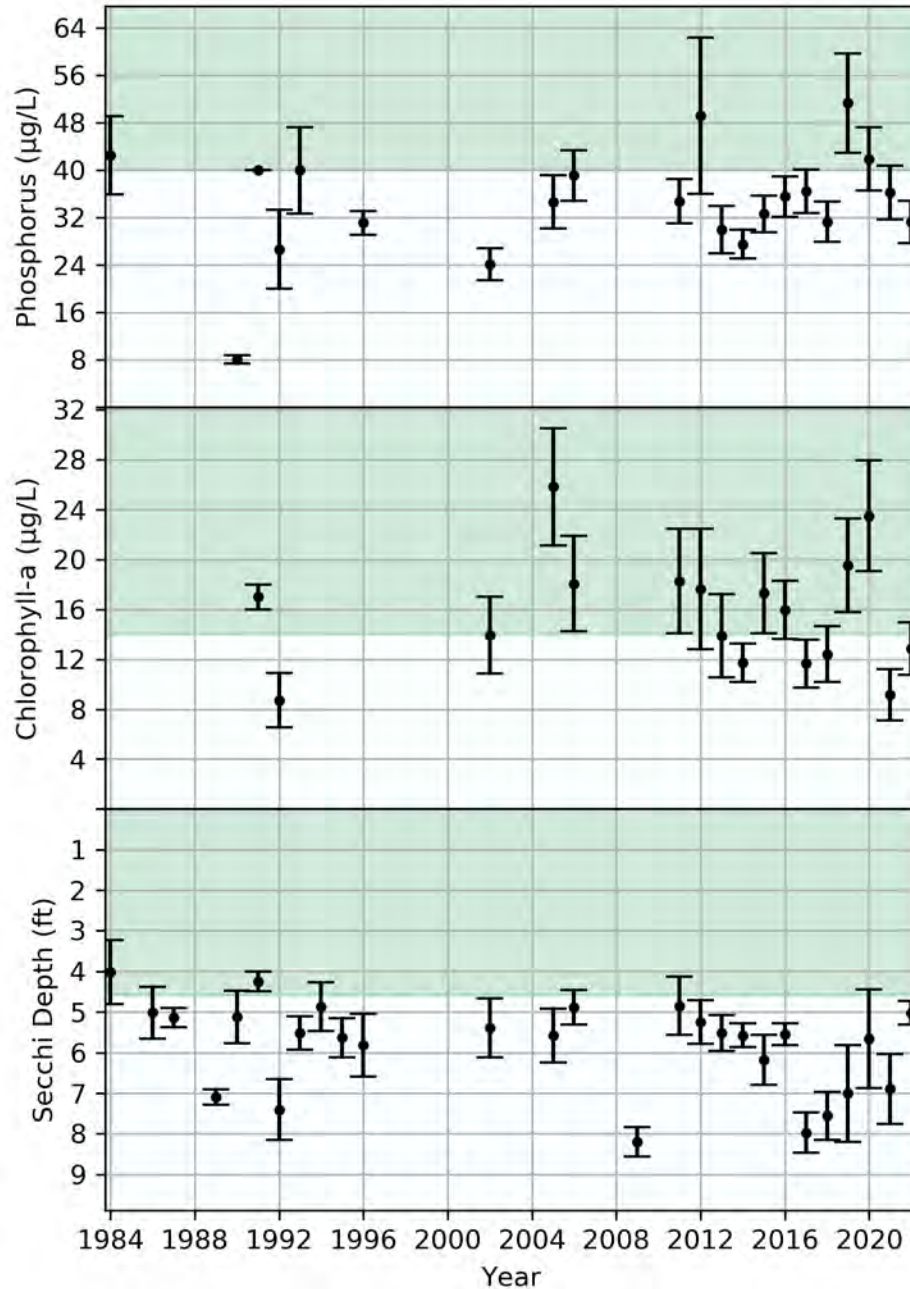
Nutrients:
June-Sept. Average
Total Phosphorus
(TP, µg/L)



Algae:
June-Sept. Average
Chlorophyll-a
(Chl-a, µg/L)

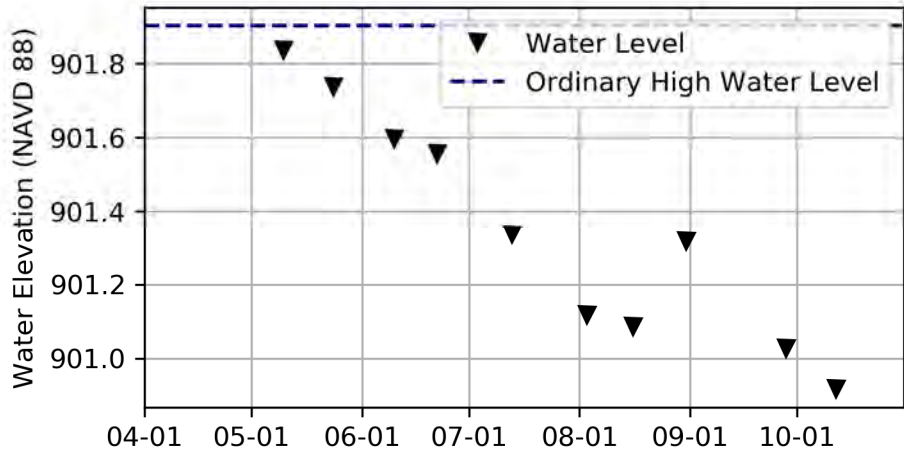


Clarity:
June-Sept. Average
Secchi Depth
(Secchi, ft)



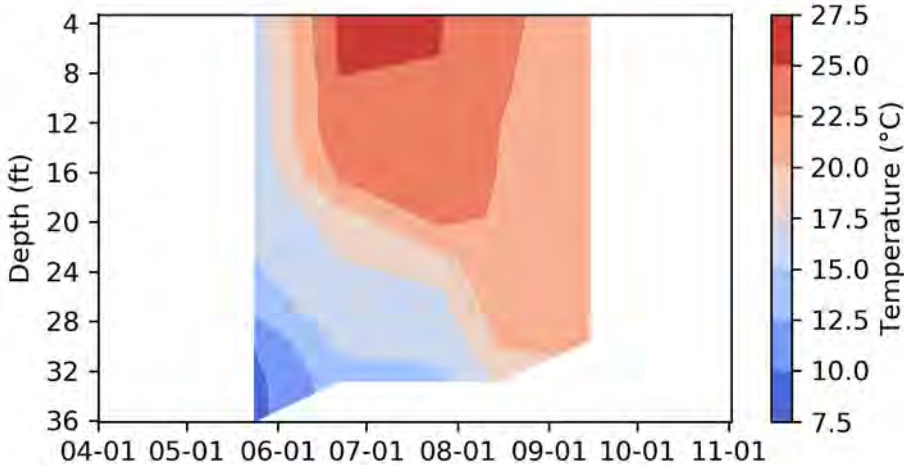
State standards are shown as the boundary between green and light blue. (Phosphorus = 40 µg/L, Chlorophyll-a = 14 µg/L, Secchi Depth = 4.6 feet. Growing season averages are shown as black points. Points in the green area are above the state standard. Points in the light blue area are better than the State standard.

FOREST LAKE – MIDDLE BASIN



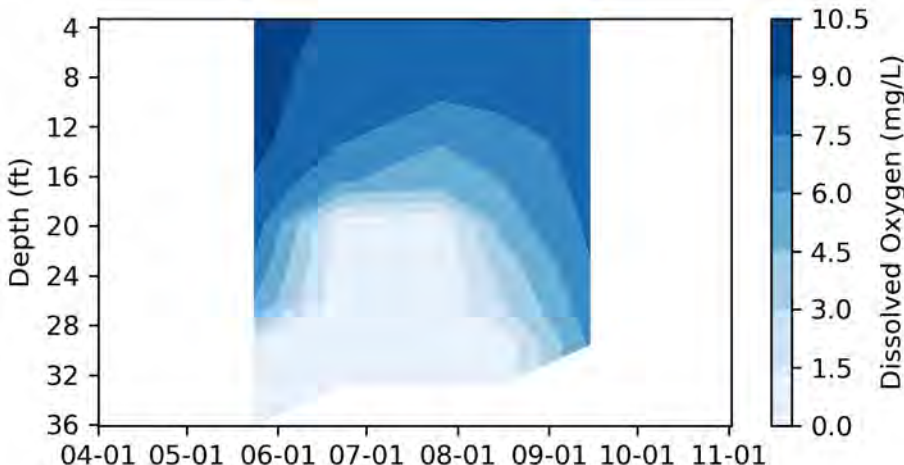
2022 Lake Levels

Lake levels ranged over a total of 0.9 feet; between a minimum of 900.9 feet on October 12, 2022 and a maximum of 901.8 feet on May 10, 2022.



2022 Temperature Profiles

The lake was stratified from early May until late August. A high wind event on August 27th likely contributed to lake mixing in early September.



2022 Dissolved Oxygen Profiles

The lightest blue represents the duration and depths where no oxygen is present and sediment phosphorus can be released and contribute to internal loading.

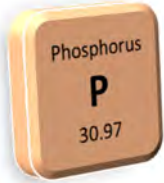
Internal loading was possible from late May until end of August. Bottom P concentrations increased to high levels by July.

FOREST LAKE – EAST BASIN

2022 Surface Water Quality Summary

Nutrients:

June-Sept. Average Total Phosphorus (TP, $\mu\text{g/L}$)



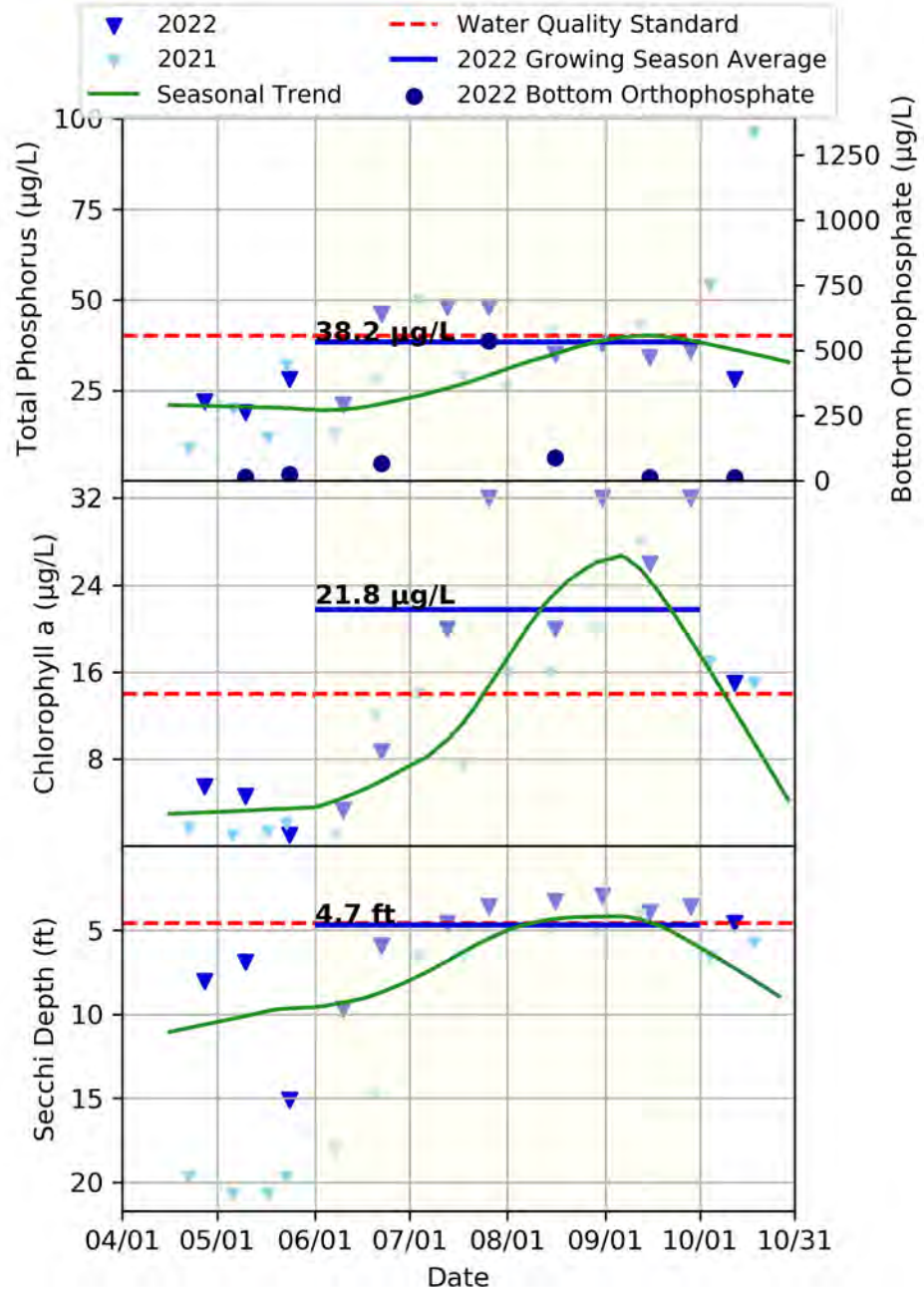
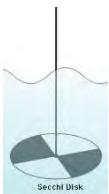
Algae:

June-Sept. Average Chlorophyll-a (Chl-a, $\mu\text{g/L}$)



Clarity:

June-Sept. Average Secchi Depth (Secchi, ft)



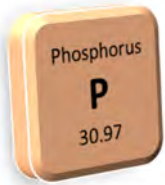
State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

FOREST LAKE – EAST BASIN

Historical Water Quality Summary

	Phosphorus ($\mu\text{g/L}$)	Chl-a ($\mu\text{g/L}$)	Secchi (feet)
State Standard	<40	<14	>4.6
10-year Average (2013-2022)	34.3	19.1	6.4
2040 District Goal	<30	n/a	>7.0
5-year Average (2018-2022)	33.1	18.1	7.2

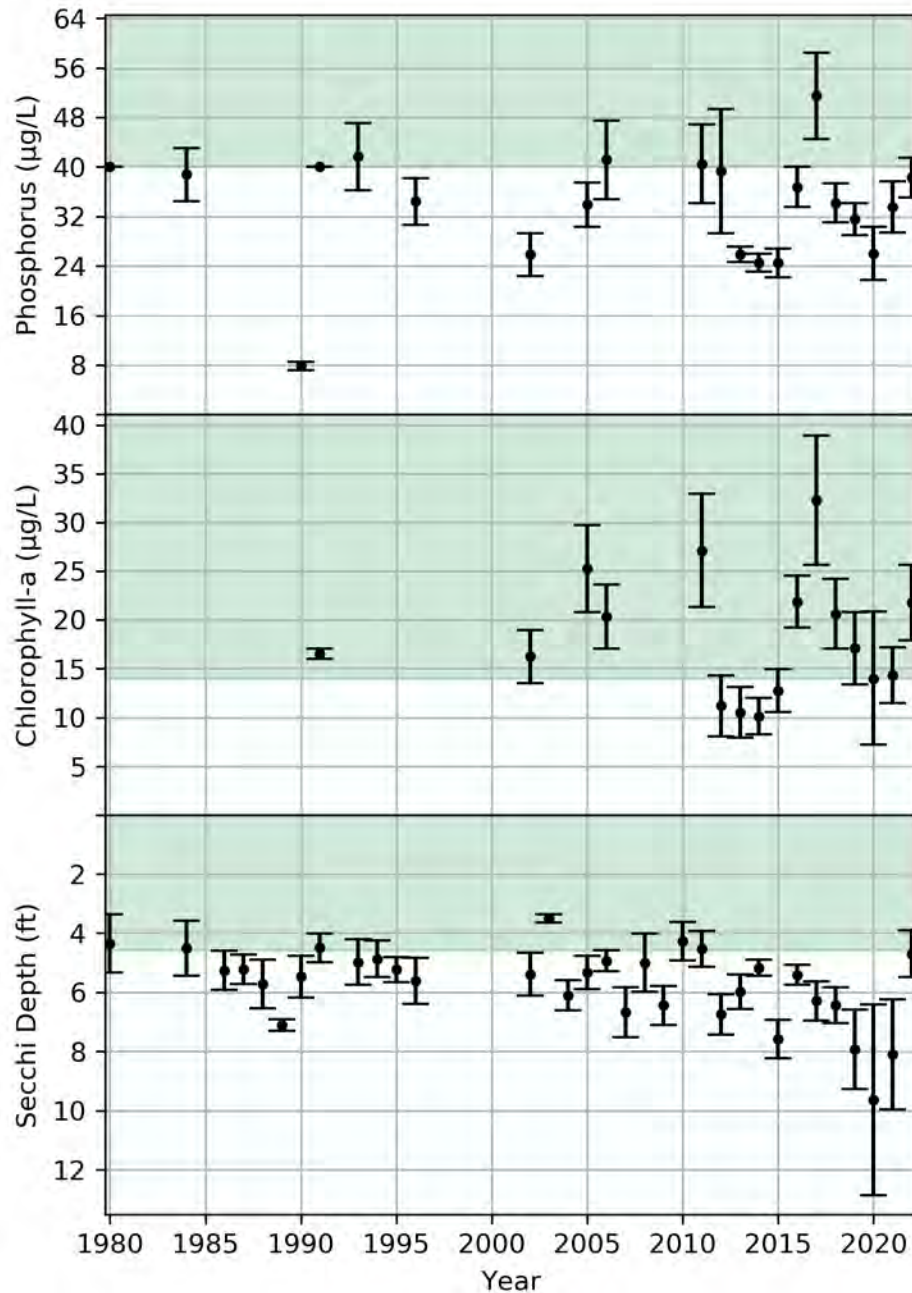
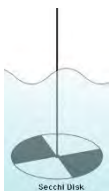
Nutrients:
June-Sept. Average
Total Phosphorus
(TP, $\mu\text{g/L}$)



Algae:
June-Sept. Average
Chlorophyll-a
(Chl-a, $\mu\text{g/L}$)

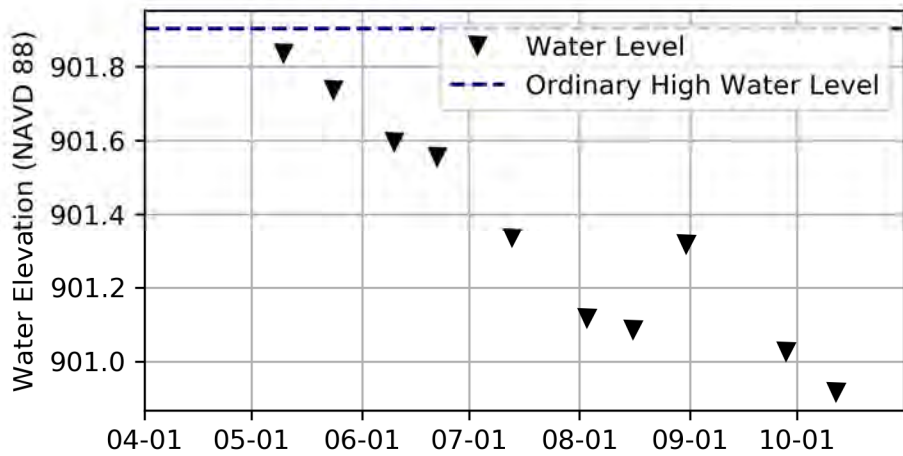


Clarity:
June-Sept. Average
Secchi Depth
(Secchi, ft)



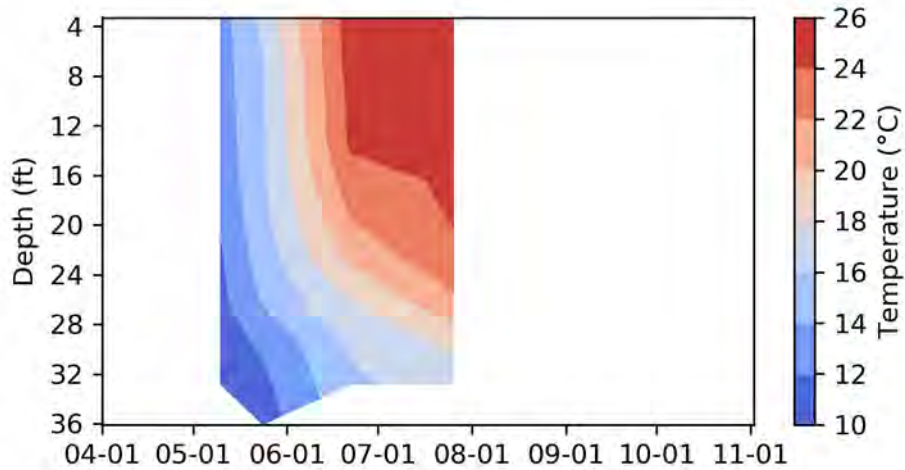
State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

FOREST LAKE – EAST BASIN



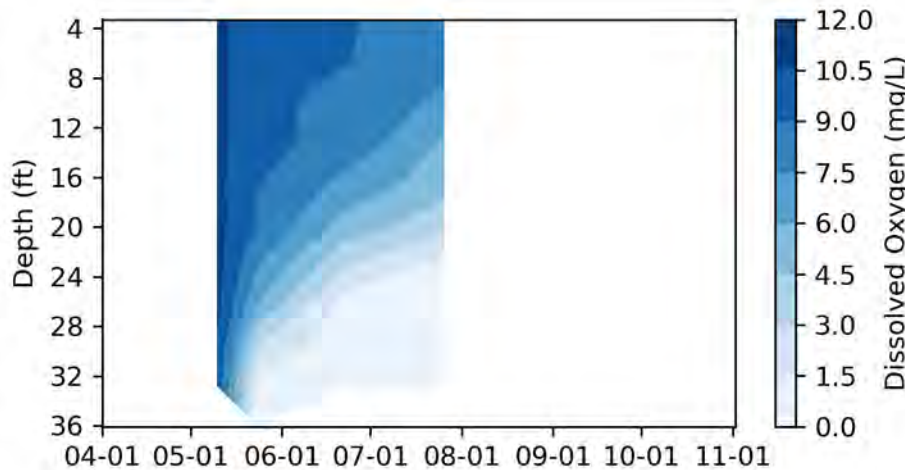
2022 Lake Levels

Lake levels ranged over a total of 0.9 feet; between a minimum of 900.9 feet on October 12, 2022 and a maximum of 901.8 feet on May 10, 2022.



2022 Temperature Profiles

The lake was stratified starting in June.



2022 Dissolved Oxygen Profiles

The lightest blue represents the duration and depths where no oxygen is present and sediment phosphorus can be released and contribute to internal loading.

Internal loading was possible starting in June. Bottom P concentrations increased until late July. A high wind event on August 3rd likely contributed to a bottom P decrease.

