Sherbrooke Lake 5-Year Water Quality Baseline Report: 2018 - 2023

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January 2024

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Executive Summary

This report outlines the activities and results of the five-year Sherbrooke Lake (SL) water quality monitoring program, initiated in response to the planned development of a municipal public access site at Sherbrooke Lake. The program's goals included determining a baseline understanding of water quality conditions within SL before the construction of the public access site, monitoring water quality during and after the construction, and the provision of evidence-based advice to MODL and MOC regarding ways to address water quality changes and concerns within the lake.

The sampling schedule and locations changed slightly over the five years of this project, changes were based on initial test results and scientific advice regarding sampling protocols. A preliminary monitoring program occurred in 2017 to determine the best monitoring methods and select sampling sites for the program, when appropriate, this data was included in the baseline summary. In 2019, lake sites Chl 1 and Chl 2 (additional sites for monitoring chlorophyll-α) were removed from the program, as they showed similar results to the lake sites and were not providing beneficial data. Hydrocarbons were initially sampled in 2018 and 2019 but removed from the program because all readings were below detection levels. Lake 3 was changed to *E. coli*-only sampling in 2022 and 2023.

Phycocyanin levels did not exceed guidelines set by the World Health Organization throughout this project. The average yearly concentration of nutrients that are known to contribute to the production of algae and cyanobacteria, total phosphorus and total nitrogen, did not exceed guidelines set by Ontario's Ministry of Environment and Climate Change guidelines, except for at-depth samples in 2021 and 2022.

All lake sites displayed a slight trend of increasing average surface water temperatures in the summer months, and the average annual temperature exceeded the 20°C temperature threshold for cold-water fish species (NSSA 2014) in 2021, 2022 and 2023. Sufficient data was not collected for statistical analyses to determine if this trend is significant or due to other factors such as time of sample collection, or weather conditions before and during sampling. The time of day and season of each sample could influence the temperature and dissolved oxygen concentrations, so continuous in-situ temperature monitoring using a temperature logger would provide more accurate trend data. If water temperatures are increasing, this could, over time, significantly impact the lake's ecosystem making it more vulnerable to other negative impacts. Cyanobacteria blooms are more likely to occur in warm, slow-moving waters with high levels of nutrients, so with increasing temperatures, there could be increased risks of blooms. The stream sites showed cooler average annual temperatures than the lake, and only three sites exceeded the threshold.

The average annual surface dissolved oxygen (DO) at all lake sites stayed above the minimum threshold of 6.5 mg/L set by the Canadian Council of Ministers of the Environment (CCME) for cold-water species (CCME 1999b). Two stream sites fell below the minimum threshold, likely due to low water flow conditions and warm average water temperatures in late summer. Dissolved oxygen levels did not appear to be detrimental to aquatic life during this study, as the readings mostly remained above thresholds.

pH measurements for most sites fell below the 6.5-pH threshold set by the CCME (2002); however, the acidity of SL waters is not uncommon for southwest NS lakes, which generally have lower pH values than the 6.5 threshold. It appears that most of the time, the acidity of the waters at SL poses minimal threat to organisms, and there was an upward trend for pH at all sites. This upward trend indicates that the waters are becoming less acidic. If this trend continues, it could improve populations of sensitive aquatic species such as salmonids, that rely on a specific range of pH values.

The average concentration of smaller particles in the water column (total dissolved solids) had a downward trend, while larger particles (total suspended solids) had an upward trend. These concentrations can be influenced by soil erosion, dead organic material, significant rainfall events, flooding, and runoff. This is an important parameter for monitoring the impacts of future lake-shore development, as development can increase sedimentation in the water which is reflected in these measurements.

The average annual *E. coli* levels at the lake and stream sites did not exceed the primary recreational guideline of 235 CFU/100 mL. The rainfall-dependent samples generally had higher levels of bacteria than the regular monthly or bi-monthly sampling. The generally low *E. coli* and nutrient levels of the lake suggest that pollution was minimal at Sherbrooke Lake during this study. Although bacteria levels were low, swimming in rivers should be avoided for 24 hours after a rainfall event and water from the lake and the rivers should always be treated prior to use (i.e., bathing, washing, drinking).

Arsenic, cadmium, and mercury levels exceeded guidelines at most lake sites in the sediment samples. Lead levels were low at most lake sites, except Lake 2, which exceeded the Interim Sediment Quality Guideline (ISQG). Metal concentrations in the stream site did not approach any of the guidelines except for the 2023 samples, which exceeded guidelines for both arsenic and cadmium. Sherbrooke Lake is at high risk of pollution from both uranium and arsenic due to the local geology. Heavy metals can biomagnify within food webs, which can pose a threat to human health if fish are consumed. For guidelines on fish consumption in Nova Scotia regarding pollutants, visit the consumption advisory at https://novascotia.ca/nse/fish-consumption-advisory.asp. Generally, sediment in aquatic systems has higher concentrations of heavy metals than the water column itself (Luoma, 1989), but for more information on drinking water guidelines visit Nova Scotia Environment https://novascotia.ca/nse/water/docs/Drop_on_Water_English.pdf.

Based on the mean depth of transparency (Secchi disk), and mean concentrations of chlorophyll-α and phosphorus, a Trophic State Index (TSI) score has been calculated annually to assess biological productivity. Trophic states range from oligotrophic (low productivity and minimal biomass) to hypereutrophic (high productivity and maximum biomass). The trophic state of SL appears to be maintaining a steady TSI score over the five years this data has been collected. The TSI of SL was consistently between oligotrophic and mesotrophic, suggesting that it has moderate biological productivity.

Sherbrooke Lake is generally healthy but is vulnerable to anthropogenic impacts. Human activities such as fertilizing lawns, removing vegetative buffers between lawns and the lake, and improper management of septic fields can all impact the lake's water quality. Currently, Sherbrooke Lake's nutrient status is at the low end for freshwater lakes. This is encouraging, but will only be sustained through continued vigilance in the face of increasing development and alteration of the lake's shoreline and surrounding watershed.

Overall, the water quality at Sherbrooke Lake and its tributaries showed no significant issues of concern within the water quality trends during the five years of this project. This baseline study provides information on the current water quality trends of the lake, that could be used to assess the impacts of future developments. While this study showed no apparent issues, residents should be aware of how land-use practices impact water quality and the occurrence of cyanobacteria blooms. Implementing good land-use practices can help to maintain or improve the trends observed in this baseline study.

Best Land-use Practices and Information:

- https://nsinvasives.ca/plant-wise/
- https://nsinvasives.ca/wp-content/uploads/2023/07/CCIS-NSISC-Grow-Me-Instead-Guide_2023_EN_web.pdf
- https://www.transcoastaladaptations.com/green-shores
- https://www.countyofkings.ca/residents/services/permits/types/Lakeshore
- https://www.countyofkings.ca/upload/All_Uploads/Living/services/permits/lakeshore/Lake%20Development%20Brochure.pdf
- https://loveyourlake.ca/project/responsible-shoreline-development/
- https://novascotia.ca/nse/wastewater/docs/homeowners.guide.to.septic.systems.pdf
- https://www.speciesatrisk.ca/stewardshipguide/

WHAT YOU CAN DO

N = Nitrogen P = Phosphorus S = Sediment

Action	Benefits	What is reduced
Leave a natural vegetative buffer along lake, stream, ditch, or other waterway.	Grass or wood buffers help filter pollutants and reduce flood damage. This can also help to reduce occurrences of algae blooms.	N P S
Remember to inspect and pump your septic every 3-5 years.	A properly maintained septic system prevents costly repairs and untreated sewage discharge into our streams.	N P S
Plant a rain garden or install a rain barrel.	Rain gardens and rain barrels help reduce stormwater runoff and can cut down on landscaping costs.	N P S
Follow the 4 Rs of fertilizer use: right source, right amount, right place and right time.	The 4 Rs approach promotes the wise use of fertilizer by farmers, residents, and landscapers to reduce costly nutrient loss that pollutes our streams.	N P
Plant cover crops.	Cover crops build healthy soils that help hold back nutrients and water and increase crop yields.	N P S
Install a drainage management system.	Managing field drainage reduces nutrient loss while saving water for when your crops need it most.	N P
Properly manage livestock and pet waste.	Properly storing and disposing of animal waste reduces nutrients and prevents harmful bacteria from entering local waters.	N P
Help your community develop a plan that supports low impact development.	Smart development fosters growth and protects the local resources and character of the community.	N P S

This table is adapted from the March 2014 Mills Creek Report Card, Erie Soil and Water Conservation District

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1.0 Introduction

The following report summarizes the results of the Sherbrooke Lake Water Quality Monitoring Program. Monitoring activities were conducted at Sherbrooke Lake (SL) by trained volunteers with support from Coastal Action from 2018 to 2023, after a preliminary monitoring program in 2017. Preliminary monitoring activities in 2017 were used to determine the best methods and select sampling sites for the program, and when appropriate, this data was included in the baseline summary. No monitoring was conducted in 2020 due to COVID-19 restrictions. This report summarizes changes and trends in the water quality of Sherbrooke Lake and its tributaries over the five years of baseline data and the additional preliminary data from 2017.

This program receives financial support from both the Municipality of the District of Lunenburg (MODL) and the Municipality of Chester (MOC).

Following several years of consultations regarding the development of a municipal public access site at Sherbrooke Lake, the Sherbrooke Lake Stewardship Committee (SLSC) was formed. The SLSC, a joint commitment between MODL and MOC, is comprised of one Coastal Action staff, two residents of MODL, two residents of MOC, a water quality expert, and supporting municipal staff.

The SLSC was tasked with developing and implementing a water quality monitoring program to: determine a baseline understanding of water quality conditions within SL before the construction of the public access site, monitor water quality during and after the construction, and provide evidence-based advice to MODL and MOC regarding ways to address water quality changes and concerns within the lake.

The sites chosen for regular monthly or bi-monthly monitoring included four lake sites; two were near the proposed public access site, one located in the deepest part of the lake at the southern basin, and one near the middle of the lake. Seven tributaries of the lake (streams or rivers that enter the lake) were also monitored for this program; four of which were part of the regular sampling and three that were only sampled following a rainfall event of ≥25 mm. Monitoring tributaries could give insight into lake water quality, as land use around these rivers and streams could differ from the lake, and impact overall water quality such as nutrient or bacteria input.

The water quality monitoring program included a combination of in-field measurements using a YSI multi-parameter probe, and samples that were submitted to a laboratory for analysis. A ProDSS YSI unit, owned jointly by MOC and MODL, was used throughout the program. This unit measures the physical characteristics of water at the time of sampling, including temperature, dissolved oxygen, pH, total dissolved solids, salinity, pressure, and specific conductivity. In 2021, the MODL purchased a ProDSS Total Algae PC Sensor for the municipal YSI to monitor chlorophyll-α and phycocyanin concentrations. Water samples were collected for total suspended solids, total phosphorus, total nitrogen, fecal coliform, and chlorophyll-α. Secchi disk readings were also taken at the lake sites, which indicates turbidity. Once annually, an at-depth sample was taken at two of the lake sites to assess nitrogen and phosphorus below the thermocline, as well as sediment samples from two lake sites and one tributary site.

Some water quality parameters that can be impacted by development include turbidity, total dissolved and total suspended solids, dissolved oxygen, bacteria and nutrients (nitrogen and phosphorus). Measuring these parameters before and after a development can give insight into how the development impacted overall water quality.

