2025 Monitoring Report

Sauk River Chain of Lakes Association

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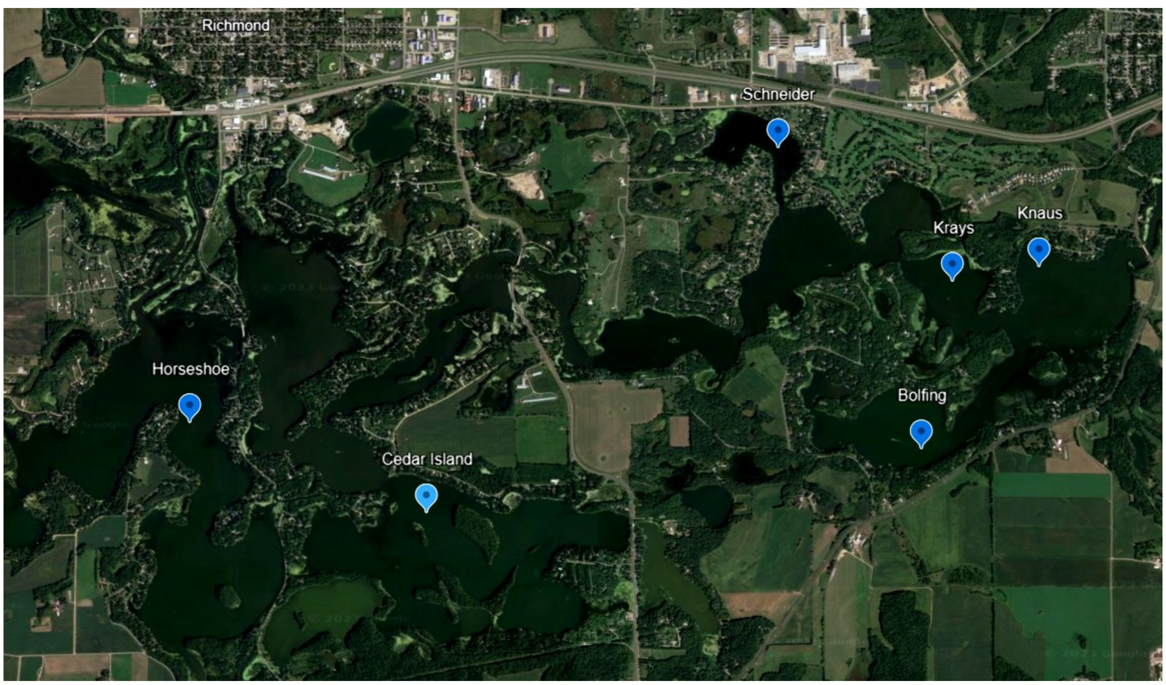
2025 SRCLA Lake Monitoring Report

Horseshoe, Cedar Island, Bolfing, Krays, Knaus, & Schneider

Sauk River Chain of Lakes Overview

One of the Sauk River Watershed District's (**SRWD**) most valuable resources for habitat and aquatic recreation is the Sauk River Chain of Lakes (**SRCL**). This water quality monitoring summary provides the 2025 sample results for six lakes within the Chain of Lakes and a review of past conditions at those sites. Lakes monitored in 2025 include: Horseshoe, Cedar Island, Schneider, Krays, Knaus, and Bolfing Lakes. Additional information regarding the Sauk River monitoring sites upstream (Richmond) and downstream (Cold Spring) of the lake system is also included, along with flow measurements during the 2025 monitoring season.

The Sauk River Chain of Lakes Association, Inc. (**SRCLA**) has been actively monitoring and collecting water quality information in the Chain since their establishment in 1982. The SRCLA was instrumental in the creation of the Sauk River Watershed District in 1986, and the organizations have worked together over the decades to plan and initiate water quality improvement projects in the region.



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Sauk River Watershed District

SRCL Water Quality Standards

The Sauk River Chain of Lakes is made up of 13 interconnected lakes (excluding Park Lake). Some lakes are classified as shallow, some are deep, and some are considered flowage lakes of the Sauk River mainstem. The Sauk River enters the Chain of Lakes system near the city of Richmond, 95 miles south of the river's headwaters at Lake Osakis, and meanders for 7 river-miles through numerous lakes before flowing over the Cold Spring Dam.

Due to the unique hydrologic conditions in the SRCL, the Minnesota Pollution Control Agency (**MPCA**) has determined that some of the lakes require site-specific standards to protect the water quality and recreational resources in this river and lake system. Water quality standards (**WQS**) can be set for a pollutant at a statewide level, by ecoregion, or be site-specific. These standards are used to describe the desired conditions of a waterbody and protect its designated uses. An ecoregion standard may be modified on a site-specific basis to account for unique characteristics such as: waterbody depth, temperature, hydrologic connectivity, drainage area, land use, regional geology, etc. To assign representative WQS, many elements of the watershed ecosystem must be taken into account.

The MPCA and the SRWD proposed site-specific standards for certain lakes in the SRCL in 2012. The Environmental Protection Agency (**EPA**) reviewed and approved these standards in 2020. The proposal was created in response to several issues that arose during the development of the Total Maximum Daily Load (**TMDL**) study for the area.

The issues that prompted the MPCA and SRWD to propose site-specific standards include, but are not limited to:

1. The SRCL is a flowage/reservoir system, and the Minnesota Administrative Rules allow for the development of site-specific standards for reservoirs;
2. Lakes directly in the flowage of the river have very short water residence time (it generally takes <7 days for water to flow through the Chain), and their water quality is largely driven by the upstream conditions of the Sauk River; and
3. Several deep lake basins in the Chain are influenced by their connection to river and lake flowage, and that influence can vary greatly from lake to lake.

MPCA Water Quality Standards			
Lakes	**TP** (µg/L)	**Chl-a** (µg/L)	**Secchi Disk** (ft)
North Central Hardwood Forest (NCHF) General: Schneider	<40	<14	>4.6
Sauk River Chain of Lakes Site Specific Standards			
Non-Flowage Lakes: Cedar Island (main), Horseshoe, Bolfing	<55	<32	>4.6
Flowage Lakes: Krays, Knaus	<90	<45	>2.6
Rivers	**TP** (µg/L)	**TSS** (mg/L)	**Secchi Tube** (cm)
Central MN River Nutrient Region (RNR): Sauk River	100	30	>35

SRCL Water Quality Standards Cont.

The table on page 3 contains the approved site-specific standards for total phosphorus (TP), chlorophyll-A (chl-A), and Secchi disk readings for the Chain of Lakes. The lakes monitored in 2025, and in past years, have been distributed throughout the Chain to incorporate shallow, deep, and flowage lakes. In 2025, the lakes monitored were: **Horseshoe** (non-flowage), **Cedar Island** (non-flowage), **Bolfing** (non-flowage), **Knaus** (flowage), **Krays** (flowage), and **Schneider** (non-flowage, general state standards).

The Carlson Trophic State Index (**TSI**) is used throughout this report to discuss annual water quality trends in each lake. The Carlson TSI is a classification system designed to rate water bodies using concentration measurements of chl-A and total phosphorus, combined with Secchi disk depth readings. The index consists of a scale ranging from 0 - 100 and is used as a predictor of poor water quality conditions. A higher score means the waterbody is more likely to experience poor water quality conditions. Under the Carlson TSI scale, the four main TSI classifications are:

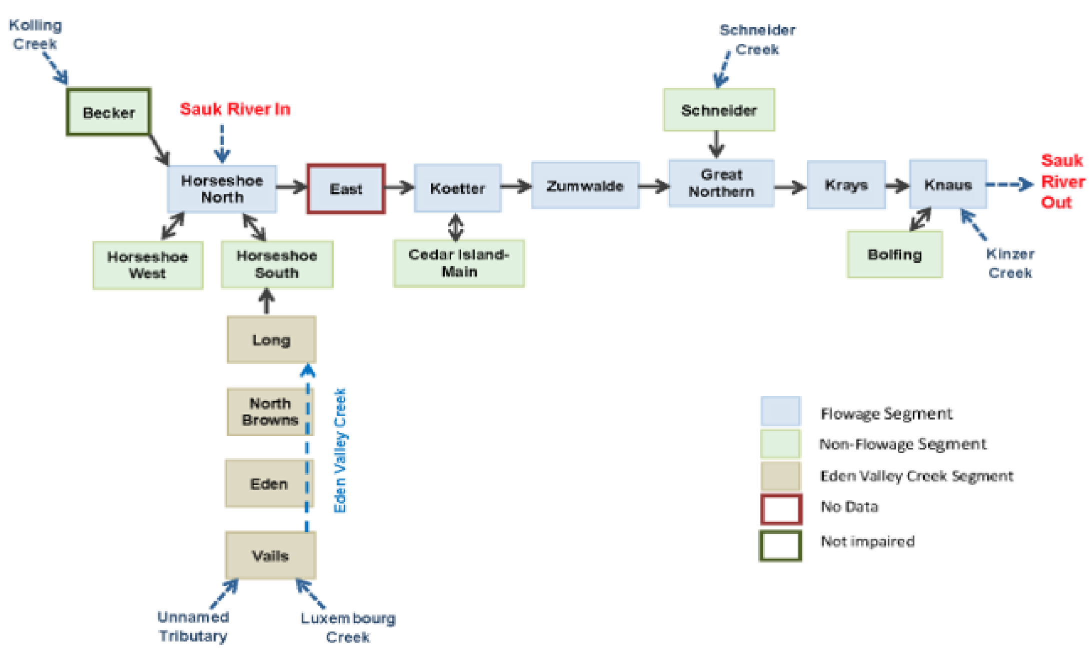
Oligotrophic: TSI 0 - 40, Clear water, good oxygen conditions, limited nutrients available, deep or shallow lake. From the Greek "oligos" meaning few, scanty.

Mesotrophic: TSI 40 - 50, Moderately clear water but increased chance of low oxygen conditions in shallow lakes. From the Greek "meso" meaning middle, moderate.

Eutrophic: TSI 50 - 70, Moderately clear to cloudy water, with a high chance of low oxygen conditions in the summer, extensive plant growth, and potential algal scum. From the Greek "eu" meaning well, plenty.

Hypereutrophic: TSI 70+, Dense plant growth, heavy algal blooms and scum possible, low oxygen conditions, fish kill possible. From the Greek "hyper" meaning over much.

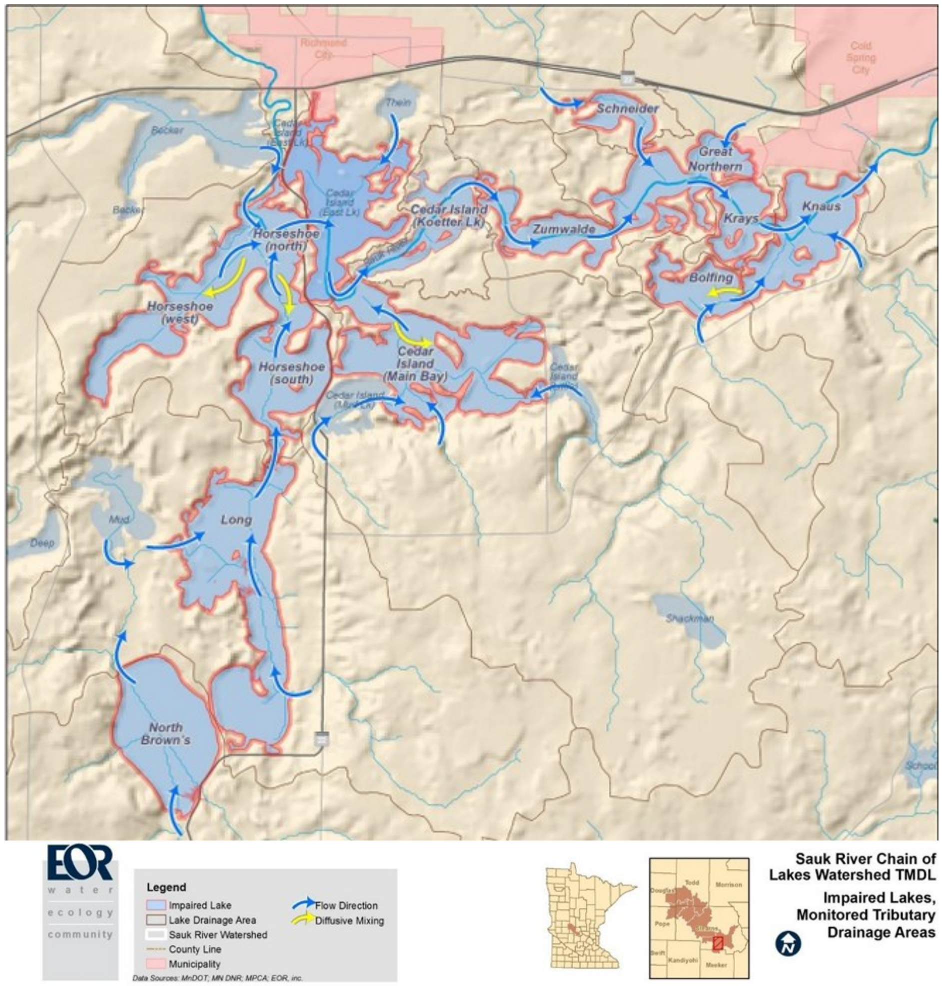
For more details on the Carlson TSI, see page 30. The graphic below is the directional flow chart for the SRCL and Eden Valley Watershed Unit, and it calls out which lakes in the system are flowage lakes and which are not. This chart was copied from the SRCL Total Maximum Daily Load report.



River & Lake Sampling

The samples from the Sauk River included in this report are taken from the mainstem Sauk River near the city of Richmond and upstream of the dam in Cold Spring. The SRWD river sampling device, called a Van Dorn, is submerged to a depth of 1-2 feet below the water surface for sample collection.

This differs from the lake sampling method, which occurred once a month from May to September for a total of 5 sampling days in 2025. The SRWD monitors and samples 28 priority lakes within the entire watershed on a 5-year rotational basis. There are around 371 established lake basins in the watershed, and priority lakes are chosen based on their impairment status and connectivity to the Sauk River. All 28 SRWD priority lakes are listed as impaired on the state's Impaired Waters List (IWL), and continued data collection is important to track water quality trends and support TMDL development. The 6 lakes sampled in the Chain are all listed as impaired for *Aquatic Recreation: Excessive Nutrients*.



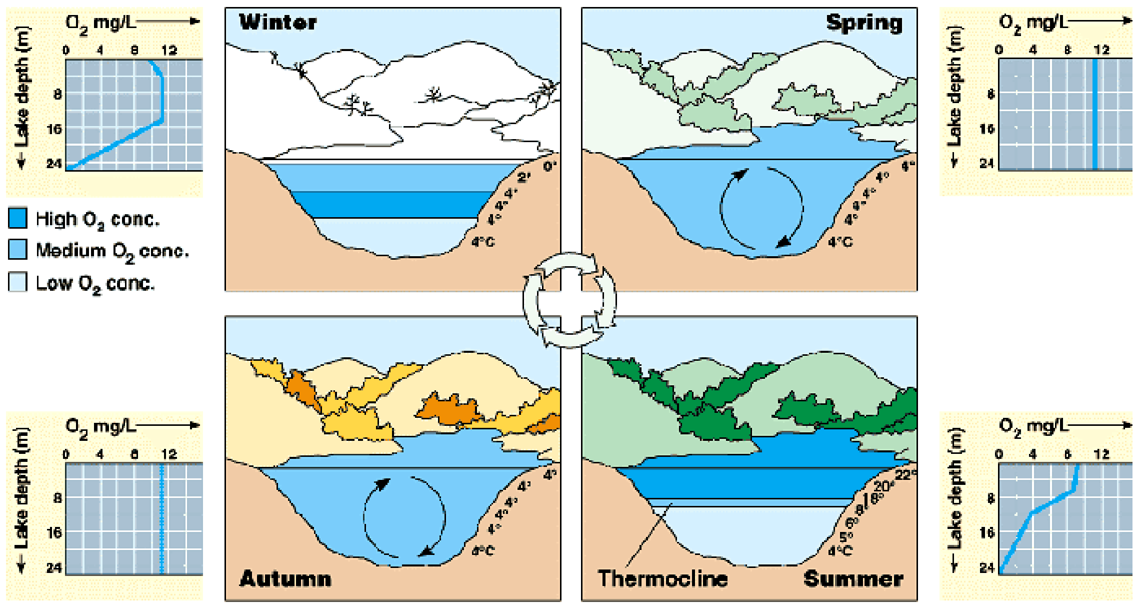
Flow paths, impaired waters in the SRCL Management Unit addressed by this TMDL report

Lake samples were collected by SRCLA volunteers with a 2-meter long pipe, called an integrated sampler, that is plunged vertically into the lake until just submerged. A stopper is then placed in the top of the submerged pipe, the pipe is quickly pulled from the water, and the water is released into a pitcher to allow for mixing before filling sample bottles. Taking a sample from the top 2 meters of the lake captures the water quality conditions in the upper zone of the water column where sunlight penetrates the water. The surface water quality parameters include total phosphorus (**TP**) and chlorophyll-A (**chl-A**). A Secchi disk depth measurement is also taken each sampling day to assess water clarity.