HEIMS LAKE

Fast Facts:

DNR Lake ID: 13-0056-00

County: Chisago

Surface Area: 91 acres

Littoral Area (depths less than 15 feet): NA acres



Maximum Depth: NA feet

Shore Length: NA miles



Date: 2023-02-24T13:18:09.647 Author: Eljensen, Layout: RM, CLFLWD_Lake
Document Path: X:\Clients_VID\00376_CLFLWD\0010_General_Watershed_Eng\3000_Program\3003A_monitoring\07_GIS\lake_aerials\022.rpt



-  Lake Management District Boundary
-  Lake



0 200 400 ft

CLFLWD
Heims Lake

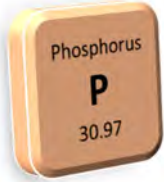
Lake Map

HEIMS LAKE

2022 Surface Water Quality Summary

Nutrients:

June-Sept. Average Total Phosphorus (TP, $\mu\text{g/L}$)



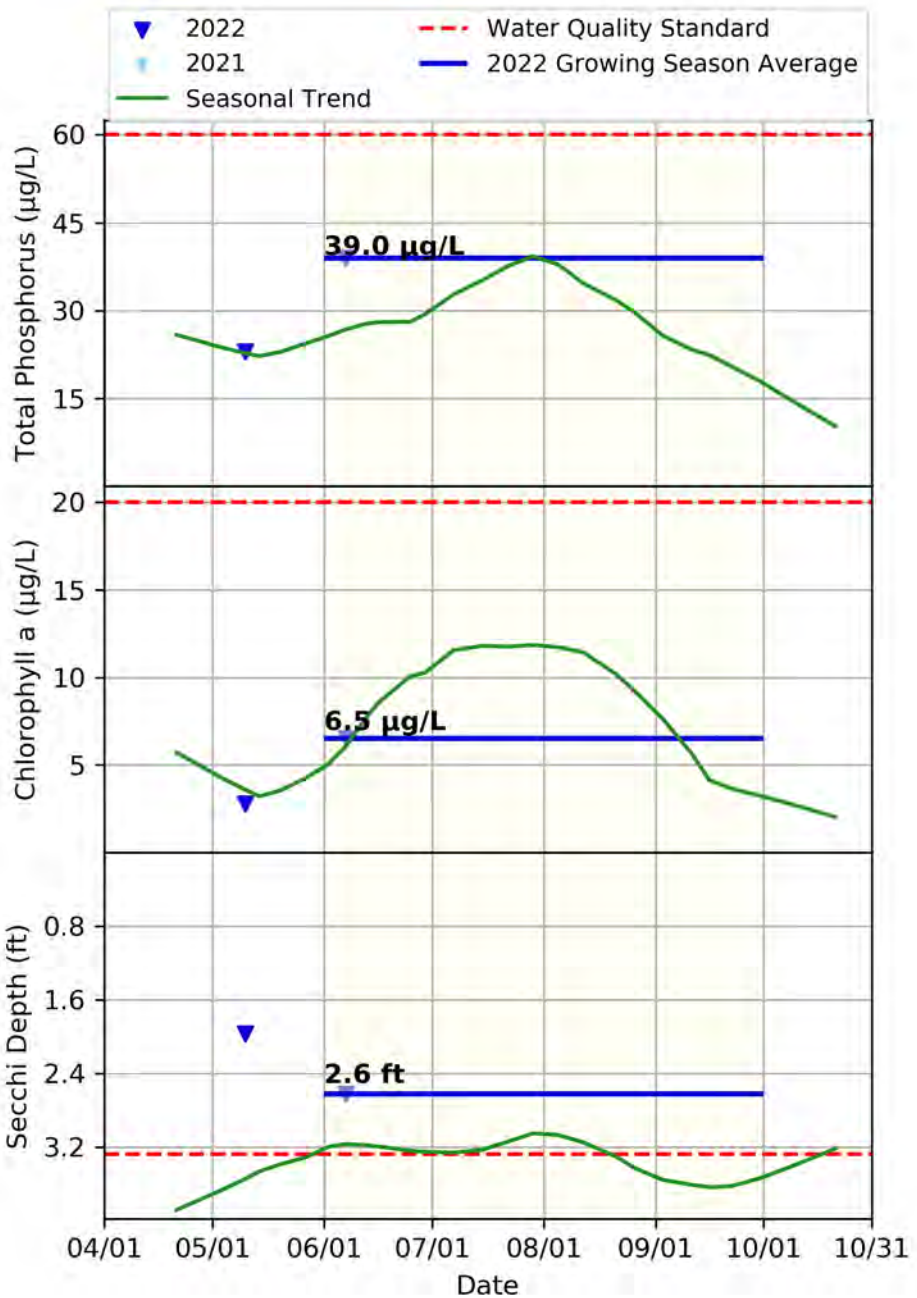
Algae:

June-Sept. Average Chlorophyll-a (Chl-a, $\mu\text{g/L}$)



Clarity:

June-Sept. Average Secchi Depth (Secchi, ft)



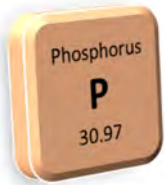
State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

HEIMS LAKE

Historical Water Quality Summary

	Phosphorus ($\mu\text{g/L}$)	Chl-a ($\mu\text{g/L}$)	Secchi (feet)
State Standard	<60	<20	>3.3
10-year Average (2013-2022)	42.2	11.8	3.3
2040 District Goal	<60	n/a	>3.3
5-year Average (2018-2022)	39.0	6.5	2.6

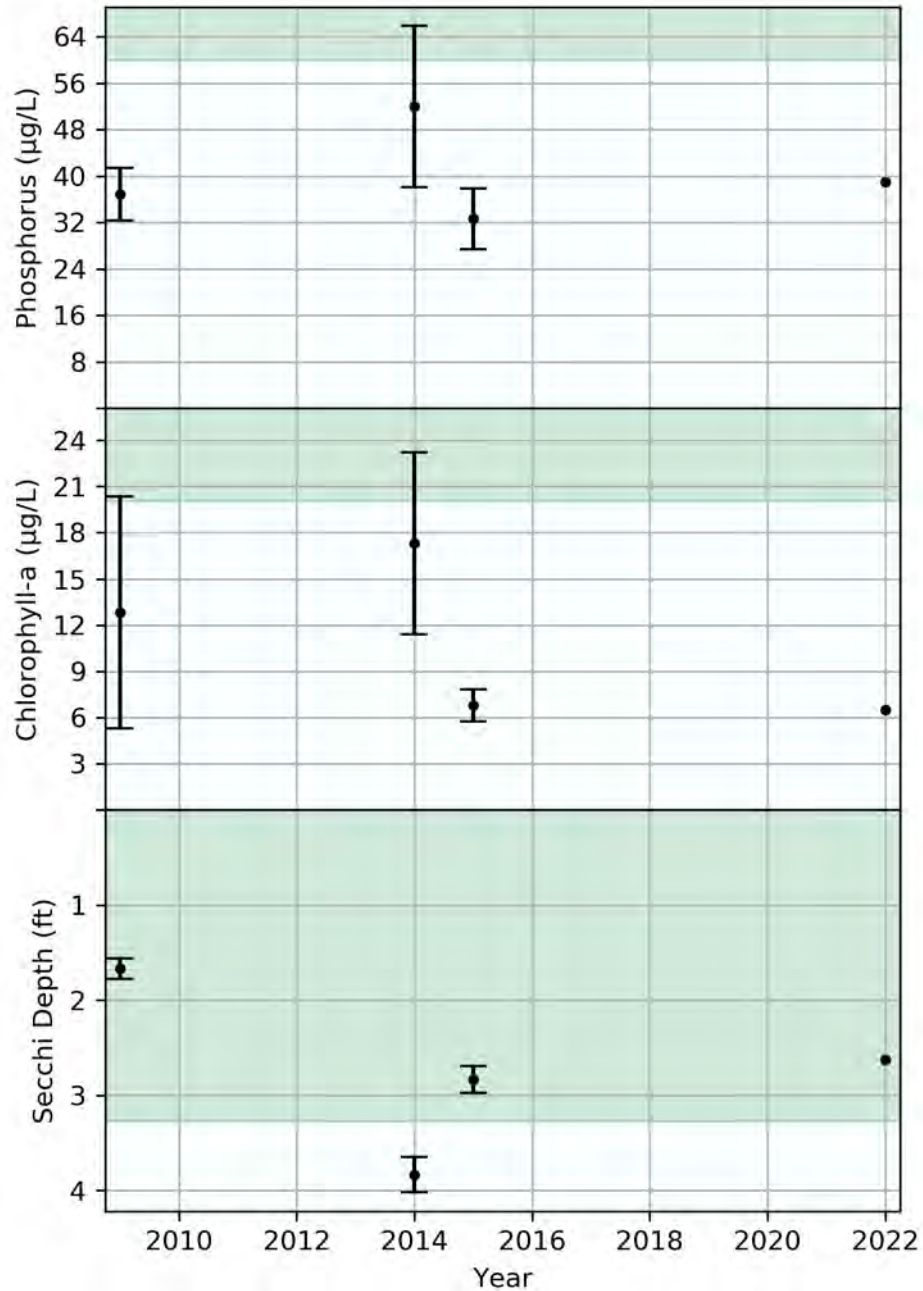
Nutrients:
June-Sept. Average
Total Phosphorus
(TP, $\mu\text{g/L}$)



Algae:
June-Sept. Average
Chlorophyll-a
(Chl-a, $\mu\text{g/L}$)



Clarity:
June-Sept. Average
Secchi Depth
(Secchi, ft)



State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

KEEWAHTIN LAKE

Fast Facts:

DNR Lake ID: 82-0080-00

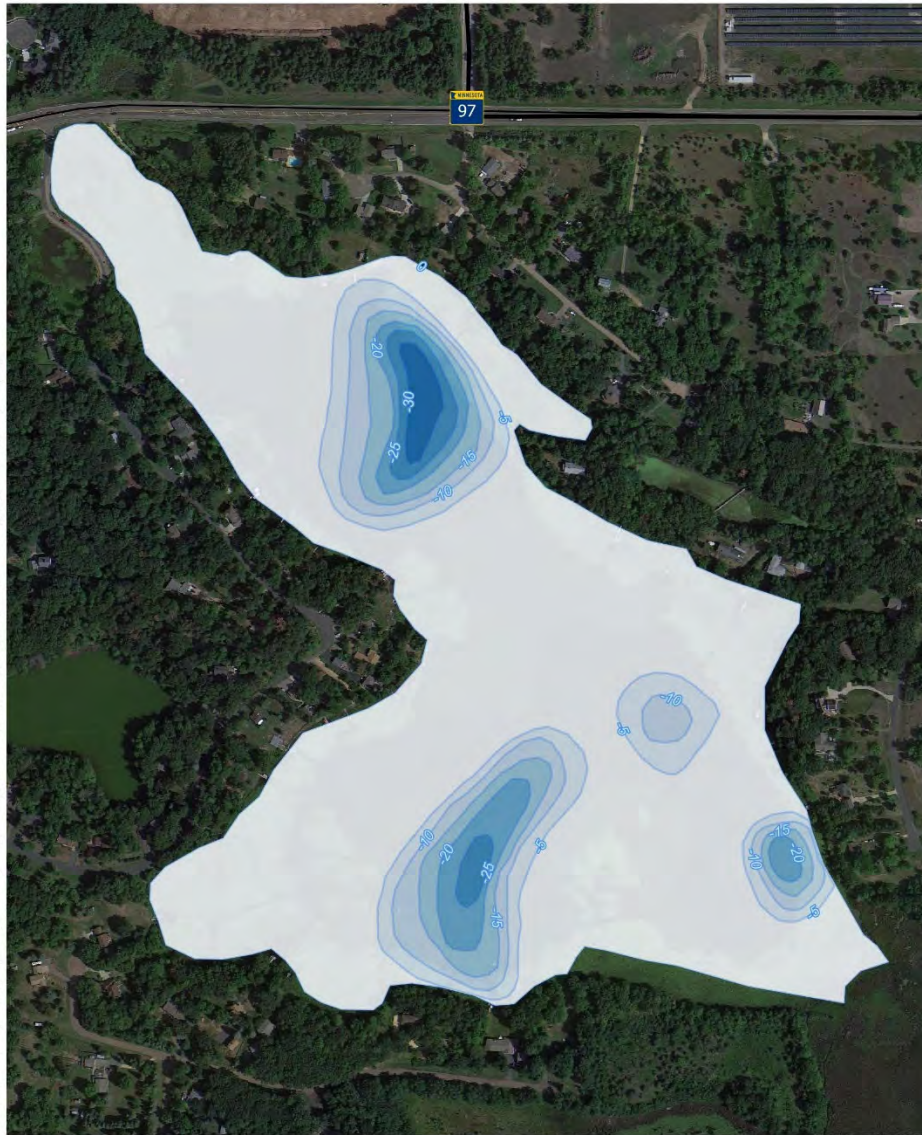
County: Washington

Surface Area: 92 acres

Littoral Area (depths less than 15 feet): 67 acres

Maximum Depth: 34 feet

Shore Length: 2.2 miles



Date: 2022-02-04T12:35:06-709 Author: Eklensen, Layout: BM_Bathymetry
Document Path: X:\Clients\WD\00376_CLFLWD\0010_General\Watershed_Eng\3000_Program\3003A_monitoring\07_GIS\lake_bathymetry.qgz



— Lake Depth (ft)



CLFLWD
Keewahtin Lake

Bathymetry

0 200 400 ft

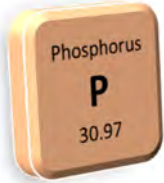


KEEWAHTIN LAKE

2022 Surface Water Quality Summary

Nutrients:

June-Sept. Average Total Phosphorus (TP, $\mu\text{g/L}$)



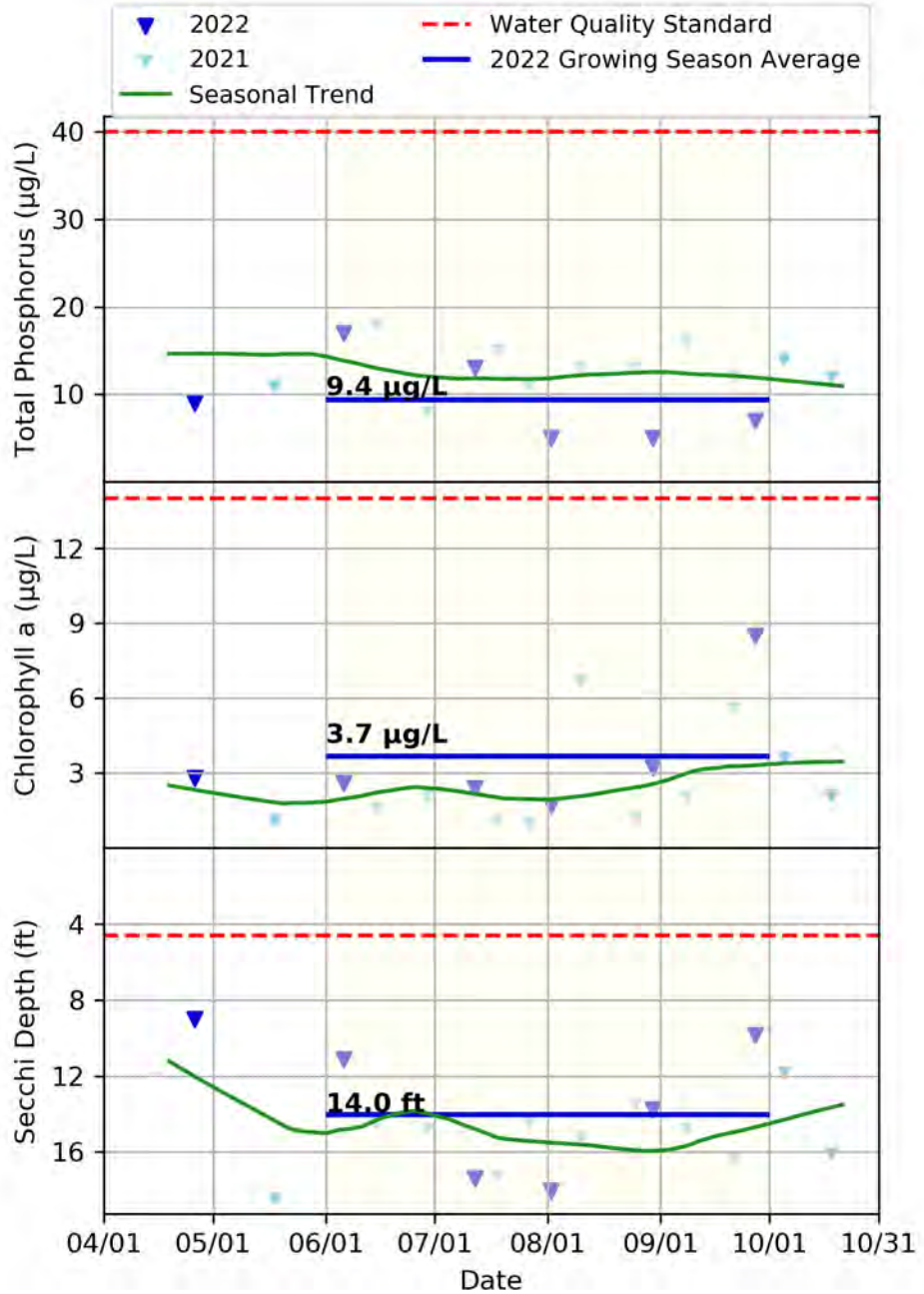
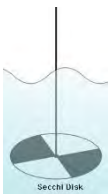
Algae:

June-Sept. Average Chlorophyll-a (Chl-a, $\mu\text{g/L}$)



Clarity:

June-Sept. Average Secchi Depth (Secchi, ft)



State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

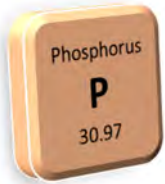
KEWAHTIN LAKE

Historical Water Quality Summary

	Phosphorus ($\mu\text{g/L}$)	Chl-a ($\mu\text{g/L}$)	Secchi (feet)
State Standard	<40	<14	>4.6
10-year Average (2013-2022)	13.9	2.7	14.3
2040 District Goal	<20	n/a	>10.0
5-year Average (2018-2022)	15.3	2.5	12.9

Nutrients:

June-Sept. Average
Total Phosphorus
(TP, $\mu\text{g/L}$)



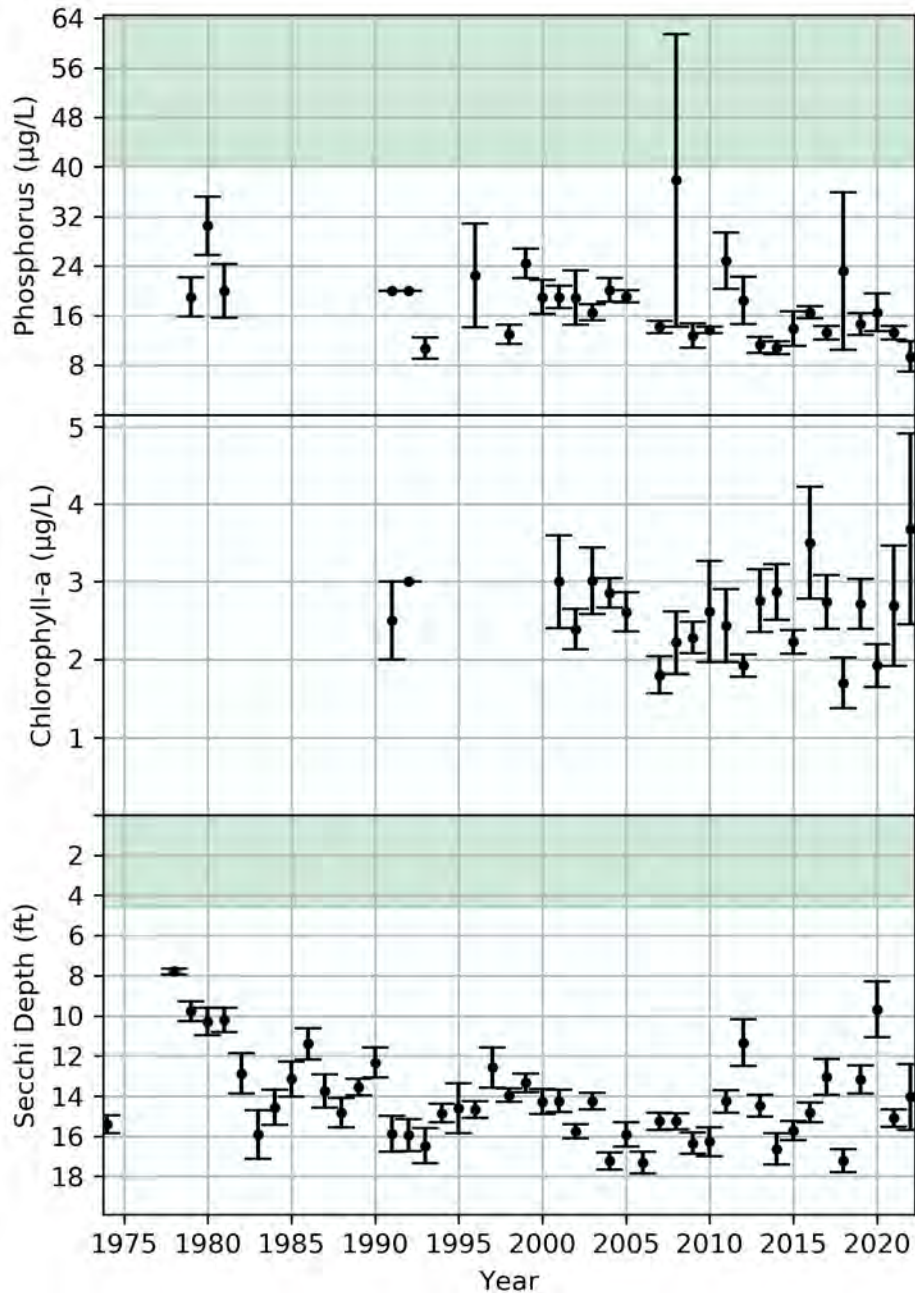
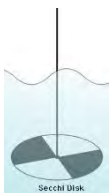
Algae:

June-Sept. Average
Chlorophyll-a
(Chl-a, $\mu\text{g/L}$)



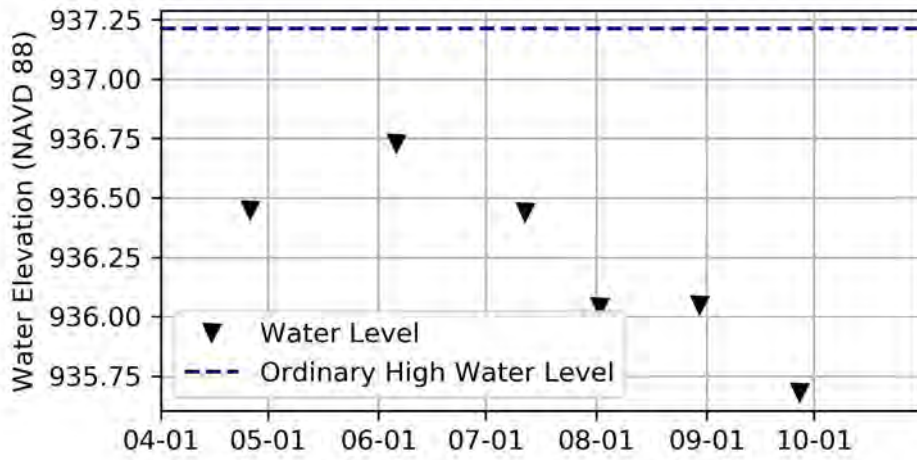
Clarity:

June-Sept. Average
Secchi Depth
(Secchi, ft)



State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

KEEWAHTIN LAKE



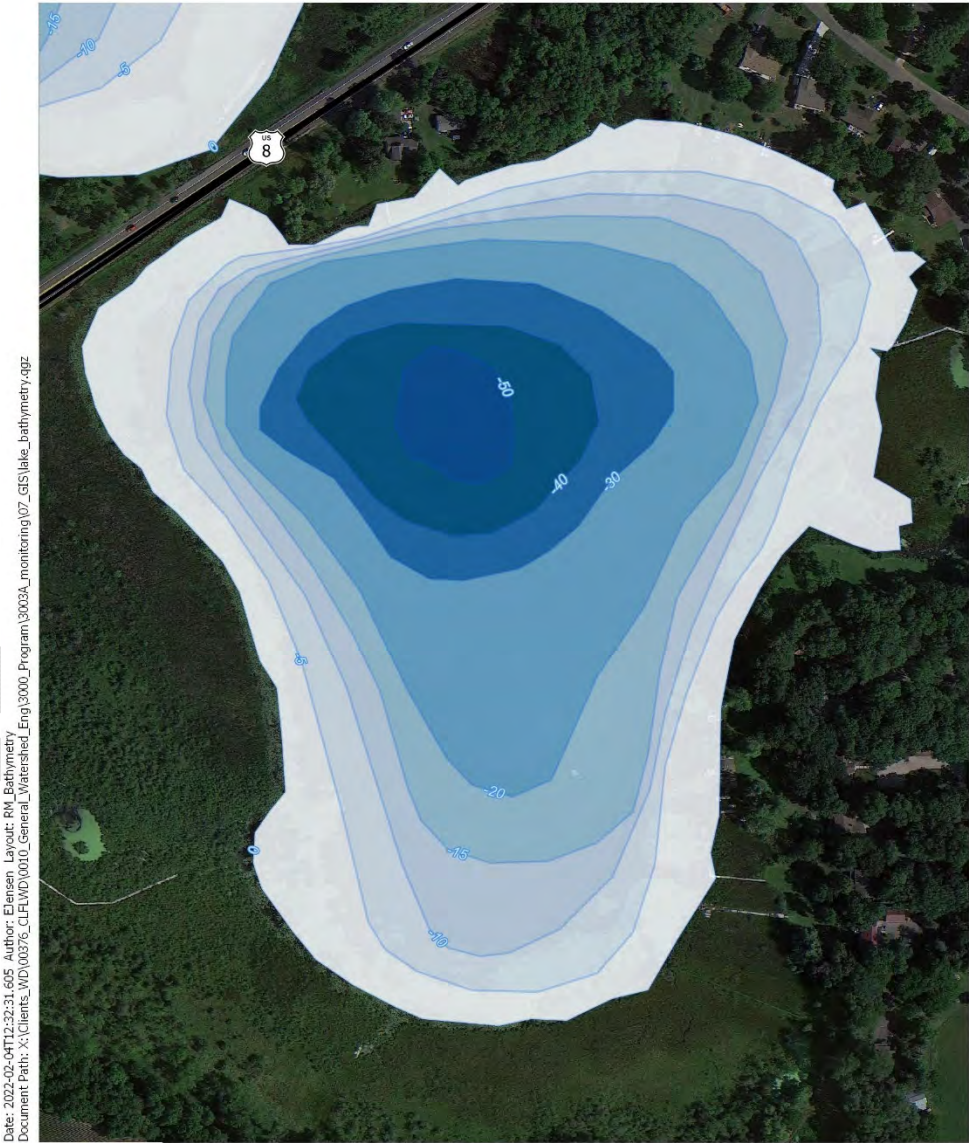
2022 Lake Levels

Lake levels ranged over a total of 1.0 feet; between a minimum of 935.70 feet on September 27, 2022, and a maximum of 936.7 feet on June 6, 2022.