Cyanobacteria, or blue-green algae, have also been a growing concern for many communities in the last few years. To measure this, chlorophyll-α gives an overview of algal production in water, while the ProDSS Algal probe measures both chlorophyll-α and phycocyanin, which is the pigment found in cyanobacteria. Factors that contribute to cyanobacteria blooms include excess amounts of nitrogen and phosphorus, temperature, and, wind and water movement that can form or dissipate blooms. Suspected blooms were sampled for the toxin microcystin and species present when possible.

As part of this program, the Trophic State Index (TSI) of the lake was analyzed annually. This uses the Secchi disk readings, total phosphorus, and chlorophyll-α concentrations to assess the overall productivity of the lake. The TSI value does not rate the lake’s water quality but describes the biological productivity of the lake. The TSI levels range from oligotrophic (low productivity) to hypereutrophic (highest productivity). Changes in the TSI value could indicate that factors influencing productivity have also changed, such as nutrient inputs.

The annual sediment sampling included heavy metals and nutrients that could be resuspended in the water column if the sediment is disturbed. This indicates the natural occurrence or pollution of heavy metals as well as nutrient loading within the sediment.

These parameters sampled over the five years of the program provide a baseline overview of lake health and trends in water quality that can be used for assessing the impact of future development.

1.1 Monitoring Program Background

Coastal Action acts as technical support for a group of trained volunteers, who conducted the monthly sampling (Figure 1). From 2018 to 2021, rainfall-dependent sampling was conducted by volunteers, in 2022 and 2023 this sampling was conducted by Coastal Action. The rainfall-dependent sampling occurred at tributaries to Sherbrooke Lake following rainfall exceeding 25 mm within 24 hours, which is defined as a “significant rainfall”. Sampling after a significant rainfall monitors the potential effect of runoff (i.e., influx of nutrients, bacteria, sediment), which may impact water quality. Following preliminary ground-truthing activities in 2017, the full Sherbrooke Lake Water Quality Monitoring Program was conducted in 2018, 2019, 2021, 2022, and 2023.

Further details on the program can be found in the *Sherbrooke Lake Water Quality Monitoring Program*, and the *Sherbrooke Lake Water Quality Monitoring Report* (2018, 2019, 2021 & 2022); all are available upon request from either MOC or MODL.

Figure 1. Sherbrooke Lake Water Quality Monitoring Program 2023 monitoring sites.

The sampling schedule and locations changed slightly over the 5 years of this project. In 2019, lake sites Chl 1 and Chl 2 (additional sites for monitoring chlorophyll-α) were removed from the program because these sites had similar results to the other lake sites and were not providing additional data (Figure 2). Hydrocarbons were initially sampled in 2018 and 2019 but removed from the program because all readings were below detection levels. Lake 3 was changed to *E. coli*-only sampling in 2022 and 2023. All changes to sites and sampling regimes were based on the newly available data and scientific advice.

In 2017 to gain baseline information, lake samples were taken in July, August, September and November. In 2018 and 2019, samples were taken at the lake sites monthly from May to October, while samples taken from stream sites during this time were collected bi-monthly. In 2020, sampling was not performed due to COVID-19 pandemic restrictions. In 2021, lake samples were taken monthly from June to October, and stream samples were taken in June, July, September, and October. In 2022, lake and stream samples were taken in June, August, and September. In 2023, lake and stream samples were taken in June, July, and September.

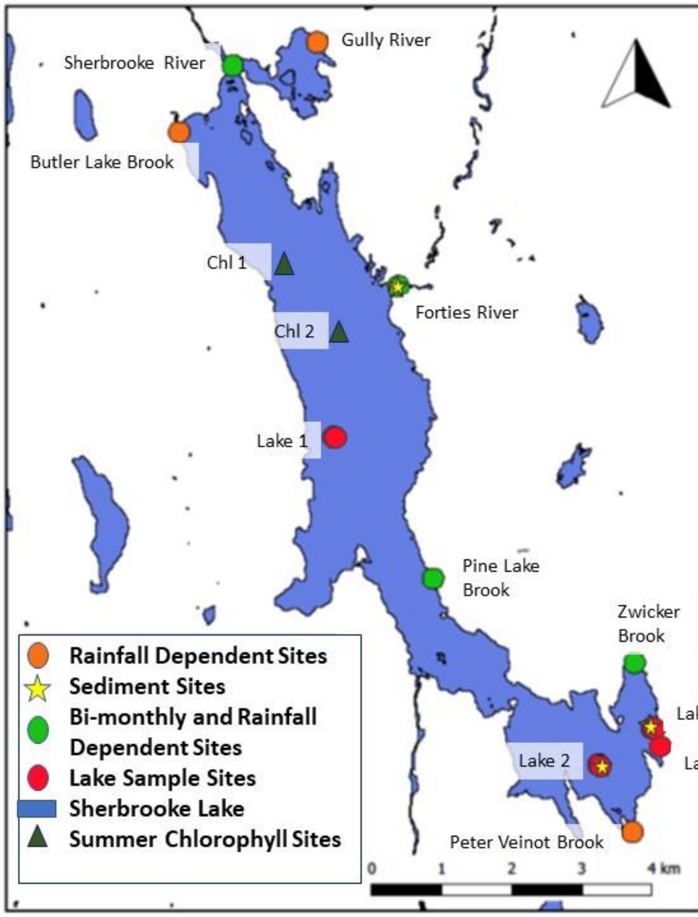

Figure 2. Sampling sites from 2018, showing the locations of Chl 1 and 2.

The rainfall-dependent samples were taken during different months each year, due to unpredictable weather and volunteer or Coastal Action staff availability (Table 1).

Table 1. Rainfall-dependent sampling dates and amount of rain (mm) from 2018 to 2023.

Date	Rainfall amount (mm) within 24 hours
19-Aug-18	30+
09-Sep-19	100+
18-Oct-21	25+
01-Dec-22	29+
07-Jun-23	70+

1.2 Sherbrooke Lake

Sherbrooke Lake is located on the South Shore of Nova Scotia, in both the Municipality of the District of Lunenburg and the Municipality of Chester. Sherbrooke Lake is the largest waterbody in the LaHave River watershed with a size of 16.94 km^2. The lake's drainage basin is 285 km^2 in size and includes 18 lakes and several large tributaries feeding into Sherbrooke Lake. The lake has 14 inlet streams, several of which are less than 1 km in length. The largest inlet streams are Sherbrooke River, with a sub-watershed drainage area of 121 km^2; Gully River, with a sub-watershed drainage area of 34 km^2; and Forties River, with a sub-watershed drainage area of 49 km^2. The lake has a single outlet called the North Branch which flows through several lakes before joining the main stem of the LaHave River at Wentzells Lake, approximately 22 km downstream from Sherbrooke Lake.

The Sherbrooke Lake drainage basin is dominated by forestry, silviculture, and agricultural land use, while cottage development and small rural communities are spread throughout the area on a smaller scale.

Coastal Action has conducted a water quality monitoring program in the LaHave River watershed since 2007. This program has a total of 15 sample sites, two of which provide some information about the conditions of Sherbrooke Lake (Figure 3). The Franey Corner sample site is located on the Sherbrooke River where it crosses Forties Road. This site allows Coastal Action to monitor the largest tributary to the lake. The Sherbrooke sample site is located on the North Branch outlet, where it crosses Newburne Road and provides information about the conditions of the water draining out of Sherbrooke Lake. Over the years, these sites have displayed some of the best water quality in the entire watershed, with a general trend of good water quality throughout the headwaters and a decline as the system flows downstream into more densely populated and developed parts of the watershed.

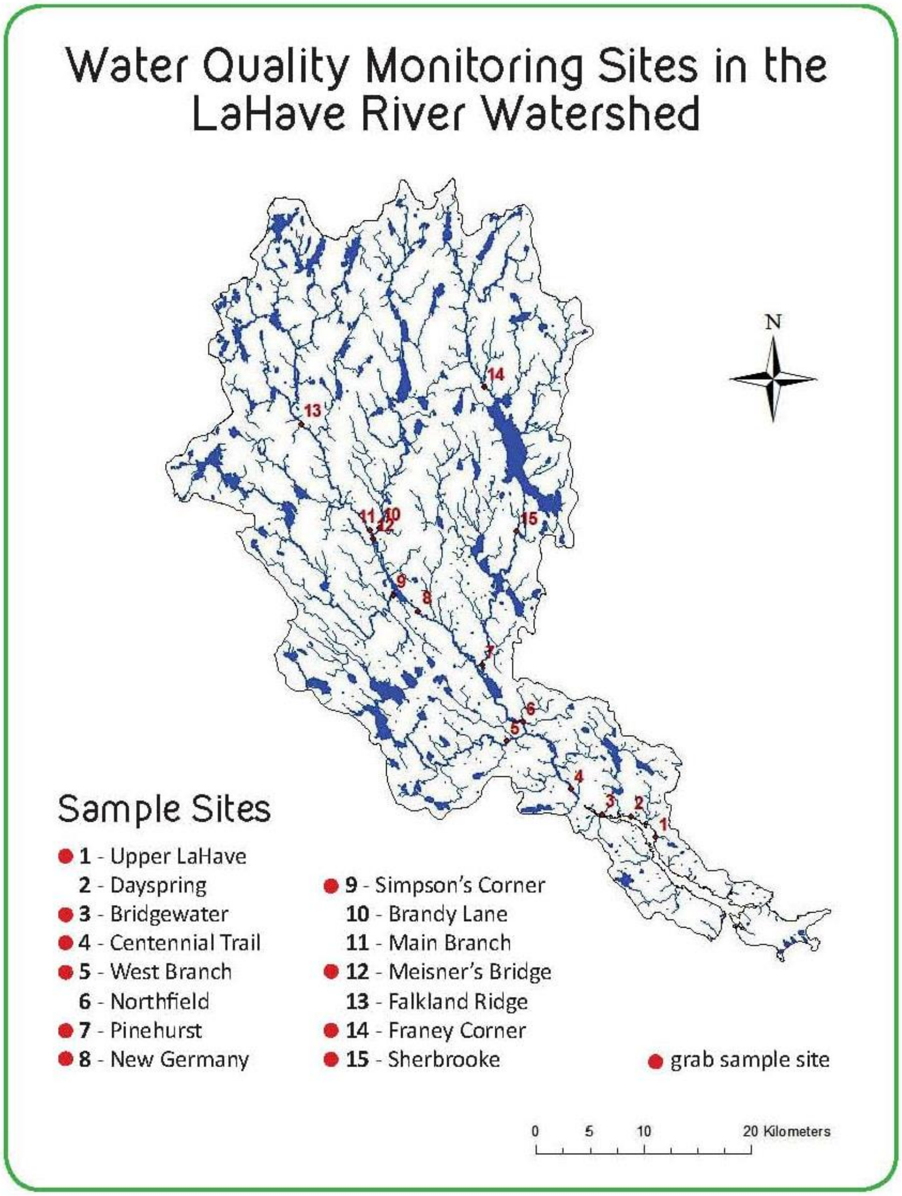

Figure 3. Regular monthly sampling sites for the LaHave River Watershed Project.