At each sampling location, a multi-parameter probe was lowered into the water to collect dissolved oxygen (**DO**) and temperature readings at one-meter increments until the probe reached the bottom. This data was used to create water column profiles for each lake and assess the presence or absence of a thermocline or oxycline. A **thermocline** is a thin, distinct transition layer in the water column at which temperature drops rapidly with depth, separating the warm surface layer from the cold bottom layer. An **oxycline** is similar, but involves a rapid change in dissolved oxygen with lower oxygen levels near the lake bottom.

Lake Stratification & Water Quality

Process of lake stratification and turnover

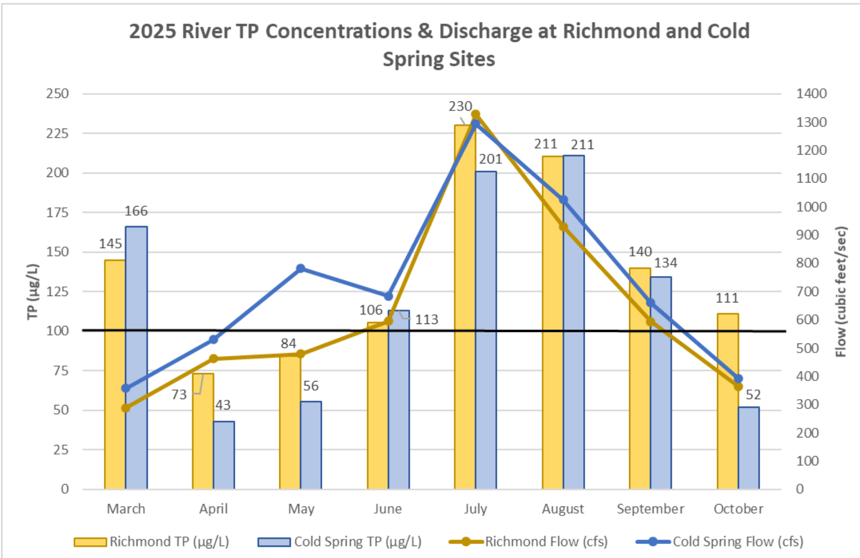


The Sauk River Chain of Lakes Association purchased a YSI brand dissolved oxygen and temperature probe in 2023 and has started monitoring the Chain for these parameters. At each SRCLA sampling site, a temperature and DO depth profile is taken from the lake surface to the lake bottom. The temperature and DO concentrations give us clues about what is happening in the depths of the Chain of Lakes system. If the oxygen and/or temperature readings fall drastically as the probe descends into the lake, this is a sign the lake is undergoing **stratification**. Stratification most commonly occurs in deep (greater than 15 feet) lakes when the surface water warms in the spring and summer. Since cold water is more dense than warm water, the colder water settles to the lake bottom (hypolimnion) and the warmer water stays near the lake surface (epilimnion). If the water remains stratified as the summer progresses, the lake bottom's oxygen concentration can become depleted due to the decomposition of organic matter by bacteria that use up all the oxygen. The bottom layer will stay oxygen-depleted throughout the season in deep lakes that lack enough wind energy to mix the water column. Lake oxygen concentrations can become **hypoxic** (when DO levels in the water drop below 2 milligrams per liter), or even become **anoxic** (oxygen-depleted). These conditions are strongly linked to lake **eutrophication** and can create a stressful, or even deadly, environment for aquatic organisms who need oxygen to survive.

Hypoxic conditions in the lake also create hypoxic conditions in the bottom sediments. This lack of oxygen changes the chemical interaction of the sediment and water, leading to more dissolved phosphorus and nitrogen being released from the sediment to the hypolimnion. Additionally, lake bottom-dwelling bacteria use oxygen to metabolize phosphorus and nitrogen into energy. Hypoxic lake bottom conditions change the bacteria's metabolism; they switch from aerobic respiration to anaerobic respiration, which can lead to the release of more phosphorus. The process of low-oxygen conditions leading to a release of sediment nutrients is known as ***internal lake nutrient loading***. Internal loading occurs naturally in many lakes, but it can lead to a large input of nutrients in the fall/winter when lake water cools and the water column mixes. This can move settled nutrients from the lake bottom into the upper water column and potentially lead to noxious algae blooms and reduce water quality.

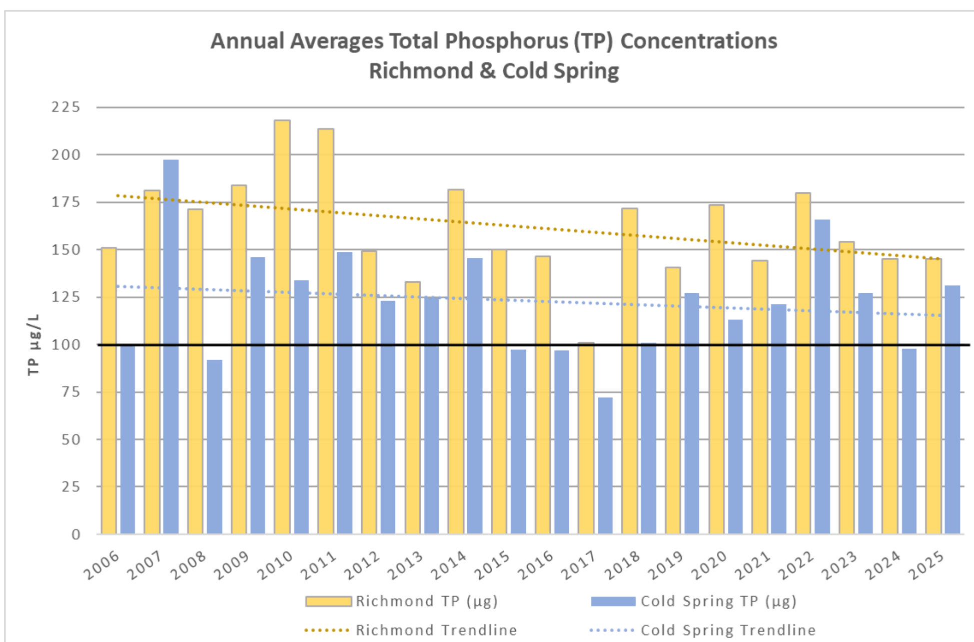
The Total Maximum Daily Load (TMDL) report for the Chain of Lakes notes that phosphorus inputs from the Sauk River has declined considerably due to substantial **point** and **nonpoint source** reductions. In fact, there have been significant reductions of TP concentrations in Horseshoe North over the years that have available monitoring data, which will be discussed more later in this report.

2025 Sauk River Phosphorus & Flows

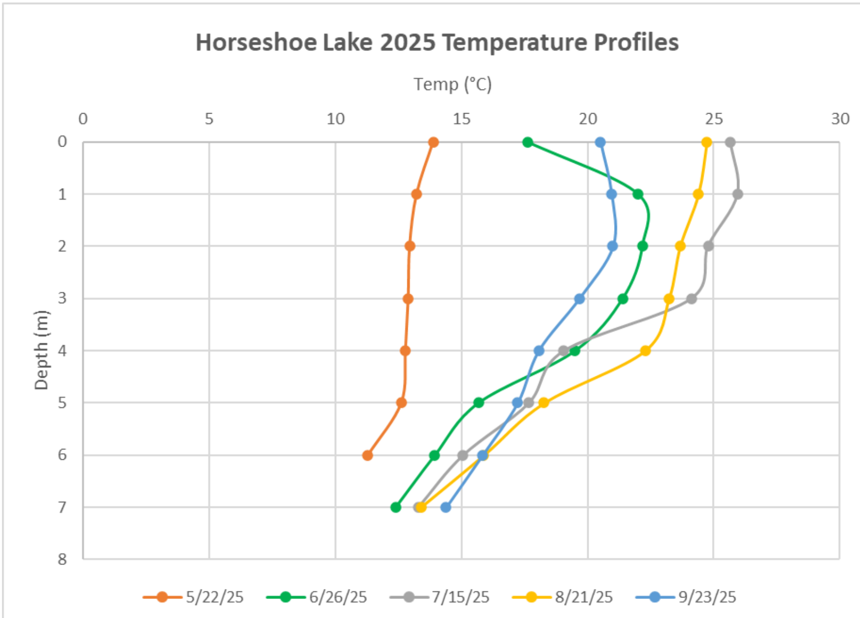


The SRWD maintains long-term monitoring sites upstream of the Chain of Lakes on County Road 111 near the city of Richmond and downstream of the Chain on County Road 2 in Cold Spring. River monitoring sites are visited regularly from March to October, and water quality samples are taken twice a month. Flow (discharge) measurements are taken by the SRWD monthly at each mainstem river site. The 2025 monitoring season was a wet one with high amounts of runoff. Flow measurements were average (graphed as lines following the right vertical axis) at the beginning of the year following snowmelt, and TP concentrations were slightly elevated during spring runoff. Flows began to increase as the rains kept coming. This also meant TP levels crept up and peaked mid to late-summer. The skies dried up in the fall, so flows and TP levels came back down. TP concentrations are usually higher at the Richmond site than at Cold Spring because sediment and nutrients have a chance to settle out of the river system once they enter the Chain. The monthly averages for TP concentration at the Cold Spring site remained below the water quality standard (WQS) of **<100 µg/L** in April, May, and October. TP at Richmond fell below the WQS in April and May. To give some context for the high TP results, according to daily precipitation data from the Melrose weather station, the 2025 monitoring season experienced total precipitation that was **5.51 inches higher** than normal years. A wet year with major runoff events leads to higher levels of phosphorus entering the system.

The bottom graph displays the annual average TP concentrations at the Richmond and Cold Spring sites since 2006. Both sites exceed the TP WQS the vast majority of the time. The annual average at Cold Spring this year was 131 µg/L and 145 µg/L at Richmond. However, there is a slight downward trend in concentrations at both sites over the past 20 years. The high TP concentrations in the Sauk River upstream of the Chain near Richmond will make it difficult to meet the WQS in the SRCL flowage lakes. Upstream water quality improvement projects are needed to reduce phosphorus loading to the Chain.



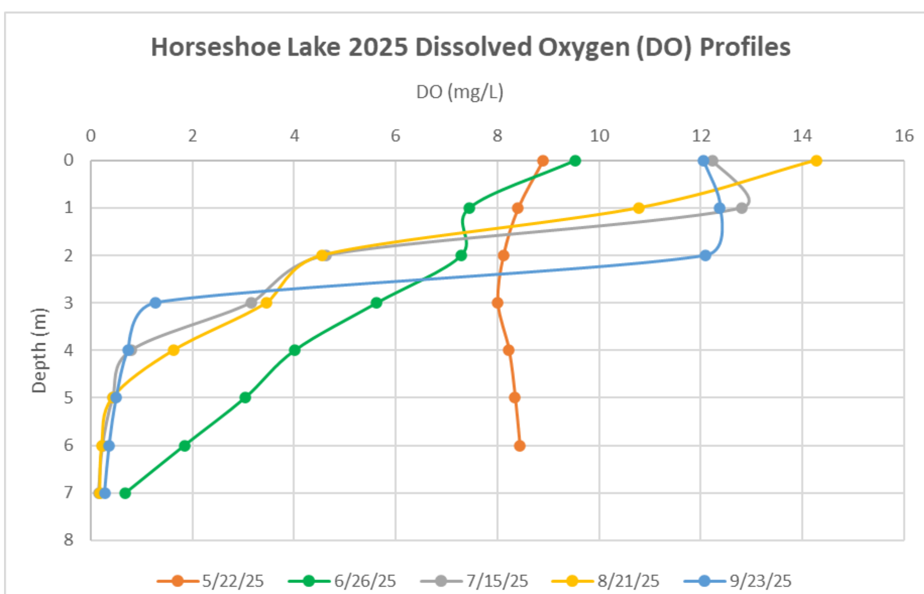
Horseshoe Lake Temp and DO Profiles



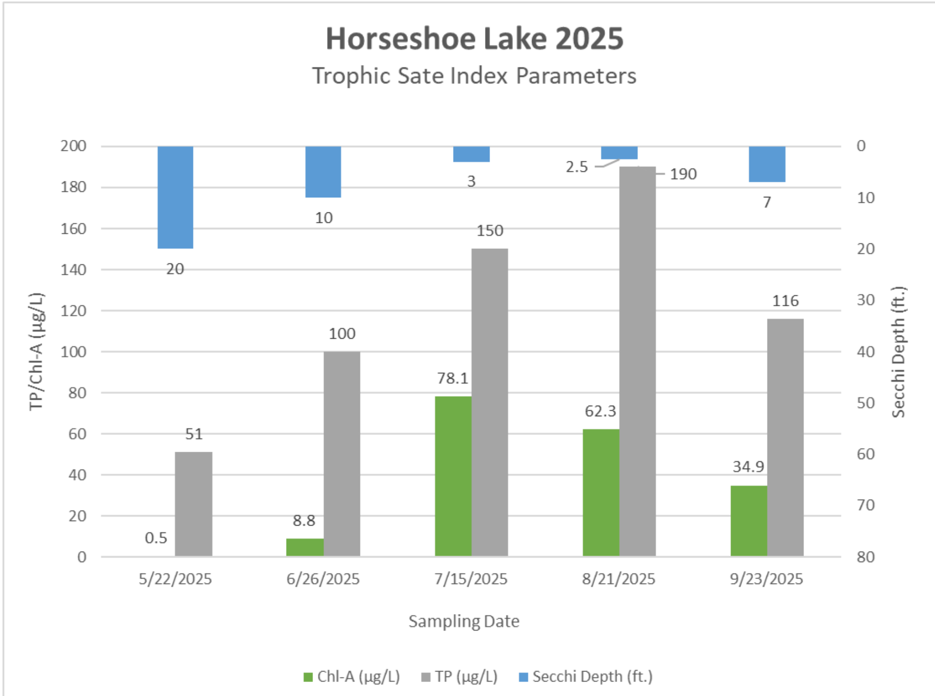
Horseshoe Lake is the first lake the Sauk River enters into the Chain's system. The monitoring site is located in the northern part of Horseshoe Lake. The first graphs shown are for the temperature and dissolved oxygen (DO) profiles. For both graphs, data points represent measurements taken at one-meter increments on each sampling day. Temperature or DO is graphed across the top, and depth is displayed on the side from the top down, demonstrating how the parameter would change in a water column.

Horseshoe Lake began the monitoring season completely mixed from top to bottom with hardly any change in water temperature or DO. As summer progressed, stratification began to occur and was quite prominent by July. For example, looking at the temperature profile (above) in July, water temp at the surface was 26°C (78°F), then dropped down to 13°C (56°F) at the bottom. The lake was still slightly stratified by temperature in September, but was beginning to mix and turn over.

The graph on the right represents the DO profiles. There were sufficient oxygen levels on the bottom on the first sampling day in May, but DO levels on the bottom were near depleted for the remainder of the year. By June, the DO concentration at the surface was 9.5 mg/L, but it plummeted down to 0.68 mg/L at the bottom. That is essentially anoxic levels. Anoxic conditions at the bottom of a lake leads to the decay of bottom sediments/dead plant matter and the release of phosphorus, which exacerbates the issue of internal nutrient loading.



Horseshoe Lake Monitoring Results



The graph above includes water quality parameters that are used to calculate a Carlson Trophic State Index (TSI) score. A breakdown of all the TSI scores will be provided in the summary section at the end of this report. This common classification method is used to evaluate the health of a waterbody based on chlorophyll-A (chl-A) levels, TP, and water clarity (measured by Secchi depth). The index is a scale from 0-100, with a low score indicating better water quality. Secchi depth is displayed from the top down (in blue) and is read on the right vertical axis.