LITTLE COMFORT LAKE

Fast Facts:

- DNR Lake ID:** 13-0054-00
- County:** Chisago
- Surface Area:** 37 acres
- Littoral Area** (depths less than 15 feet): 16 acres
- Maximum Depth:** 56 feet
- Shore Length:** 1.04 miles



Date: 2022-02-04T12:32:31-605 Author: Elnesen Layout: RM Bathymetry
Document Path: X:\Clients_WD\00376_CLFLWD\0010_General_Watershed_Eng\3000_Program\3003A_monitoring\07_GIS\lake_bathymetry.qgz

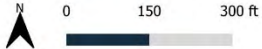


— Lake Depth (ft)



CLFLWD
Little Comfort Lake

Bathymetry

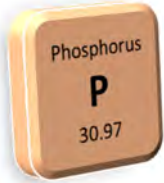


LITTLE COMFORT LAKE

2022 Surface Water Quality Summary

Nutrients:

June-Sept. Average Total Phosphorus (TP, $\mu\text{g/L}$)



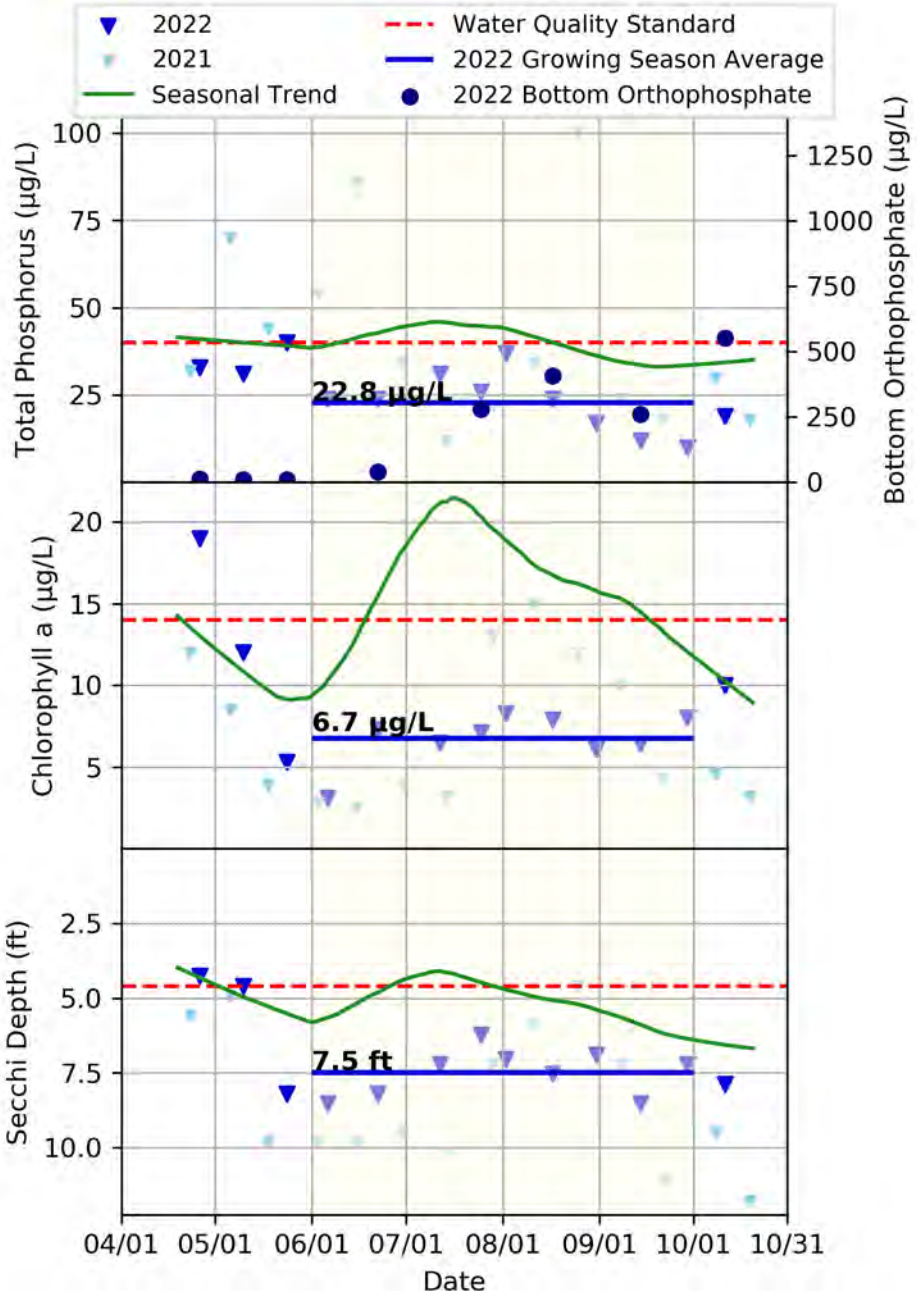
Algae:

June-Sept. Average Chlorophyll-a (Chl-a, $\mu\text{g/L}$)



Clarity:

June-Sept. Average Secchi Depth (Secchi, ft)



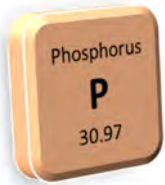
State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

LITTLE COMFORT LAKE

Historical Water Quality Summary

	Phosphorus ($\mu\text{g/L}$)	Chl-a ($\mu\text{g/L}$)	Secchi (feet)
State Standard	<40	<14	>4.6
10-year Average (2013-2022)	48.3	19.4	5.3
2040 District Goal	<30	n/a	>7.0
5-year Average (2018-2022)	42.2	16.3	5.9

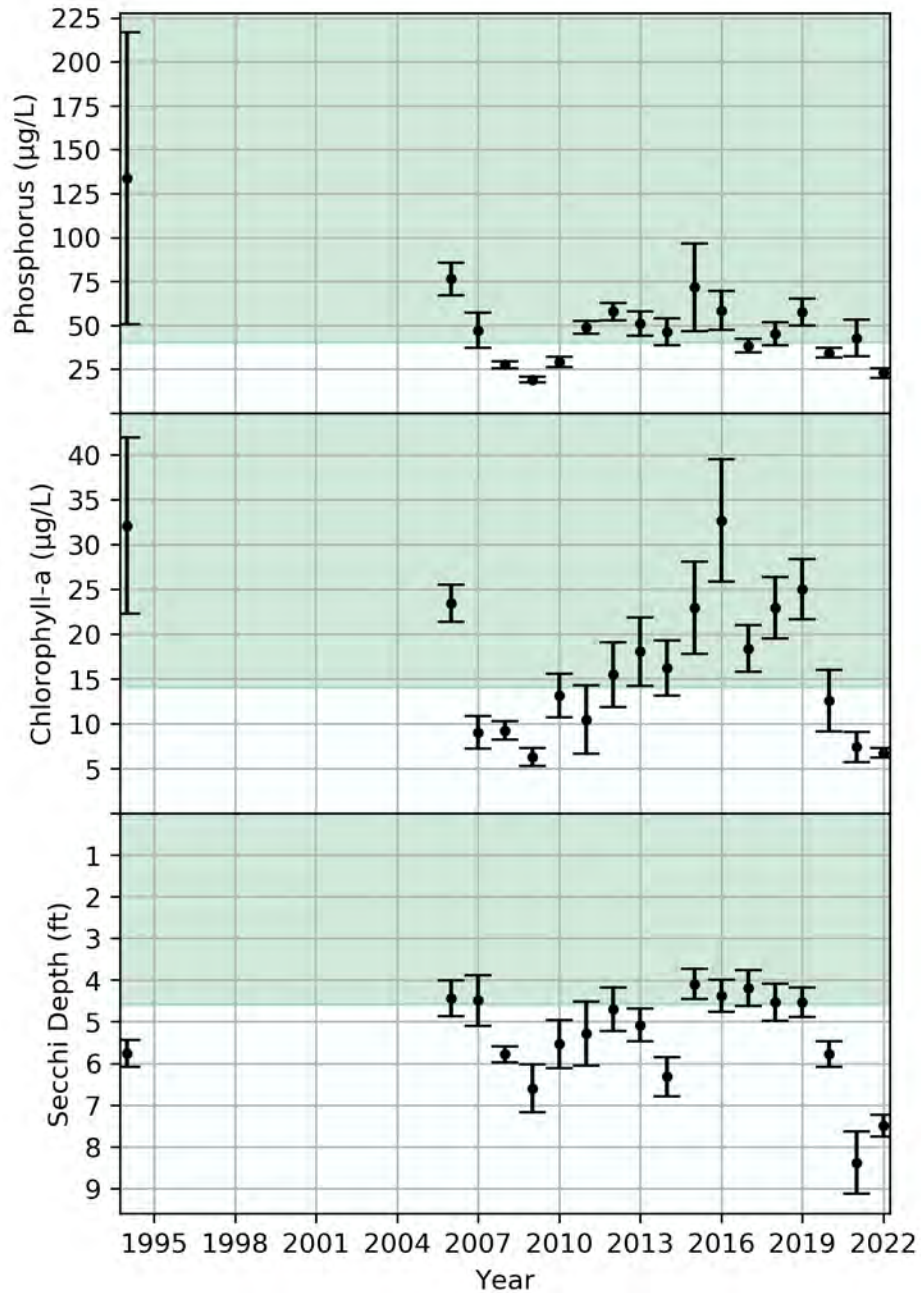
Nutrients:
June-Sept. Average
Total Phosphorus
(TP, $\mu\text{g/L}$)



Algae:
June-Sept. Average
Chlorophyll-a
(Chl-a, $\mu\text{g/L}$)

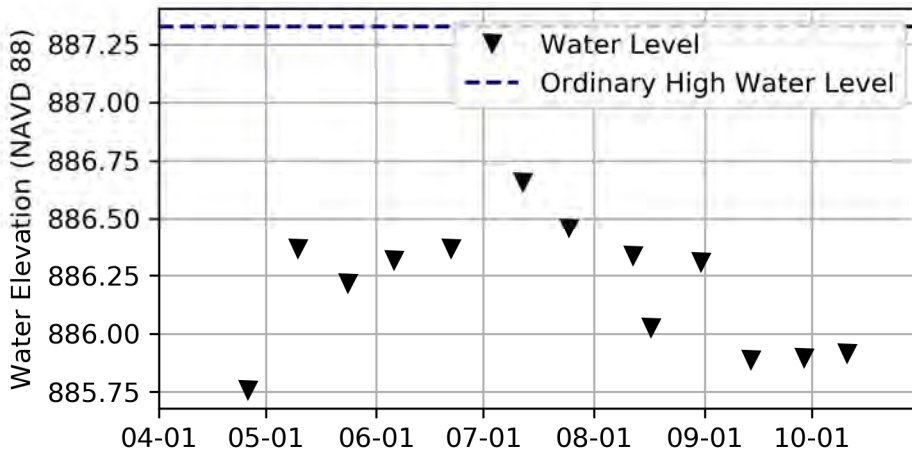


Clarity:
June-Sept. Average
Secchi Depth
(Secchi, ft)



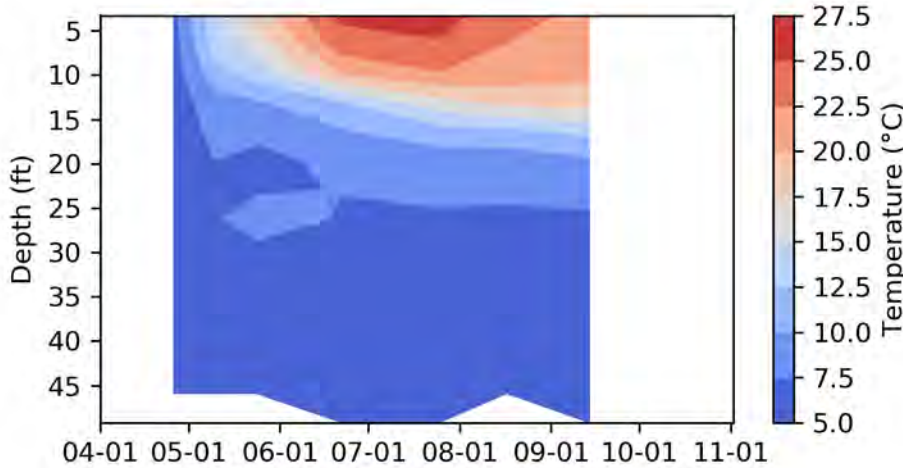
State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

LITTLE COMFORT LAKE



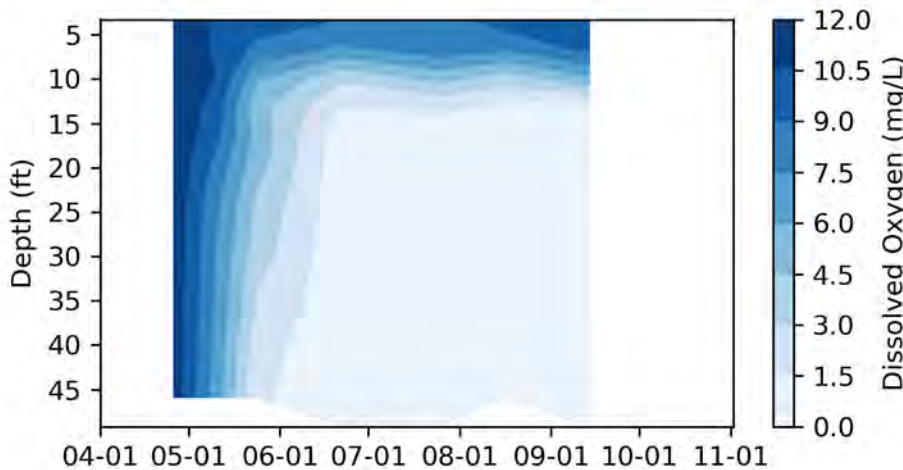
2022 Lake Levels

Lake levels ranged over a total of 0.9 feet; between a minimum of 885.8 feet on April 26, 2022 and a maximum of 886.7 feet on July 12, 2022.



2022 Temperature Profiles

The lake was stratified starting in June.



2022 Dissolved Oxygen Profiles

The lightest blue represents the duration and depths where no oxygen is present and sediment phosphorus can be released and contribute to internal loading.

Internal loading was possible starting in June. Bottom P concentrations increased throughout most of the monitoring season.

LENDT LAKE

Fast Facts:

DNR Lake ID: 13-0103-00

County: Chisago

Surface Area: 42 acres

Littoral Area (depths less than 15 feet): NA acres

Maximum Depth: NA feet

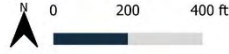
Shore Length: NA miles



Date: 2023-02-24T13:16:55.070 Author: Eljensen, Layout: RM, CLFLWD_Lake
Document Path: X:\Clients_VD\00376_CLFLWD\0010_General_Watershed_Eng\3000_Program\3003A_monitoring\07_GIS\lake_aerials\022.gpr



- Lake Management District Boundary
- Lake



CLFLWD
Lendt Lake
Lake Map

LENDT LAKE

2022 Surface Water Quality Summary

Nutrients:

June-Sept. Average Total Phosphorus (TP, $\mu\text{g/L}$)



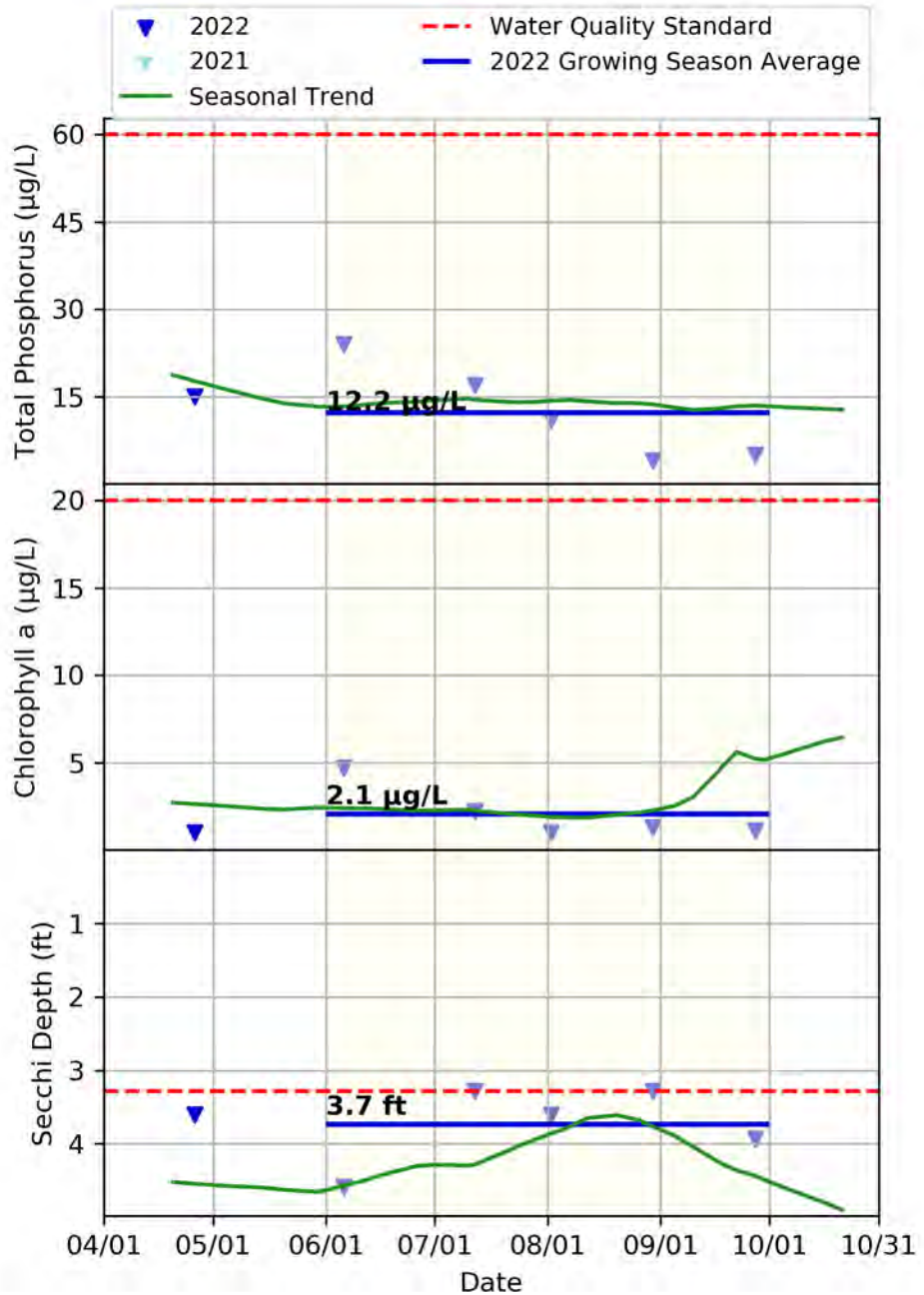
Algae:

June-Sept. Average Chlorophyll-a (Chl-a, $\mu\text{g/L}$)



Clarity:

June-Sept. Average Secchi Depth (Secchi, ft)



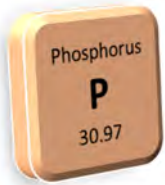
State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

LENDT LAKE

Historical Water Quality Summary

	Phosphorus ($\mu\text{g/L}$)	Chl-a ($\mu\text{g/L}$)	Secchi (feet)
State Standard	<60	<20	>3.3
10-year Average (2013-2022)	14.8	5.7	4.1
2040 District Goal	<60	n/a	>3.3
5-year Average (2018-2022)	15.6	3.7	4.2

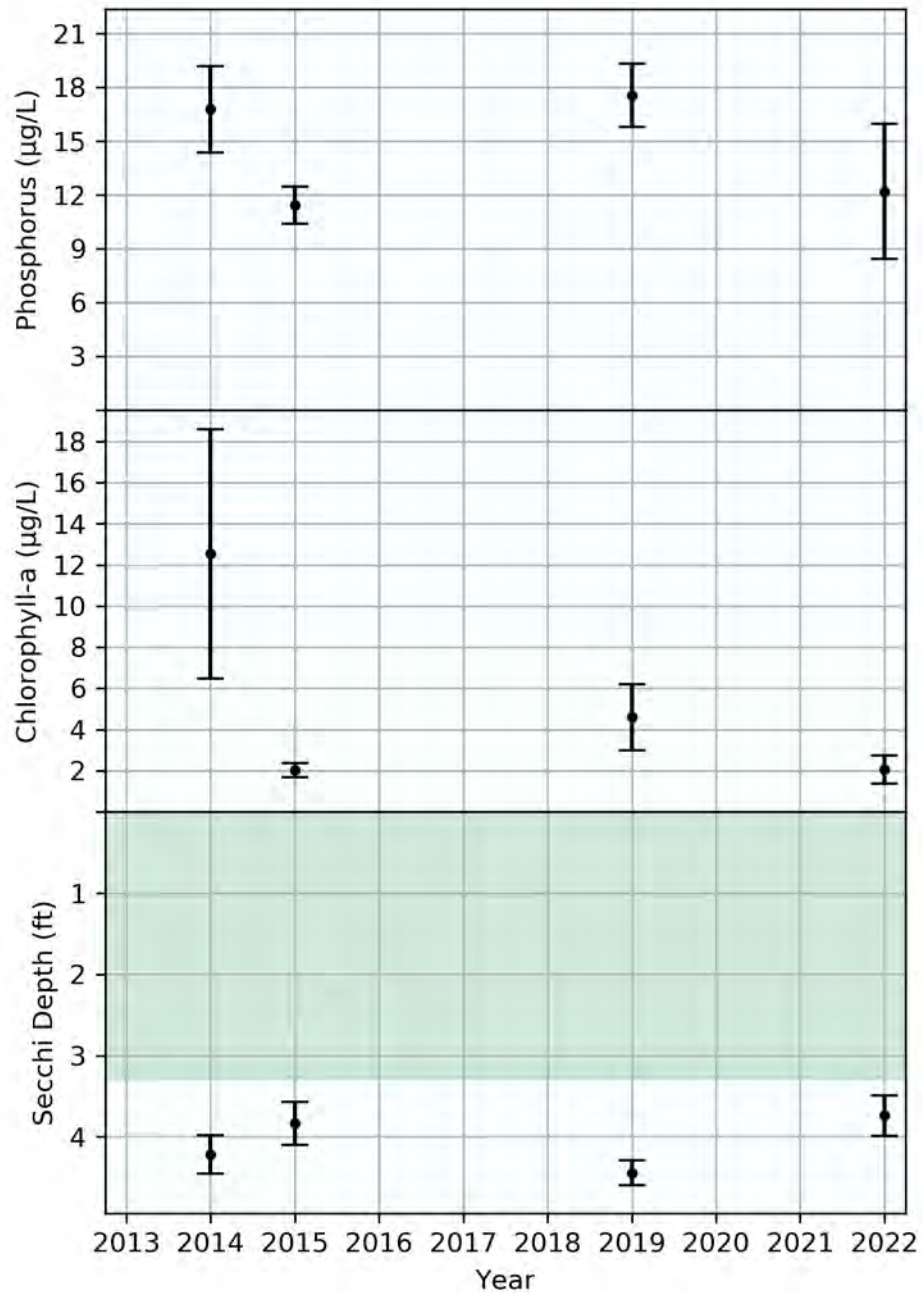
Nutrients:
June-Sept. Average
Total Phosphorus
(TP, $\mu\text{g/L}$)



Algae:
June-Sept. Average
Chlorophyll-a
(Chl-a, $\mu\text{g/L}$)



Clarity:
June-Sept. Average
Secchi Depth
(Secchi, ft)



State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

MOODY LAKE

Fast Facts:

DNR Lake ID: 13-0023-00

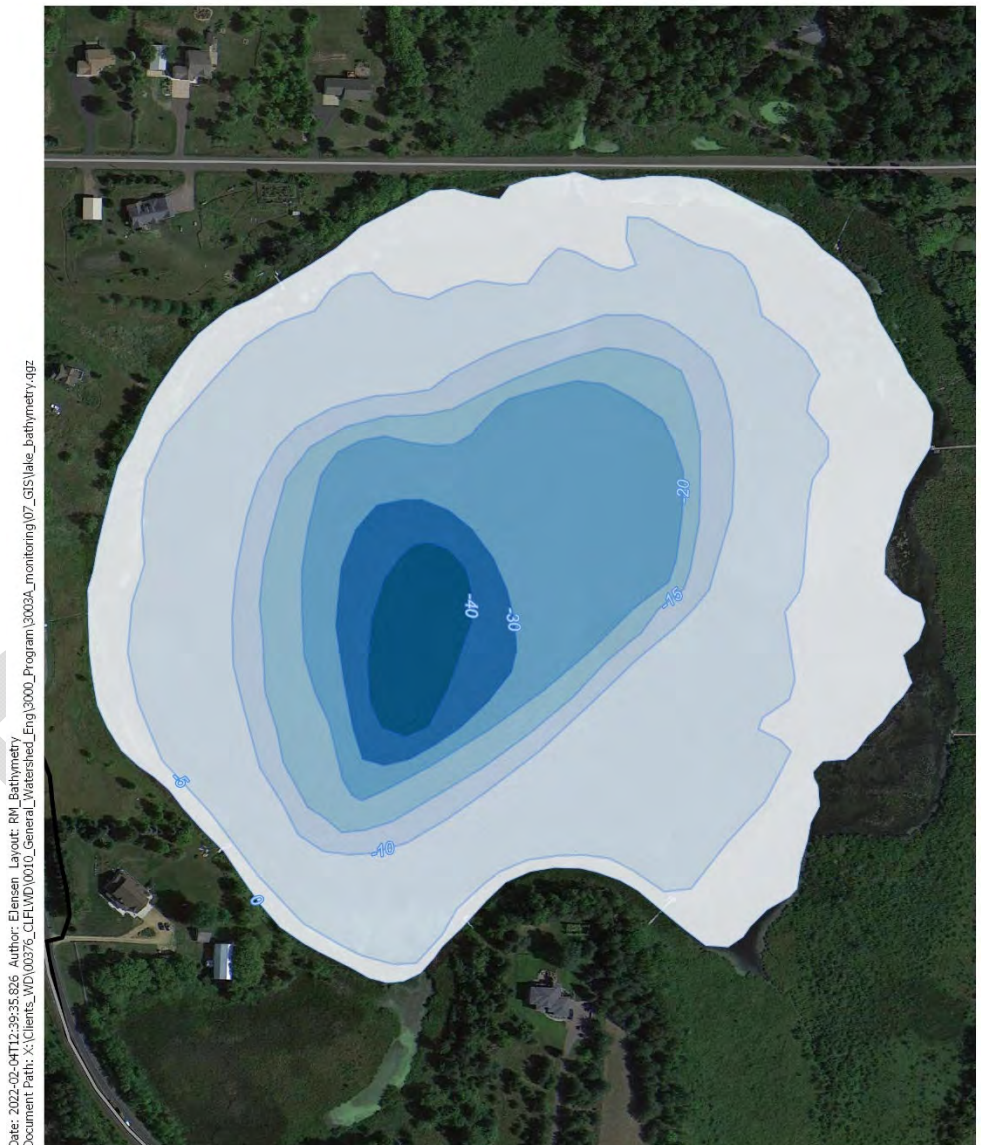
County: Chisago

Surface Area: 45 acres

Littoral Area (depths less than 15 feet): 22 acres

Maximum Depth: 48 feet

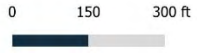
Shore Length: 1.04 miles



Date: 2022-02-04T12:39:35.836 Author: Eljensen Layout: RM_Bathymetry
Document Path: X:\Clients_VD\00376_CLFLWD\0010_General_Watershed_Eng\3000_Program\3003A_monitoring\07_GIS\lake_bathymetry.qgz