Additionally, Sherbrooke Lake is unique because it hosts one of two known populations of lake trout (*Salvelinus namaycush*) in Nova Scotia. Lake trout require a large, deep, well-oxygenated hypolimnion and follow a unique life cycle of moving from shallow to deep regions when surface water temperatures reach 15^0C in the spring (Inland Fisheries 2005). Sherbrooke Lake provides this species with the water depth and substrate characteristics needed to complete its life cycle. Since 2020, there have been studies conducted by the NS Department of Aquaculture and Fisheries, Acadia University, Saint Mary's University and Coastal Action on the lake trout in Sherbrooke Lake.

1.3 Southwest Nova Scotia

Southwest Nova Scotia generally has lower surface water pH than other places in Canada (Clair et al. 2007), which is attributed to local geology, high abundance of wetlands, and historic acid rain deposition. Granite and shale bedrock, which have low base cations (alkaline metals such as calcium, aluminum, magnesium, potassium, etc.), are common in this area (Shilts 1981; White & Horne 2012). These bedrock parent materials produce soils with low base cations and water that drains through these soils is more vulnerable to acidification due to its limited buffering capacity (Stumm et al. 1987). Southwest Nova Scotia also has an abundance of peat-dominated wetlands, which generally have a low pH (ECCNS 2009b).

Acid rain has also contributed to the low pH of surface waters in Nova Scotia. Acid rain occurs when pollutants in the atmosphere mix with water in the air to form acidic compounds. Due to the existing low buffering capacity from natural conditions, southwest Nova Scotia has a low tolerance for acid deposition (ECCNS 2009a). However, new regulations have decreased emissions contributing to acid deposition (Nixon & Curran 1998) and studies are showing the effects of acid deposition on North American soils are beginning to reverse (Lawrence et al. 2015).

2.0 Water Quality Monitoring Results

2.1 YSI Water Quality Parameters

2.1.1. Chlorophyll-α, and Phycocyanin

In 2021, a ProDSS Total Algae PC Sensor was purchased by MODL to use on the ProDSS YSI unit owned jointly by MOC and MODL. This probe measures concentrations of chlorophyll-α and phycocyanin present in water. Phycocyanin is a pigment found in cyanobacteria, or blue-green algae, and provides an estimate of total cyanobacteria production. Chlorophyll-α is a pigment produced by all types of algae and provides an estimate of total algae production.

Collecting this data over multiple seasons provides baseline concentrations of phycocyanin in SL. Long-term monitoring with this probe, paired with the collection of Microcystin-LR water samples during blooms, will help to identify spikes in phycocyanin concentrations. This data can also be used to develop a predictive curve for the relationship between the concentrations of these algal pigments and the occurrence of algal blooms in SL.

Algal concentrations are measured as Relative Fluorescence Units (RFU), which is a measurement of the fluorescence of pigment in algae. Phycocyanin RFU were converted to the total number of phycocyanin cells per mL of water (Genzoli & Kann 2016). World Health Organization (WHO) provides two guideline levels, 'alert level 1' is reached when 20,000 phycocyanin cells/mL are observed, and 'alert level 2' is reached when 100,000 phycocyanin cells/mL are observed. Readings outside of the probe's detection limits (i.e., negative RFU values) were replaced with zero (Ma et al. 2023). At no point were the WHO guidelines exceeded or approached (Figure 4, Figure 5, Figure 6).

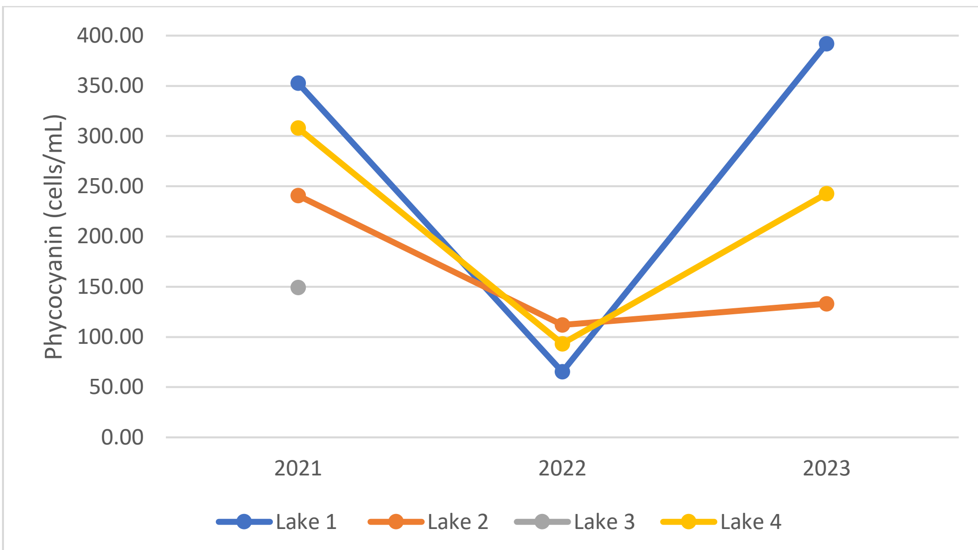

Figure 4. Average yearly phycocyanin (cells/mL) levels from the 2021 - 2023 summer sampling events at the lake sites. The WHO provides two guidelines; Alert level 1 at 20,000 cells/mL, and Alert level 2 at 100,000 cells/mL.

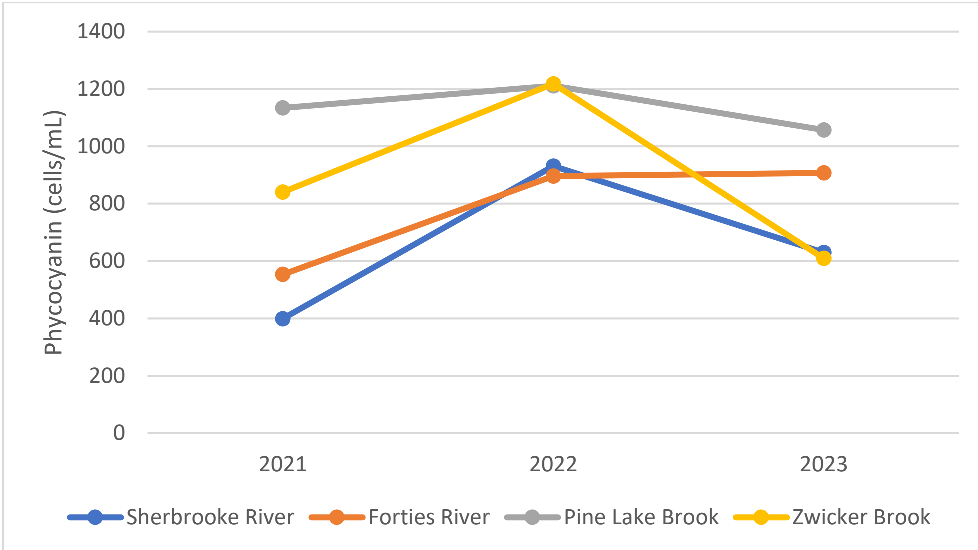

Figure 5. Summer months average yearly phycocyanin (cells/mL) levels from the 2021 - 2023 sampling events at the stream sites. The WHO provides two guidelines; Alert level 1 at 20,000 cells/mL, and Alert level 2 at 100,000 cells/mL.

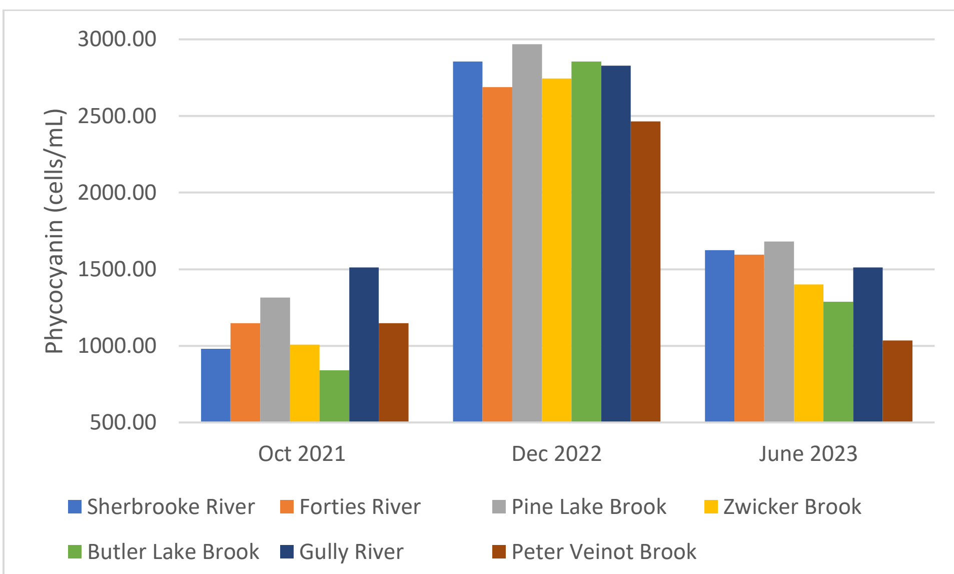

Figure 6. Phycocyanin (cells/mL) levels from the rainfall-dependent sampling events at the stream sites from 2021 - 2023, including the additional, rainfall-specific sites. The WHO provides two guidelines: Alert level 1 at 20,000 cells/mL, and Alert level 2 at 100,000 cells/mL.

2.1.2. Surface Water Temperatures

Average yearly temperatures of the lake ranged from 14.1°C to 22.5°C (Figure 7). At Lake 4 in 2018, temperature readings were only taken in September and October. The highest average annual temperature occurred at Lake 3 in 2021, where readings were only taken during the warmer summer months, June to September. The average yearly surface temperature at all lake sites exceeded the threshold of 20°C for cold-water fish species in 2021, 2022, and 2023 (Nova Scotia Salmon Association [NSSA] 2014). All lake sites show a trend of slightly increasing surface water temperatures in the summer months; however, there is not enough data for statistical analyses to determine if this trend is significant or due to other factors such as time of sample collection or weather conditions before sampling. See the Appendix for graphs of individual site surface water readings showing the variance of data.

The stream sites showed cooler average temperatures than the lake, ranging from 10.3°C to 20.4°C (Figure 8). The highest average annual temperature at the tributaries occurred in 2021 at Forties River. Sherbrooke River also exceeded the threshold for coldwater species in 2018. Forties River was just below the threshold (19.9°C) in 2018 and exceeded it in 2021.