Horseshoe exceeded the chl-A site-specific standard of <32 µg/L for all but the first 2 sampling days. The highest chl-A result was 78.1 µg/L on 7/15. The lake exceeded the TP WQS of <55 µg/L for each sample except for in May. TP levels peaked in August, reaching 190 µg/L. The average for all 2025 samples was **121.4 µg/L**. For Secchi depth, it met the WQS of >4.6 feet for 3 sampling visits, reaching a whopping 20 feet in May.

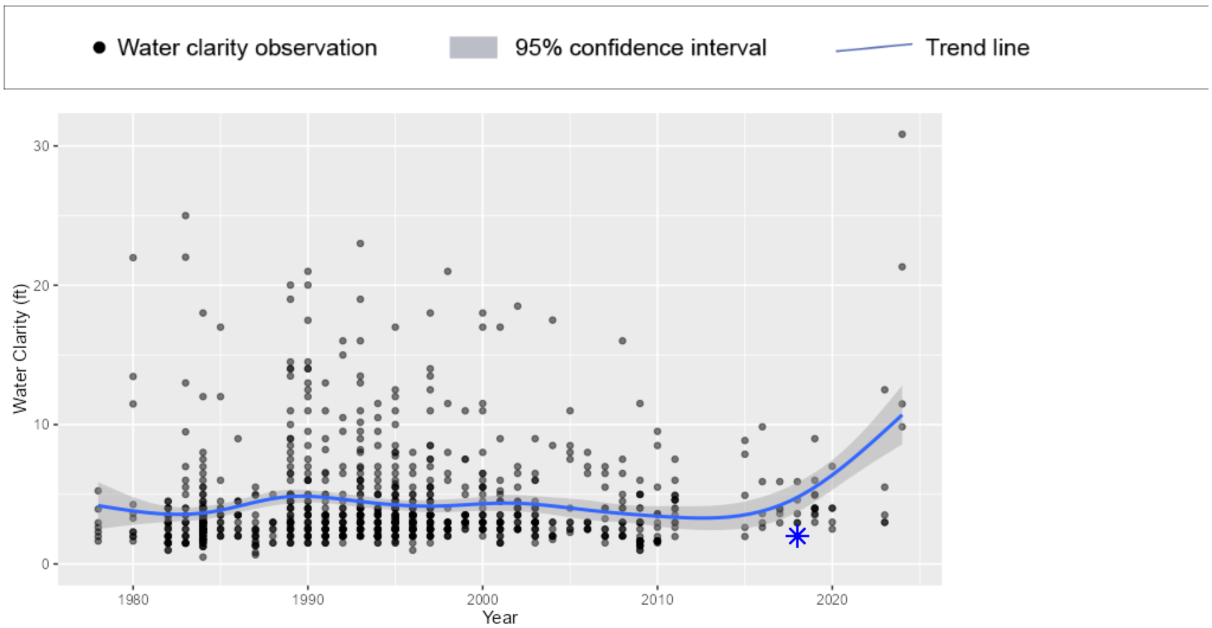
The table below contains sample results for each of the 5 sampling days in 2025 with the averages at the bottom. The yellow highlighted cells represent values that do not meet WQS. Surface temperature and DO levels are also included.

Lake Name	Site ID	Sample Date	Surface Temp (°F)	Surface DO (mg/L)	Secchi Disk Depth (feet)	Chl-A (µg/L)	TP (µg/L)
Horseshoe	73-0157-00-211	5/22/2025	57.0	8.9	20.0	0.5	51
Horseshoe	73-0157-00-211	6/26/2025	63.7	9.5	10.0	8.8	100
Horseshoe	73-0157-00-211	7/15/2025	78.3	12.2	3.0	78.1	150
Horseshoe	73-0157-00-211	8/21/2025	76.5	14.3	2.5	62.3	190
Horseshoe	73-0157-00-211	9/23/2025	68.9	12.1	7.0	34.9	116
2025 Annual Averages			**68.9**	**11.4**	**8.5**	**36.9**	**121.4**

Horseshoe Lake Transparency Trend

Trend analysis result:

For years 1978 to 2024 there is no identifiable water clarity trend at this lake. For the most recent year of the analysis, median water clarity was 4.40 feet deeper than the watershed median. Zebra mussels were discovered in this lake in 2018.



Since there has been a long history of volunteer monitoring on the Sauk River Chain of Lakes, there is a robust dataset of Secchi disk depth measurements dating back to 1978. The MPCA Surface Water online dashboard displays transparency trend graphs for lakes with a long enough history of Secchi depth data. Each individual water clarity reading is graphed, and the shaded gray area around the trend line is the range in which the actual measured clarity falls within a 95% certainty. The graph encompasses all monitoring sites on the lake that have reported data. The blue asterisk indicates when zebra mussels were discovered in the lake, which in this case was 2018.

There is no discernable trend for water clarity since monitoring began in 1978, but there has been a slight increase over the past 5 years. The average Secchi disk depth in 2025 was **8.5 feet** on Horseshoe.

There have also been significant TP reductions in Horseshoe Lake North since 1978. Horseshoe North is the headwaters and a "king-pin" lake, or primary focus since it receives the majority of the loading from the Sauk River. Changes in this lake will be transferred to downstream lakes. The TP decline has also been accompanied by smaller oscillations of year-to-year average summer concentrations between wet and dry years.

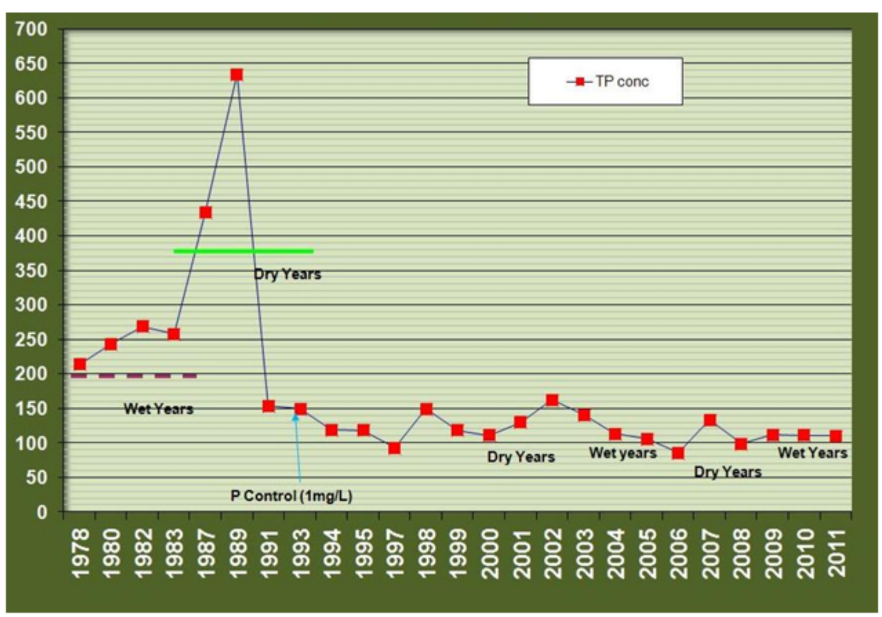
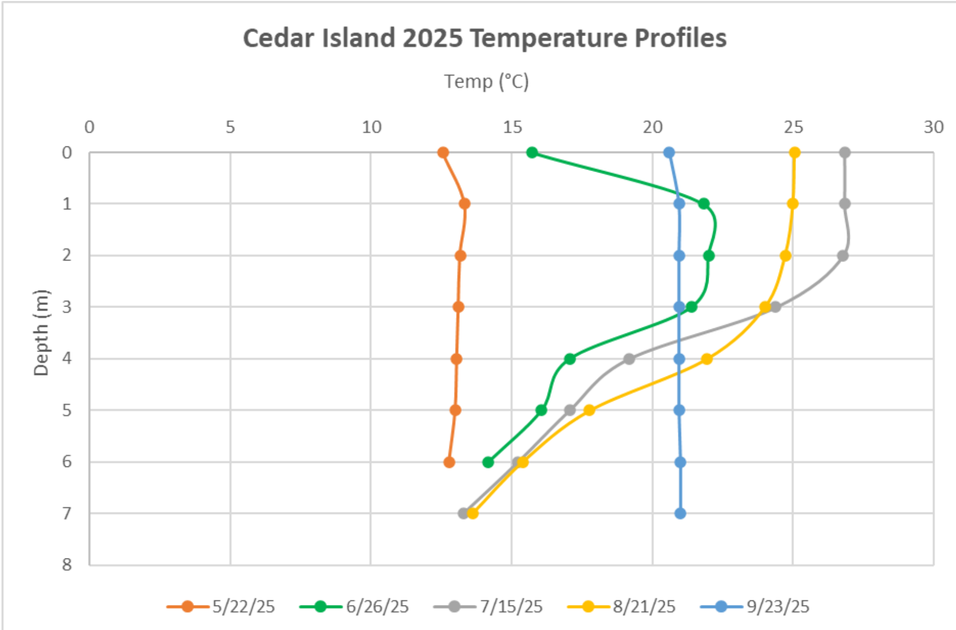


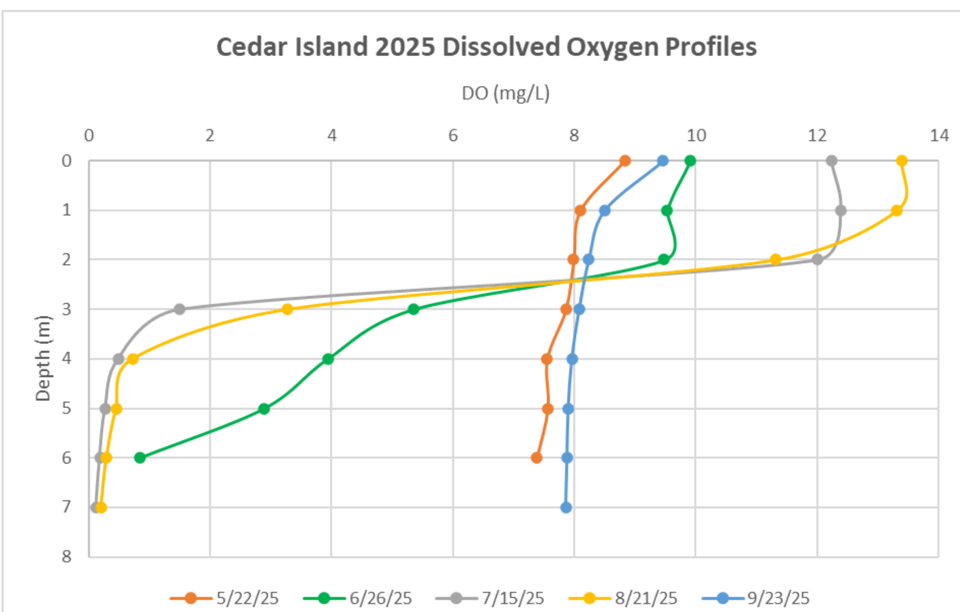
Figure 8. Historic June–September mean TP in Horseshoe Lake North, Richmond, Minnesota.
Figure courtesy of Steve Heiskary, MPCA (2012).

Cedar Island Temp and DO Profiles

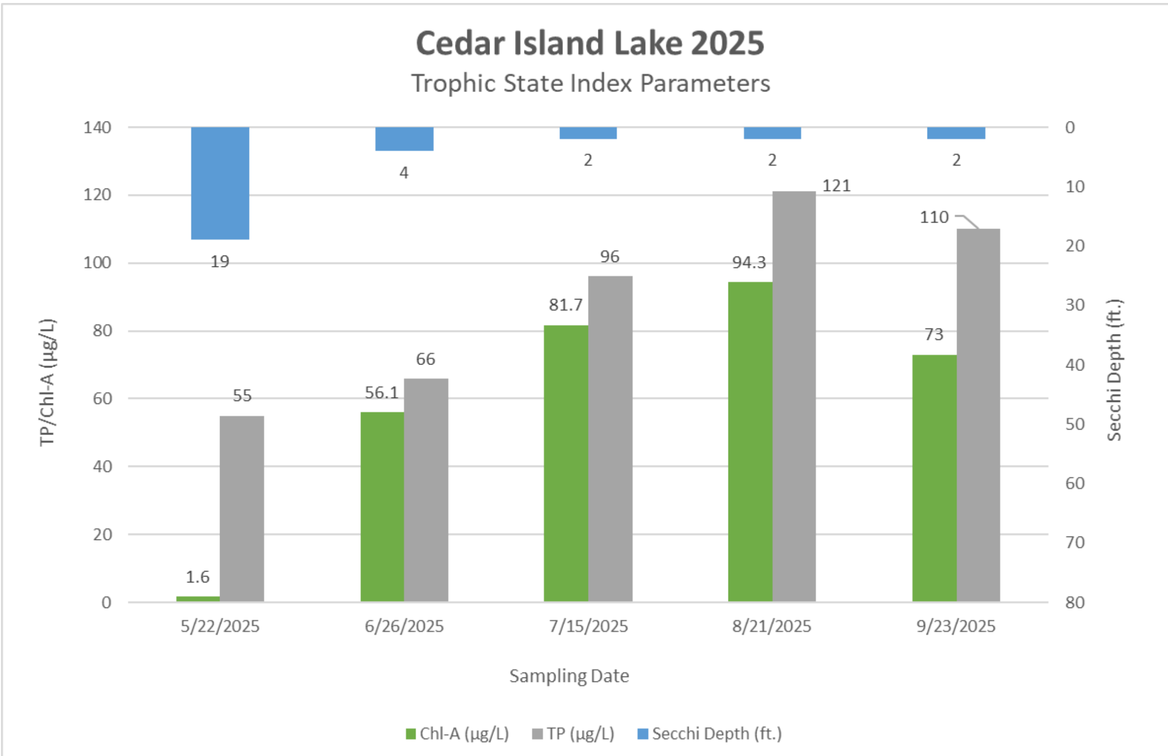


Cedar Island Lake is one of the larger lakes in the Chain with 27 miles of shoreline and 77% of the lake being 15 feet deep or less. The maximum depth is 75 feet. It is broken up into Cedar Island-Main Bay, East Lake, Koetter Lake, and Mud Lake, with the SRCL samples being taken in the Main Bay. Considering the temperature profile, Cedar Island began and ended the year with the water column completely mixed. The lake was stratified by June with the temperature near the surface at 22°C (72°F), then went down to 14°C (57°F) at the bottom.

Similar to the temp profile, DO was also uniform throughout the water column in May and September (see the graph below). There was distinct stratification in the summer during which DO levels at the bottom were basically depleted. The column was completely mixed again by the September sampling day. DO remained at around 8 mg/L throughout the entire profile.



Cedar Island Monitoring Results



Looking at the TSI parameters, Cedar Island was clearly eutrophic in 2025, meaning there were high amounts of nutrients available to feed weed and algae growth. Chl-A levels (which is a measure of algae growth) were low on the first sampling day, but they exceeded the WQS of <32 µg/L for the remaining sampling days. Chl-A increased throughout the summer and peaked in August. The average chl-A in 2025 was **61.3 µg/L**.