— Lake Depth (ft)



CLFLWD
Moody Lake

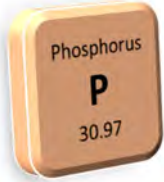
Bathymetry

MOODY LAKE

2022 Surface Water Quality Summary

Nutrients:

June-Sept. Average Total Phosphorus (TP, $\mu\text{g/L}$)



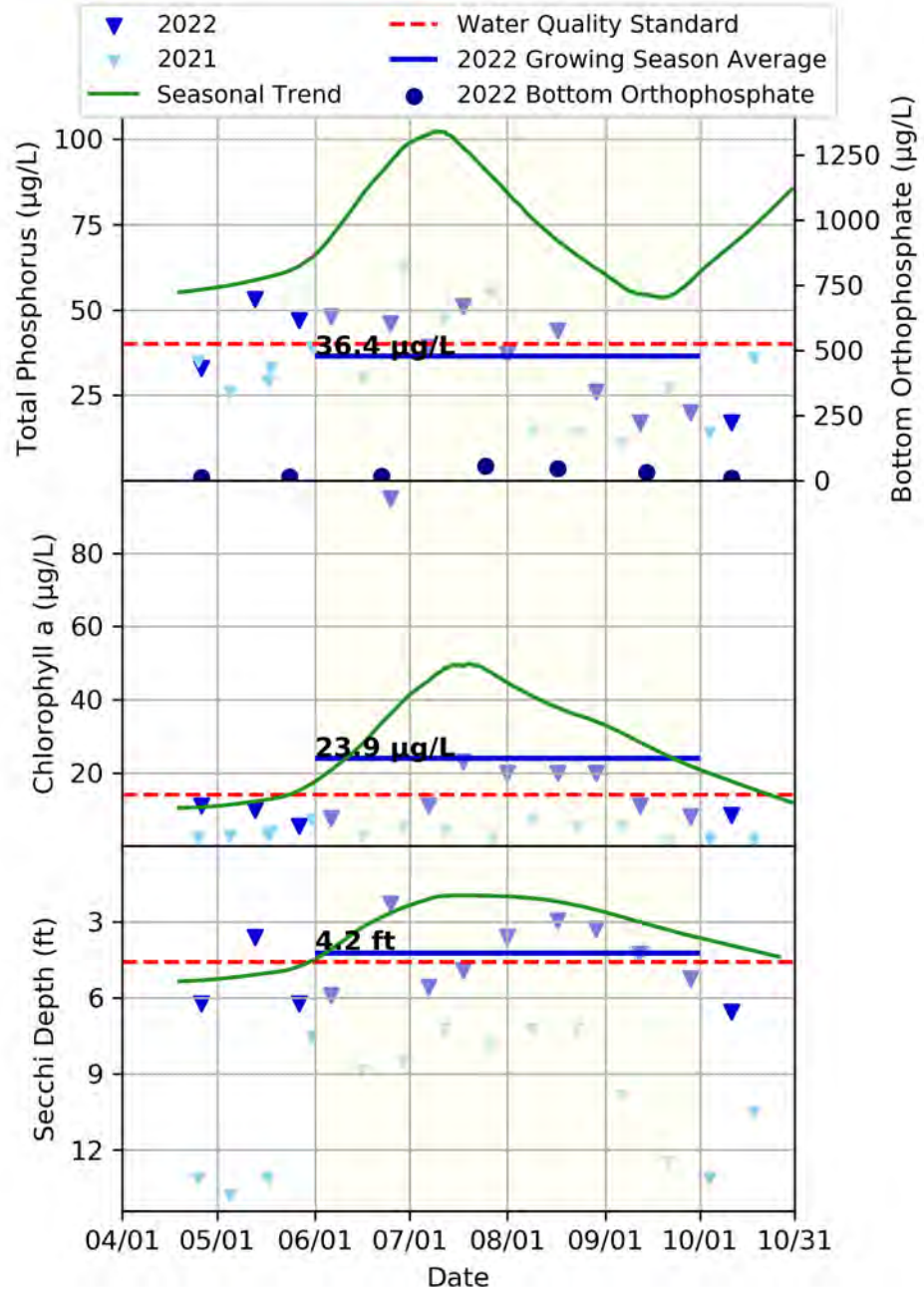
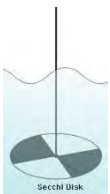
Algae:

June-Sept. Average Chlorophyll-a (Chl-a, $\mu\text{g/L}$)



Clarity:

June-Sept. Average Secchi Depth (Secchi, ft)



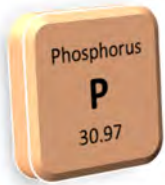
State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

MOODY LAKE

Historical Water Quality Summary

	Phosphorus ($\mu\text{g/L}$)	Chl-a ($\mu\text{g/L}$)	Secchi (feet)
State Standard	<40	<14	>4.6
10-year Average (2013-2022)	81.6	43.2	3.0
2040 District Goal	<40	n/a	>4.6
5-year Average (2018-2022)	55.9	36.5	3.8

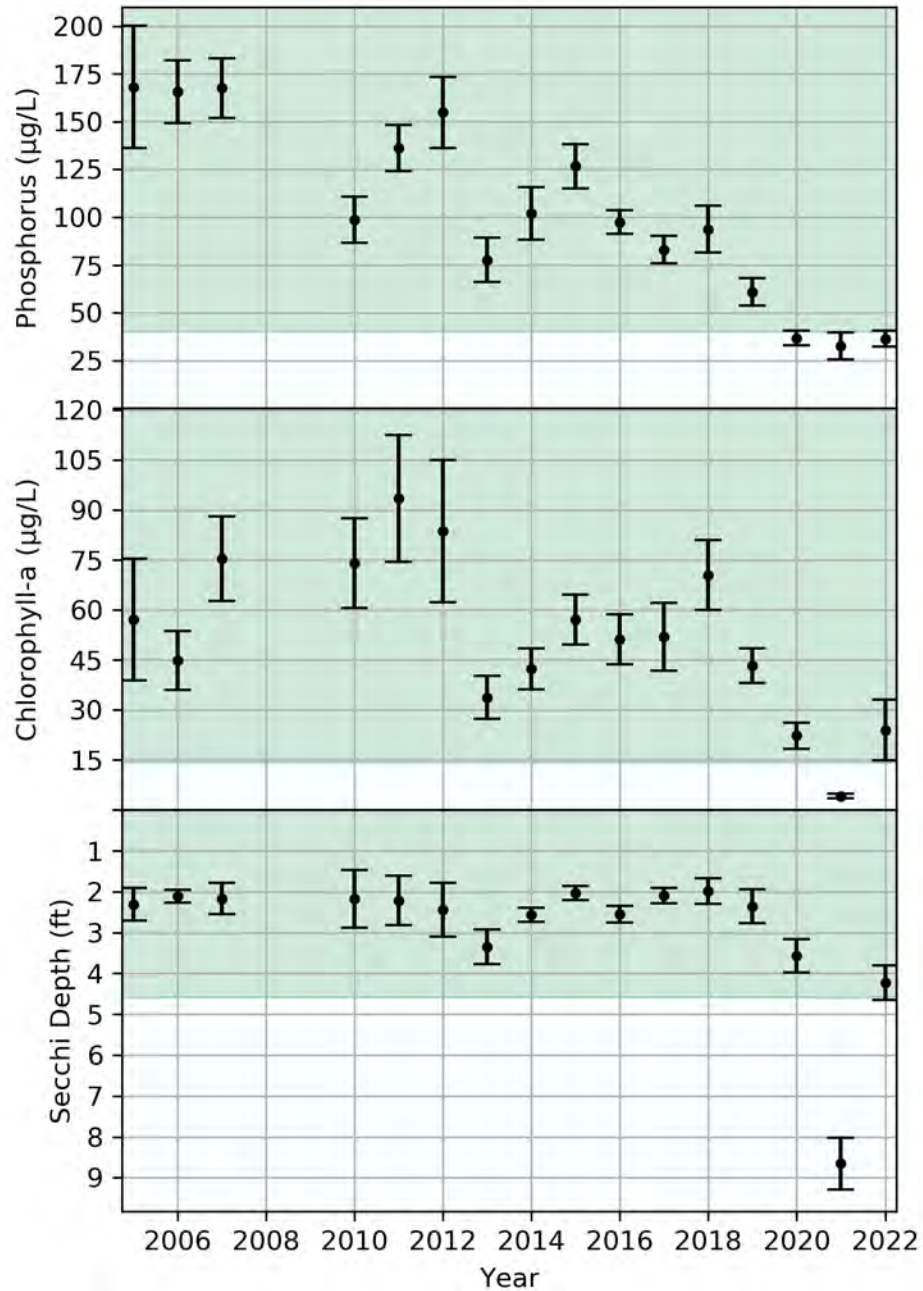
Nutrients:
June-Sept. Average
Total Phosphorus
(TP, $\mu\text{g/L}$)



Algae:
June-Sept. Average
Chlorophyll-a
(Chl-a, $\mu\text{g/L}$)

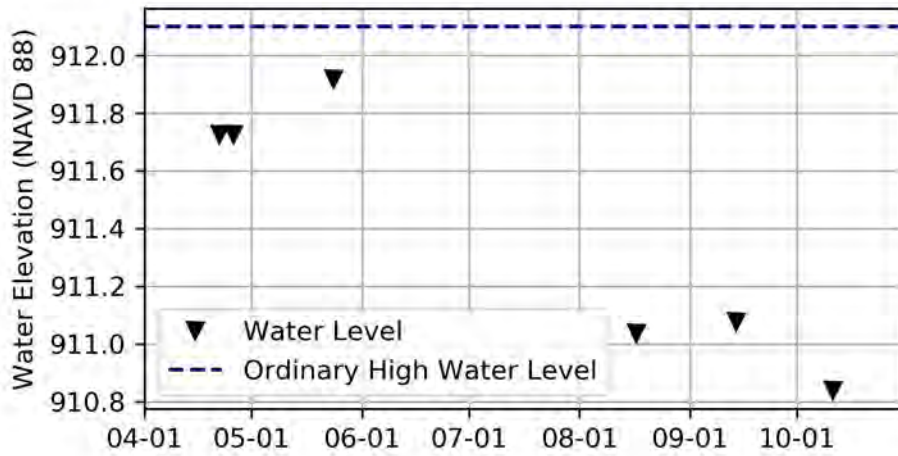


Clarity:
June-Sept. Average
Secchi Depth
(Secchi, ft)



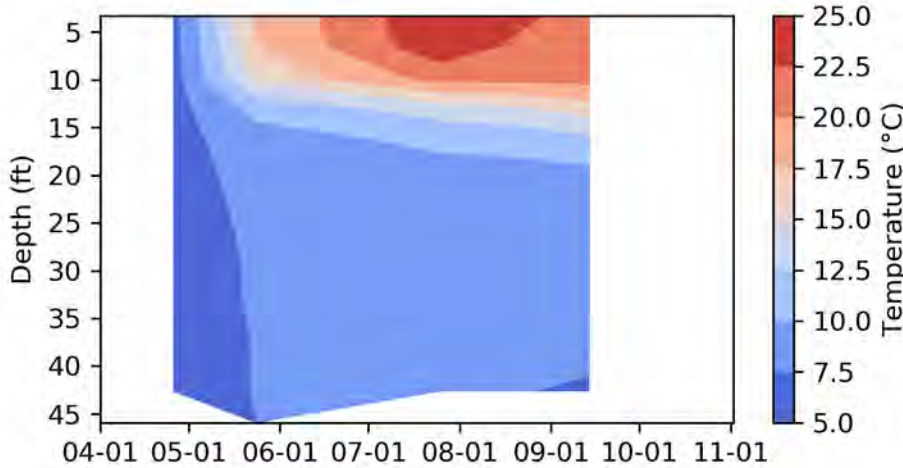
State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

MOODY LAKE



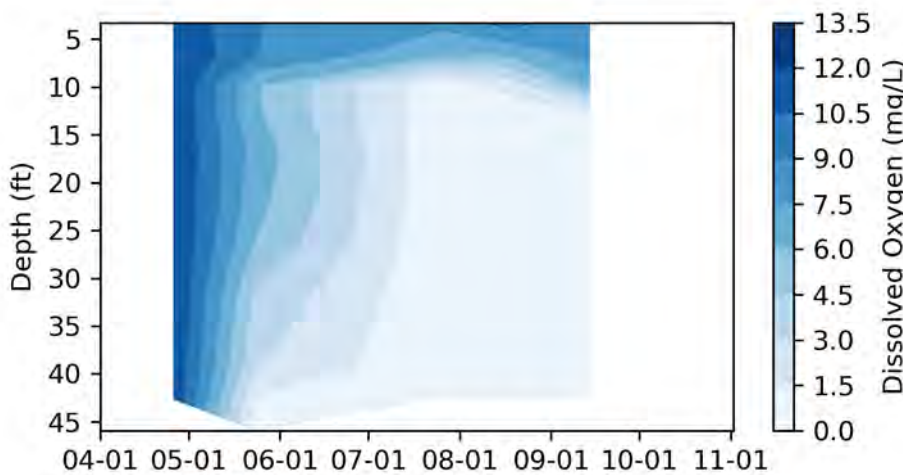
2022 Lake Levels

Lake levels ranged over a total of 1.1 feet; between a minimum of 910.8 feet on October 11, 2022 and a maximum of 911.80 feet on May 24, 2022.



2022 Temperature Profiles

The lake was stratified starting in mid-May.



2022 Dissolved Oxygen Profiles

The lightest blue represents the duration and depths where no oxygen is present and sediment phosphorus can be released and contribute to internal loading.

Internal loading was possible starting in mid-May, but bottom P concentrations remained low.

SCHOOL LAKE

Fast Facts:

DNR Lake ID: 13-0044-00

County: Chisago

Surface Area: 49 acres

Littoral Area (depths less than 15 feet): 32 acres

Maximum Depth: 24 feet

Shore Length: 1.36 miles



Date: 2022-03-14T13:00:08.579 Author: Etelsen, Layout: Comfort Lake CLFLWD
Document Path: X:\Clients_WD\00376_CLFLWD\0010_General_Watershed_Fig\3000_Program\3003A_monitoring\07_GIS\lake_aerials.ggz



-  Lakes
-  Lake Management District



CLFLWD School Lake



0 100 200 ft

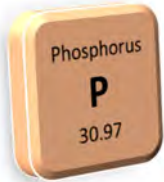


SCHOOL LAKE

2022 Surface Water Quality Summary

Nutrients:

June-Sept. Average Total Phosphorus (TP, $\mu\text{g/L}$)



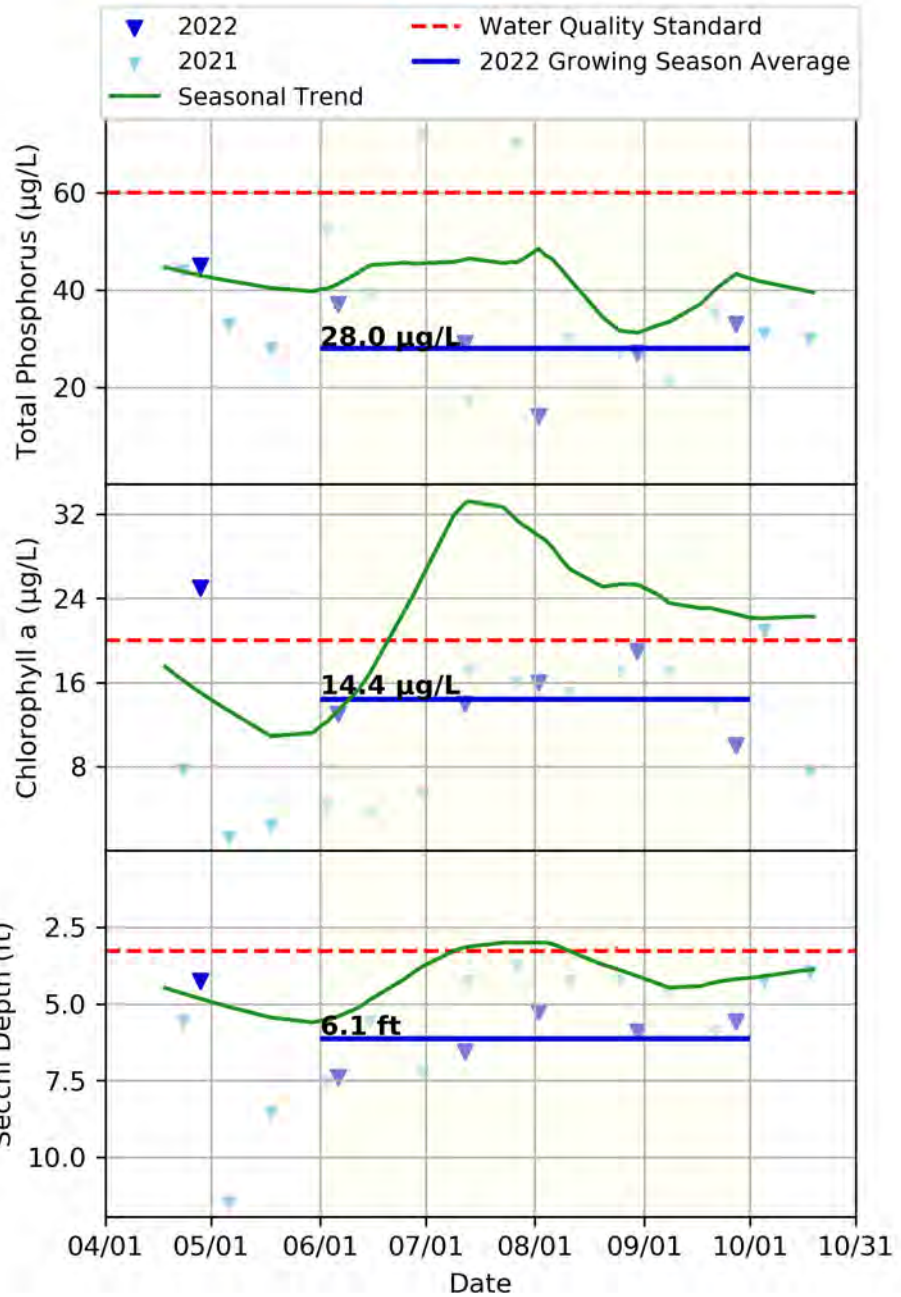
Algae:

June-Sept. Average Chlorophyll-a (Chl-a, $\mu\text{g/L}$)



Clarity:

June-Sept. Average Secchi Depth (Secchi, ft)



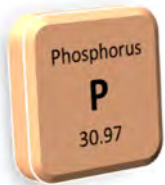
State standards are shown with a dashed red line. Phosphorus = $40 \mu\text{g/L}$, Chlorophyll-a = $14 \mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

SCHOOL LAKE

Historical Water Quality Summary

	Phosphorus ($\mu\text{g/L}$)	Chl-a ($\mu\text{g/L}$)	Secchi (feet)
State Standard	<60	<20	>3.3
10-year Average (2013-2022)	45.2	26.5	4.1
2040 District Goal	<60	n/a	>3.3
5-year Average (2018-2022)	43.1	25.0	4.5

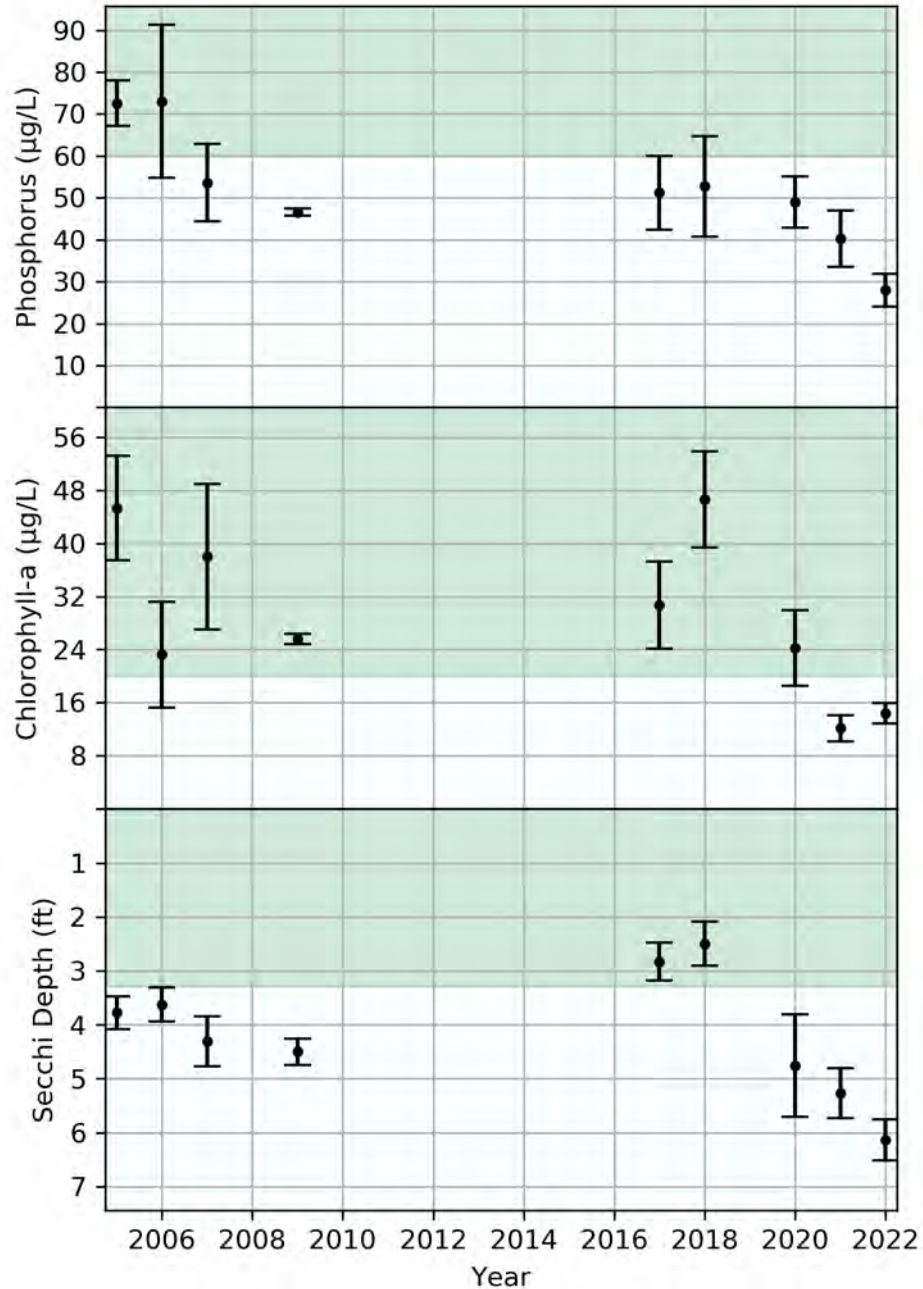
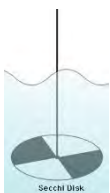
Nutrients:
June-Sept. Average
Total Phosphorus
(TP, $\mu\text{g/L}$)



Algae:
June-Sept. Average
Chlorophyll-a
(Chl-a, $\mu\text{g/L}$)

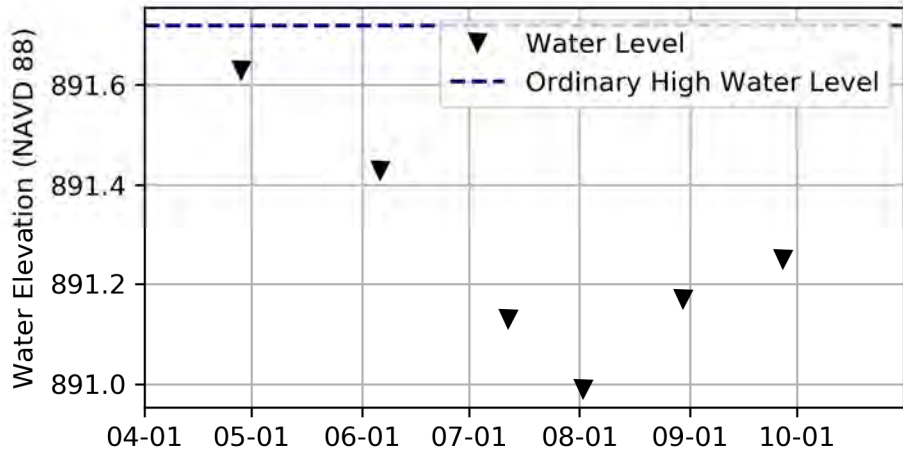


Clarity:
June-Sept. Average
Secchi Depth
(Secchi, ft)



State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

SCHOOL LAKE



2022 Lake Levels

Lake levels ranged over a total of 0.6 feet; between a minimum of 891.0 feet on August 2, 2022, and a maximum of 891.6 feet on April 28, 2022.