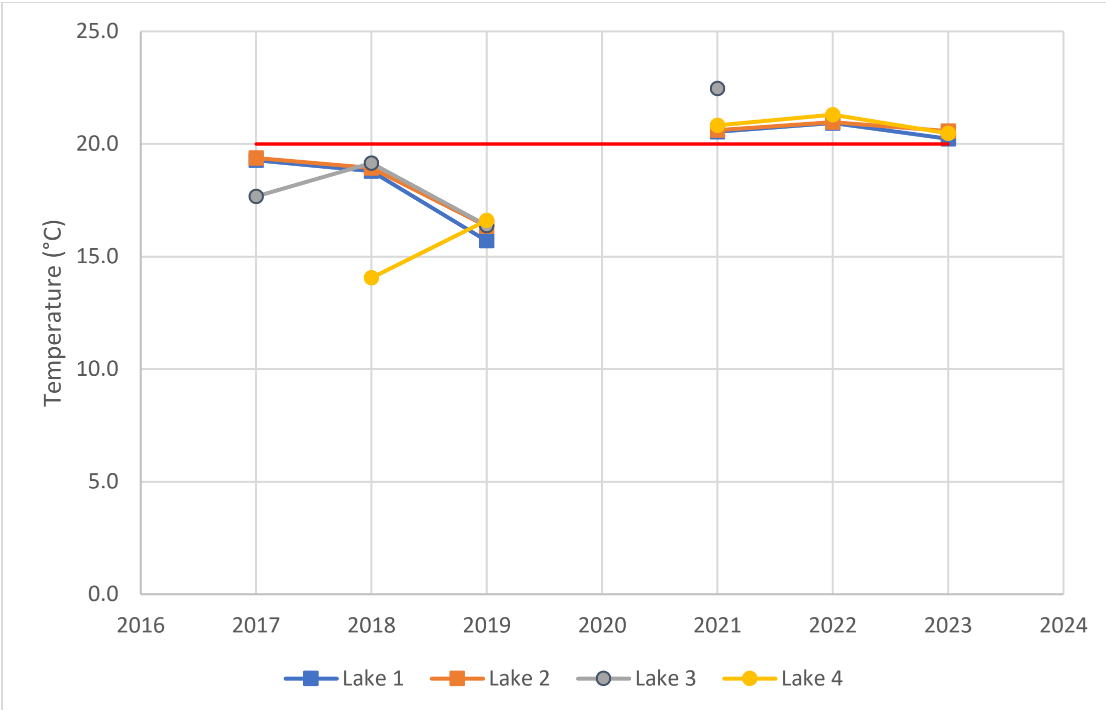

Figure 7. Average annual temperature (°C) readings from the 2017 to 2023 summer month sampling events at the lake sites. The red line indicates the 20°C threshold for cold-water fish set by NSSA.

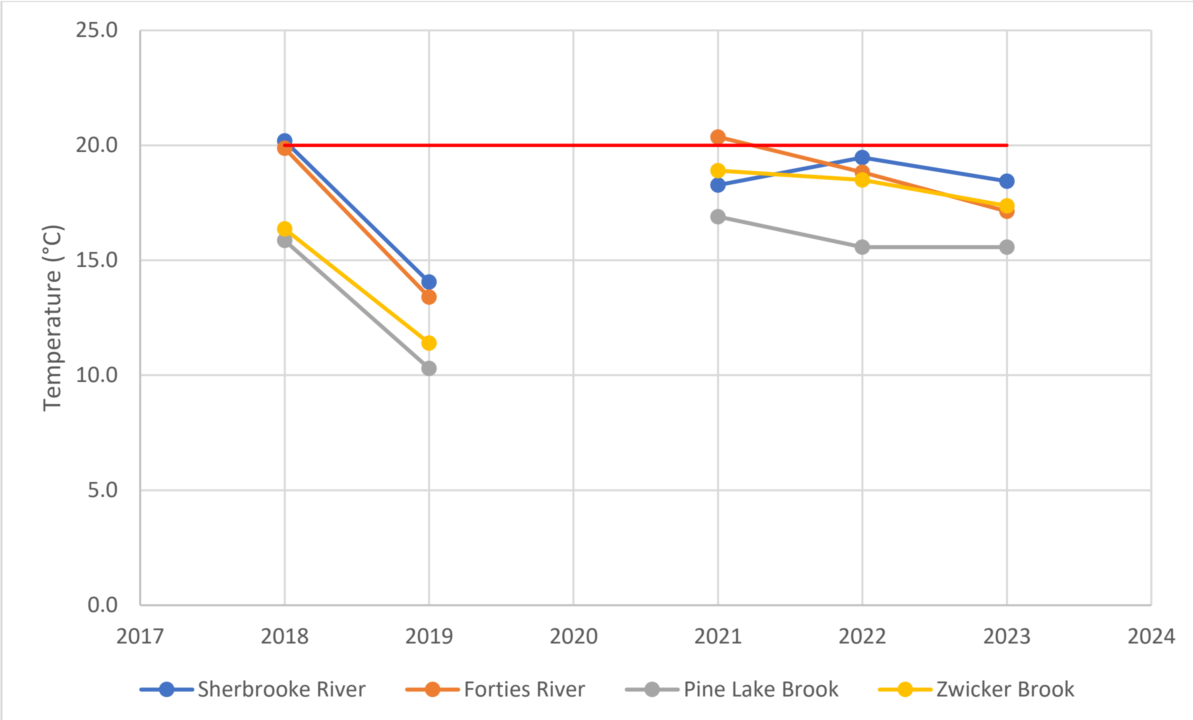

Figure 8. Average annual temperature (°C) readings from the 2017 to 2023 summer month sampling events at the stream sites. The red line indicates the 20°C threshold for cold-water fish set by NSSA.

Surface water temperature readings were taken during rainfall-dependent sampling events, at each of the stream sites, including three additional sites not sampled during regular monthly sampling. The 2022 samples were collected later into the year than usual due to a lack of significant rainfall events during the summer and fall months. Temperatures from the rainfall-dependent sampling datasets range from 5°C to 21.5°C (Figure 9).

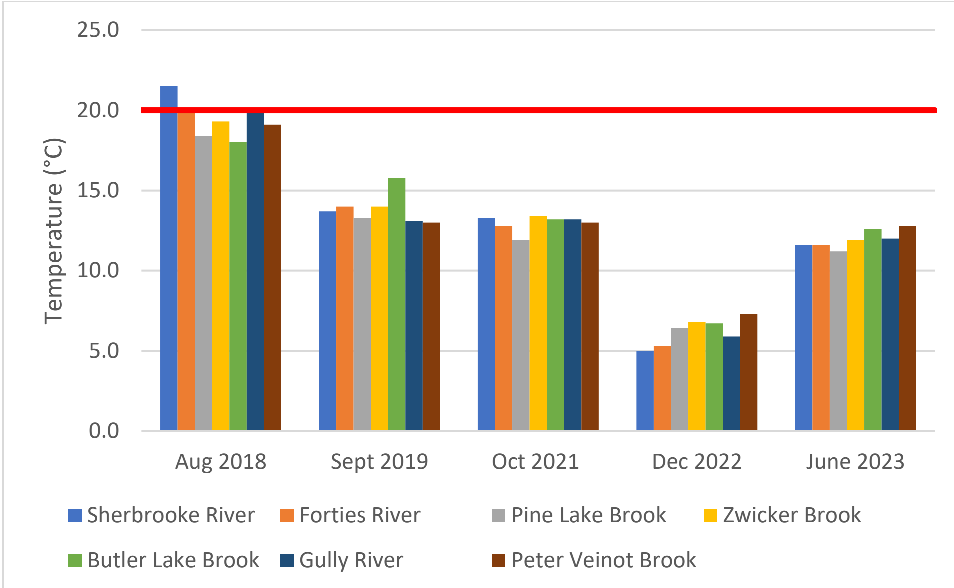

Figure 9. Temperature (°C) readings from the rainfall-dependent sampling at the stream sites, including the additional, rainfall-specific sites from 2018 - 2023. The red line indicates the 20°C threshold for cold-water fish set by NSSA.

2.1.3 Surface Dissolved Oxygen

Average dissolved oxygen (DO) readings at the lake sites ranged from 8.28 mg/L to 9.50 mg/L (Figure 10). The lowest average DO concentration of the lake sites was at Lake 3 in 2021. DO is a requirement for the survival of aquatic organisms, with a minimum threshold of 6.5 mg/L set by the Canadian Council of Ministers of the Environment (CCME) for cold-water species (CCME 1999b). None of the average yearly DO readings were below this threshold at the lake sites. The DO concentrations at each site show a slight downward trend. See the Appendix for graphs of individual site DO readings showing the variance of data.

Pine Lake Brook had the lowest and highest yearly average DO readings of the stream sites ranging from 4.80 mg/L to 10.79 mg/L (Figure 11). The average DO at Pine Lake Brook and Zwicker Brook were below the 6.5 mg/L threshold in 2017 and 2022, respectively. See the Appendix for graphs of individual site readings showing the variance of data.

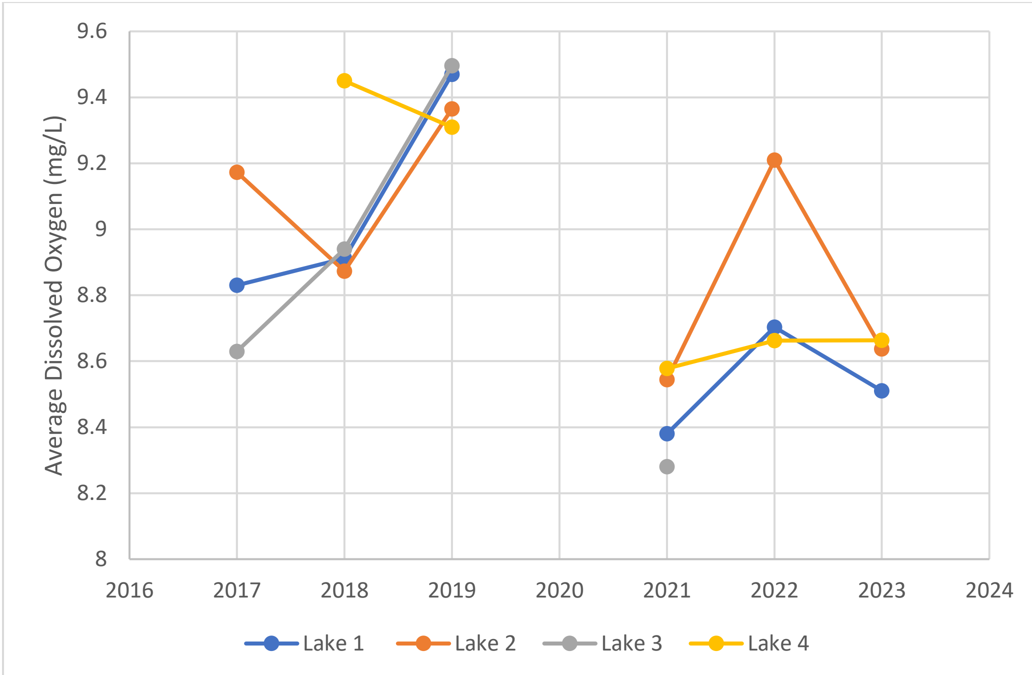

Figure 10. Average annual dissolved oxygen (mg/L) readings from the 2017 to 2023 summer month sampling events at the lake sites. Note vertical scale starts at 8 mg/L and does not show the CCME threshold of 6.5 mg/L.