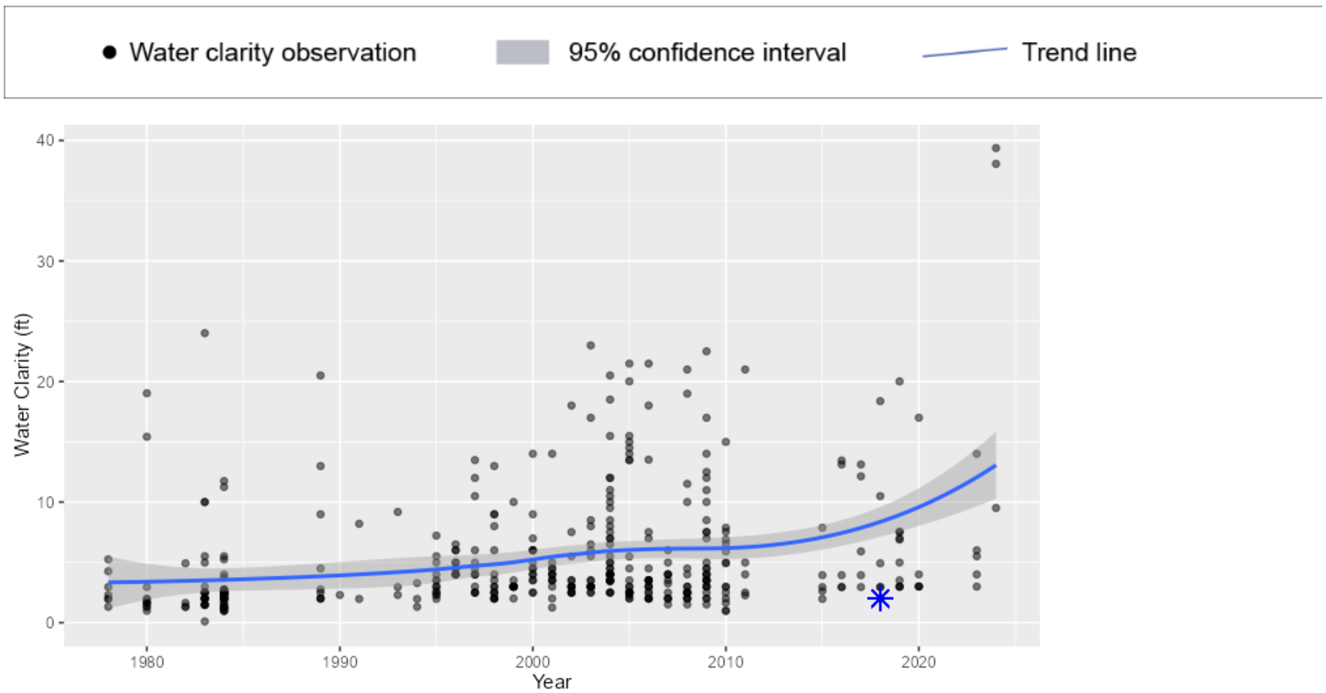
TP levels were also high and exceeded the WQS on each sampling day besides the first in May. The average for 2025 was **89.6 µg/L**, which is lower than the average for Horseshoe Lake. As for Secchi disk depth, it started out strong with a clarity measurement of 19 feet, but the remaining measurements were less than the WQS of >4.6 feet. With warm water temperatures, it is common to see algae growth increase and clarity decline as the summer progresses.

Lake Name	Site ID	Sample Date	Surface Temp (°F)	Surface DO (mg/L)	Secchi Disk Depth (feet)	Chl-A (µg/L)	TP (µg/L)
Cedar Island	73-0133-01-205	5/22/2025	54.1	8.8	19	1.6	55
Cedar Island	73-0133-01-205	6/26/2025	60.3	9.9	4	56.1	66
Cedar Island	73-0133-01-205	7/15/2025	80.2	12.2	2	81.7	96
Cedar Island	73-0133-01-205	8/21/2025	77.2	13.4	2	94.3	121
Cedar Island	73-0133-01-205	9/23/2025	69.1	9.5	2	73.0	110
2025 Annual Averages			**68.2**	**10.8**	**5.8**	**61.3**	**89.6**

Cedar Island Transparency Trend

Trend analysis result:

For years 1978 to 2024 there is evidence of no change in water clarity at this lake. For the most recent year of the analysis, median water clarity was 26.05 feet deeper than the watershed median. Zebra mussels were discovered in this lake in 2018.

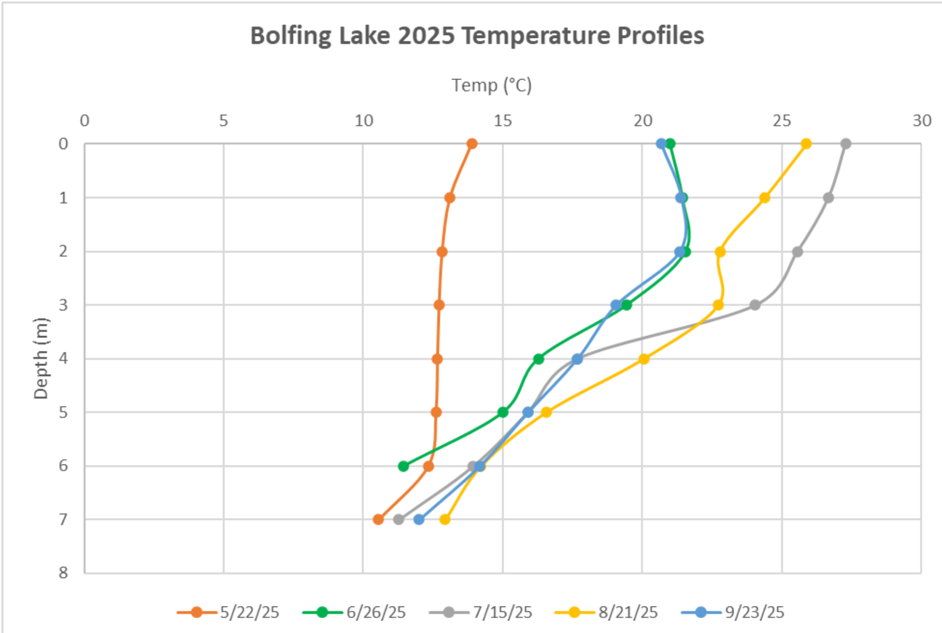


Since there has been a long history of volunteer monitoring on the Sauk River Chain of Lakes, there is a strong dataset of Secchi disk depth measurements dating back to 1978. The graph includes all monitoring sites on Cedar Island that have reported data. The blue asterisk indicates when zebra mussels were discovered in the lake, which was in 2018 for this lake.

There is no discernable trend for water clarity since 1978, but increases have been seen since 2015. The average Secchi disk depth in 2025 was **5.8 feet** on Cedar Island.

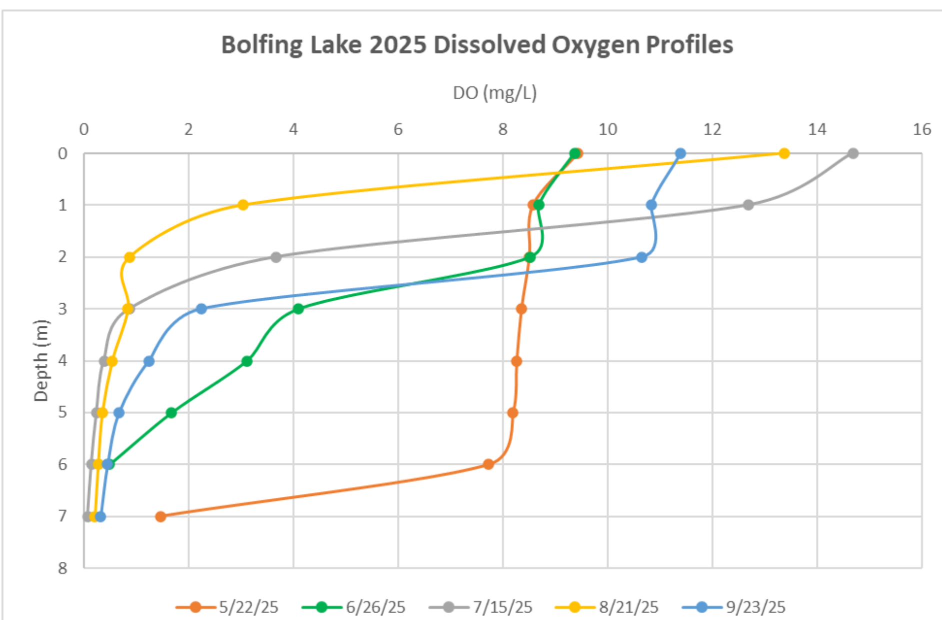
Photo courtesy of Sauk River Chain of Lakes Association

Bolfing Lake Temp and DO Profiles

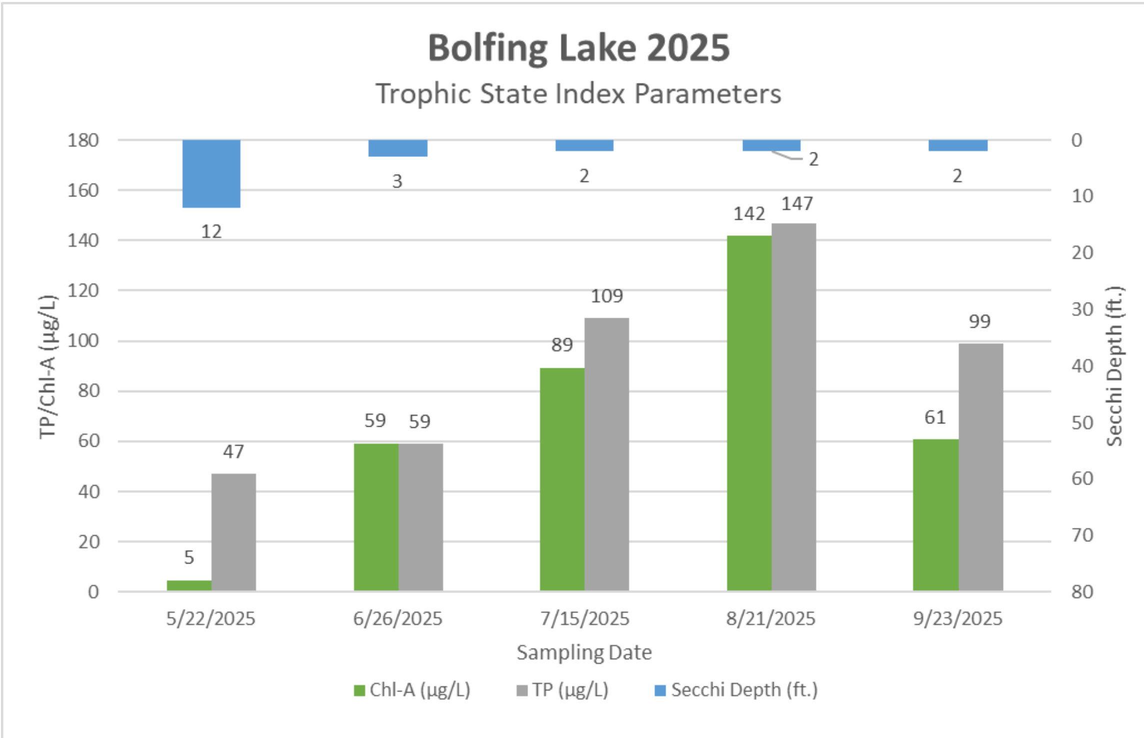


Bolfing Lake is just south of the SRCL flowage lakes Knaus and Krays Lakes. Bolfing slowly drains to the Sauk River flowage area at its outlet. The water quality of the lake is also influenced by Knaus Lake due to their proximity and mixing of waters. As can be seen in the temperature profile, Bolfing had a mixed water column at the beginning of the monitoring season, but it did become stratified by temperature during the summer months. The lake was still slightly stratified on the September sampling day starting at 20.7°C (69°F) on the surface, then dipped down to 12°C (54°F) at the bottom.

The DO stratification is more prominent. In May, the water column was still mostly mixed, but the lake was stratified for the rest of the sampling days. This means that the DO levels on the bottom of the lake were effectively devoid of oxygen throughout the monitoring season, which promotes phosphorus loading from the bottom sediments of the lake.



Bolfing Lake Monitoring Results



Similar to the results on Cedar Island, there were high levels of TP and chl-A on Bolfing Lake. The WQS for the three parameters included in the graph above were all met on the first sampling day, but were not met for the remainder of the year. Chl-A levels peaked in August at 142 µg/L and finally came back down in September. Growth of algae usually coincides with warmer surface water temperatures, which are included in the table below.

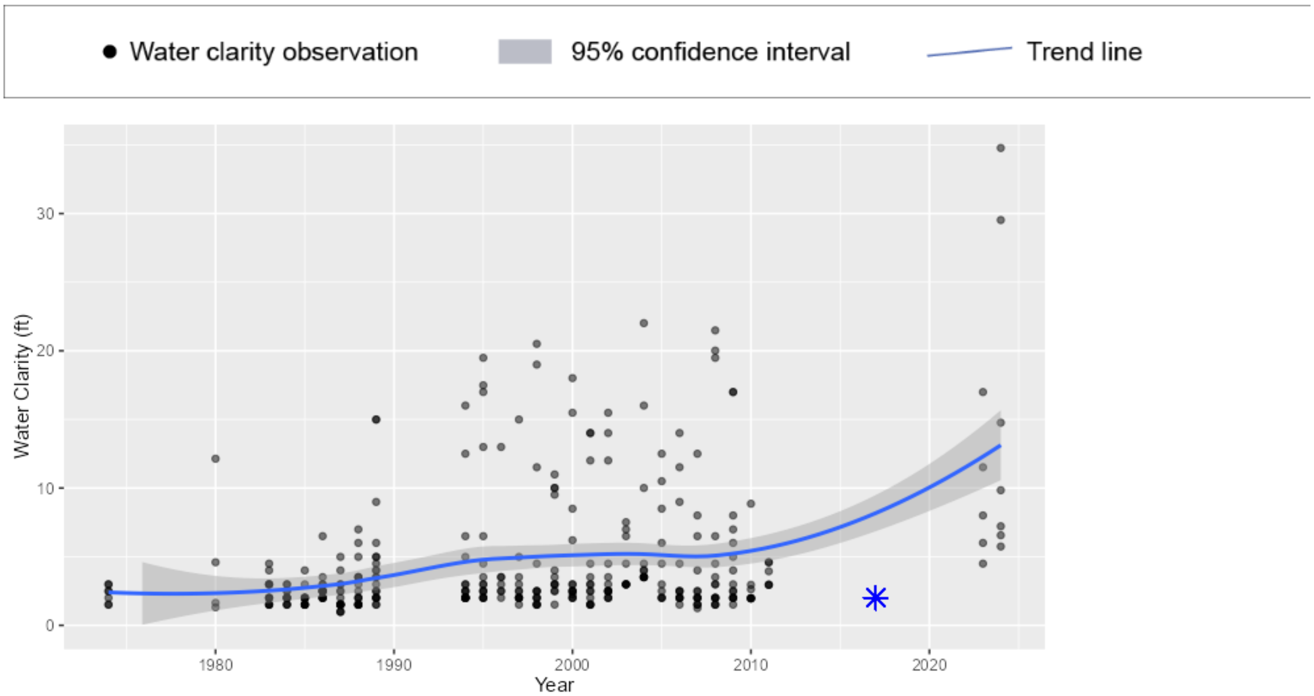
TP levels also peaked in August at 147 µg/L. The average TP result in 2025 was **92.2 µg/L**, which is higher than Cedar Island but lower than Horseshoe Lake. As for Secchi depth (which measures water clarity), there was a good start to the year with a 12 feet measurement, but the remaining measurements all fell below 4 feet. The average Secchi depth in 2025 was **4.2 feet**.

Lake Name	Site ID	Sample Date	Surface Temp (°F)	Surface DO (mg/L)	Secchi Disk Depth (feet)	Chl-A (µg/L)	TP (µg/L)
Bolfing Lake	73-0088-00-203	5/22/2025	57.0	9.5	12	4.8	47
Bolfing Lake	73-0088-00-203	6/26/2025	69.8	9.4	3	59.2	59
Bolfing Lake	73-0088-00-203	7/15/2025	81.1	14.7	2	89.4	109
Bolfing Lake	73-0088-00-203	8/21/2025	78.6	14.2	2	142.0	147
Bolfing Lake	73-0088-00-203	9/23/2025	69.3	11.4	2	60.9	99
2025 Annual Averages			**71.2**	**11.8**	**4.2**	**71.3**	**92.2**

Bolfing Lake Transparency Trend

Trend analysis result:

For years 1974 to 2024 there is evidence of no change in water clarity at this lake. For the most recent year of the analysis, median water clarity was 2.17 feet shallower than the watershed median. Zebra mussels were discovered in this lake in 2017.