DRAFT

SHIELDS LAKE

Fast Facts:

DNR Lake ID: 82-0162-00

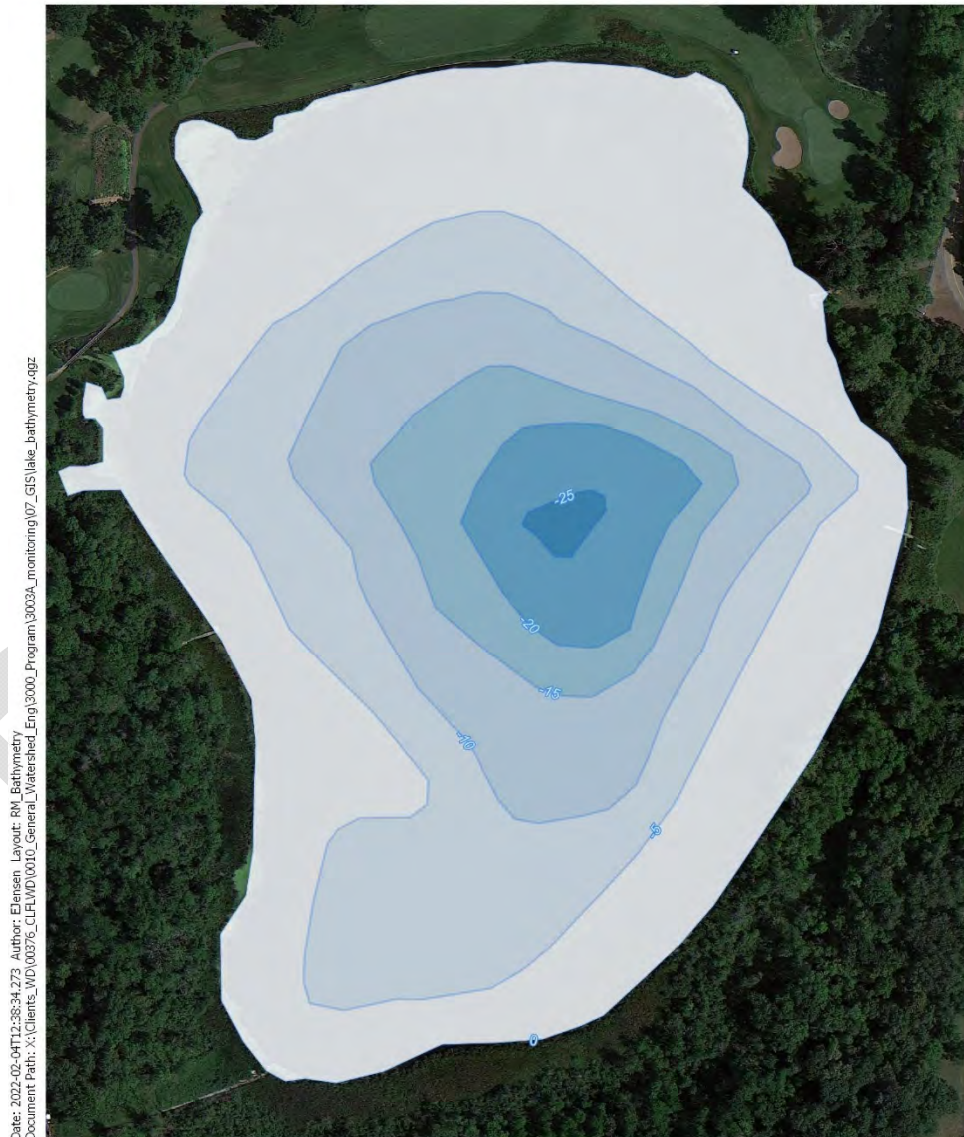
County: Washington

Surface Area: 30 acres

Littoral Area (depths less than 15 feet): 22 acres

Maximum Depth: 27 feet

Shore Length: 0.85 miles



Date: 2022-02-04T12:38:34-273 Author: Elensen Layout: RM_Bathymetry
Document Path: X:\Clients_WD\00876_CLFLWD\0010_General_Watershed_Eng\3000_Program\3003A_monitoring\07_GIS\lake_bathymetry.qgz



— Lake Depth (ft)



0 100 200 ft

CLFLWD
Shields Lake

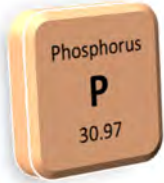
Bathymetry

SHIELDS LAKE

2022 Surface Water Quality Summary

Nutrients:

June-Sept. Average Total Phosphorus (TP, $\mu\text{g/L}$)



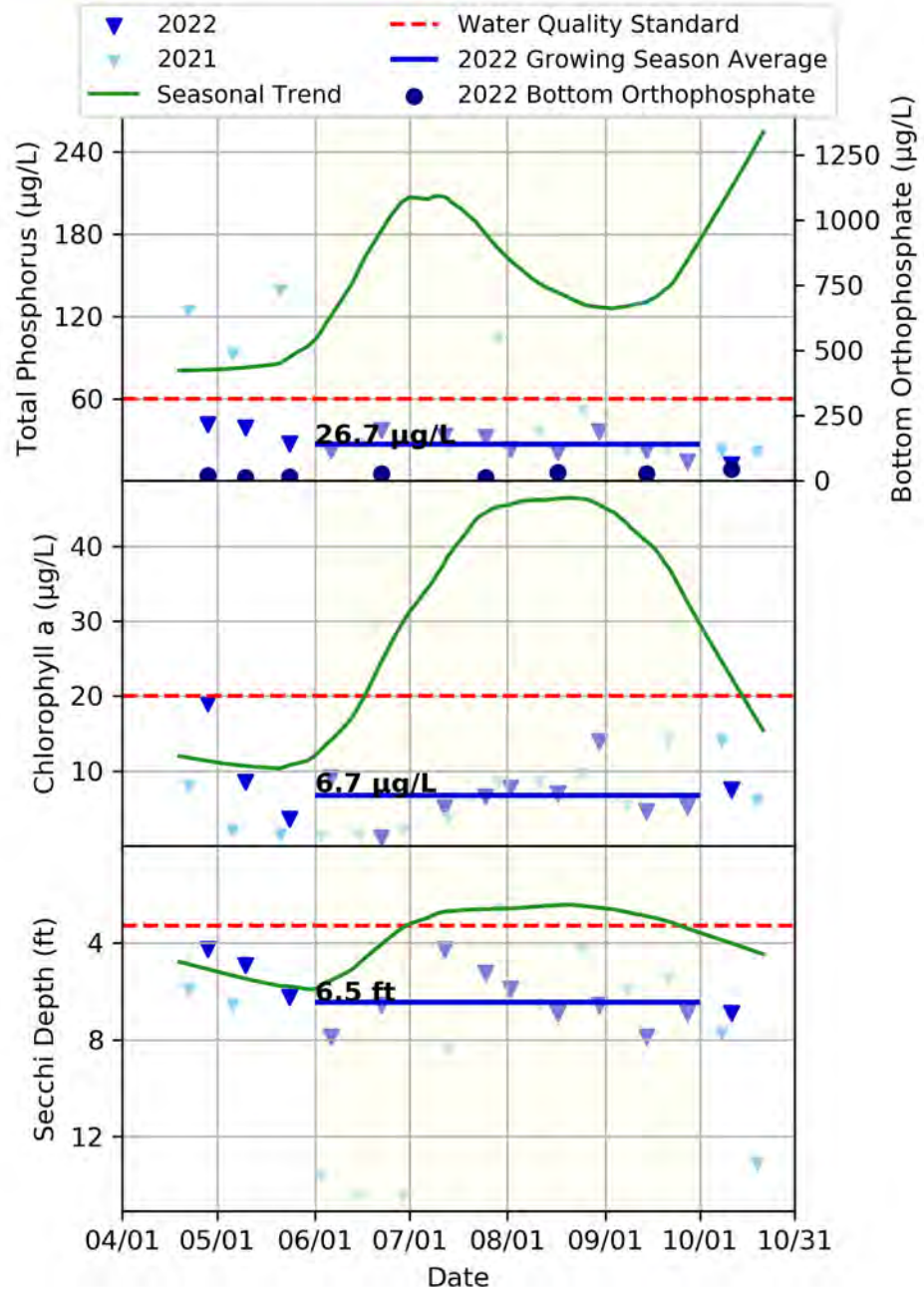
Algae:

June-Sept. Average Chlorophyll-a (Chl-a, $\mu\text{g/L}$)



Clarity:

June-Sept. Average Secchi Depth (Secchi, ft)



State standards are shown with a dashed red line. Phosphorus = $40 \mu\text{g/L}$, Chlorophyll-a = $14 \mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

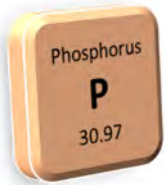
SHIELDS LAKE

Historical Water Quality Summary

	Phosphorus ($\mu\text{g/L}$)	Chl-a ($\mu\text{g/L}$)	Secchi (feet)
State Standard	<60	<20	>3.3
10-year Average (2013-2022)	160.9	41.6	3.7
2040 District Goal	<60	n/a	>4.3
5-year Average (2018-2022)	84.4	31.9	4.7

Nutrients:

June-Sept. Average
Total Phosphorus
(TP, $\mu\text{g/L}$)



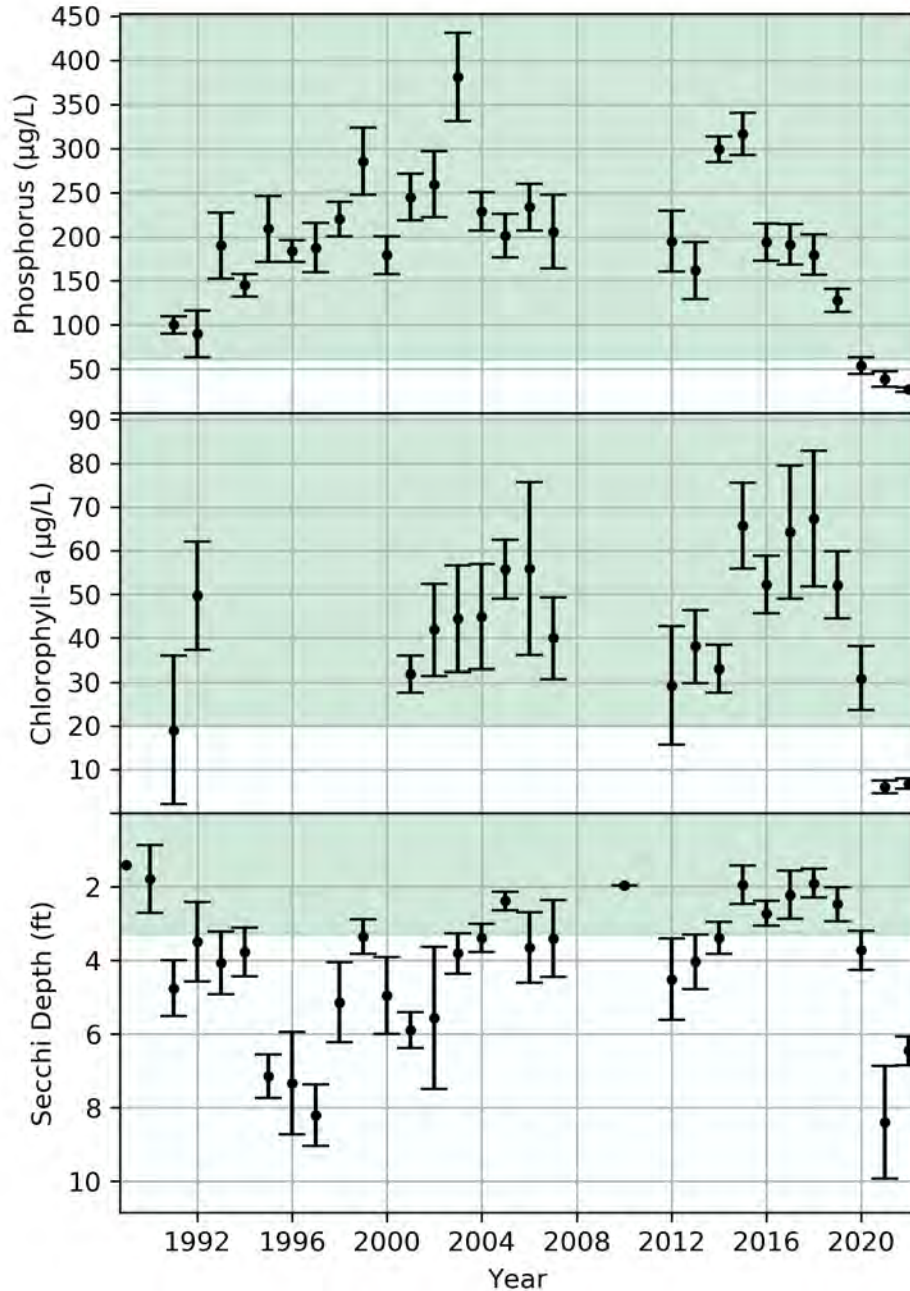
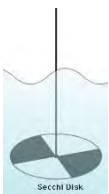
Algae:

June-Sept. Average
Chlorophyll-a
(Chl-a, $\mu\text{g/L}$)



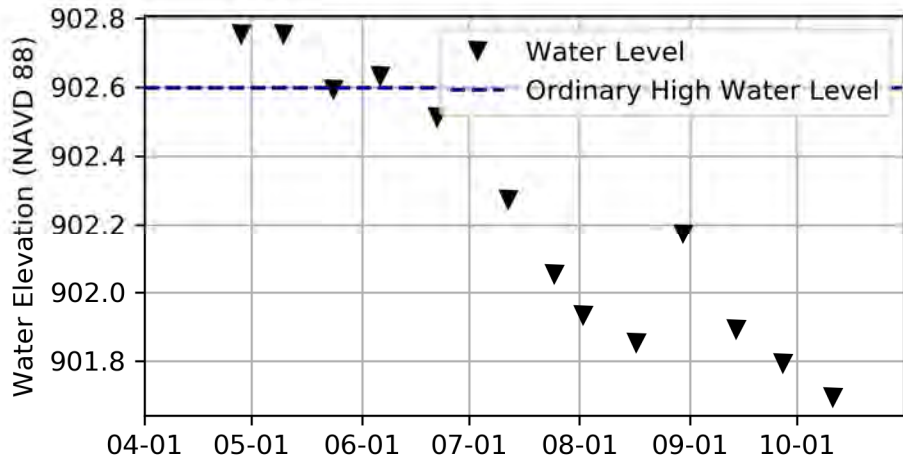
Clarity:

June-Sept. Average
Secchi Depth
(Secchi, ft)



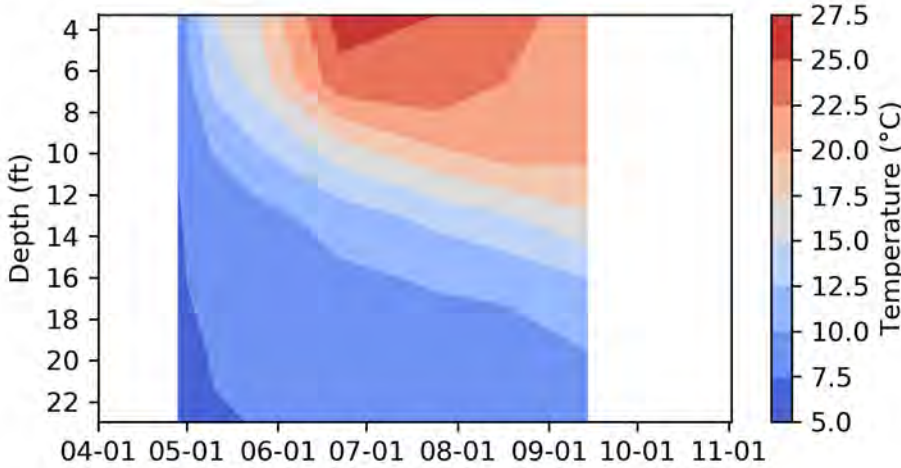
State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

SHIELDS LAKE



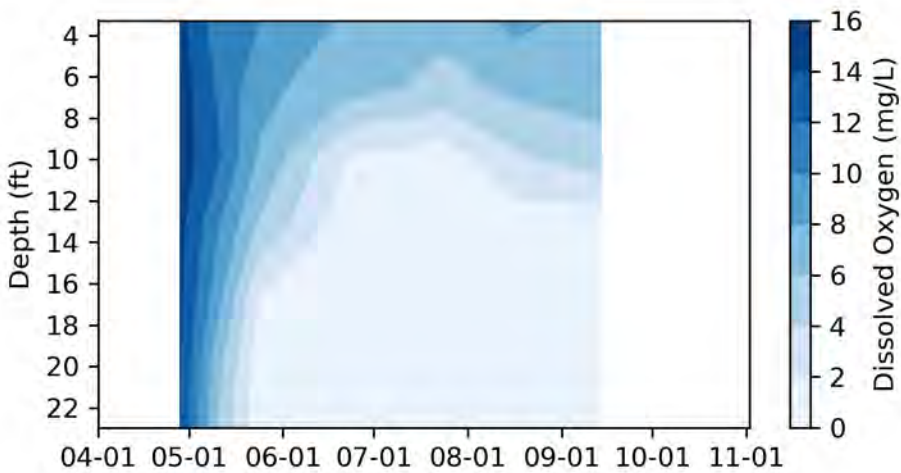
2022 Lake Levels

Lake levels ranged over a total of 1.1 feet; between a minimum of 901.7 feet on October 11, 2022 and a maximum of 902.8 feet on April 28, 2022.



2022 Temperature Profiles

The lake was stratified starting in mid-May



2022 Dissolved Oxygen Profiles

The lightest blue represents the duration and depths where no oxygen is present and sediment phosphorus can be released and contribute to internal loading.

Internal loading was possible starting in Mid-May but, bottom P concentrations remained low.

THIRD LAKE

Fast Facts:

DNR Lake ID: 13-0024-00

County: Chisago

Surface Area: 42 acres

Littoral Area (depths less than 15 feet): NA acres



Maximum Depth: NA feet

Shore Length: NA miles



Date: 2023-02-24T13:17:28 SCS Author: Eljensen, Layout: RM, CLFLWD_Lake
Document Path: X:\Clients_VD\00376_CLFLWD\0010_General_Watershed_Eng\3000_Program\3003A_monitoring\07_GIS\lake_aerials\022.jpg



-  Lake Management District Boundary
-  Lake



CLFLWD
Third Lake

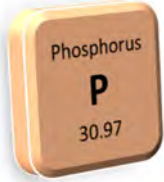
Lake Map

THIRD LAKE

2022 Surface Water Quality Summary

Nutrients:

June-Sept. Average Total Phosphorus (TP, $\mu\text{g/L}$)



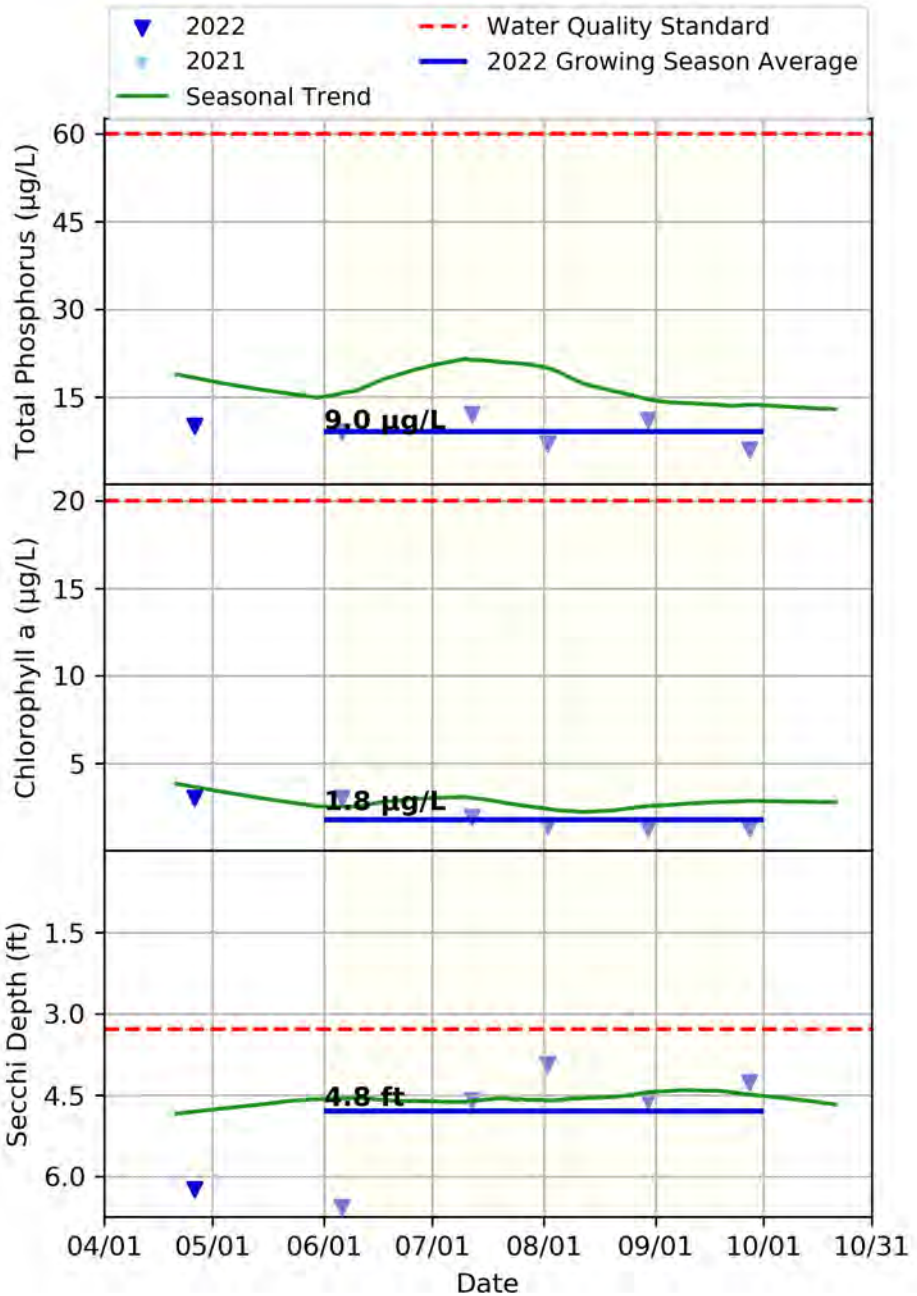
Algae:

June-Sept. Average Chlorophyll-a (Chl-a, $\mu\text{g/L}$)



Clarity:

June-Sept. Average Secchi Depth (Secchi, ft)



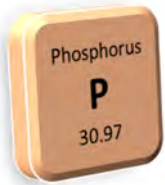
State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

THIRD LAKE

Historical Water Quality Summary

	Phosphorus ($\mu\text{g/L}$)	Chl-a ($\mu\text{g/L}$)	Secchi (feet)
State Standard	<60	<20	>3.3
10-year Average (2013-2022)	19.2	4.5	4.5
2040 District Goal	<60	n/a	>3.3
5-year Average (2018-2022)	15.5	3.2	4.9

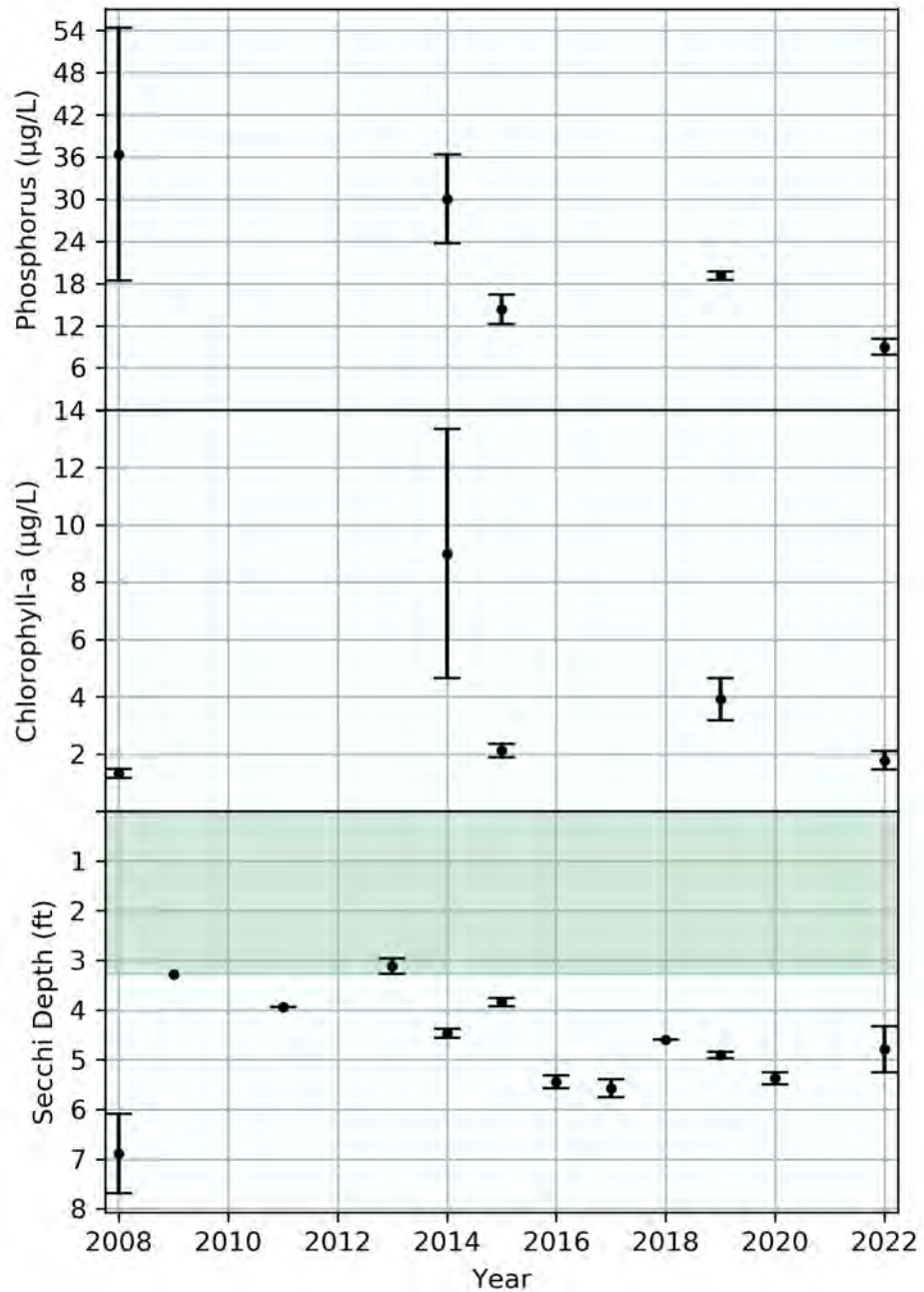
Nutrients:
June-Sept. Average
Total Phosphorus
(TP, $\mu\text{g/L}$)