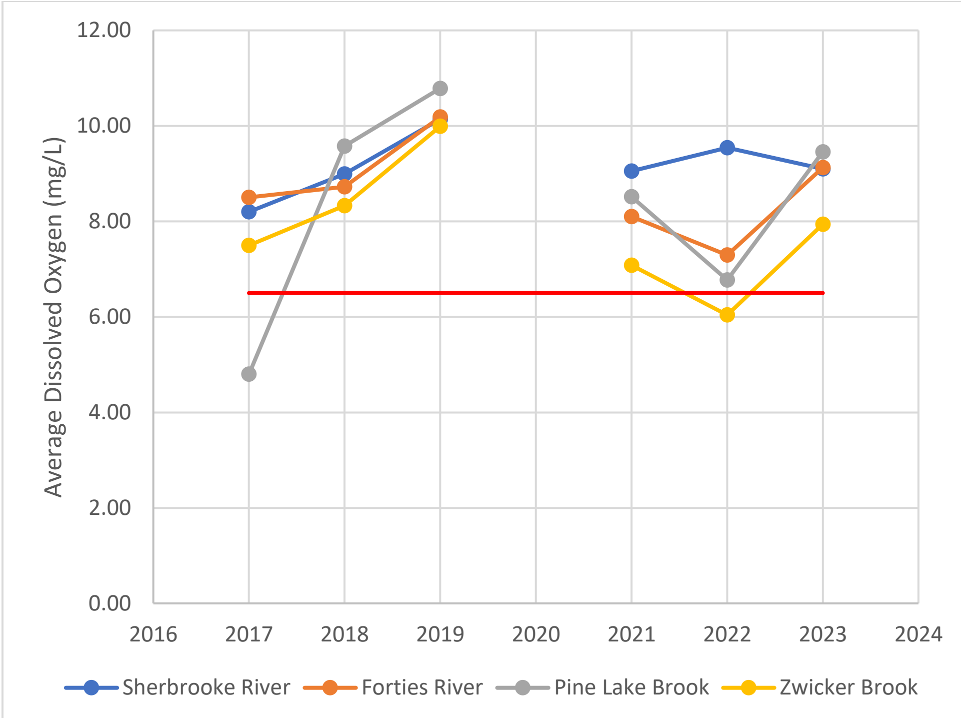

Figure 11. Average annual dissolved oxygen (mg/L) readings from the 2017 to 2023 summer month sampling events at the stream sites. The red line indicates the 6.5 mg/L minimum for aquatic species set by CCME.

Dissolved oxygen readings were taken yearly, excluding 2020, during each rainfall-dependent sampling event, including three additional sites not included in the regular monthly samples. DO levels within the tributaries ranged from 6.15 mg/L to 12.56 mg/L (Figure 12). Peter Veinot Brook was below the 6.5 mg/L threshold in 2018 and 2021.

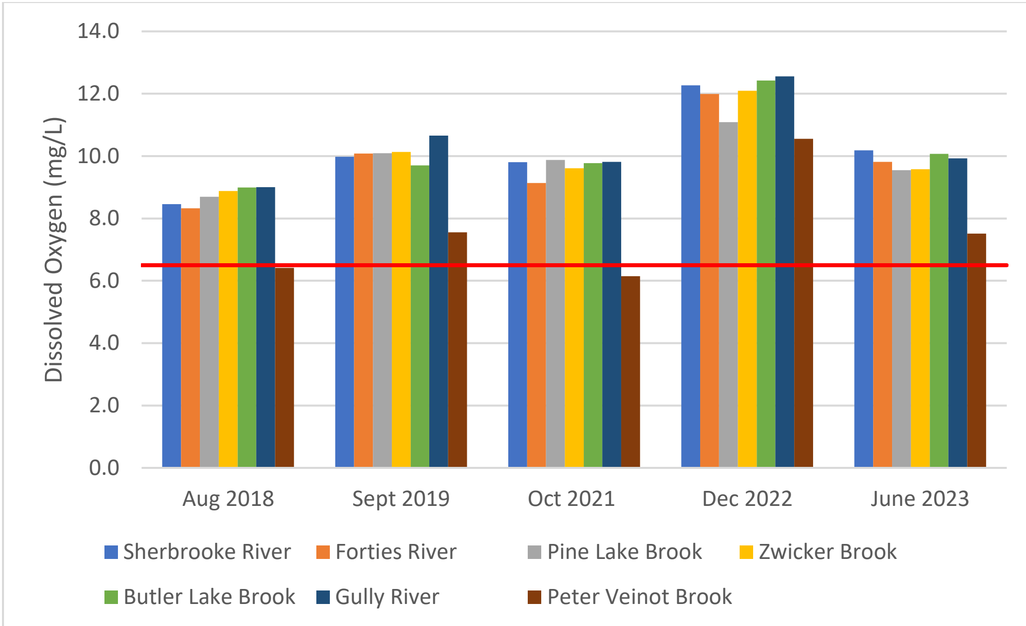

Figure 12. Dissolved Oxygen (mg/L) readings from the 2018 to 2023 rainfall-dependent sampling event at the stream sites, including the additional, rainfall-specific sites. The red line indicates the 6.5 mg/L minimum for aquatic species set by CCME.

2.1.4 pH

Although almost all of the average pH measurements fell below the 6.5-pH threshold set by the CCME (CCME 2002), the acidity of SL waters is not uncommon for southwest NS lakes. At the lake sites, the average summer month pH ranged from 4.79 to 6.88 (Figure 13), while the stream sites ranged from 3.12 to 6.11 (Figure 14). Readings taken during the yearly rainfall-dependent sampling were also consistently below the threshold of 6.5 (Figure 15). As Nova Scotia has experienced high amounts of acid precipitation in the past, and its geology limits the replenishment of base cations to soils (NSSA 2015), surface waters in southwest Nova Scotia are generally lower than the 6.5-pH threshold. In addition, though the Sherbrooke Lakes' pH values are lower than 6.5 pH, many fish species can survive in waters >5.0-pH (NSSA 2014) and therefore it appears that most of the time, the acidity of the waters in SL poses minimal threat to organisms, except for some stream sites. All lake and stream sites had a trend of increasing pH values from 2018 to 2023. See the Appendix for graphs of individual site pH readings showing the variance of data.

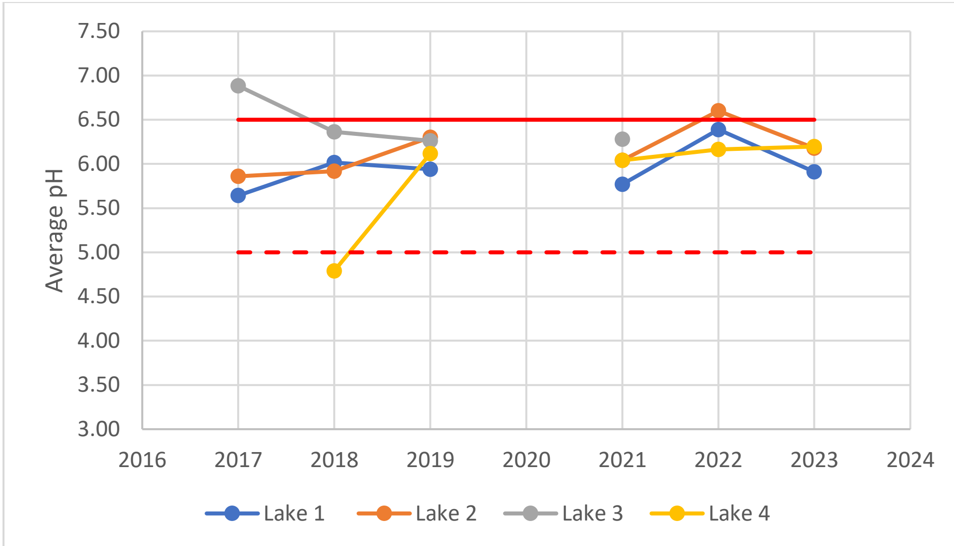

Figure 13. Average annual pH readings from the 2017 - 2023 summer month sampling events at the lake sites. The solid red line indicates the 6.5 pH threshold set by CCME, and the dotted red line indicates the 5.0 pH threshold identified by NSSA.

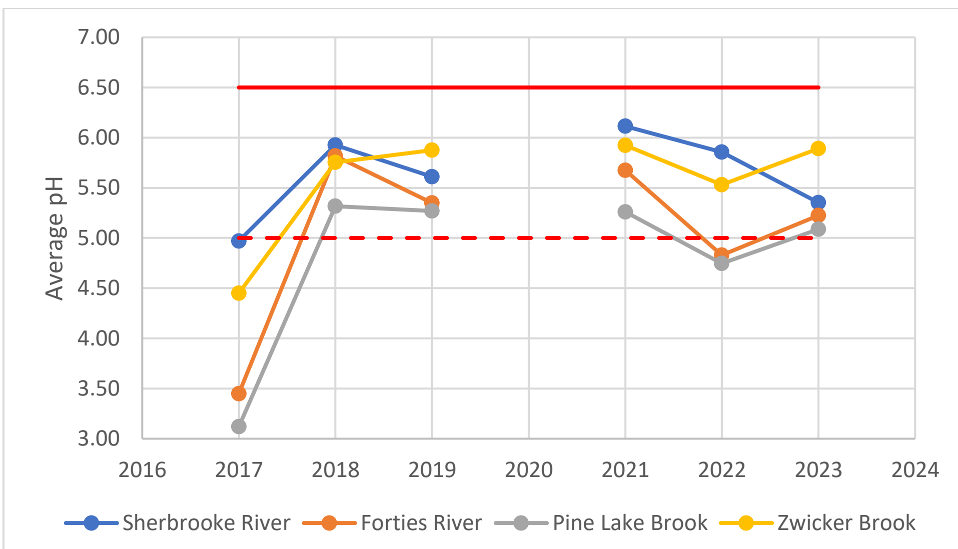

Figure 14. Average annual pH readings from the 2017 - 2023 summer month sampling events at the stream sites. The solid red line indicates the 6.5 pH threshold set by CCME, and the dotted red line indicates the 5.0 pH threshold identified by NSSA.

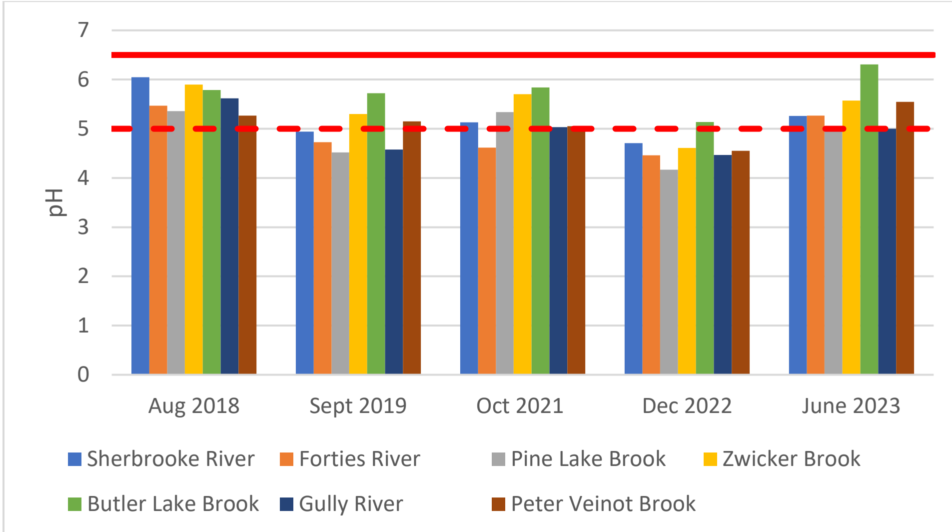

Figure 15. pH readings from the 2017 - 2023 rainfall-dependent sampling event at the stream sites, including the additional, rainfall-specific sites. The solid red line indicates the 6.5 pH threshold set by CCME, and the dotted red line indicates the 5.0 pH threshold identified by NSSA.

2.1.5 Total Dissolved Solids

Average yearly Total Dissolved Solids (TDS) readings at the lake sites ranged from 14.0 mg/L to 18.8 mg/L (Figure 16), and 13.5 mg/L to 22 mg/L at the stream sites (Figure 17). The highest average TDS at all lake sites was Lake 1 in 2018, and the highest reading of the stream sites was taken at Zwicker Brook in 2022. Overall trends show TDS levels have been declining at both lake and stream sites. See the Appendix for graphs of individual site TDS readings showing the variance of data.