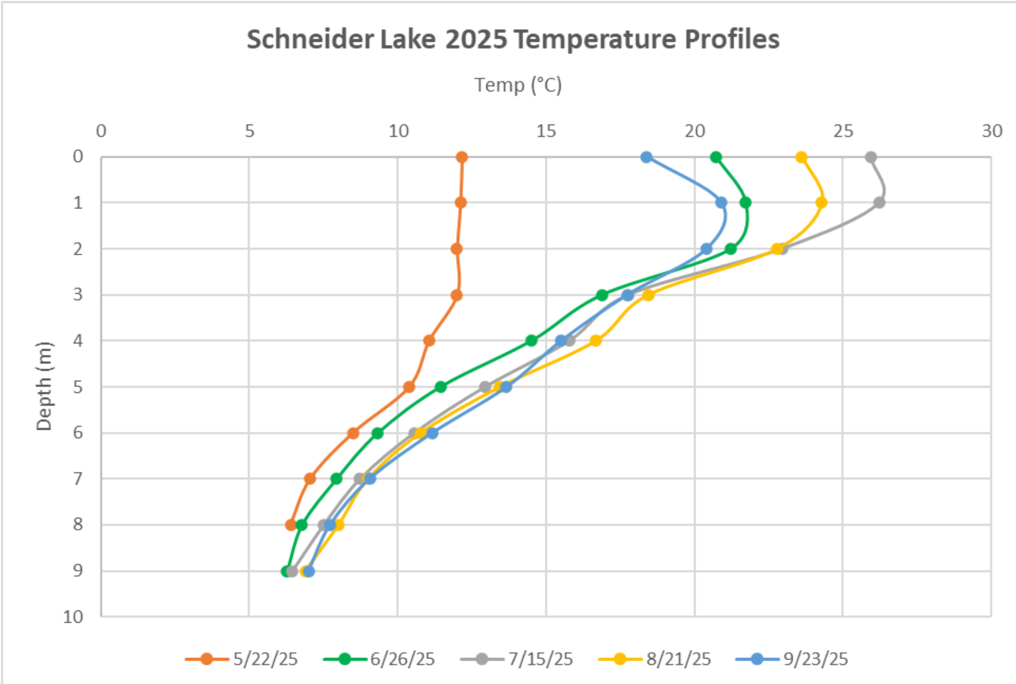


The MPCA Surface Water online dashboard displays transparency trend graphs for lakes with a long history of Secchi depth data. Each individual water clarity reading is graphed, and the gray area around the trend line displays the range in which the actual clarity measurement falls within 95% certainty. The blue asterisk indicates when zebra mussels were discovered in the lake, which was in 2017 for Bolfing.

This dataset dates back to 1974, but there is a period of time missing from 2012 to 2022. There is no discernable trend, but there are indications of improved clarity in recent years compared to the 1994-2011 period. We would still like to see Secchi disk readings that are consistently higher and continue to build the dataset.

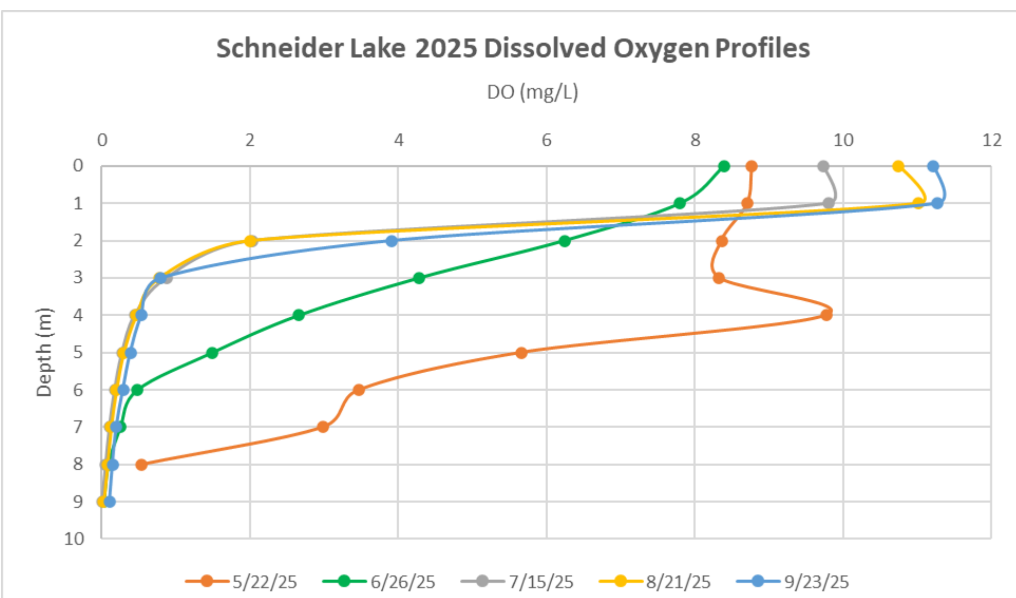
Monitoring volunteers (from left): Jon Folkedahl, Gary Schnobrich, Wayne Karg, and Jamie Juelfs

Schneider Lake Temp and DO Profiles

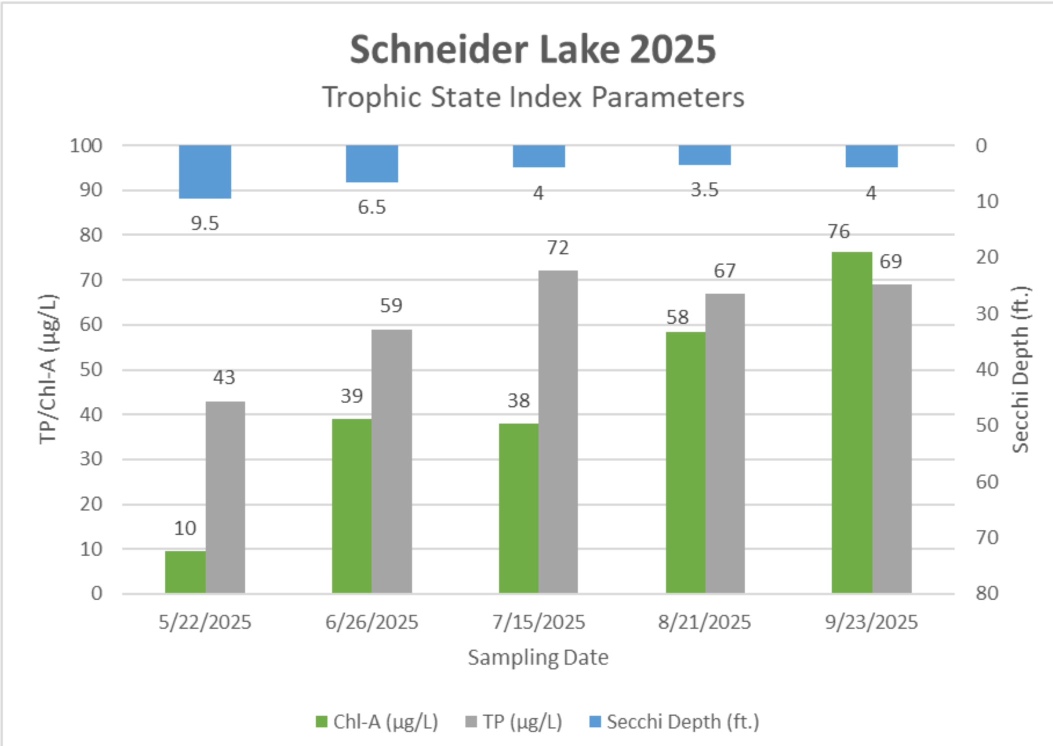


Schneider Lake is situated just north of the SRCL flowage lakes and is considered a natural lake because of its small, singular outlet into Great Northern Lake. It has a maximum depth of 52 feet and a mean depth of 19 feet. Looking at the temperature profiles, the lake was mostly mixed throughout the water column in May and temperature gradually went down toward the bottom. However, the column became stratified in June and remained that way for the rest of the sampling days. In September, the temperature at the surface was 18°C (65°F), then dropped down to 7°C (45°F) at the bottom.

The DO profiles indicate stratification by oxygen levels throughout the entire monitoring season. Even in late September, DO levels plummeted 2 meters into the column and dropped to hypoxic levels the rest of the depth.



Schneider Lake Monitoring Results



The graph above for TSI parameters is the same setup as the other lakes, but bear in mind that the WQS follow those for the general NCHF ecoregion since Schneider is removed from the flowage system of the river. That means the chl-A WQS is <14 µg/L, and the TP WQS is <40 µg/L. The yellow highlighted cells in the table below represent values that do not meet WQS. Chl-A samples exceeded the WQS on each sampling day except for the first. The highest result was 76 µg/L in September, most likely because of the above-average fall temperatures we experienced. The average chl-A result in 2025 was **44.2 µg/L**.

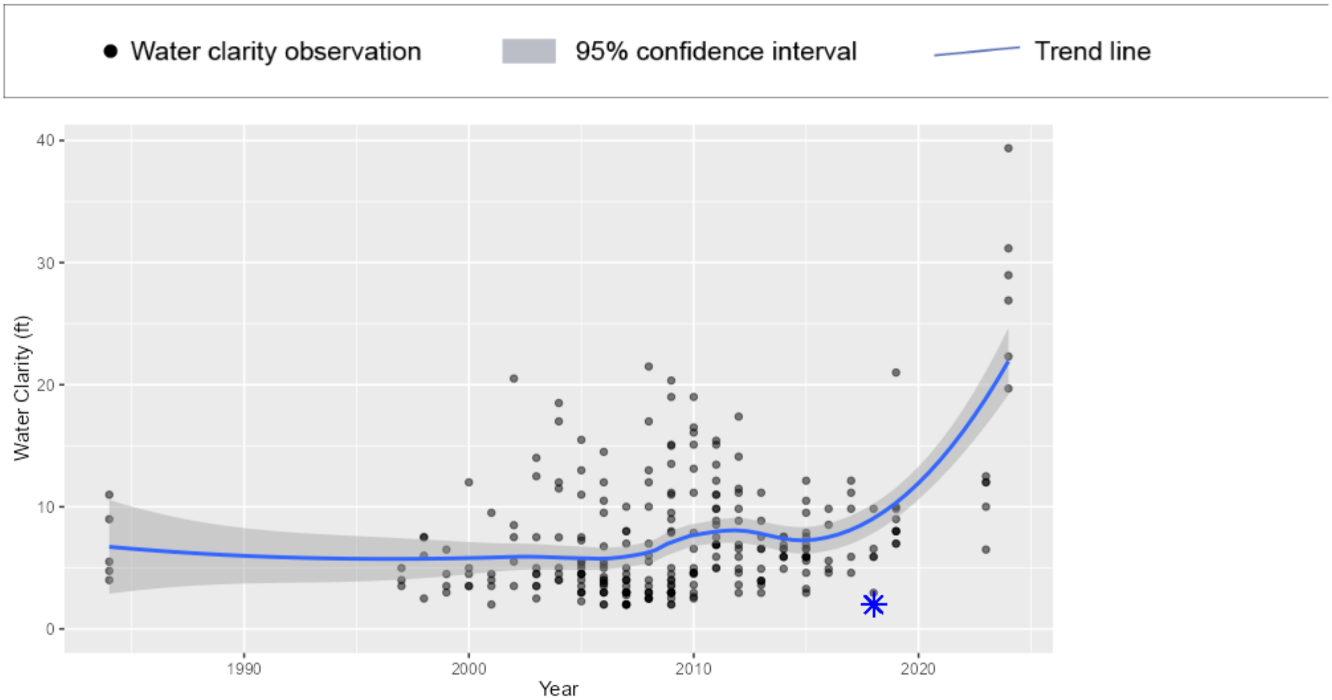
The TP WQS was exceeded for each sampling event. The highest TP result was 72 µg/L in July. The average TP concentration was **62 µg/L**. As for Secchi depth, the WQS of >4.6 feet was not met on 3 sampling days. The highest Secchi depth result was 9.5 feet on 5/22.

Lake Name	Site ID	Sample Date	Surface Temp (°F)	Surface DO (mg/L)	Secchi Disk Depth (feet)	Chl-A (µg/L)	TP (µg/L)
Schneider Lake	73-0082-00-202	5/22/2025	54.0	8.8	9.5	10	43
Schneider Lake	73-0082-00-202	6/26/2025	69.3	8.4	6.5	39	59
Schneider Lake	73-0082-00-202	7/15/2025	78.6	9.7	4.0	38	72
Schneider Lake	73-0082-00-202	8/21/2025	74.5	10.8	3.5	58	67
Schneider Lake	73-0082-00-202	9/23/2025	65.1	11.2	4.0	76	69
2025 Annual Averages			**68.3**	**9.8**	**5.5**	**44.2**	**62.0**

Schneider Lake Transparency Trend

Trend analysis result:

For years 1984 to 2024 there is evidence of improving water clarity at this lake, of approximately 1.4 feet per decade. For the most recent year of the analysis, median water clarity was 15.93 feet deeper than the watershed median. Zebra mussels were discovered in this lake in 2018.

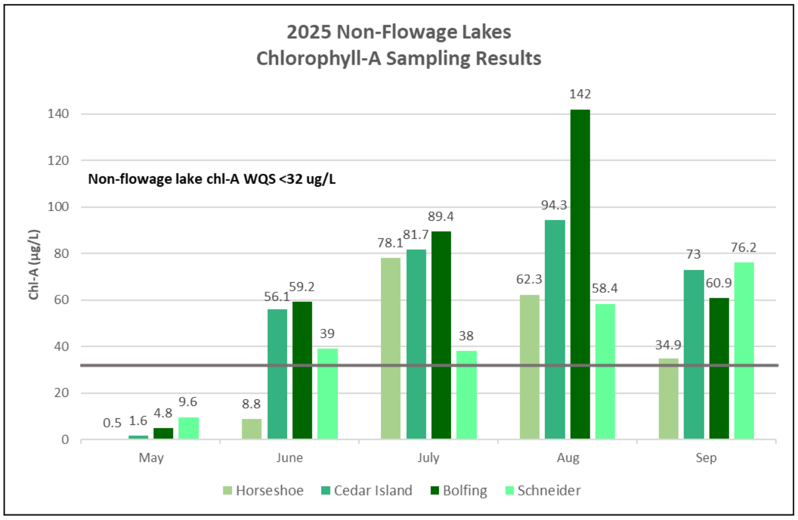


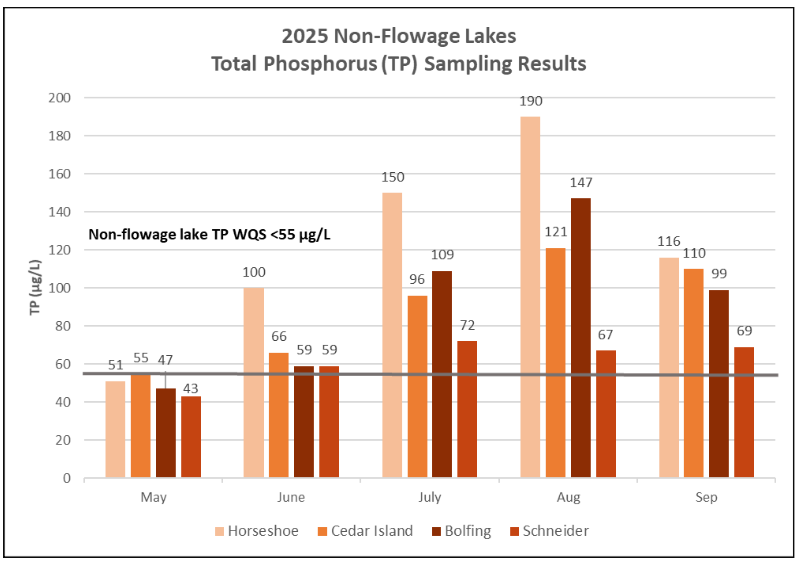
Although not as comprehensive as other lakes in the Chain, there is still a considerable history of Secchi data for Schneider Lake. Consistent measurements began in 1997. As indicated by the blue asterisk, zebra mussels were discovered in the lake in 2018.

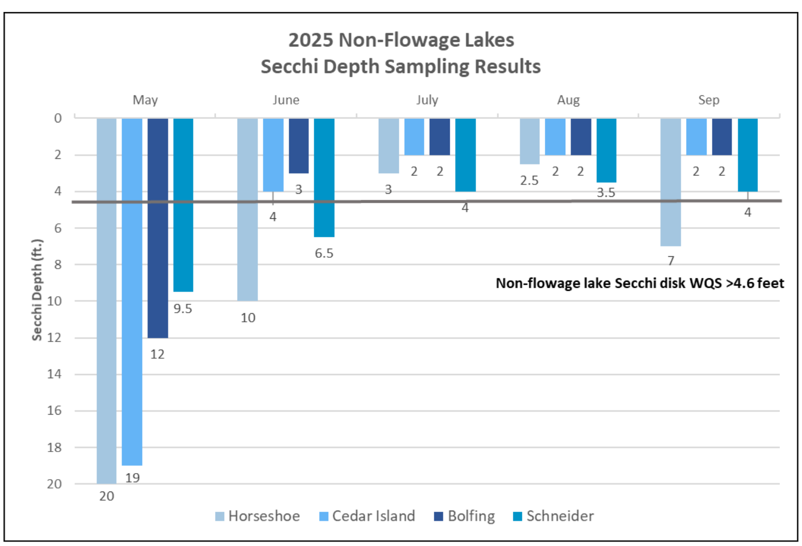
According to the MPCA, there is evidence indicating improving water clarity (approximately 1.4 feet per decade). Since there is no data for 2020-2022, more measurements are necessary to determine a trend. The average Secchi disk depth in 2025 was **5.5 feet**.