Algae:
June-Sept. Average
Chlorophyll-a
(Chl-a, $\mu\text{g/L}$)



Clarity:
June-Sept. Average
Secchi Depth
(Secchi, ft)



State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

TWIN LAKE

Fast Facts:

DNR Lake ID: 82-0157-00

County: Chisago

Surface Area: 13 acres

Littoral Area (depths less than 15 feet): NA acres



Maximum Depth: NA feet

Shore Length: NA miles



Date: 2023-02-24T13:15:38-518 Author: Eljensen Layout: RM CLFLWD_Lake
Document Path: X:\Clients_VD\00376_CLFLWD\0010_General_Watershed_Eng\3000_Program\3003A_monitoring\07_GIS\lake_aerials\022.jpg



-  Lake Management District Boundary
-  Lake



CLFLWD
Twin Lake

Lake Map

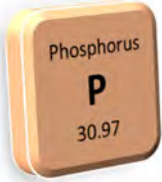
0 100 200 ft

TWIN LAKE

2022 Surface Water Quality Summary

Nutrients:

June-Sept. Average Total Phosphorus (TP, $\mu\text{g/L}$)



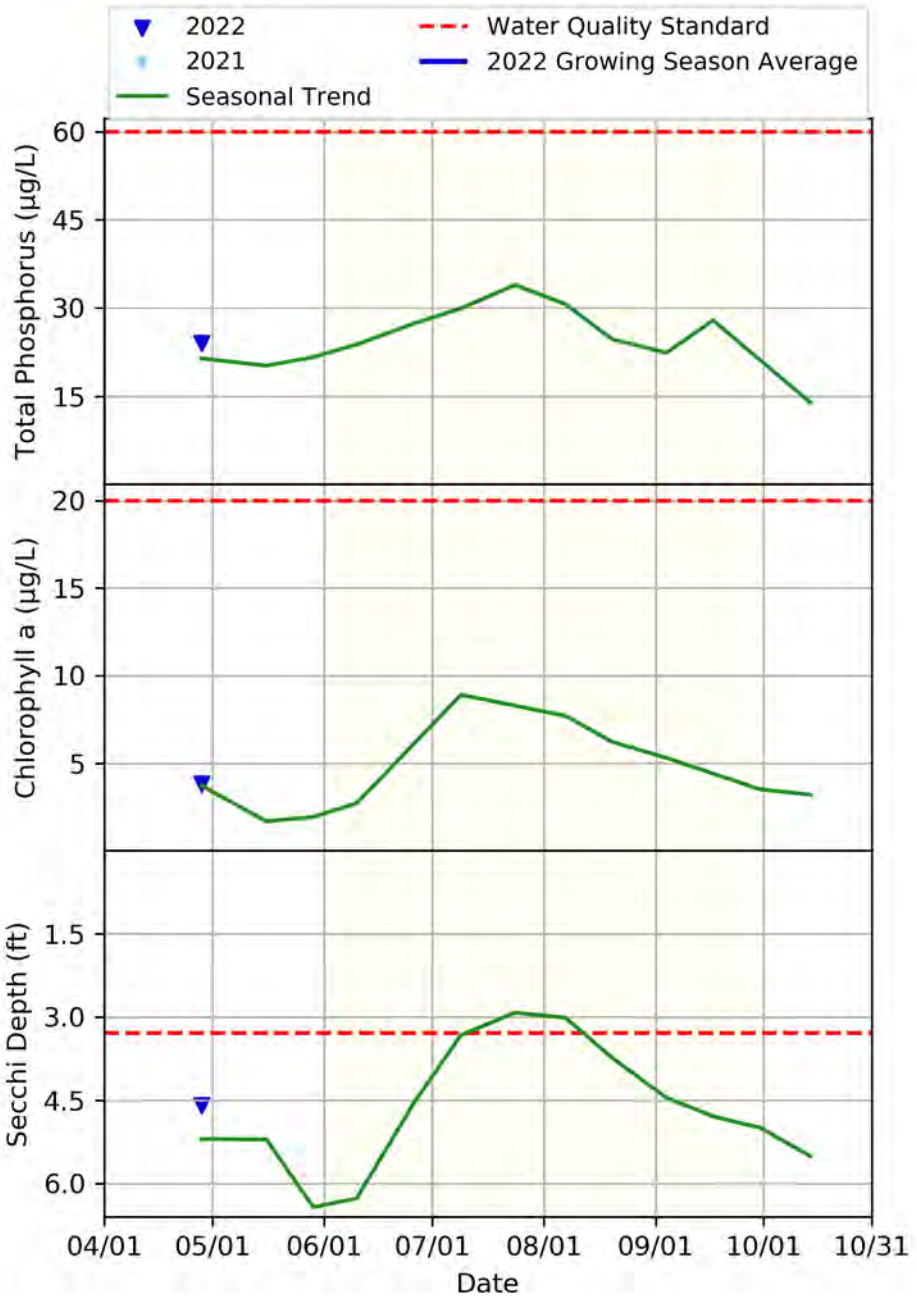
Algae:

June-Sept. Average Chlorophyll-a (Chl-a, $\mu\text{g/L}$)



Clarity:

June-Sept. Average Secchi Depth (Secchi, ft)



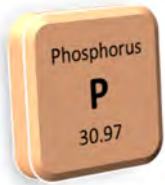
State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

TWIN LAKE

Historical Water Quality Summary

	Phosphorus ($\mu\text{g/L}$)	Chl-a ($\mu\text{g/L}$)	Secchi (feet)
State Standard	<60	<20	>3.3
10-year Average (2013-2022)	27.8	5.6	4.2
2040 District Goal	<60	n/a	>3.3
5-year Average (2018-2022)	27.8	5.6	4.2

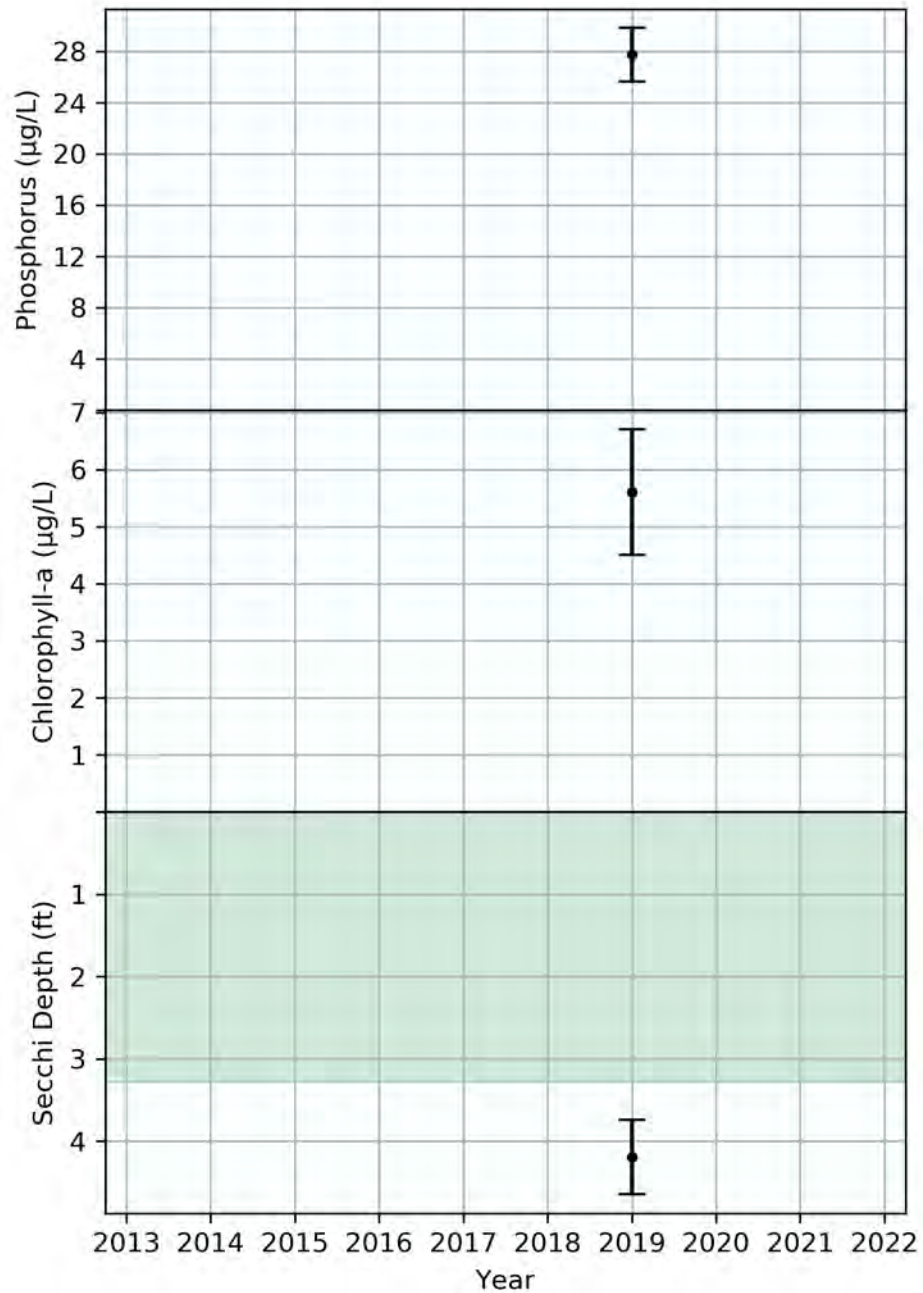
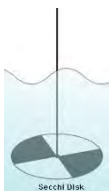
Nutrients:
June-Sept. Average
Total Phosphorus
(TP, $\mu\text{g/L}$)



Algae:
June-Sept. Average
Chlorophyll-a
(Chl-a, $\mu\text{g/L}$)



Clarity:
June-Sept. Average
Secchi Depth
(Secchi, ft)



State standards are shown with a dashed red line. Phosphorus = 40 $\mu\text{g/L}$, Chlorophyll-a = 14 $\mu\text{g/L}$, Secchi Depth = 4.6 feet. Sample points are shown in black dots. Points above the line are worse than the State standard. Points below the line are better than the State standard.

APPENDIX B. 2022 LONG-TERM STREAM SITE SUMMARY

Appendix B.1. Comfort Lake Management District

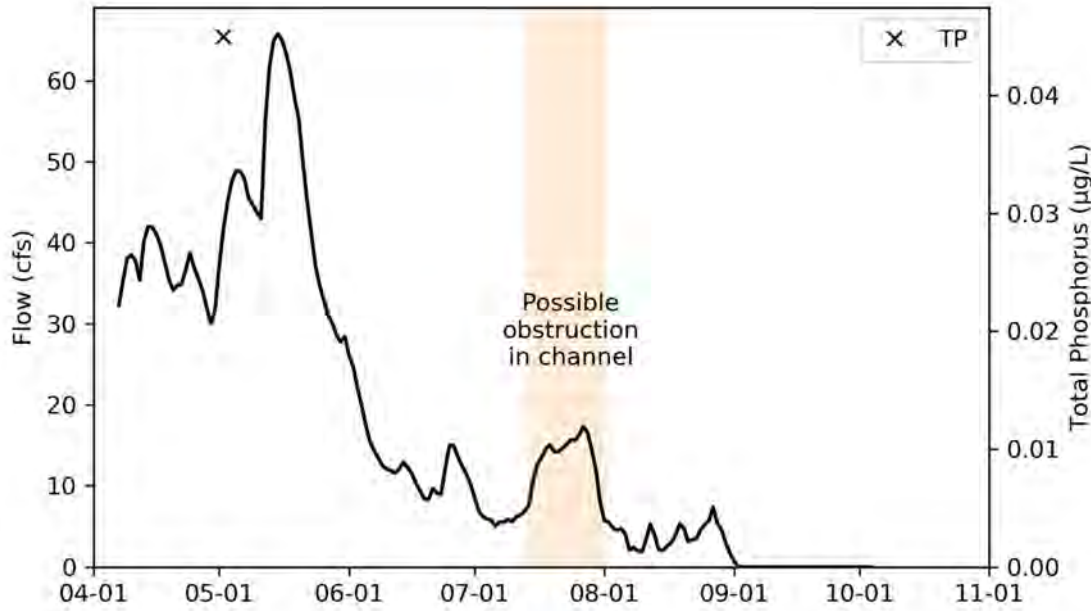


Figure 18. CL1 (outlet) TP and Daily Flow

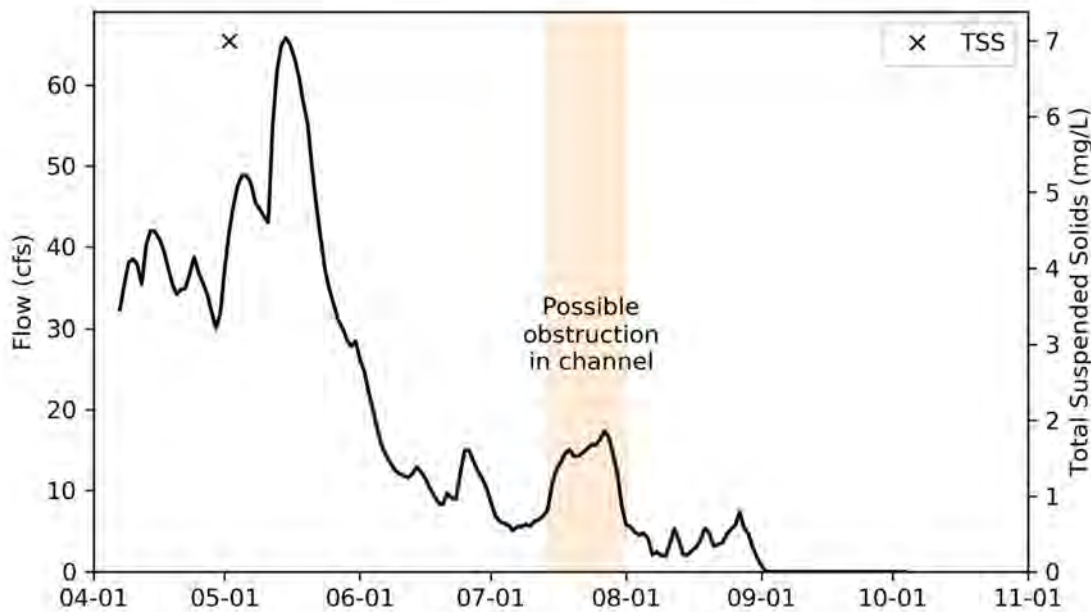


Figure 19. CL1 (outlet) TSS and Daily Flow

Table 23. CL1 2022 Stream Water Chemistry Sample Results

Bold values do not meet the MN Class 2B standard.

Date/Time	Chloride (mg/L)	Iron (mg/L)	TKN (mg/L)	TP (mg/L)	Ortho-P (mg/L)	NO3-N (mg/L)	NO2-N (mg/L)	Nitrate-Nitrite (mg/L)	NH4-N (mg/L)	TSS (mg/L)	TVS (mg/L)
MN Class 2B Standards	< 230			< 0.1						<30	
5/2/2022	47.6	0.5	1.1	0.045	0.01	0.27	0.06	0.27	0.16	7	3

TKN = Total Kjeldahl Nitrogen which is a measure of nitrogen contained in organic form

TP = total phosphorus which is the measure of all particulate, dissolved, inorganic and organic forms of phosphorus

Ortho-P = ortho-phosphorus which is a measure of all dissolved inorganic forms of phosphorus

NO3-N = nitrate-nitrogen which is a measure of inorganic nitrogen in nitrate form

NO2-N = nitrite-nitrogen which is a measure of inorganic nitrogen in nitrite form

NH4-N = ammonia-nitrogen which is a measure of inorganic nitrogen in ammonia form

TSS = total suspended solids which is a measure of all solids in inorganic and organic form

TVS = total volatile solids which is a measure of all solids in organic form

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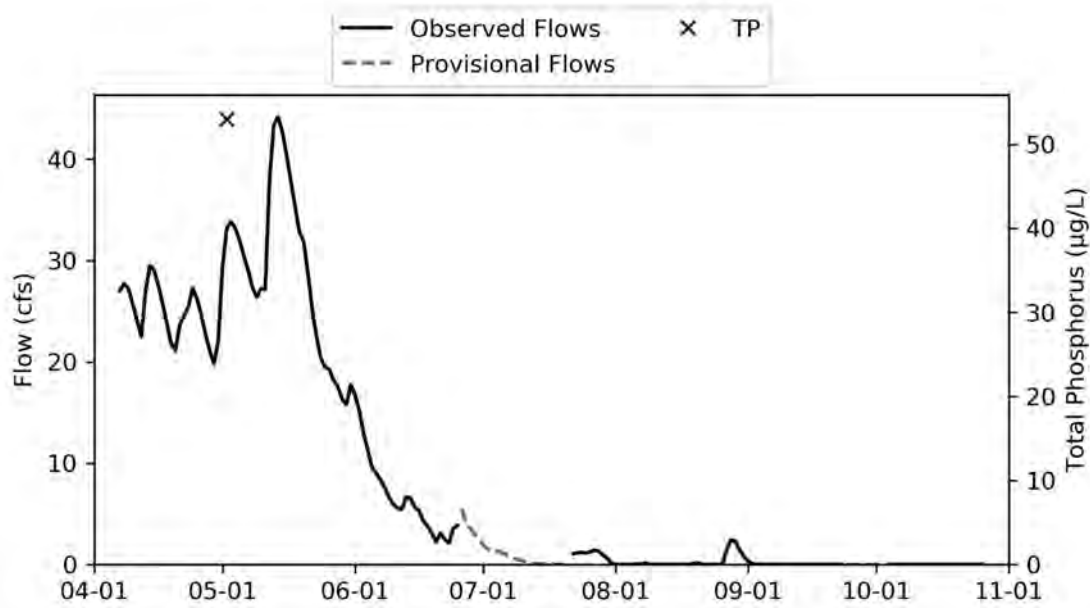


Figure 20. CL2 (inlet) TP and Daily Flow

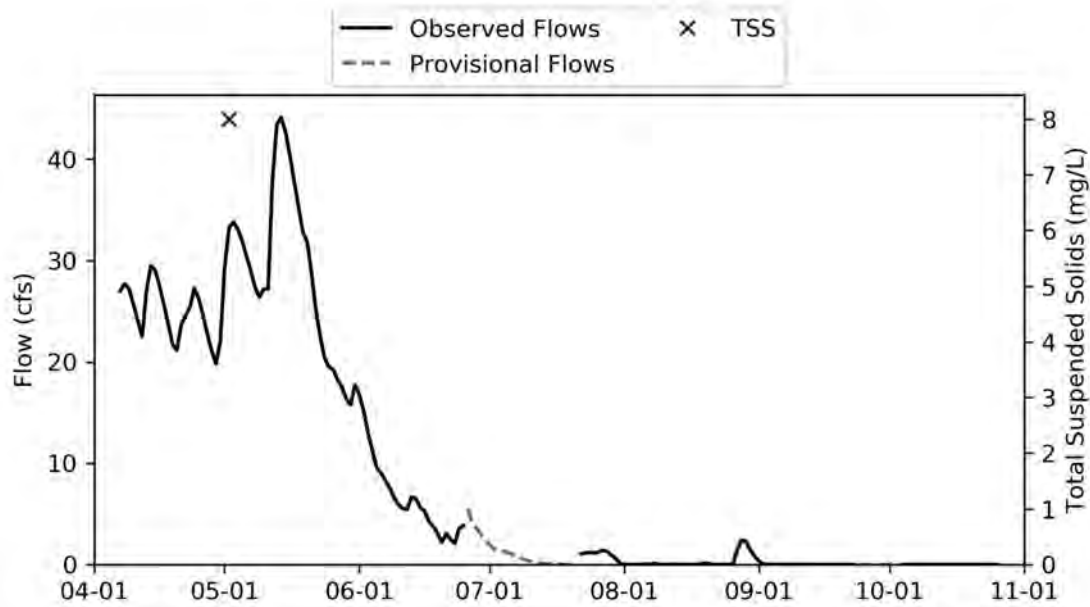


Figure 21. CL2 (inlet) TSS and Daily Flow

Table 24. CL2 2022 Stream Water Chemistry Sample Results

Bold values do not meet the MN Class 2B standard.

Date/Time	Chloride (mg/L)	Iron (mg/L)	TKN (mg/L)	TP (mg/L)	Ortho-P (mg/L)	NO3-N (mg/L)	NO2-N (mg/L)	Nitrate-Nitrite (mg/L)	NH4-N (mg/L)	TSS (mg/L)	TVS (mg/L)
MN Class 2B Standards	< 230			< 0.1						<30	
5/2/2022	70.7	0.5	1.2	0.053	0.011	0.23	0.06	0.23	0.06	8	5

TKN = Total Kjeldahl Nitrogen which is a measure of nitrogen contained in organic form

TP = total phosphorus which is the measure of all particulate, dissolved, inorganic and organic forms of phosphorus

Ortho-P = ortho-phosphorus which is a measure of all dissolved inorganic forms of phosphorus

NO3-N = nitrate-nitrogen which is a measure of inorganic nitrogen in nitrate form

NO2-N = nitrite-nitrogen which is a measure of inorganic nitrogen in nitrite form

NH4-N = ammonia-nitrogen which is a measure of inorganic nitrogen in ammonia form

TSS = total suspended solids which is a measure of all solids in inorganic and organic form

TVS = total volatile solids which is a measure of all solids in organic form

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Appendix B.2. Little Comfort Lake Management District

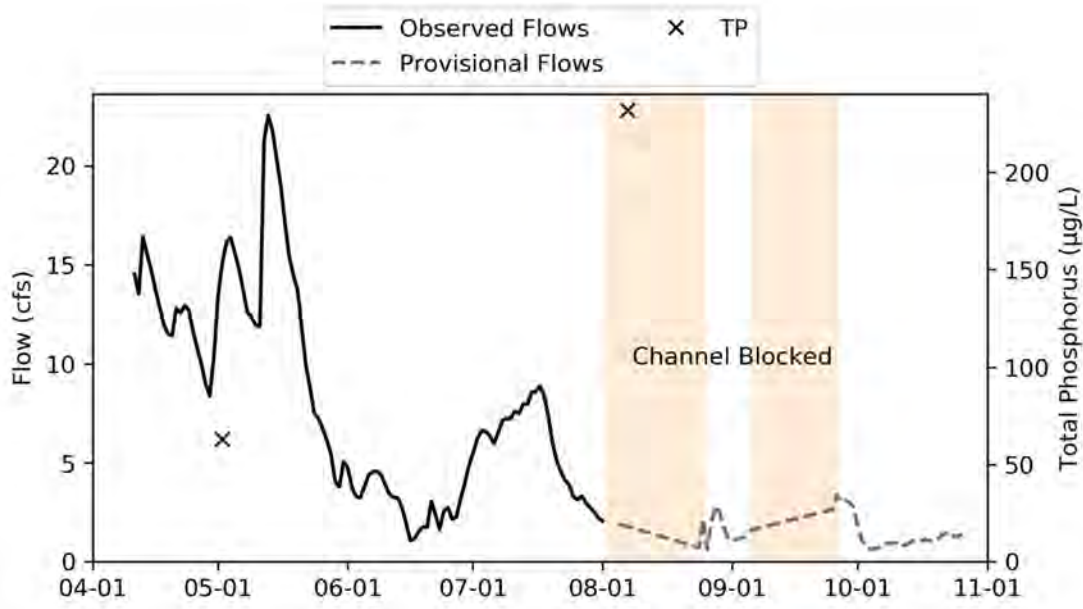


Figure 22. LC1 (inlet) TP and Daily Flow

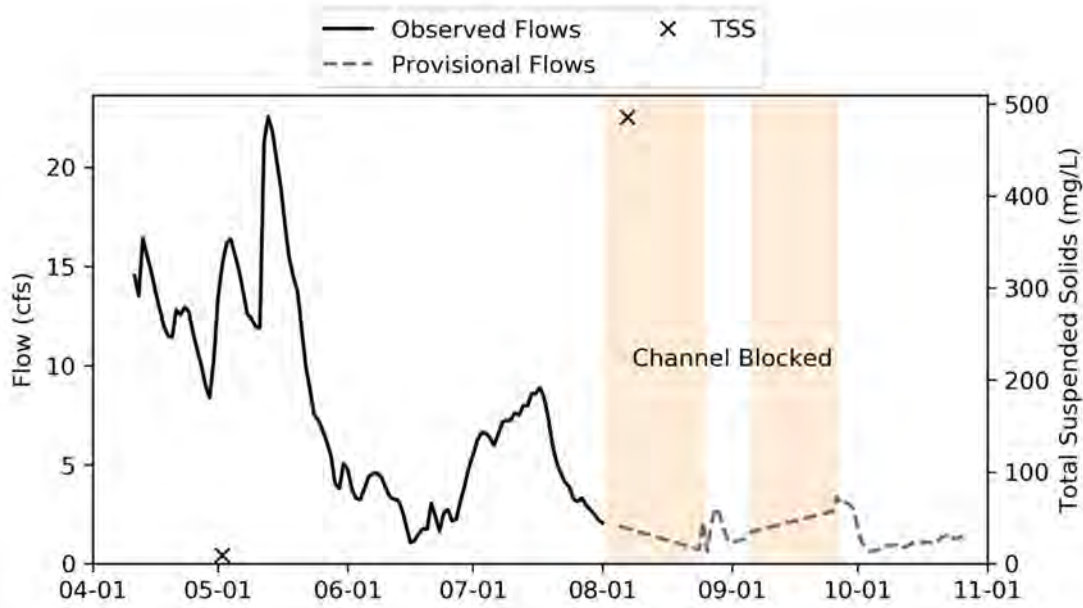


Figure 23. LC1 (inlet) TSS and Daily Flow

Table 25. LC1 2022 Stream Water Chemistry Sample Results

Bold values do not meet the MN Class 2B standard.