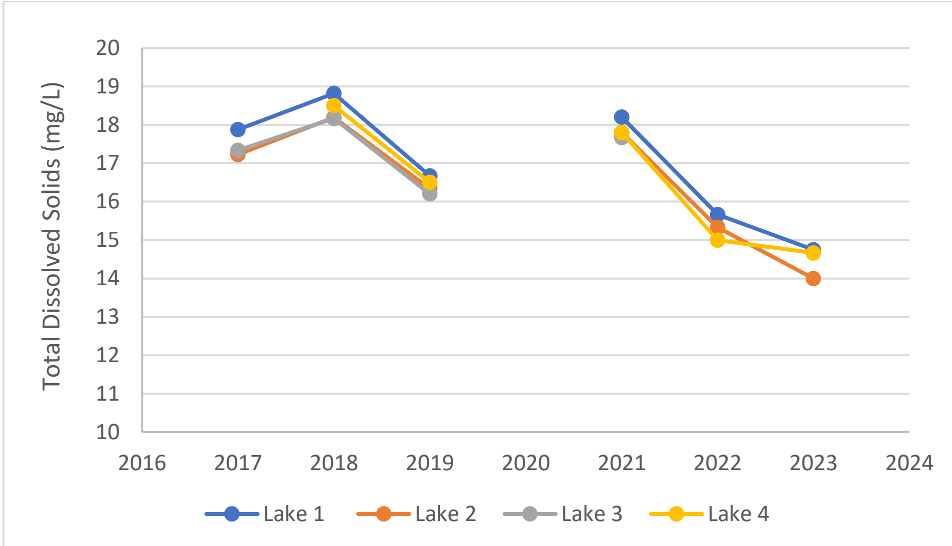

Figure 16. Average annual Total Dissolved Solids (mg/L) readings from the 2017 - 2023 summer month sampling events at the lake sites.

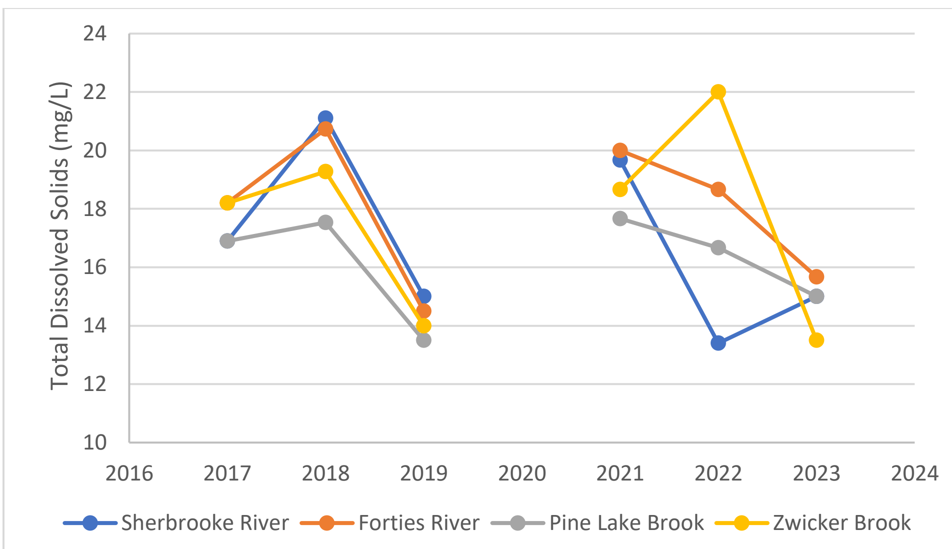

Figure 17. Average annual Total Dissolved Solids (mg/L) readings from the 2017 - 2023 summer month sampling events at the stream sites.

TDS readings during the yearly rainfall-dependent sampling event ranged from 10 mg/L at Zwicker Brook in 2023 to 39 mg/L at Butler Lake Brook in 2018 (Figure 18).

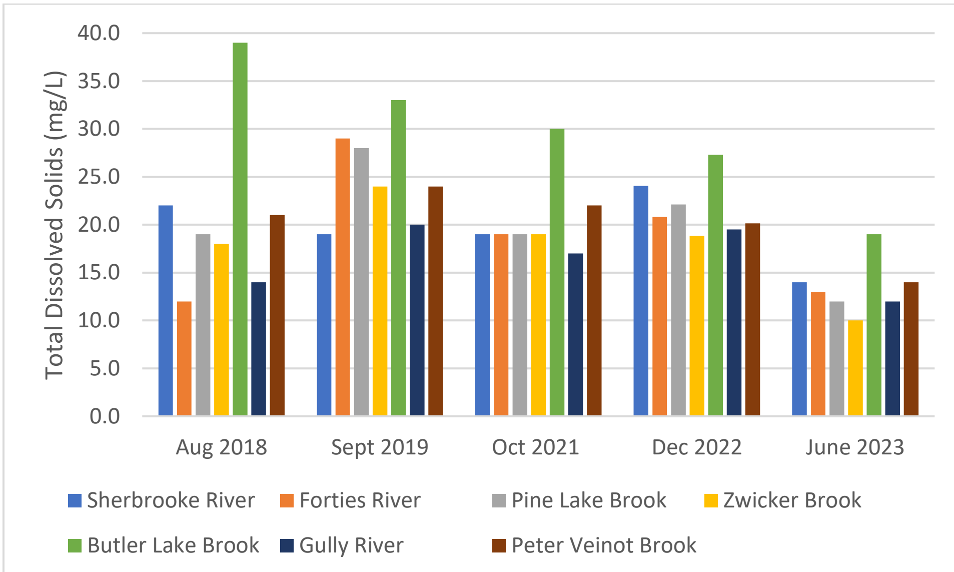

Figure 18. Total Dissolved Solids (mg/L) readings from the 2017 - 2023 rainfall-dependent sampling event at the stream sites, including the additional, rainfall-specific sites

There is no guideline for TDS set by the CCME for the protection of aquatic health; however, Hinch and Underwood (1985) found that pristine Nova Scotian lakes had an average of 20 mg/L. The presence of high TDS is not necessarily harmful as dissolved materials can be from both anthropogenic and natural sources. As TDS does not have a guideline for the protection of aquatic organisms, TDS concentrations do not appear to be detrimental to Sherbrooke Lake.

2.2 Chemical Water Quality Parameters

2.2.1 Total Suspended Solids

Total Suspended Solids (TSS) are measured as the value of solids suspended in a water column that do not pass through a 45 µm glass fibre filter. Overall TSS has shown a trend of slightly increasing at the lake sites. At the lake sites, the average yearly TSS readings ranged from 1.00 mg/L to 2.73 mg/L (Figure 19), while stream sites ranged from 1.1 mg/L to 14.5 mg/L (Figure 20). Some stream sites show a declining trend in TSS, while others are showing a slight increase.

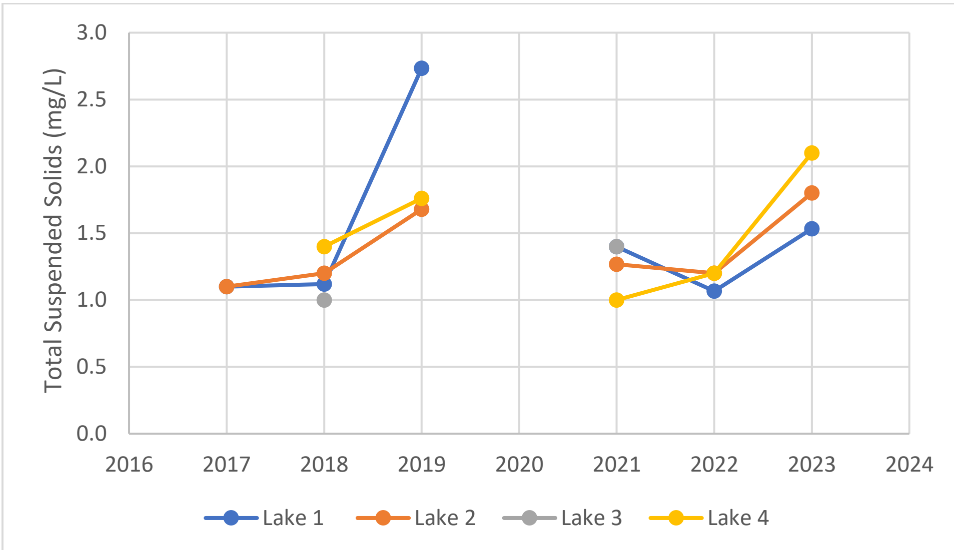

Figure 19. Average annual Total Suspended Solids (mg/L) readings from the 2017 - 2023 summer month sampling events at the lake sites.

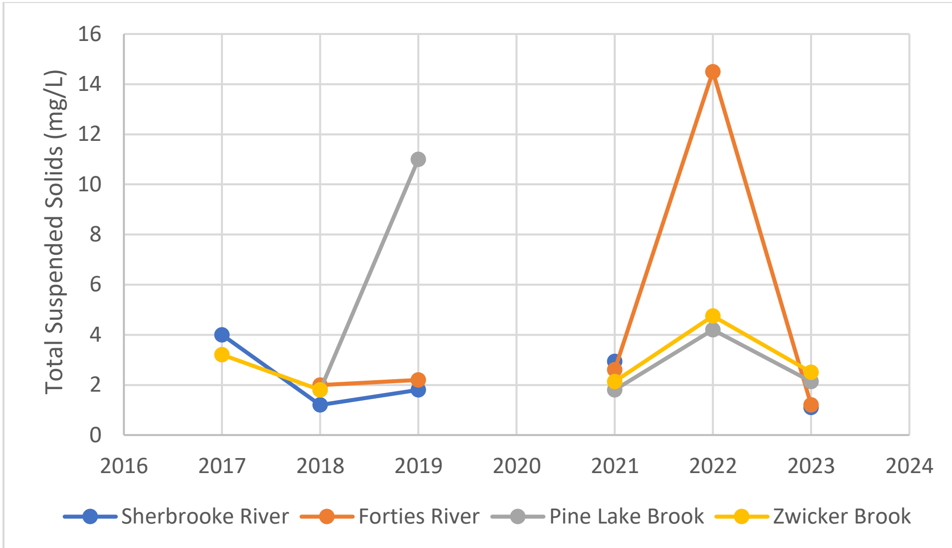

Figure 20. Average annual Total Suspended Solids (mg/L) readings from the 2017 - 2023 summer month sampling events at the stream sites.

TSS levels from the yearly rainfall-dependent sampling events ranged from not detected (<1 mg/L) to 14.5 mg/L at Forties River in 2022 (Figure 21).