Photo courtesy of Sauk River Chain of Lakes Association

Non-Flowage Lakes Comparison





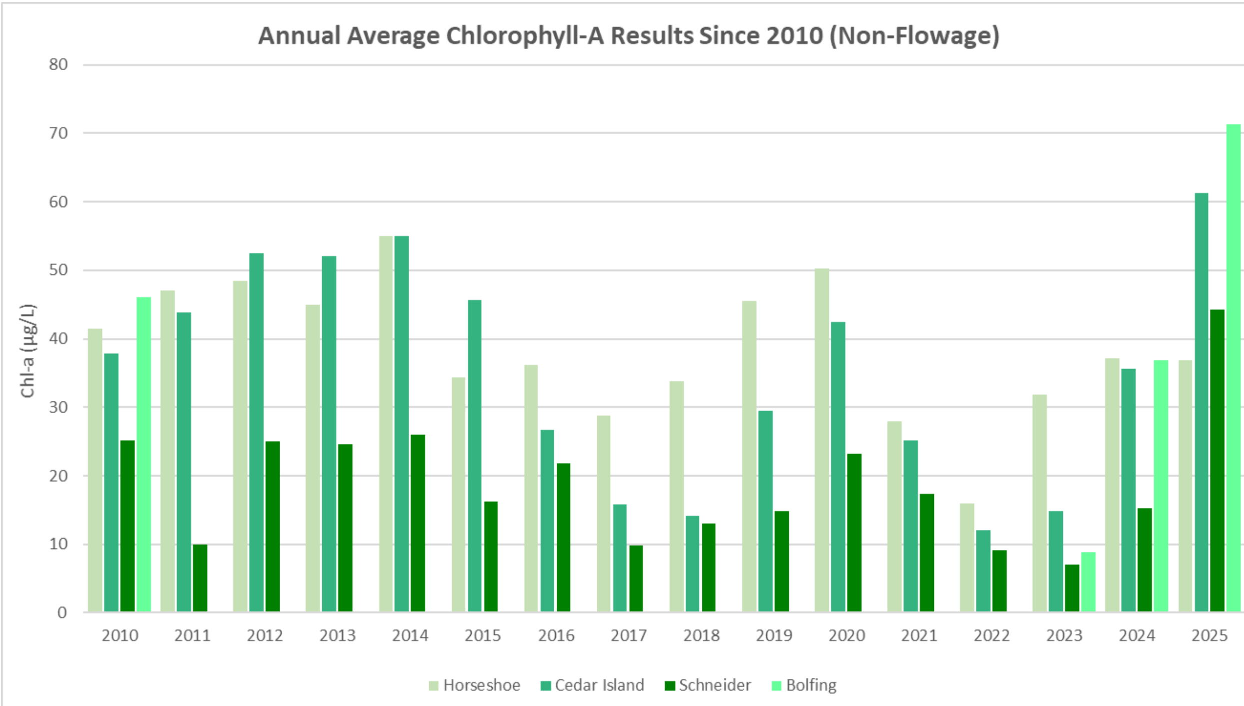


The site-specific WQS for the non-flowage lakes in the Chain are balanced between the standards for the Sauk River and the lakes in the North Central Hardwood Forest (NCHF) Ecoregion (except for Schneider Lake). This is due to the increased connectivity of these non-flowage lakes with the Sauk River, which is much different than a traditional lake outlet. These next graphs show a comparison of sampling results for chlorophyll-A, TP, and Secchi depth. Chl-A is shown in the top graph, which displays several high concentrations. For the first sampling day in May, all 4 lakes had low levels that fell below the WQS, but that status did not continue. High results persisted throughout the rest of the year, especially on Bolfing, which had the highest annual average at **71.3 µg/L**.

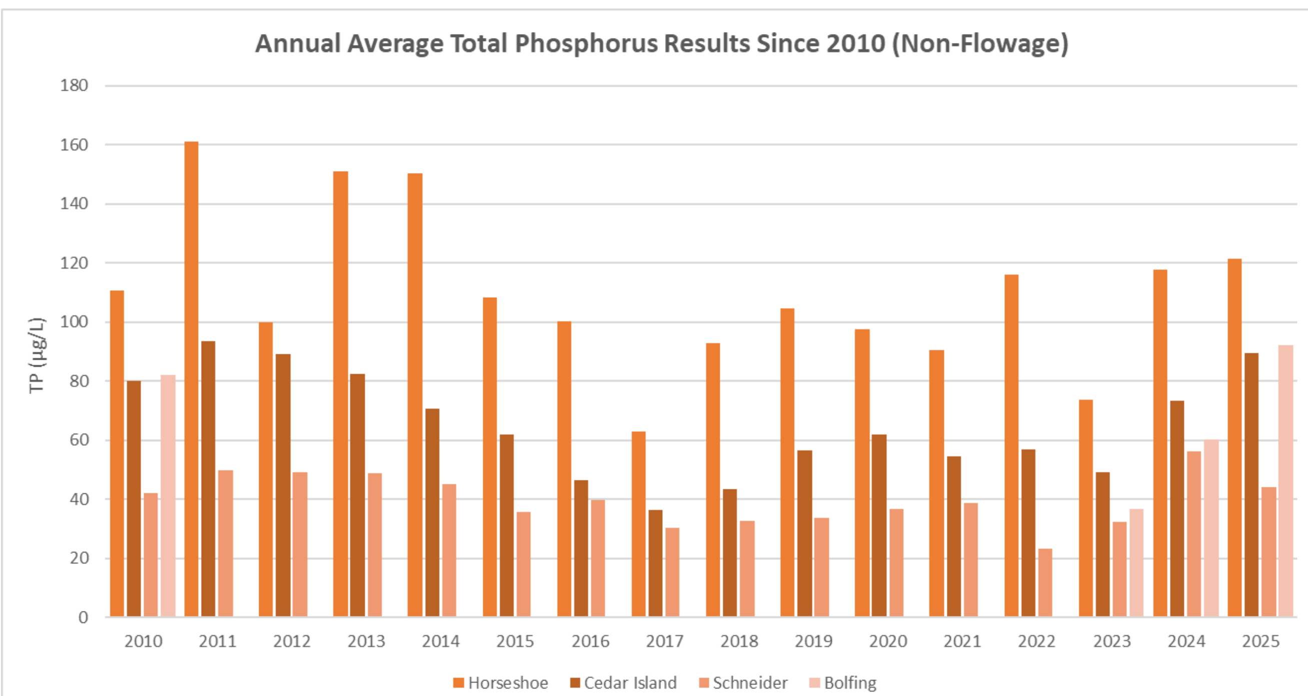
For TP (middle), this graph is more consistent with what would be expected for the breakdown of the non-flowage lakes considering Horseshoe is the first lake that the Sauk River enters into the Chain. By the time flow has reached Bolfing Lake, the nutrients that entered the system have had a chance to settle out. Schneider Lake has even lower levels because it is not greatly influenced by the flow of the Sauk River, and it does not have the same site-specific standards as the other non-flowage lakes. It falls under the general NCHF standards. Each lake either met or fell below the TP WQS in May, but the rest of the samples exceeded the WQS. Horseshoe Lake had the highest annual average at **121 µg/L**.

Secchi depth was generally higher on Horseshoe and Schneider. As a reminder, higher results are desirable for this parameter since that indicates deeper water clarity. As is typical, clarity declined across the board as the warm summer months progressed. Horseshoe Lake had the highest Secchi depth average at **8.5 feet**.

Annual Averages Non-Flowage Lakes

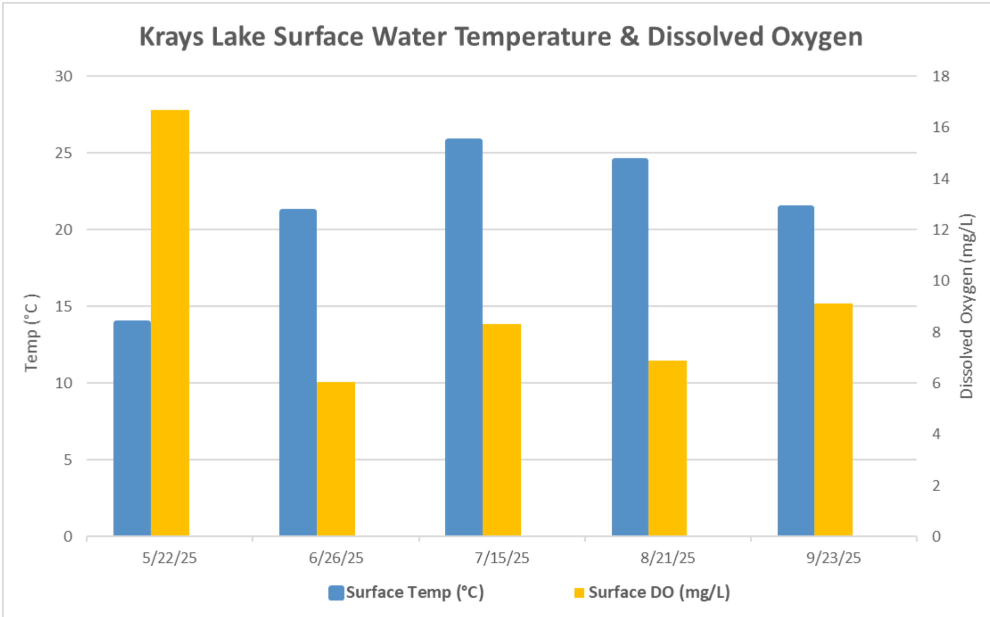


Thanks to the SRWD's long partnership with the SRCLA, there has been consistent sampling on the Chain for over a decade. Since weather conditions fluctuate drastically from year to year, it is important to have a comprehensive dataset to understand how lake conditions have changed over time. As seen in the graph above, while there have been notable declines in chl-A averages since 2014, some of the 2025 averages were above normal, especially for Cedar Island and Schneider.



The story is slightly different for TP levels. As expected, Horseshoe has the highest TP averages without fail, but that average has come down significantly since 2011. There was a low dip across the board in 2017, and levels have fluctuated since then. The past couple years have seen slight increases, but not consistent enough to be considered a trend. Overall, the Chain has seen substantial improvements in TP levels over many decades.

Krays Lake Surface Temp & DO

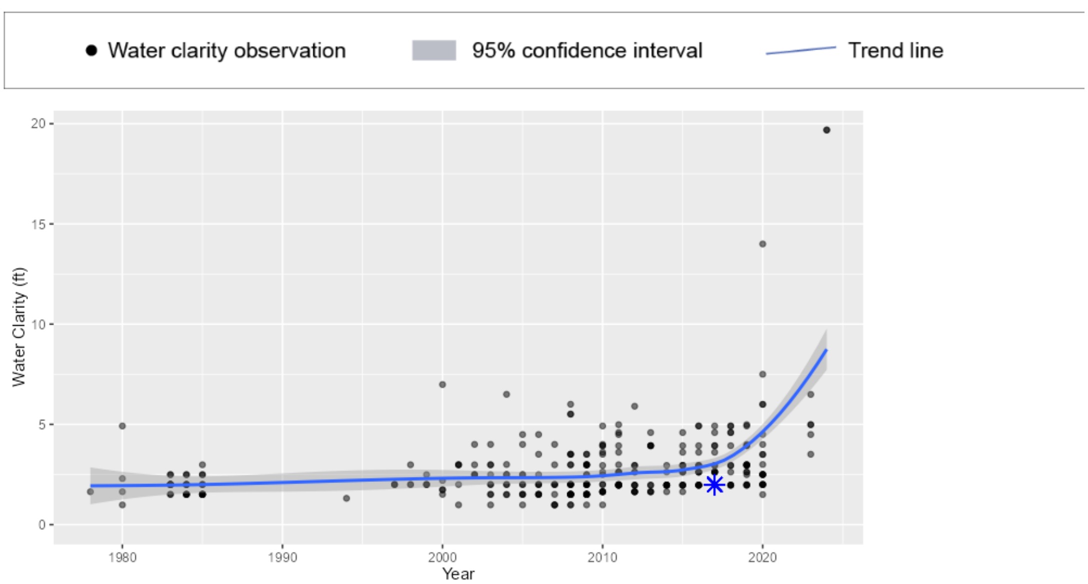


Moving further downstream, Krays Lake is considered a flowage lake in the Chain and has different site-specific standards for those unique conditions. It is more shallow, with a mean depth of only 7 feet. These shallow and flowage conditions do not allow for Krays to stratify, so water temperature and DO are mostly consistent throughout each profile. This is why the temperature and DO graph above only shows surface results. Surface temperature, which is graphed on the left vertical axis, started at 14°C (57°F) in May and peaked on 7/15 at 26°C (78°F). DO (graphed on the right) started off at 16.7 mg/L in May and dropped significantly by June at 6 mg/L.

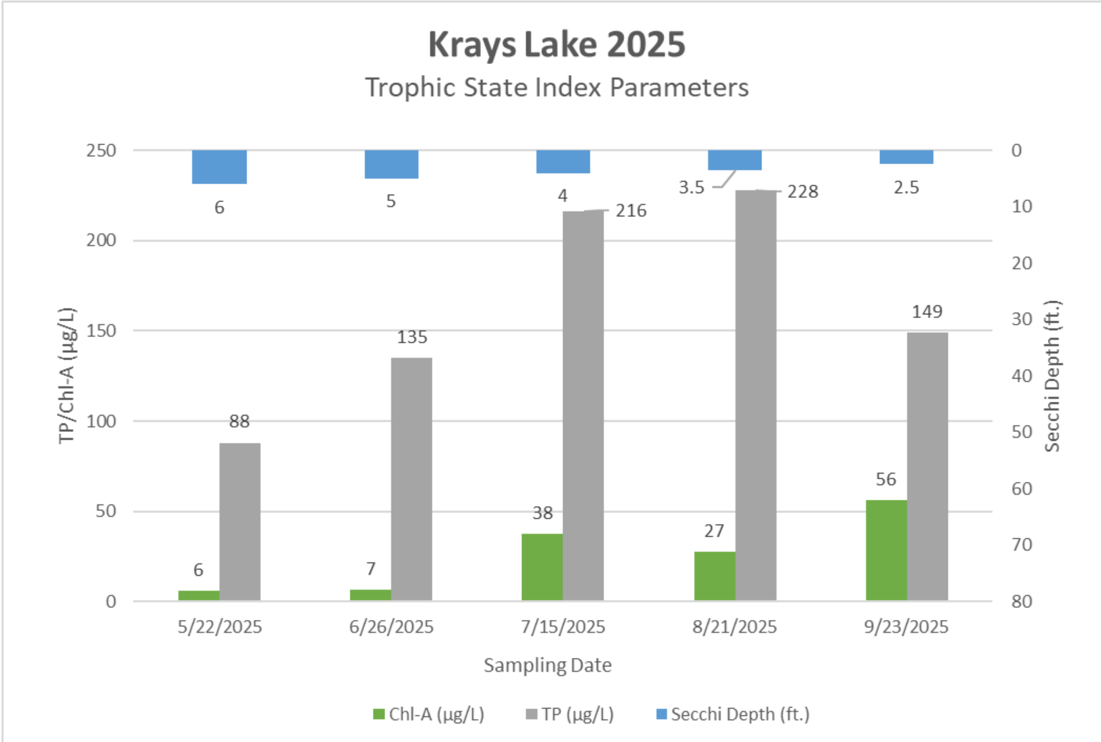
The transparency trend does have periods of time when no data was collected, but measurements go back to 1978. Zebra mussels were first discovered in 2017. Although there is not enough data for a trend to be determined, there have been increases in Secchi depth since 2019. The average Secchi depth in 2025 was **4.2 feet**.

Trend analysis result:

For years 1978 to 2024 there is evidence of no change in water clarity at this lake. For the most recent year of the analysis, median water clarity was 7.68 feet deeper than the watershed median. Zebra mussels were discovered in this lake in 2017.