Date/Time	Chloride (mg/L)	Iron (mg/L)	TKN (mg/L)	TP (mg/L)	Ortho-P (mg/L)	NO3-N (mg/L)	NO2-N (mg/L)	Nitrate-Nitrite (mg/L)	NH4-N (mg/L)	TSS (mg/L)	TVS (mg/L)
MN Class 2B Standards	< 230			< 0.1						<30	
5/2/2022	21.2	0.5	1	0.063	0.01	0.2	0.06	0.2	0.08	9	6
8/7/2022	22.8	11.4	2.3	0.232	0.027	0.2	0.06	0.2	0.06	486	203

TKN = Total Kjeldahl Nitrogen which is a measure of nitrogen contained in organic form

TP = total phosphorus which is the measure of all particulate, dissolved, inorganic and organic forms of phosphorus

Ortho-P = ortho-phosphorus which is a measure of all dissolved inorganic forms of phosphorus

NO3-N = nitrate-nitrogen which is a measure of inorganic nitrogen in nitrate form

NO2-N = nitrite-nitrogen which is a measure of inorganic nitrogen in nitrite form

NH4-N = ammonia-nitrogen which is a measure of inorganic nitrogen in ammonia form

TSS = total suspended solids which is a measure of all solids in inorganic and organic form

TVS = total volatile solids which is a measure of all solids in organic form

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Appendix B.3. Forest Lake Management District

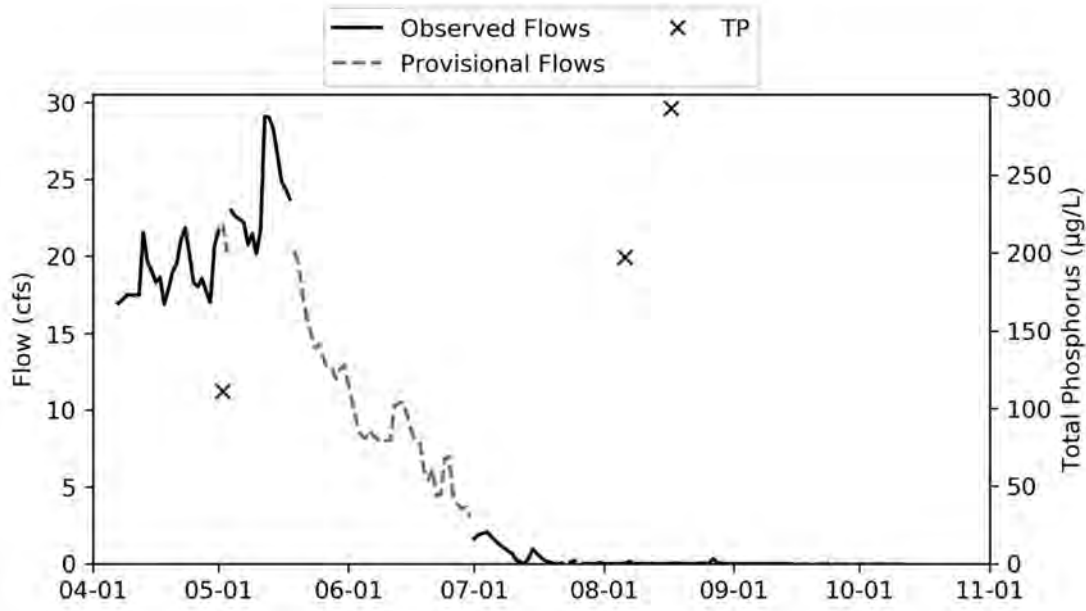


Figure 24. FL1 (outlet) TP and Daily Flow

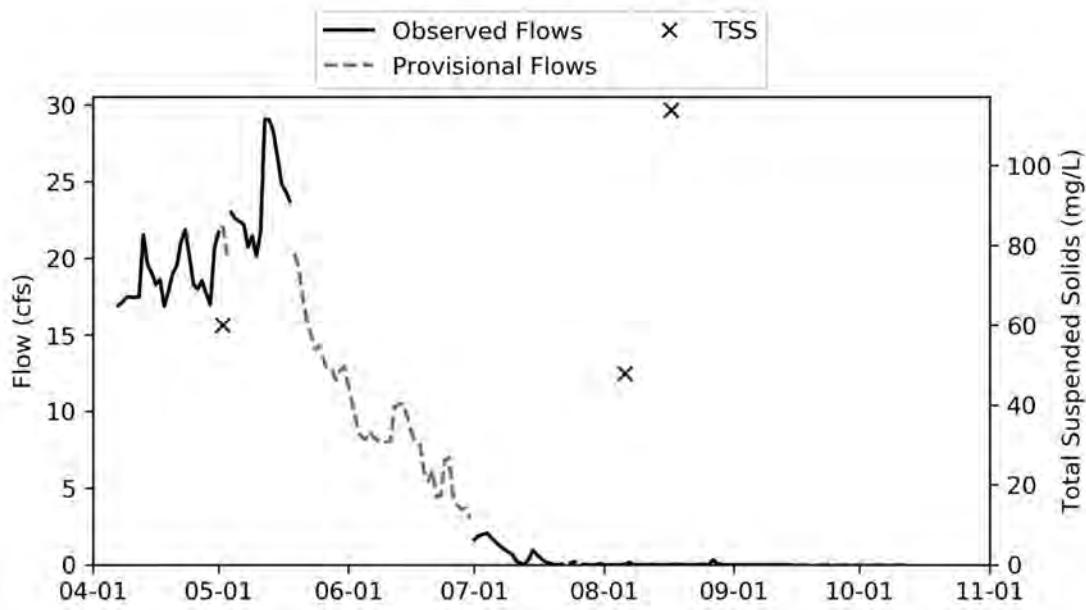


Figure 25. FL1 (outlet) TSS and Daily Flow

Table 26. FL1 2022 Stream Water Chemistry Sample Results

Bold values do not meet the MN Class 2B standard.

Date/Time	Chloride (mg/L)	Iron (mg/L)	TKN (mg/L)	TP (mg/L)	Ortho-P (mg/L)	NO3-N (mg/L)	NO2-N (mg/L)	Nitrate-Nitrite (mg/L)	NH4-N (mg/L)	TSS (mg/L)	TVS (mg/L)
MN Class 2B Standards	< 230			< 0.1						<30	
5/2/2022	33.8	0.56	1.4	0.111	0.2	0.06	0.2	0.06	0.01	60	15
8/6/2022	9.6	1.5	0.88	0.197	1.02	0.06	1.02	0.13	0.153	48	15
8/17/2022	9.9	1.6	1.7	0.293	1.26	0.06	1.26	0.11	0.064	114	39

TKN = Total Kjeldahl Nitrogen which is a measure of nitrogen contained in organic form

TP = total phosphorus which is the measure of all particulate, dissolved, inorganic and organic forms of phosphorus

Ortho-P = ortho-phosphorus which is a measure of all dissolved inorganic forms of phosphorus

NO3-N = nitrate-nitrogen which is a measure of inorganic nitrogen in nitrate form

NO2-N = nitrite-nitrogen which is a measure of inorganic nitrogen in nitrite form

NH4-N = ammonia-nitrogen which is a measure of inorganic nitrogen in ammonia form

TSS = total suspended solids which is a measure of all solids in inorganic and organic form

TVS = total volatile solids which is a measure of all solids in organic form

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Appendix B.4. Bone Lake Management District

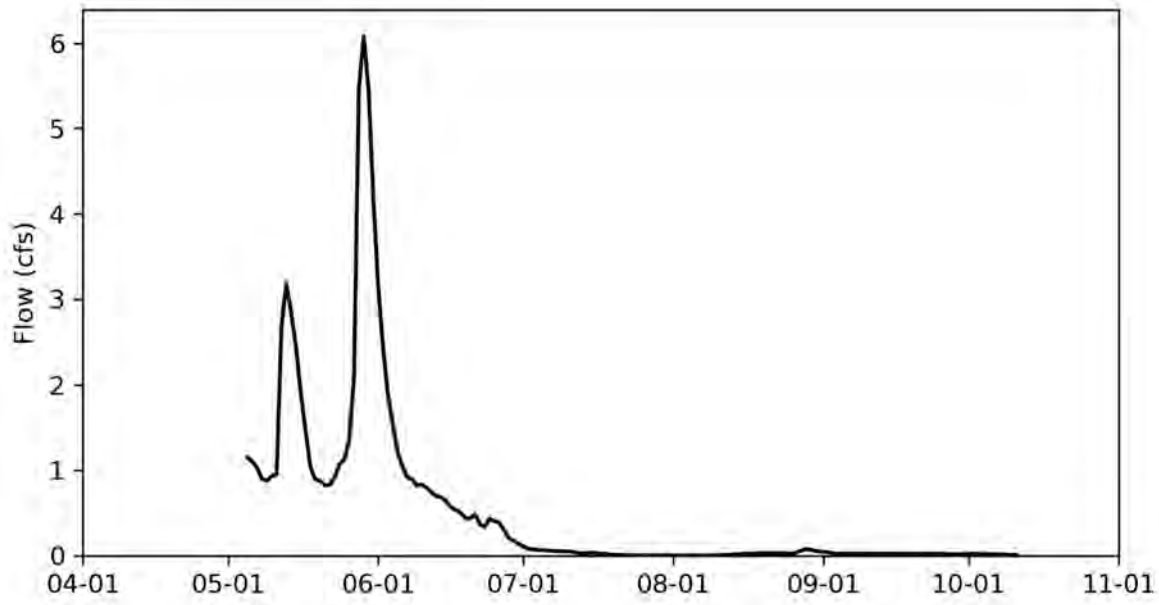


Figure 26. BL1 (inlet) Daily Flow

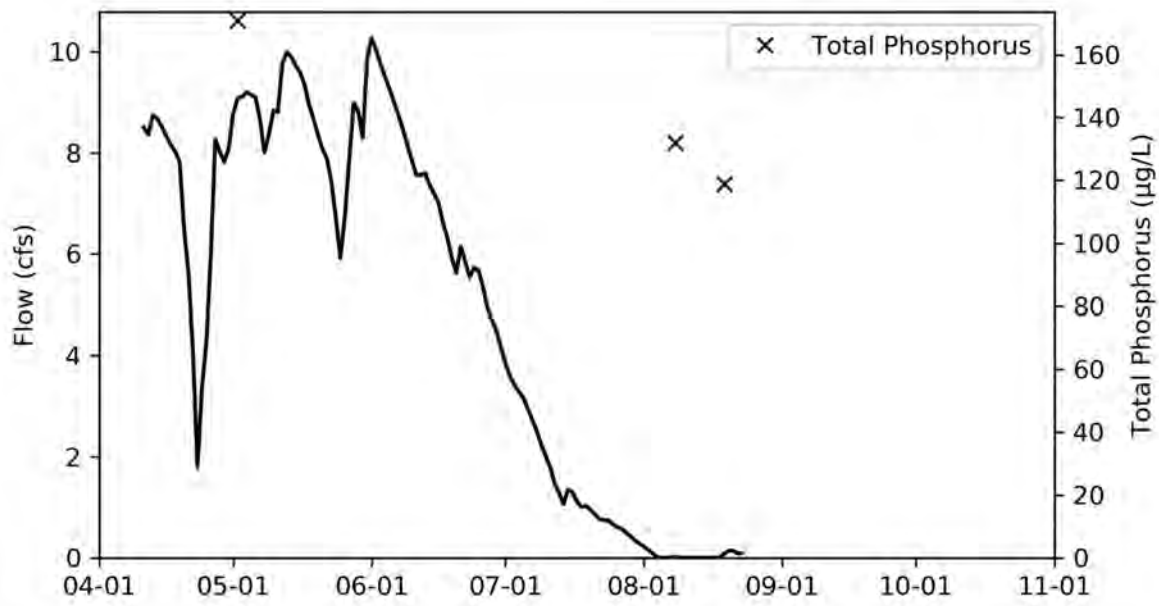


Figure 27. BL2 (outlet) TP and Daily Flow

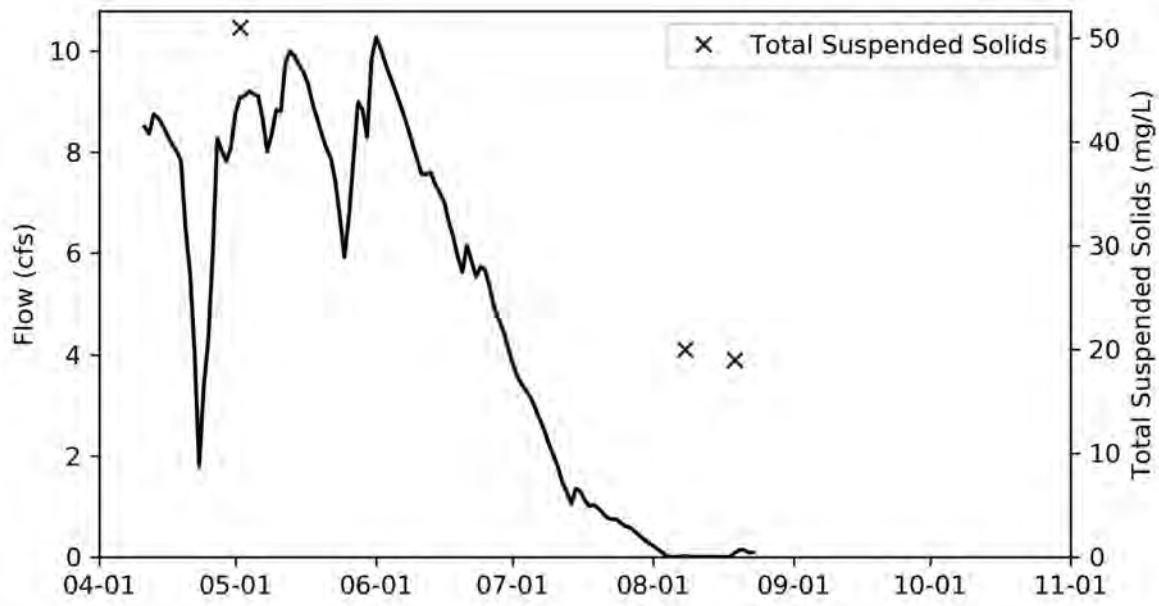


Figure 28. BL2 (outlet) TSS and Daily Flow

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Table 27. BL2 2022 Stream Water Chemistry Sample Results

Bold values do not meet the MN Class 2B standard.

Date/Time	Chloride (mg/L)	Iron (mg/L)	TKN (mg/L)	TP (mg/L)	Ortho-P (mg/L)	NO3-N (mg/L)	NO2-N (mg/L)	Nitrate-Nitrite (mg/L)	NH4-N (mg/L)	TSS (mg/L)	TVS (mg/L)
MN Class 2B Standards	< 230			< 0.1						<30	
5/2/2022	17.3	0.68	2.2	0.171	0.01	0.2	0.06	0.2	0.16	51	23
8/8/2022	23.9	0.5	2.4	0.132	0.016	1.62	0.06	1.62	0.48	20	13
8/19/2022	18.8	0.5	1.6	0.119	0.01	0.53	0.06	0.59	0.27	19	13

TKN = Total Kjeldahl Nitrogen which is a measure of nitrogen contained in organic form

TP = total phosphorus which is the measure of all particulate, dissolved, inorganic and organic forms of phosphorus

Ortho-P = ortho-phosphorus which is a measure of all dissolved inorganic forms of phosphorus

NO3-N = nitrate-nitrogen which is a measure of inorganic nitrogen in nitrate form

NO2-N = nitrite-nitrogen which is a measure of inorganic nitrogen in nitrite form

NH4-N = ammonia-nitrogen which is a measure of inorganic nitrogen in ammonia form

TSS = total suspended solids which is a measure of all solids in inorganic and organic form

TVS = total volatile solids which is a measure of all solids in organic form

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APPENDIX C. 2022 DIAGNOSTIC SITE SUMMARY