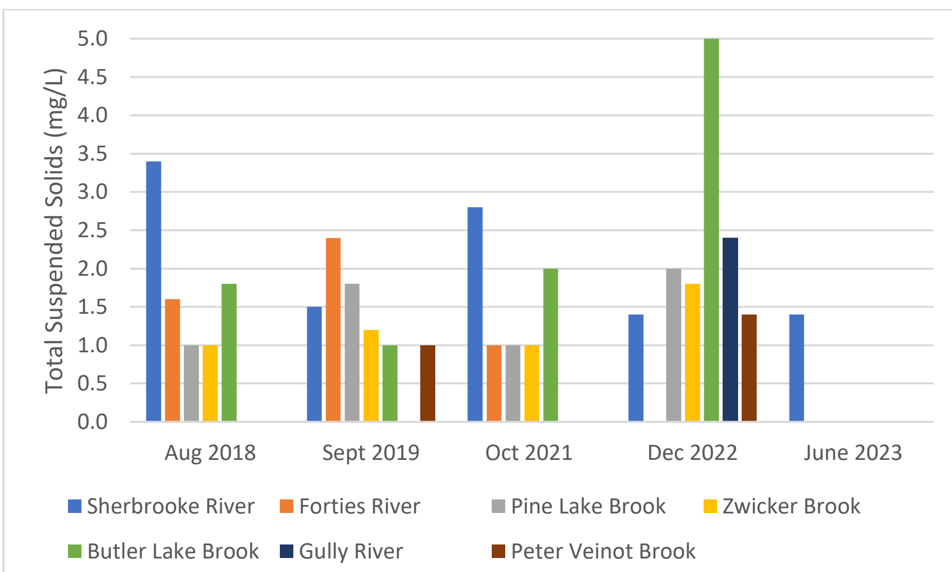

Figure 21. Total Suspended Solids (mg/L) readings from the 2017 - 2023 rainfall-dependent sampling event at the stream sites, including the additional, rainfall-specific sites. TSS was below detection levels at Gully River in 2018, 2019, 2021 and 2023; at Peter Veinot Brook in 2018, 2021, and 2023; at Forties River in 2022 and 2023; at Pine Lake Brook, Zwicker Brook and Butler Lake Brooke in 2023.

As the CCME has a guideline of a 10 mg/L allowable increase from baseline in waterbodies with TSS ≤ 100 mg/L (CCME 2002), the TSS levels observed in 2022 at Forties River exceed this guideline for both the rainfall event and regular monthly sampling. The rest of the TSS levels observed are not a threat to aquatic organisms based on CCME guidelines.

2.2.2 Total Phosphorus

At the lake sites, the average yearly surface total phosphorus (TP) levels ranged from 0.004 mg/L at Lake 3 to 0.011 mg/L at Lake 1 (Figure 22). All lake sites show a trend of declining average TP levels, except Lake 2, which shows a slight increase (Figure 23). Lake sites 2, 3, and 4 show little variance within the samples, while Lake 1 shows the most variance indicated by error bars in Figure 23. Some TP readings were below the detectable limit of 0.004 mg/L. The average yearly TP readings at the stream sites ranged from 0.007 mg/L to 0.024 mg/L (Figure 24).

Ontario's Ministry of Environment and Climate Change (MOECC) has established two guidelines for phosphorus in water bodies: ≤ 0.02 mg/L for lakes, and ≤ 0.03 mg/L for rivers and streams (Ontario's Ministry of Environment [MOE] 1979). The average yearly TP concentrations at the lake and stream sites did not exceed the MOECC guidelines.

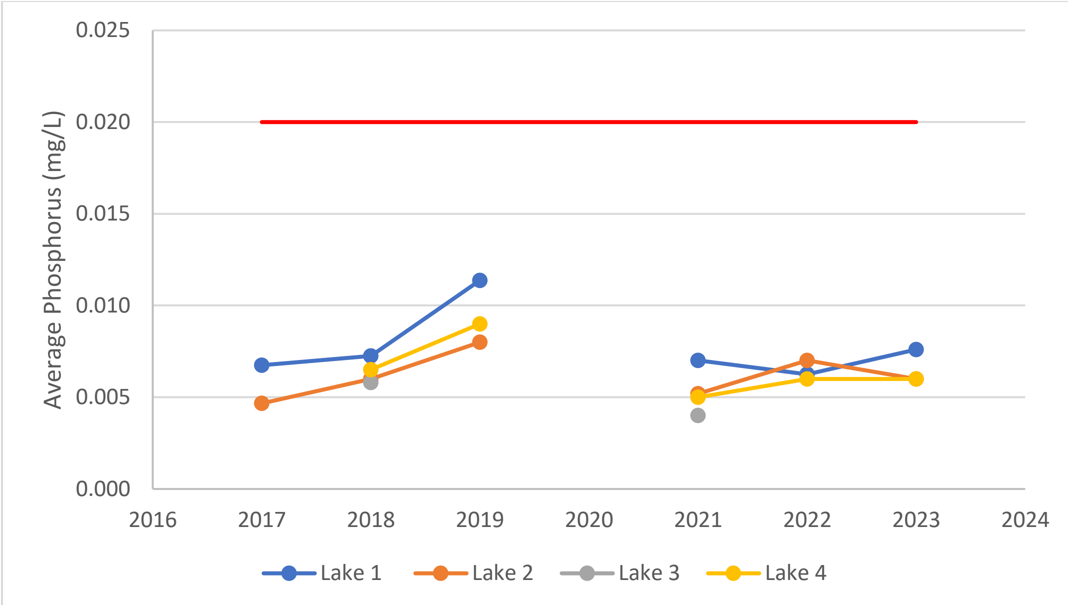

Figure 22. Average annual total phosphorus (mg/L) readings from the 2017 - 2023 summer month sampling events at the lake sites.

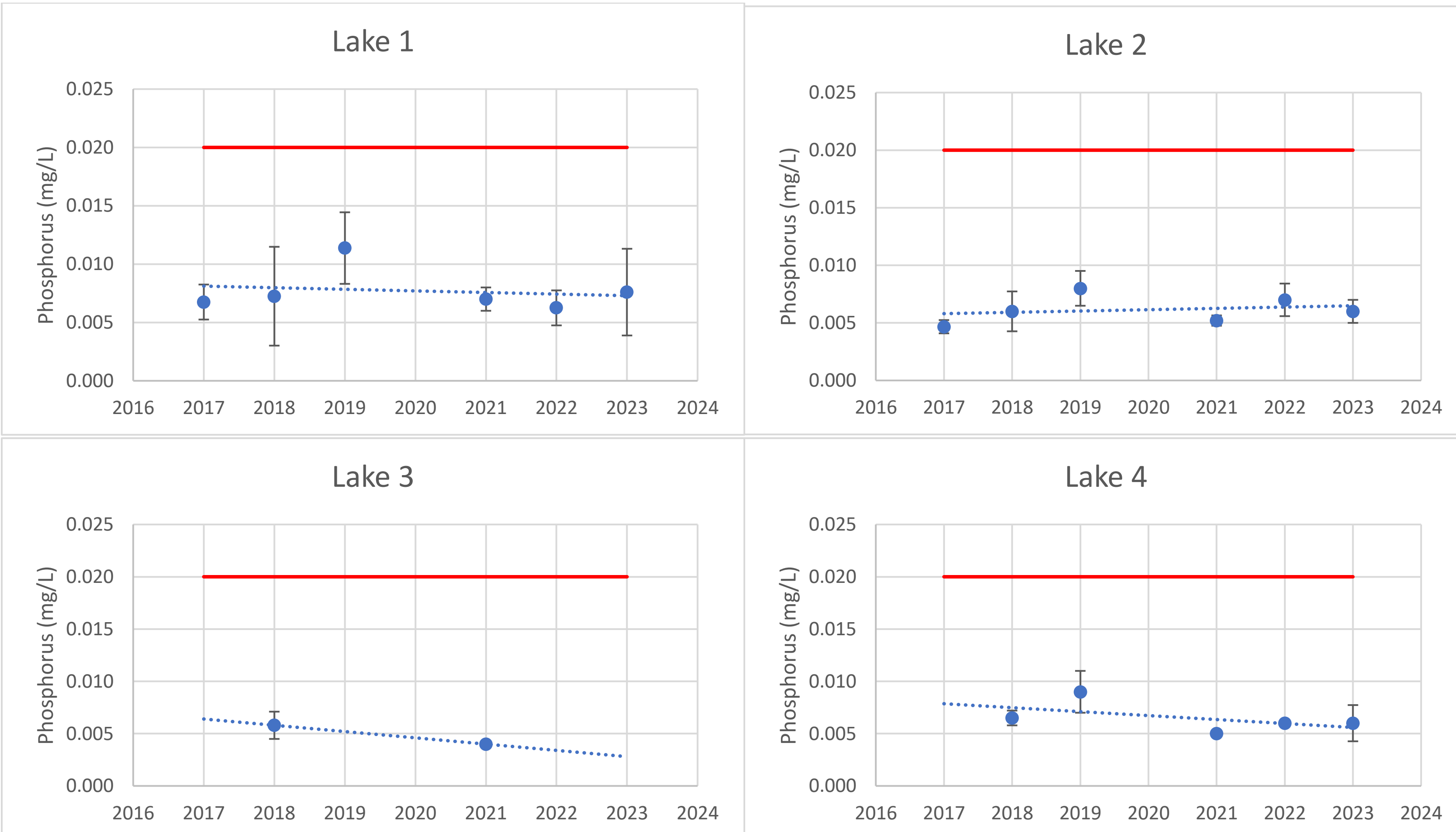

Figure 23. Average annual Total Phosphorus (mg/L) levels from the summer month sampling events at the lake sites. The red line indicates the MOECC guideline for phosphorus in lakes. Error bars indicate standard error. The blue dotted line indicates the trendline.

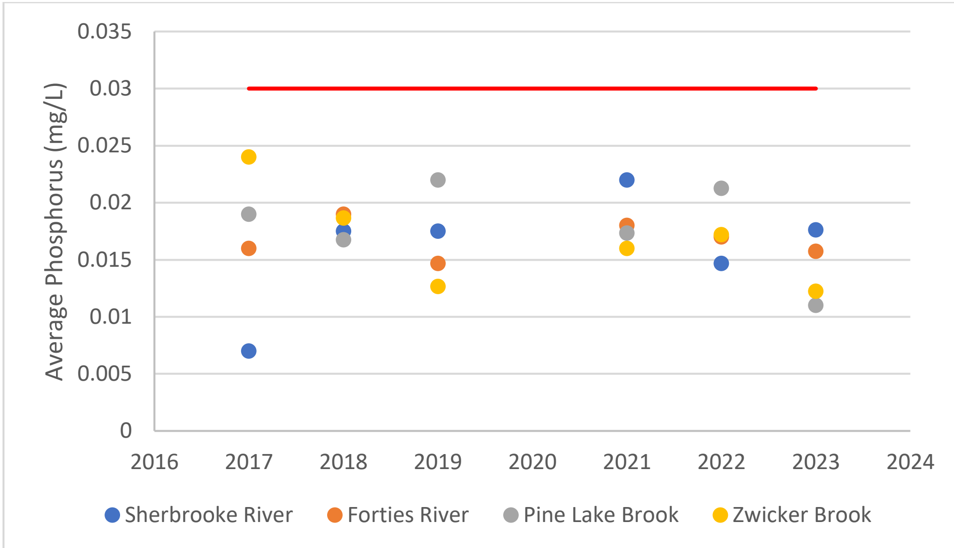

Figure 24. Average annual Total Phosphorus (mg/L) readings from the 2017 - 2023 summer month sampling events at the stream sites. The red line indicates the MOECC guideline for total phosphorus in streams.

Total phosphorus samples taken during the yearly rainfall-dependent sampling event ranged from 0.007 mg/L to 0.04 mg/L (Figure 25).