Krays Lake Monitoring Results

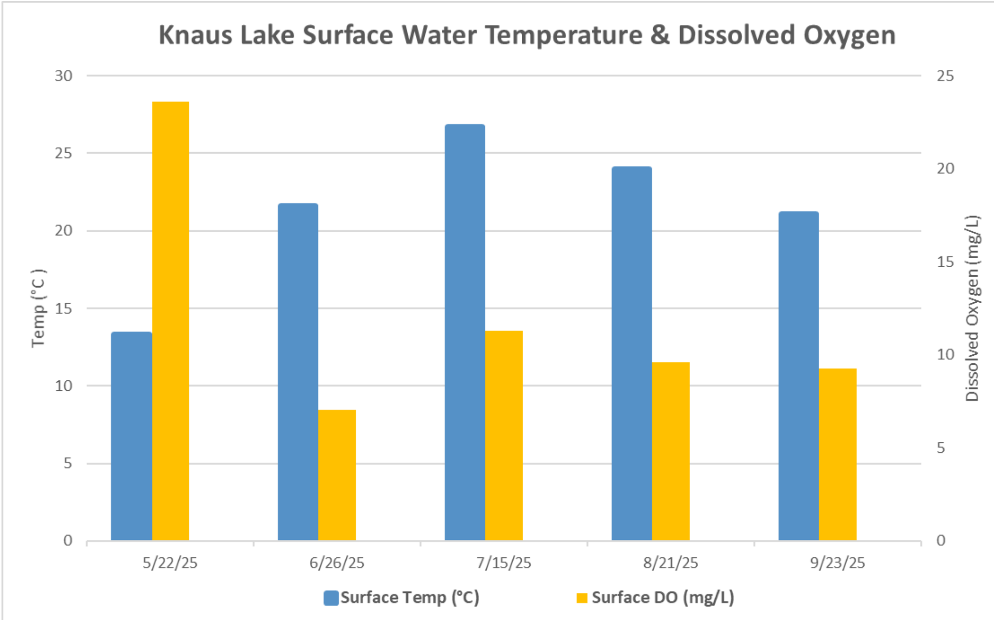


As a reminder, the site-specific standards for flowage lakes in the Chain are TP: **<90 µg/L**; chl-A: **<45 µg/L**; Secchi depth: **>2.6 feet**. With that in mind, it can be seen that chl-A samples in 2025 only exceeded the WQS once, which happened in September. The average chl-A result for the year was 26.8 µg/L.

TP results were much higher and exceeded the WQS 4 out of 5 times. The highest result was 228 µg/L on 8/21. The average TP result in 2025 was **163.2 µg/L**. As for Secchi depth, the WQS was met for each sampling day except on 9/23.

Lake Name	Site ID	Sample Date	Surface Temp (°F)	Surface DO (mg/L)	Secchi Disk Depth (feet)	Chl-A (µg/L)	TP (µg/L)
Krays Lake	73-0087-00-201	5/22/2025	57.0	16.7	6.0	6	88
Krays Lake	73-0087-00-201	6/26/2025	70.2	6.0	5.0	7	135
Krays Lake	73-0087-00-201	7/15/2025	78.4	8.3	4.0	38	216
Krays Lake	73-0087-00-201	8/21/2025	76.1	6.9	3.5	27	228
Krays Lake	73-0087-00-201	9/23/2025	70.5	9.1	2.5	56	149
2025 Annual Averages			**70.4**	**9.4**	**4.2**	**26.8**	**163.2**

Knaus Lake Surface Temp & DO

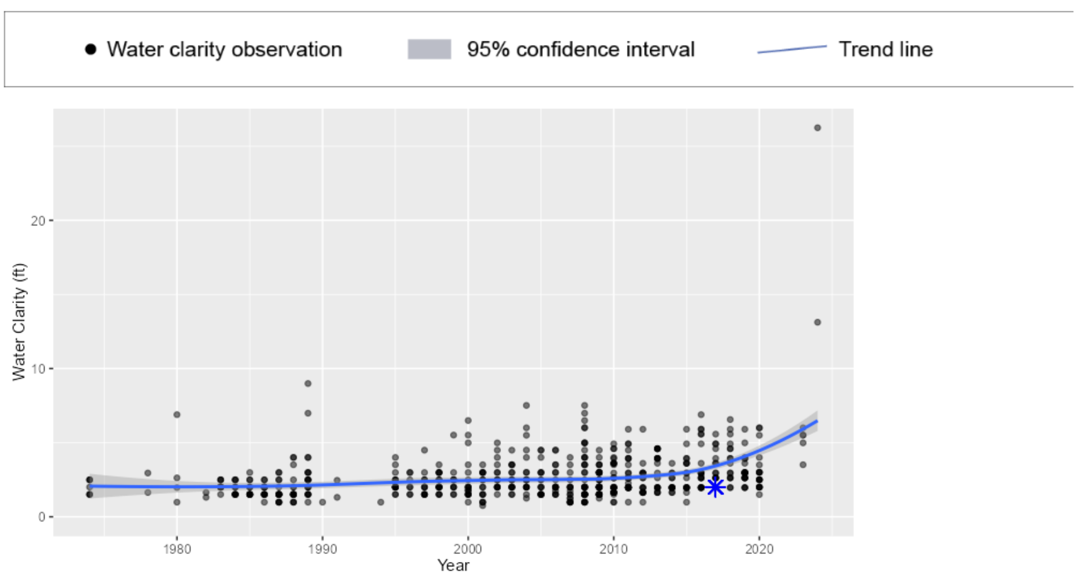


Knaus Lake, which lies east of Krays, is also considered a flowage lake in the Chain and has different site-specific standards for those unique conditions. It is particularly shallow, with a mean depth of only 6.4 feet. These shallow and flowage conditions do not allow for Knaus to stratify, so water temperature and DO are mostly consistent throughout the profile. Surface temperature, which is graphed on the left vertical axis in blue, started out at 13°C (56°F) in May and peaked on 7/15 at 27°C (80°F). Those warm surface water temperatures allow for an abundance of algae growth. DO levels, graphed in yellow, started off quite high at 23.6 mg/L on 5/22 and dropped to 7 mg/L on 6/26.

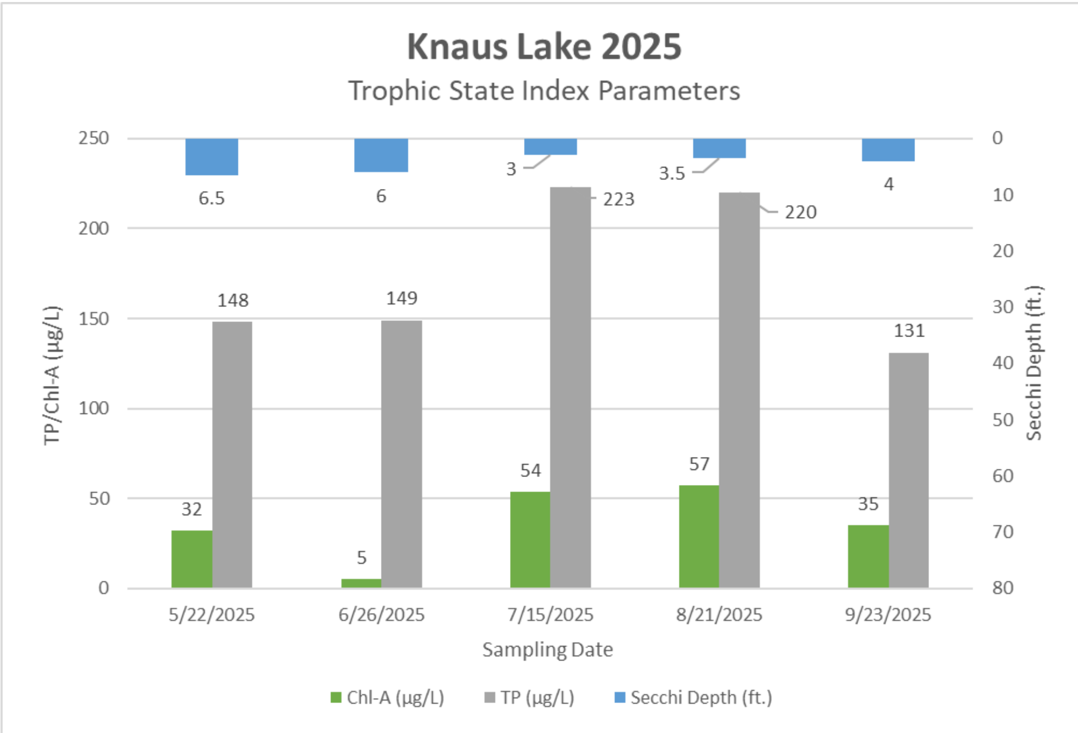
There are more years of Secchi data for Knaus Lake than on Krays. This dataset extends back to 1974. Zebra mussels were discovered in the lake in 2017. Secchi depth has held steady over the years, and there is no increasing or decreasing trend at this time.

Trend analysis result:

For years 1974 to 2024 there is evidence of no change in water clarity at this lake. For the most recent year of the analysis, median water clarity was 7.68 feet deeper than the watershed median. Zebra mussels were discovered in this lake in 2017.



Knaus Lake Monitoring Results

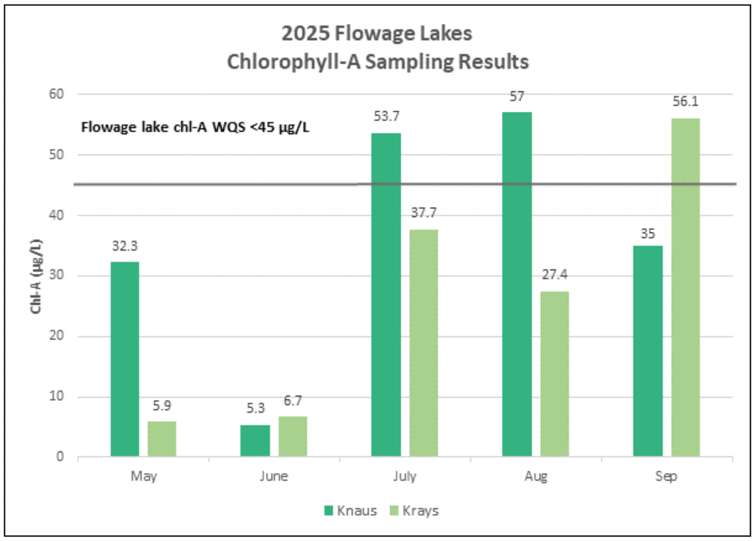


Knaus Lake had high results for TP, similar to Krays Lake. It exceeded the chl-A WQS of <45 µg/L two times. The average chl-A result for 2025 was **36.7 µg/L**.

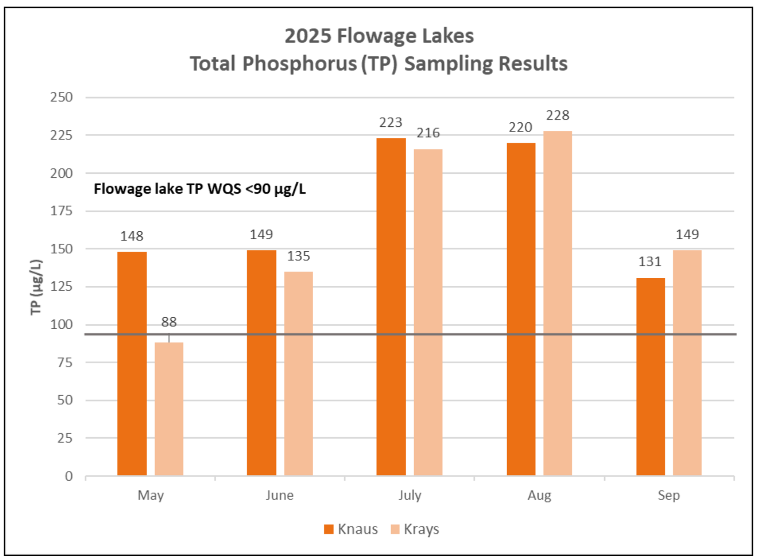
For TP, Knaus had the highest overall average out of all 6 lakes sampled in 2025. It exceeded the WQS of <90 µg/L on each sampling day. The highest result was 223 µg/L on 7/15. The average TP result was **174.2 µg/L**, almost double the WQS. For Secchi depth, the average was slightly higher than on Krays, and it met the WQS on each sampling day. The average Secchi depth was **4.6 feet**.

Lake Name	Site ID	Date	Surface Temp (°F)	Surface DO (mg/L)	Secchi Disk Depth (feet)	Chl-A (µg/L)	TP (µg/L)
Knaus Lake	73-0086-00-205	5/22/2025	55.9	23.6	6.5	32	148
Knaus Lake	73-0086-00-205	6/26/2025	70.9	7.1	6.0	5	149
Knaus Lake	73-0086-00-205	7/15/2025	80.1	11.3	3.0	54	223
Knaus Lake	73-0086-00-205	8/21/2025	75.2	9.6	3.5	57	220
Knaus Lake	73-0086-00-205	9/23/2025	70.0	9.3	4.0	35	131
2025 Annual Averages			**70.4**	**12.2**	**4.6**	**36.7**	**174.2**

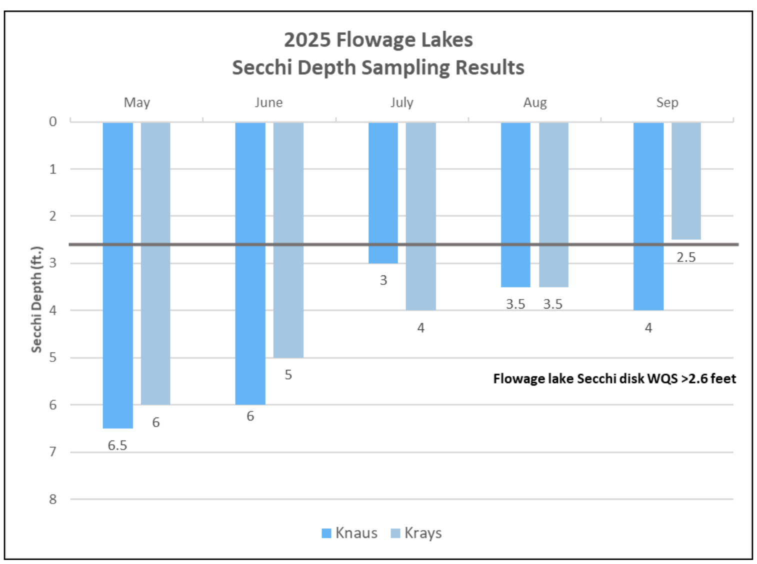
Flowage Lakes Comparison



The following graphs compare sampling results of Carlson TSI parameters for each sampled flowage lake. Chl-A concentrations, shown to the left in green, only had a few exceedances. There is no clear pattern as to which lake has higher chl-A levels at any given time, but the annual average was slightly higher for Knaus Lake. Chl-A levels are greatly influenced by water temperature and nutrient inputs.

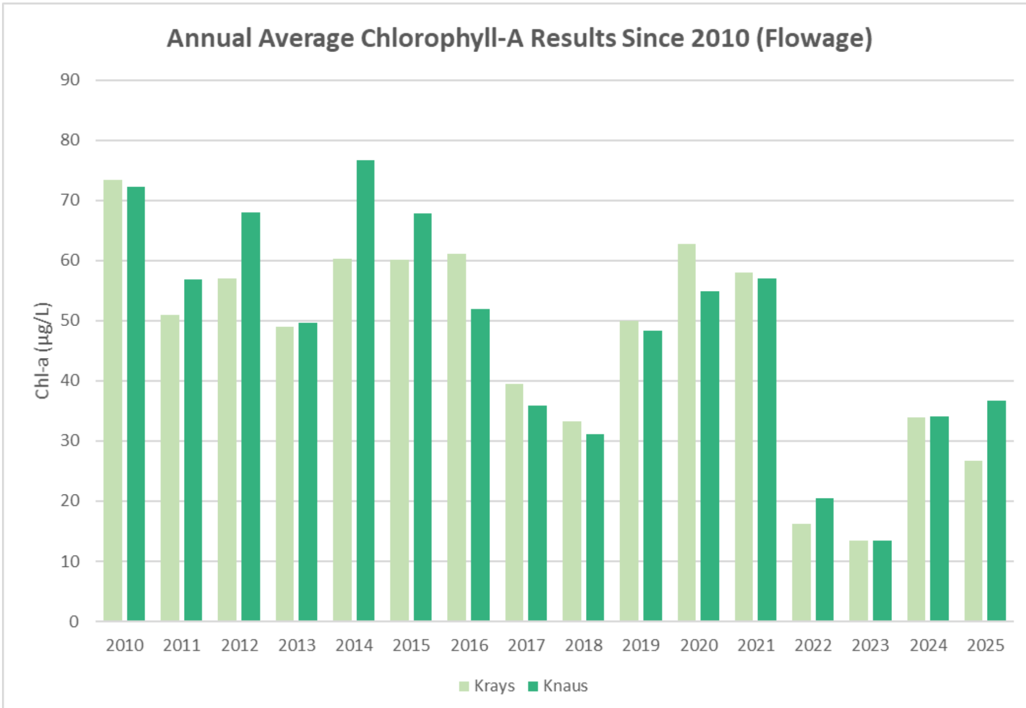


The next graph displays TP results for both flowage lakes. Samples from Knaus exceeded the WQS on each sampling day, with the highest result in July. Again, Knaus Lake had a higher TP average for 2025 than Krays. TP levels for Krays only met the WQS in May, with the highest result on that lake being in August.