Appendix C.1. Sunrise River

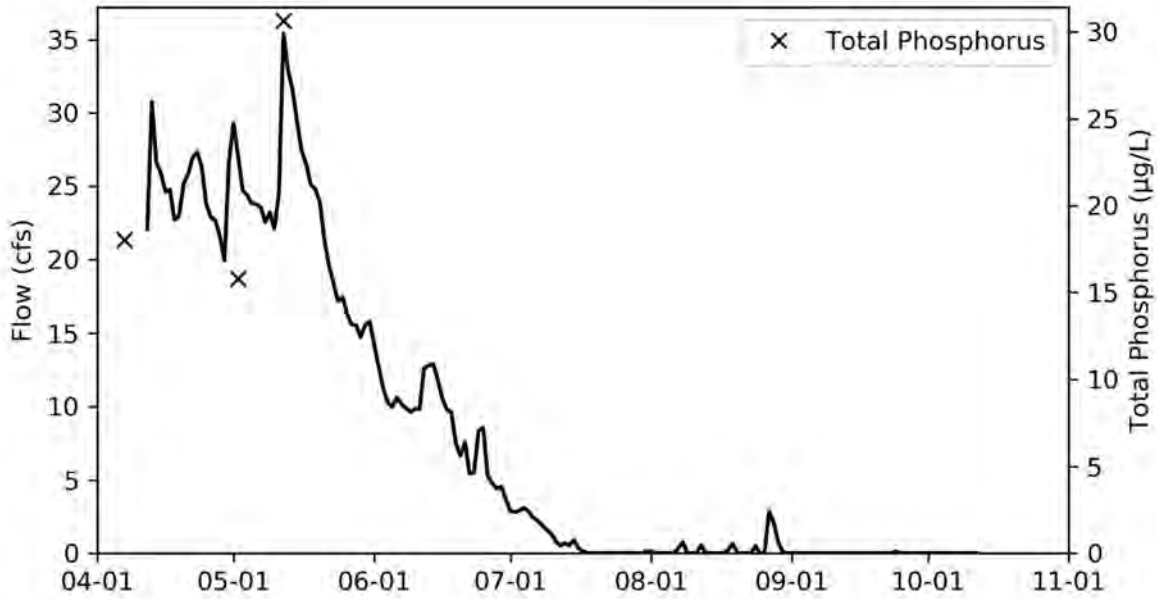


Figure 29. CL7-E TP and Daily Flow

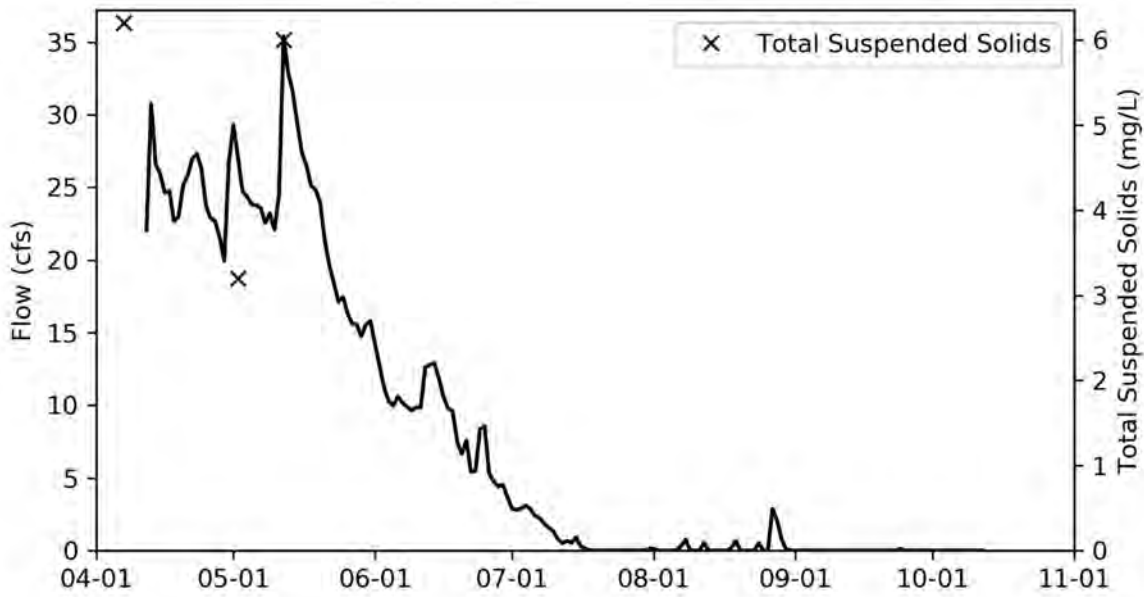


Figure 30. CL7-E TSS and Daily Flow

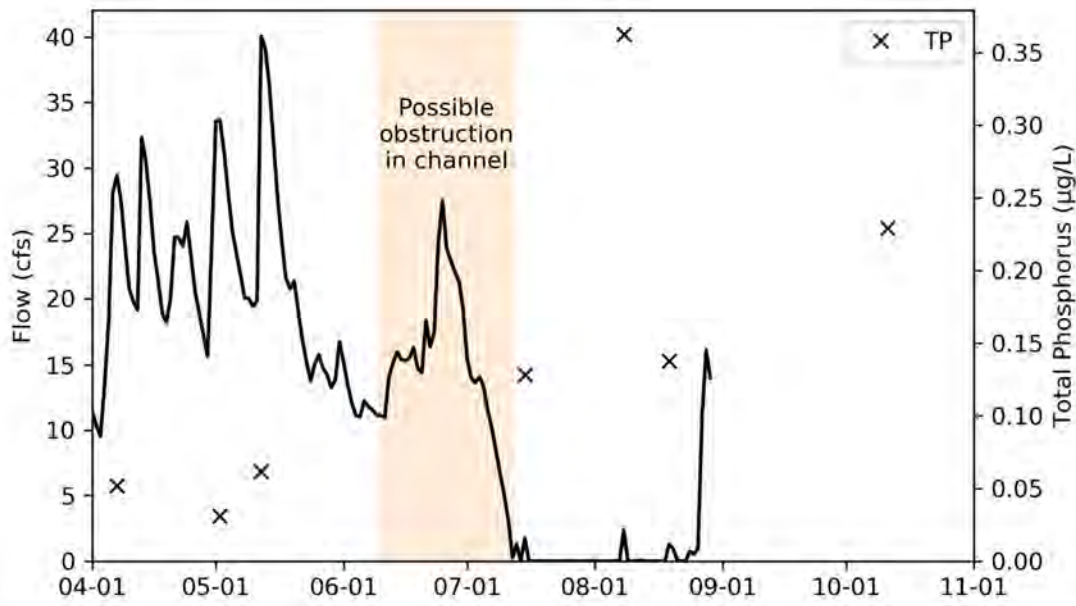


Figure 31. CL7-G TP and Daily Flow

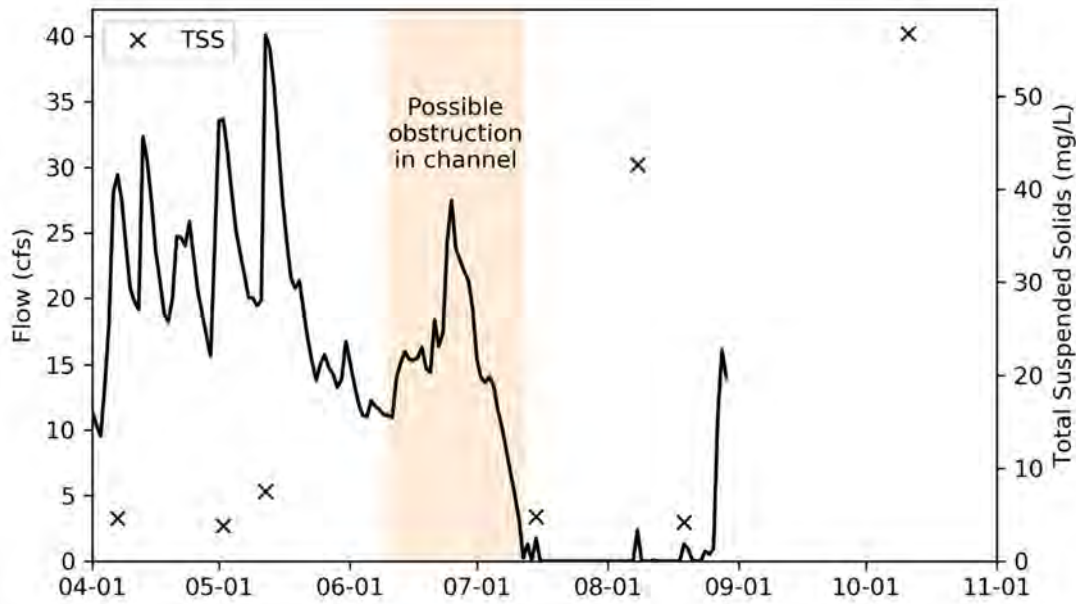


Figure 32. CL7-G TSS and Daily Flow

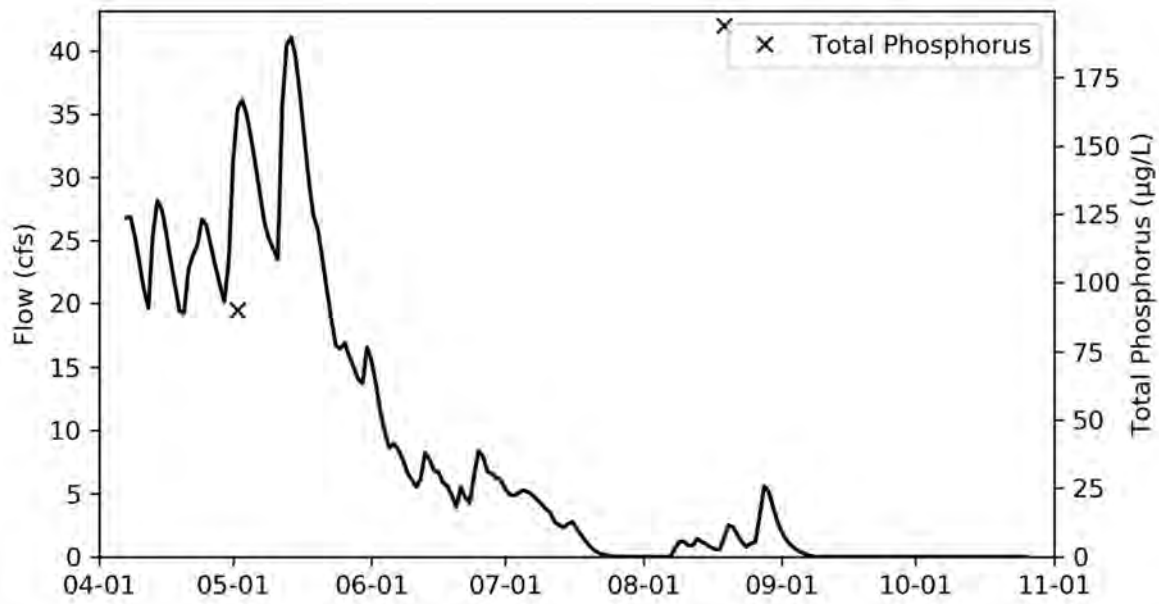


Figure 33. CL4 TP and Daily Flow

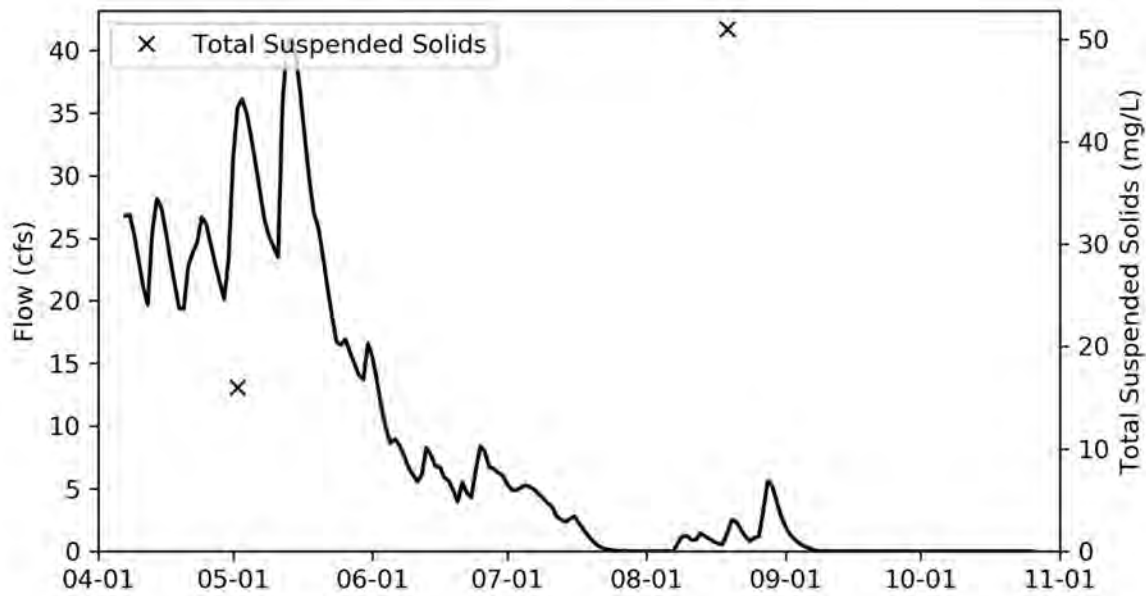


Figure 34. CL4 TSS and Daily Flow

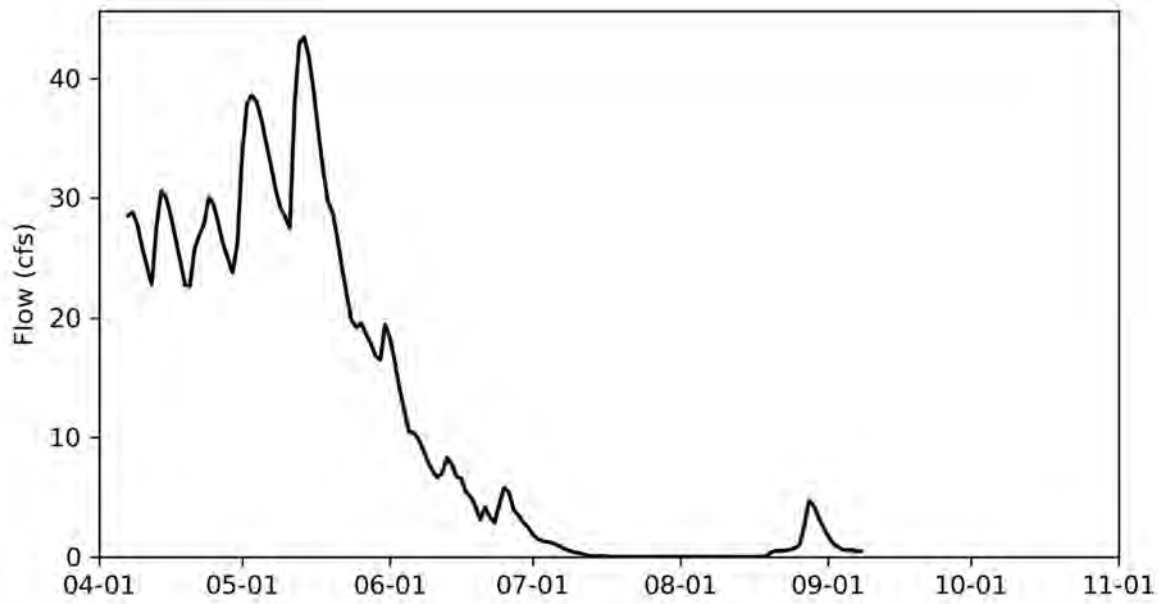


Figure 35. CL3 Daily Flow

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Appendix C.2. Heims Drainage Ditch Sites

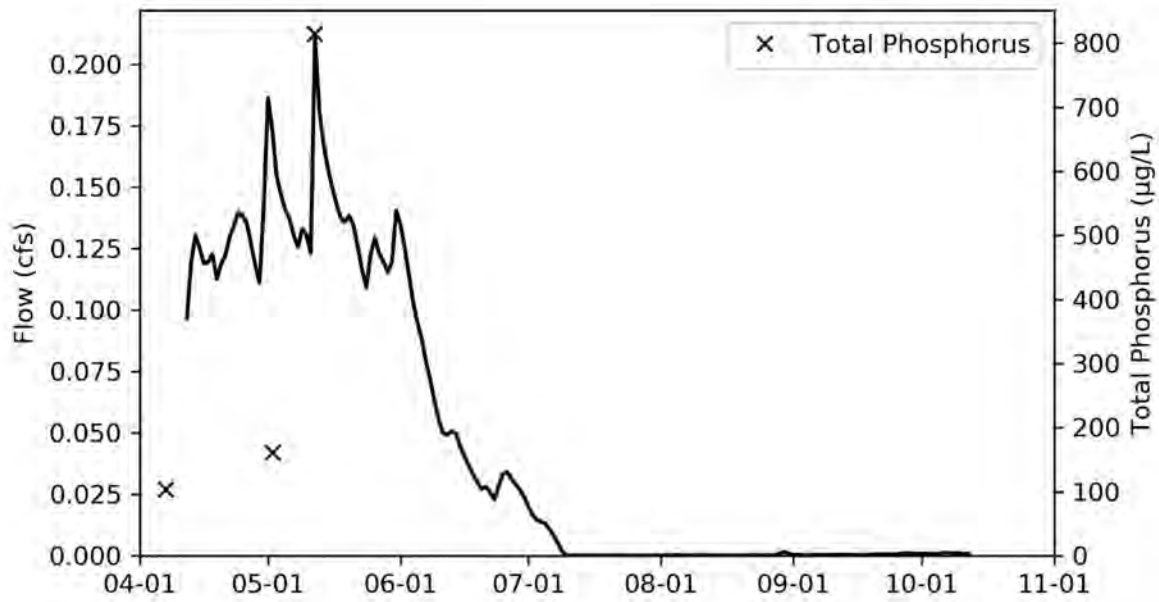


Figure 36. CL6 TP and Daily Flow

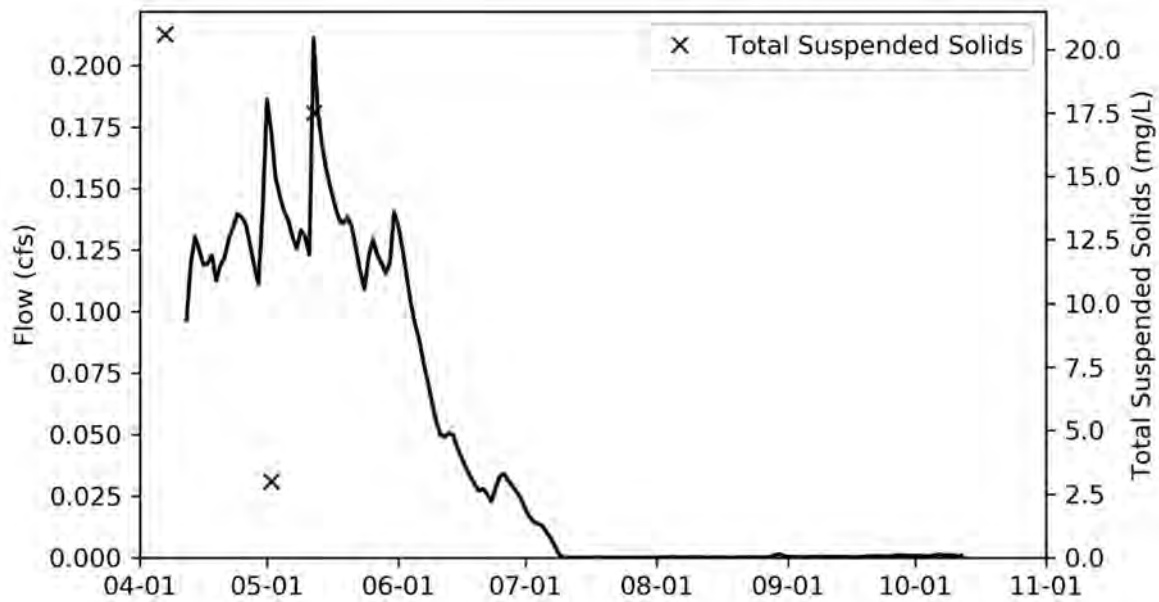


Figure 37. CL6 TSS and Daily Flow

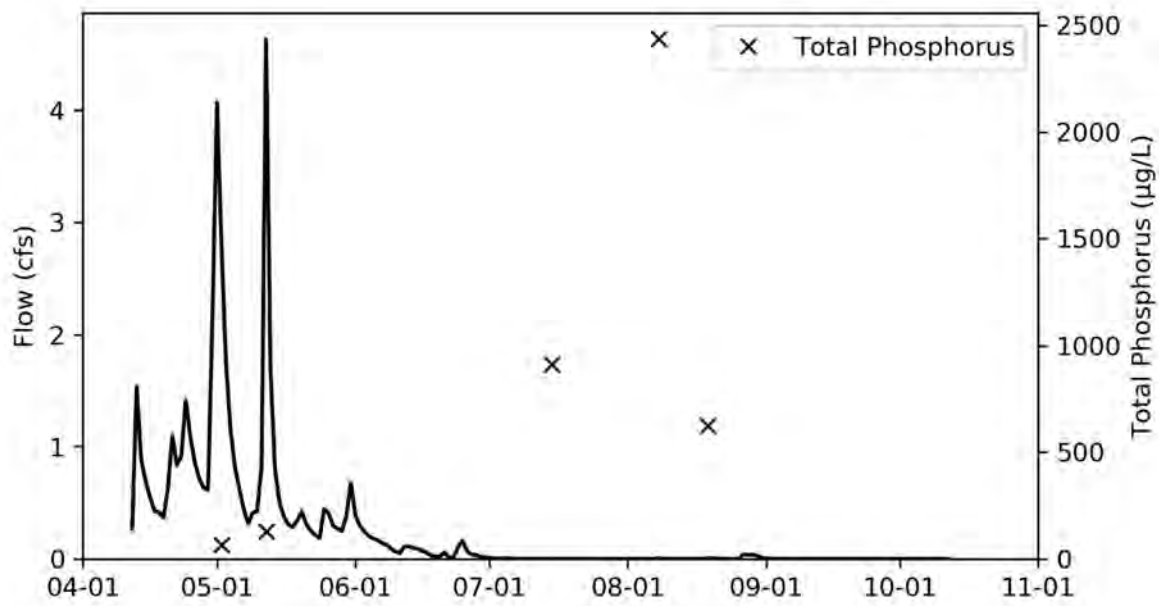


Figure 38. CL5 TP and Daily Flow

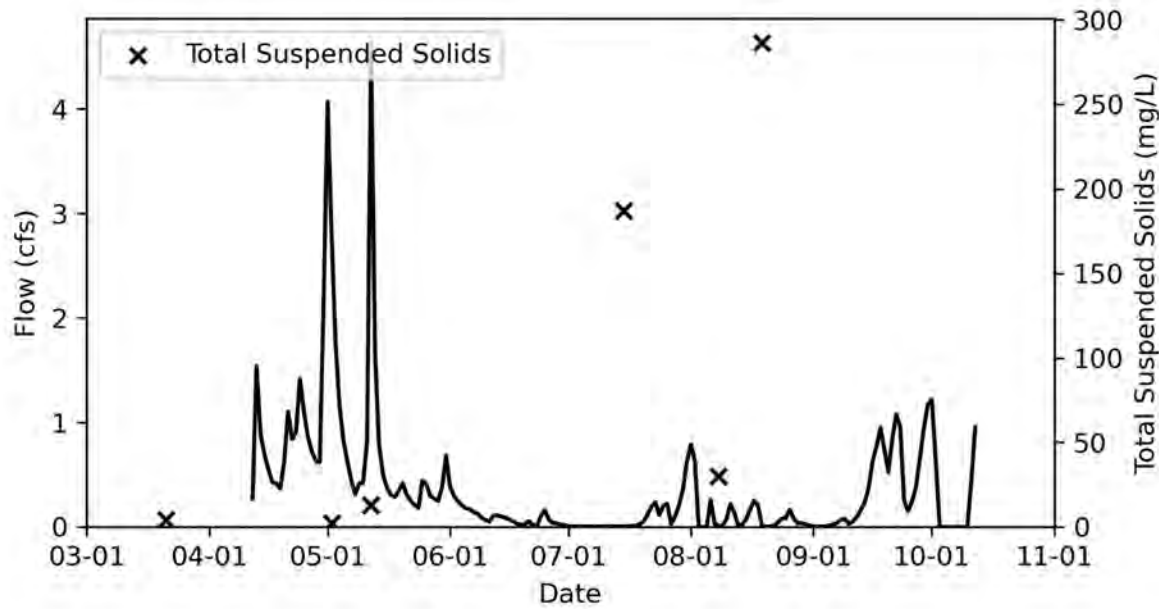


Figure 39. CL5 TSS and Daily Flow

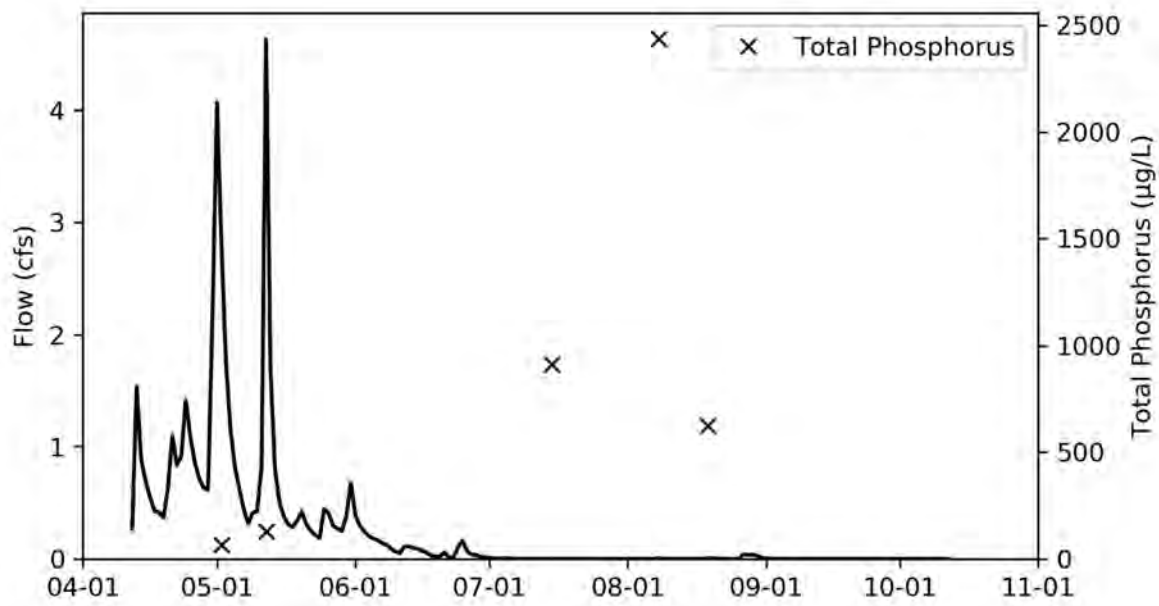


Figure 40. CL5-A TP and Daily Flow

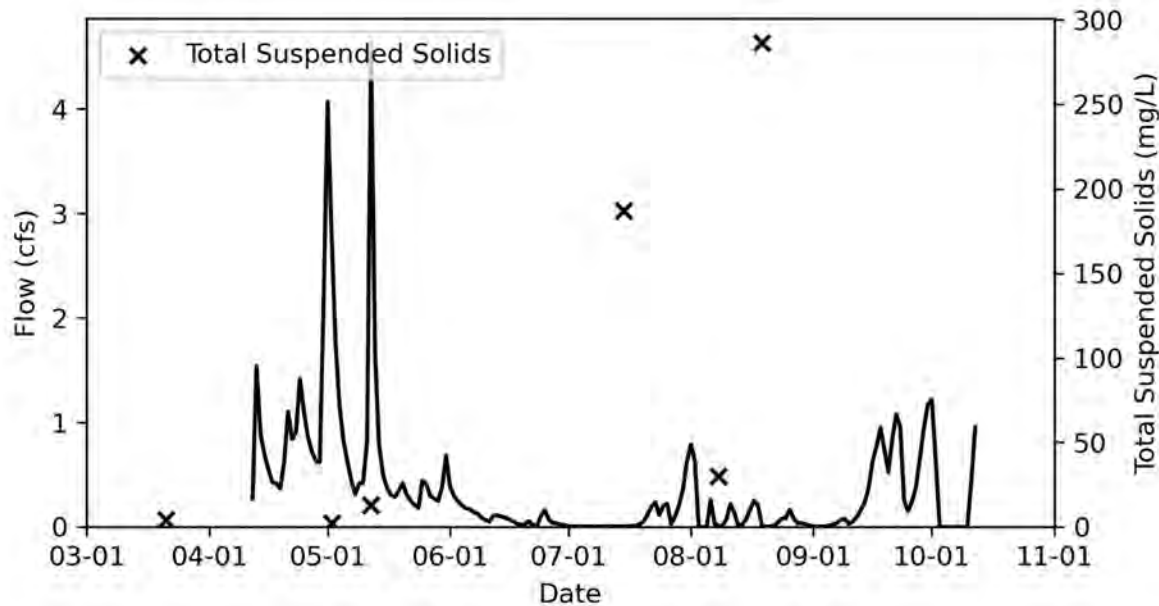


Figure 41. CL5-A TSS and Daily Flow

Appendix C.3. Other tributaries

The CL7-F (JD2) site did not have a rating curve.

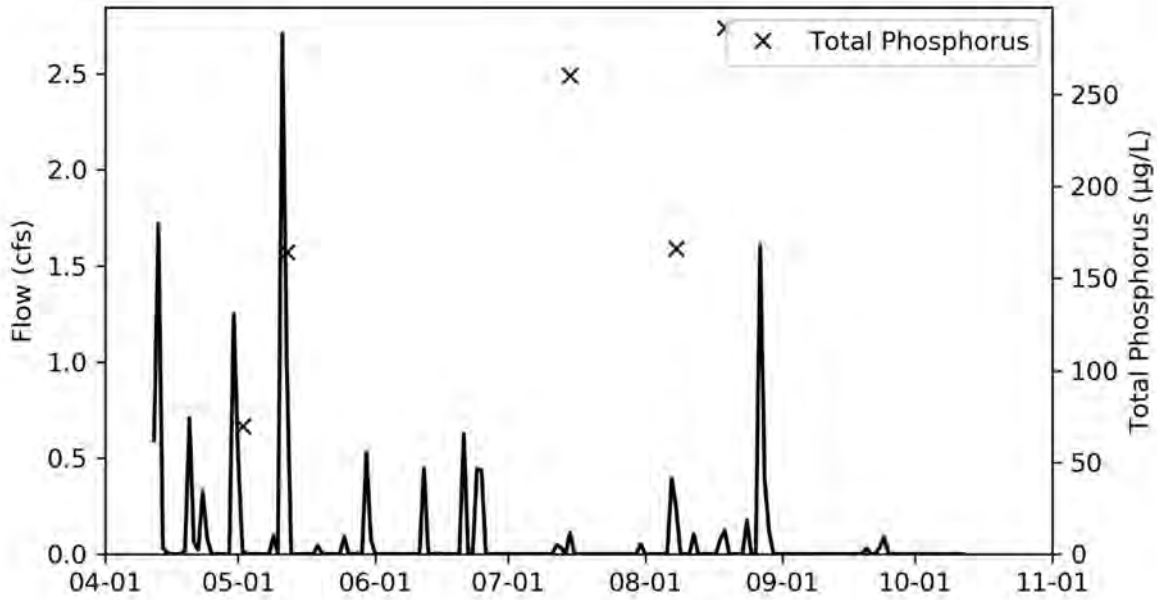


Figure 42. CL7-D TP and Daily Flow

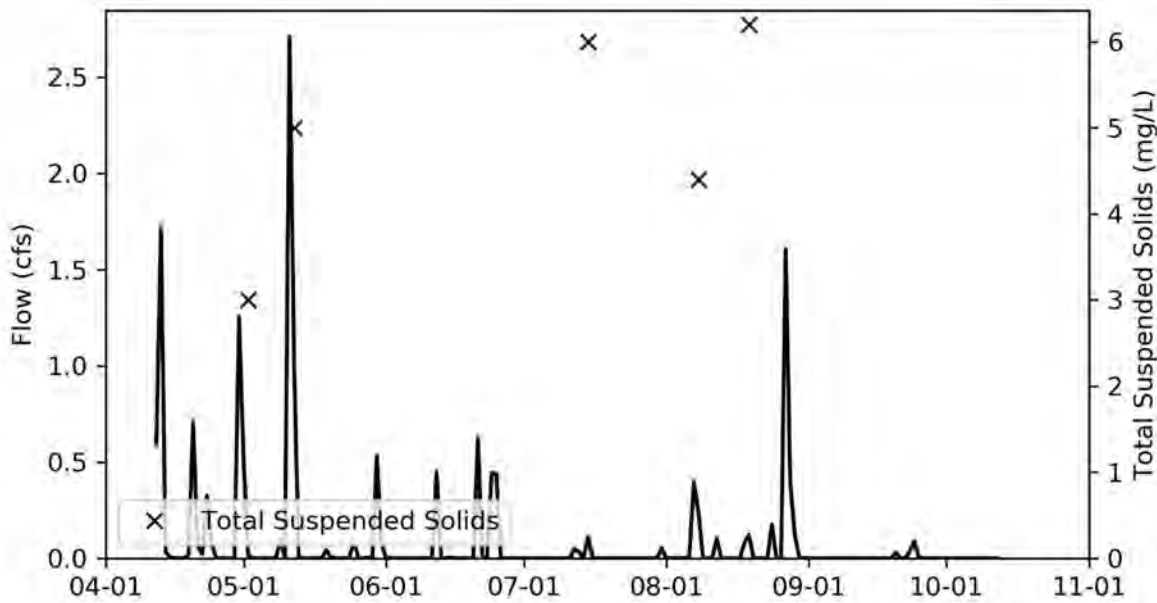


Figure 43. CL7-D TSS and Daily Flow