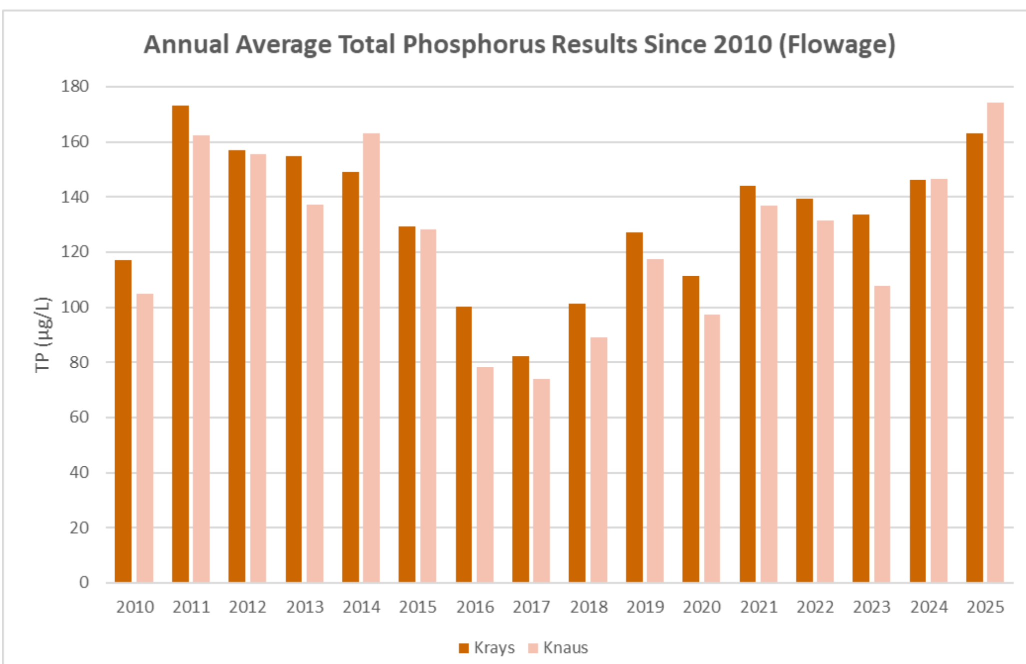


Lastly, the graph to the left compares Secchi disk depth results. Unlike with chl-A and TP, higher results are better. For both lakes, the WQS was met on each sampling day except for Krays in September. It is typical to see water clarity degrade as the monitoring season progresses and algae growth increases.

Annual Averages Flowage Lakes



There is a long history of water quality sampling on both Krays and Knaus. Looking at the annual averages from past years gives us a better big-picture of how conditions are changing in the Chain. For chl-A, there have been significant decreases in levels since 2010. There were especially low levels experienced in 2023.



Looking at TP levels, results are similar to those for the non-flowage lakes. Average concentrations were slightly declining until 2017, then levels started creeping back up. As noted in its TMDL report, sediments in the Chain of Lakes have been enriched from decades of high phosphorus loading from the Sauk River and have a high potential for anoxic release rates. It is likely that these lakes are undergoing substantial and periodic internal loading that pulses TP into the water column, particularly during hot, calm summer periods.

SRCL 2025 Summary

Looking back at 2025, it was a wet year with an abnormally warm fall. The total accumulated precipitation during the monitoring season was **5.51 inches higher** than normal years. This allows for more runoff from the surrounding watershed to enter the lakes. Plus, fall of 2025 was the second warmest fall in Minnesota history, averaging nearly 6°F above normal. Warmer temperatures extending later in the year means a longer growing season for algae and weeds. It also means lakes will turn over (mixing of the water column) later in the year since the surface layer takes longer to cool down.

According to the Carlson TSI scores, Horseshoe experienced the best water quality in 2025 with a score of 60, closely followed by Schneider at 61. Lower scores are more desirable. Each lake's TSI score increased from 2024 except for Horseshoe Lake, which actually went down. Each lake also falls within the *Eutrophic* category, often indicated by somewhat cloudy water and reduced oxygen conditions as summer progresses, along with a presence of algae growth. Knaus (flowage) and Bolfing (non-flowage) had the highest TSI scores at 66, much of that being attributed to high TP levels.

Knaus had notably high TP concentrations with an annual average at **174.2 µg/L**, the highest out of all 6 lakes. Knaus and Krays are greatly affected by the water quality in the Sauk River, which is likely why they are consistently higher in TP levels. Chl-A levels were not high across the board for all the lakes, but they were particularly high on Cedar Island and Bolfing. The highest chl-A average in 2025 was for Bolfing at **71.3 µg/L**. Secchi disk depths were encouraging on Horseshoe and Schneider Lakes since their 2025 averages were above the WQS for their respective standards. Knaus met the Secchi WQS on each sampling day, and Krays failed to meet it only once.

Looking at past sampling results, since 2010, there have been substantial improvements in chl-A levels for most of the monitored lakes. TP concentrations over the past several years do not have as clear of a trend, but there have certainly been decreases in averages compared to those in the 1980s and '90s. The transparency trend graphs for these 6 lakes generally demonstrated improved clarity in recent years.

Year	Horseshoe TSI	Cedar Isl TSI	Bolfing TSI	Schneider TSI	Krays TSI	Knaus TSI
2009	66	66	63	58	72	-
2010	67	63	-	55	69	69
2011	67	68	-	53	70	70
2012	-	-	-	56	70	71
2013	-	-	-	58	69	69
2014	69	65	-	-	-	-
2015	63	63	-	54	69	70
2016	63	57	-	56	68	65
2017	60	54	-	51	65	64
2018	64	54	-	54	66	64
2019	65	59	-	52	68	67
2020	65	61	-	56	68	67
2021	63	59	-	56	69	68
2022	60	54	-	48	63	64
2023	61	56	51	49	62	60
2024	64	62	60	55	62	64
2025	**60**	**64**	**66**	**61**	**64**	**66**

The SRCL is a unique lake system with unique conditions. It also thankfully has an active Lake Association that is devoted to monitoring and protecting its health. Continued monitoring will help identify water quality changes and emerging issues to inform the actions of local governments and citizens on how to preserve and protect this invaluable resource. As stated in the TMDL report, this lake system is a story of success due to over 25 years of collaborative point and nonpoint source rehabilitations. The SRWD appreciates the time and dedication of the Sauk River Chain of Lakes Association and looks forward to continue working alongside them to achieve fishable and swimmable water in our watershed.

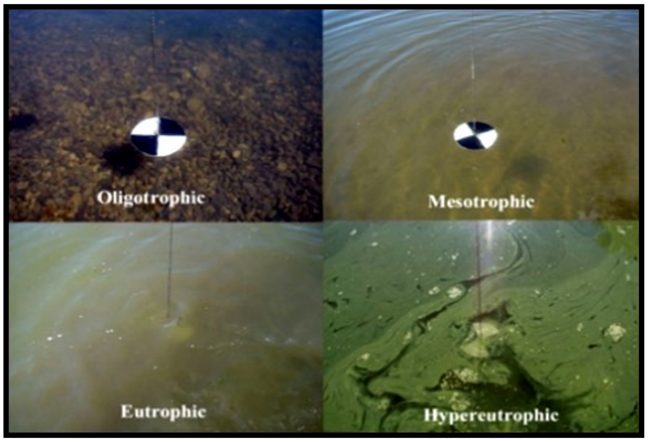
Water Quality Monitoring Parameters

Chlorophyll-A (chl-A): Chlorophyll-A is a measure of the amount of algae growing in a waterbody and can be used as an indicator of water quality. It is a comparable analysis to TSS in streams. As water warms, algae begins to grow, and the amount of growth is dependent on the amount of nutrients in the water body. Although algae is a natural part of freshwater ecosystems, too much algae can result in decreased levels of oxygen in the waterbody and cause aesthetic problems, such as green scum and bad odors. Some algae naturally produce toxins as well, which can be a public health concern in high concentrations. Waterbodies that receive septic systems discharges and agricultural and urban runoff may have high concentrations of chl-A in response to the excess nutrients. The general water quality standard for chl-A in lakes within the North Central Hardwood Forest (NCHF) ecoregion is <14 µg/L.

Secchi Disk: Water clarity is measured using a Secchi disk (also known as a transparency disk) that is lowered into the water until it can no longer be seen, and the depth of visibility is noted. Secchi disk readings are used to assess water visibility and quality. The general water quality standard for lake Secchi disk readings in the North Central Hardwood Forest (NCHF) ecoregion is >4.6 feet (1.4 meters).

Total Phosphorus (TP): Total phosphorus is a measure of both the organic and inorganic forms of phosphorus. Organic phosphorus is not commonly found in suspension in the water column and is not as chemically available as food. Inorganic phosphorus, referred to as ortho-phosphorus, is commonly dissolved in water and is readily available to plants and animals. Phosphorus is an essential nutrient for growth, but is only necessary in small concentrations to sustain life. Phosphorus can also be found in the water column and embedded in water bottom materials. Most rivers and lakes have elevated phosphorus, with point source contributions from wastewater and industrial releases, and nonpoint source contributions from agricultural fertilizers and contaminated groundwater. Minnesota is broken up into ecoregions to account for the variability in landscape, land use, and weather across the state, and each ecoregion has unique water quality standards. The Central River Nutrient Region standard for total phosphorus in the Sauk River is <100 µg/L. The TP level for lakes in the Chain varies depending on depth and connectivity to the river.

Common Terms



Anoxic: The absence of dissolved oxygen in a portion or all of a waterbody.

Carlson Trophic State Index (TSI): The Carlson Trophic State Index (TSI) is a classification system designed to rate water bodies using concentration measurements of both chlorophyll-A and total phosphorus, combined with Secchi disk readings. This rating indicates how much aquatic life, both plants and animals, a waterbody can sustain, and can be applied across all lake types and ecoregions uniformly. The higher the rating, the more likely it is that poor water quality will be observed. The word *trophic* is Greek, meaning nourishment or food. Under the TSI scale, waterbodies may be defined as:

Oligotrophic: TSI 0 - 40, Clear water, good oxygen conditions, limited nutrients available, deep or shallow lake. From the Greek "oligos" meaning few, scanty.

Mesotrophic: TSI 40 - 50, Moderately clear water but increased chance of low oxygen conditions in shallow lakes. From the Greek "meso" meaning middle, moderate.

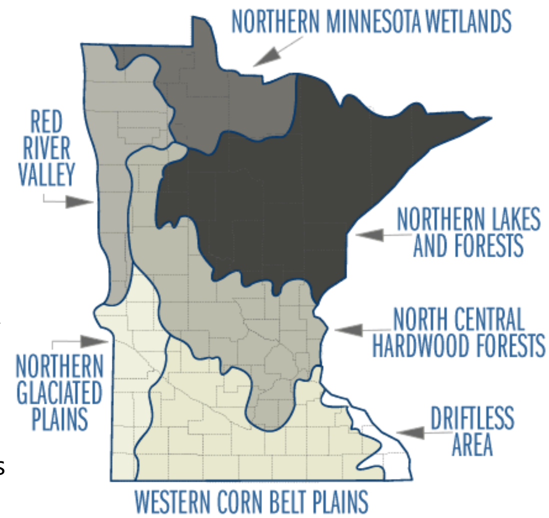
Eutrophic: TSI 50 - 70, Moderately clear to cloudy water, with a high chance of low oxygen conditions in the summer, extensive plant growth, and potential algal scum. From the Greek "eu" meaning well, plenty.

Hypereutrophic: TSI 70+, Dense plant growth, heavy algal blooms and scum possible, low oxygen conditions, fish kill possible. From the Greek "hyper" meaning over much.

Ecoregion: A region defined by distinctive geography, plant and animal communities, land uses, soil profiles, and sun and moisture patterns. Ecoregions are used by the Environmental Protection Agency (EPA) and Minnesota Pollution Control Agency (MPCA) to characterize regional differences in the state and their effects on water quality. The Minnesota ecoregion the Sauk River watershed resides in is the North Central Hardwood Forest (NCHF). The NCHF ecoregion is a transitional zone between the predominantly forested northern lakes region and the corn belt plains in southern Minnesota. In addition to the ecoregion classification, lakes are further classified as shallow or deep, depending on the maximum and average lake depths. The size and depth of a lake influences characteristics such as water clarity, water temperature, and aquatic plant growth.

Eutrophication: The term comes from the Greek *eutrophos*, meaning "well-nourished." Eutrophication occurs when an excess of nutrients that are usually environmentally limited enter a river or lake system and contribute to excessive plant and algae growth. Eutrophication can have negative impacts on aquatic communities' health. The excessive plant growth can clog up boat motors, outcompete native plants, and change the animals that are able to survive in the waterbody. When the excessive plant growth dies back and decomposes, microbes in the water break down the plant material and use up the majority of the available oxygen in the waterbody. This creates low oxygen (anoxic) conditions and will stress and even kill aquatic animals. Additionally, water clarity and recreational suitability are greatly reduced in eutrophic conditions, and physical contact with or ingestion of the water could result in indigestion or even death.

Common Terms Cont.



Flowage Lakes: A flowage lake is a lake that forms upstream of a dam and can be used synonymously with reservoir lake. Water in flowage lakes acts like a very slow river, as the water keeps flowing downstream, but is slowed down markedly by the dam structure. A *non-flowage* lake is a lake that was formed without the effects of downstream damming. Water enters non-flowage lakes and resides there significantly longer than in flowage lakes.

Hypoxic: Low or near depleted dissolved oxygen in a waterbody; commonly refers to dissolved oxygen concentrations below 2 mg/L.

Internal Nutrient Loading: The release of previously accumulated nutrients, primarily phosphorus, from bottom sediments back into the water column of a lake or reservoir. This process usually occurs under anoxic conditions in bottom waters, where chemical reactions facilitate the release of nutrients. This internal source can amplify water quality problems, such as algal blooms, long after external nutrient inputs have been reduced.

Point Source & Nonpoint Source: These terms are used when referring to how a pollutant enters a water-body. Point sources are single and identifiable locations, such as the end of a pipe, and are regulated by state and federal agencies. Nonpoint sources can be rain and snow runoff, which accumulate pollutants as water drains. Places like parking lots, farmland, construction sites, and eroding streambanks are considered nonpoint sources of pollution and are harder to track, control, and regulate.

River Nutrient Region: The EPA and MPCA did not develop nationwide or even statewide water quality criteria for surface waters, but instead developed guidelines for each unique ecoregion. Each ecoregion has been studied to identify reference conditions for that area. Reference conditions are used to reflect what a pristine or minimally-impacted stream condition would be and what the normal range of conditions are in that ecosystem. The MPCA has further researched and developed river nutrient criteria for each of Minnesota's ecoregions. This is the basis for creating water quality standards (WQS) appropriate to each ecoregion's background conditions. See page 2 for the specific standards for our parameters of interest.

Stratification: The formation of distinct layers in a waterbody due to differing temperatures and densities. Warm water is less dense than cool water, so cool water sinks below warmer water. As summer progresses, the light-penetrated surface waters of a lake become warmer than the deeper water, and the water column stratifies by temperature and density. Stratification is a barrier to water column mixing, which moves oxygen, heat, and nutrients throughout the waterbody. Stratification commonly leads to dissolved oxygen depletion in the bottom layer of a lake.

Total Maximum Daily Load (TDML): The amount of a pollutant that can enter a water-body that allows it to still meet water quality standards. A TMDL allocates pollutant loading to four separate categories:
TMDL= Waste load allocation (WLA) + Load Allocation (LA) + Margin of Safety (MOS) + Reserve Capacity (RC)
WLA includes pollutant loading from permitted sources (point sources), LA includes sources not covered by a permit (nonpoint sources), MOS accounts for uncertainty in these estimates, and RC allows for future growth.

Bolfing Lake has also been referred to as "Bolting" and "Bolfung" Lake. Zumwalde Lake is also referred to as "Zumwalles."