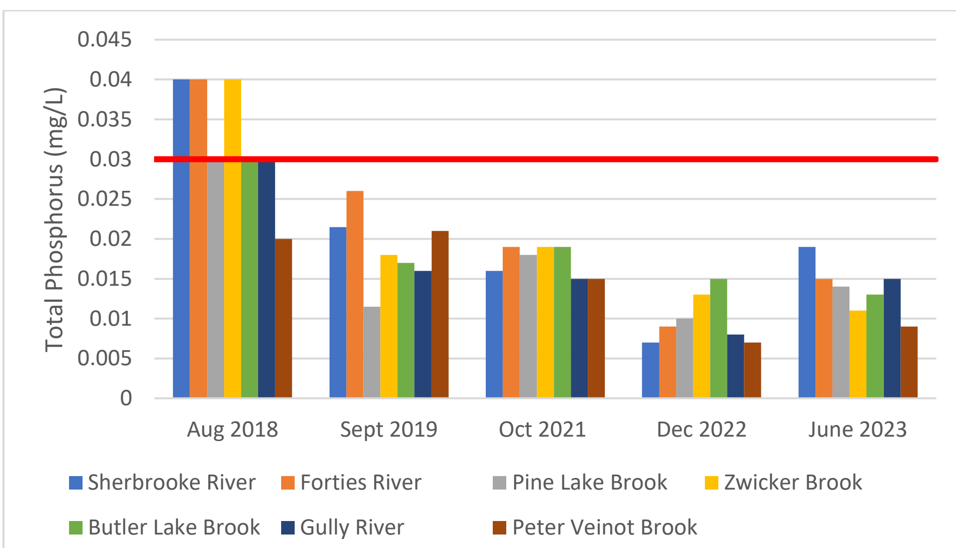

Figure 25. Total Phosphorus (mg/L) readings from the 2018 - 2023 rainfall-dependent sampling event at the stream sites, including the additional, rainfall-specific sites.

Once each year during the sediment sampling, at-depth water samples were analyzed for total phosphorus. These samples were taken below the thermocline at Lake 1 and Lake 2. TP at-depth ranges from 0.007 mg/L at Lake 1 to 0.430 mg/L at Lake 2 in 2021 (Figure 26). These results exceed the MOECC guidelines at Lake 2 in 2018 and 2021, indicating the deeper waters at this site were nutrient-enriched during these years.

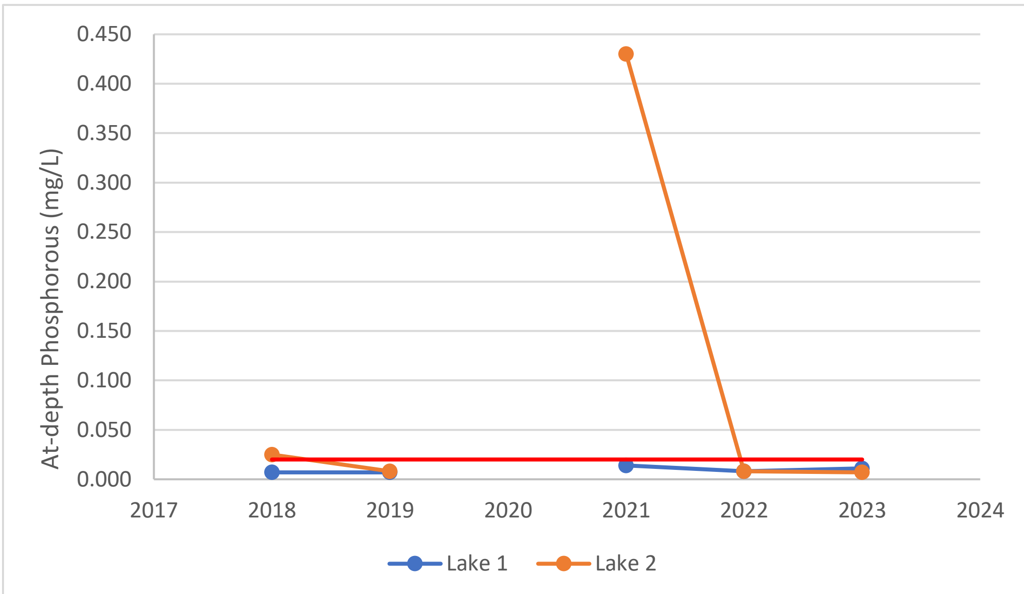

Figure 26. At-depth total phosphorus readings from the once-yearly sampling.

2.2.3 Total Nitrogen

At the lake sites, the average yearly surface total nitrogen (TN) levels ranged from 0.193 mg/L to 0.588 mg/L (Figure 27). Lake 1 and 2 show a trend of slightly increasing average TN levels, and Lake 3 shows a slight decline but was only sampled during two years (Figure 28). Lake 4 shows a strong trend of increasing TN values; however, there was a single spike to 1.14 mg/L in July 2023, which was an outlier value. The average yearly TN readings at the stream sites ranged from 0.244 mg/L to 0.78775 mg/L (Figure 29). Dodds and Welch (2000) have established a guideline for nitrogen in waterbodies of 0.9 mg/L. The average yearly TN levels did not exceed this at any lake or stream site.

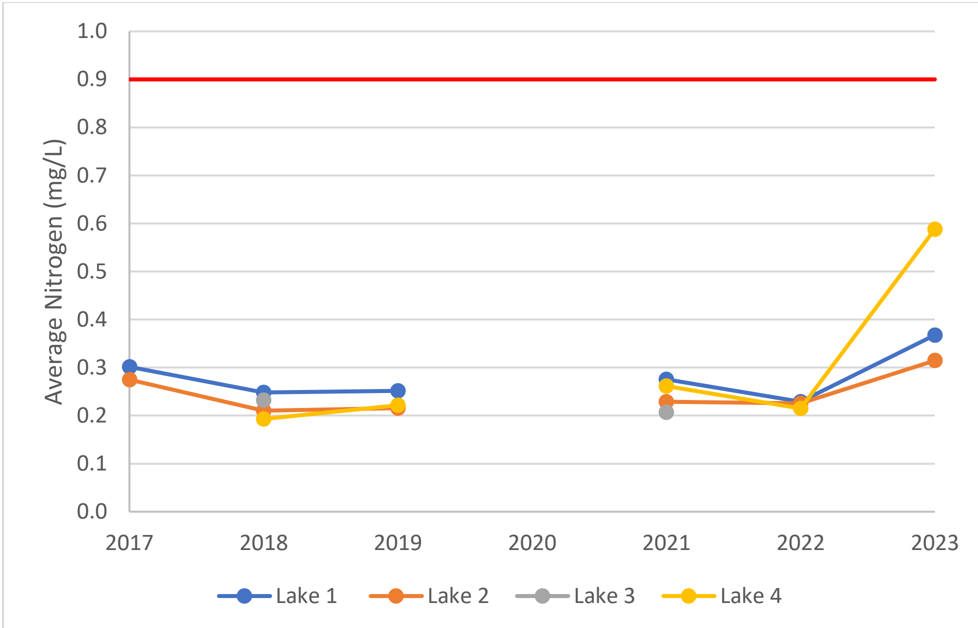

Figure 27. Average annual total nitrogen (mg/L) readings from the 2017 - 2023 summer month sampling events at the lake sites.

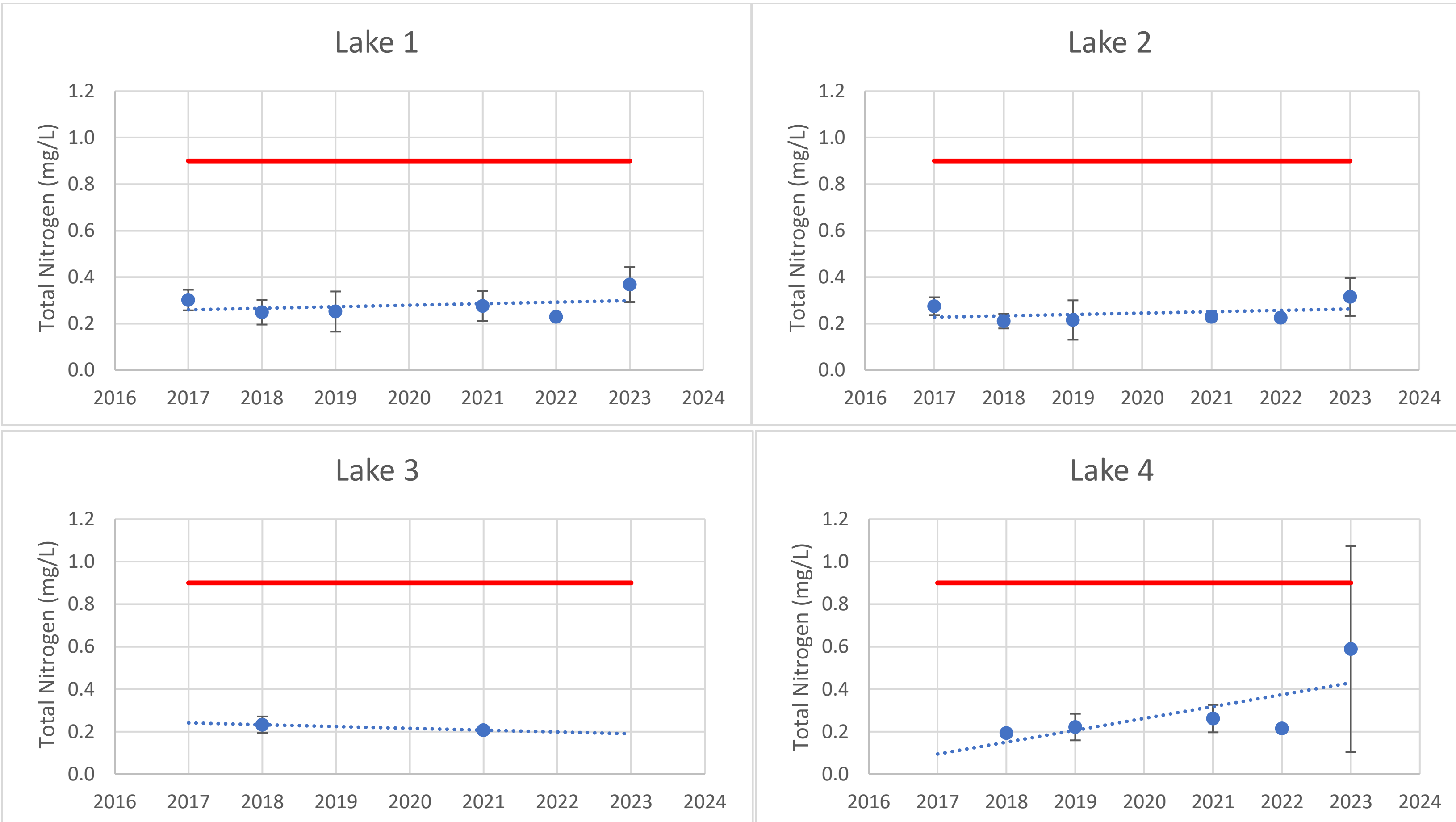

Figure 28. Average annual Total Nitrogen (mg/L) levels from the summer month sampling events at the lake sites. The red line indicates the Dodds and Welch guideline for nitrogen in lakes. Error bars indicate standard error. The blue dotted line indicates the trendline.

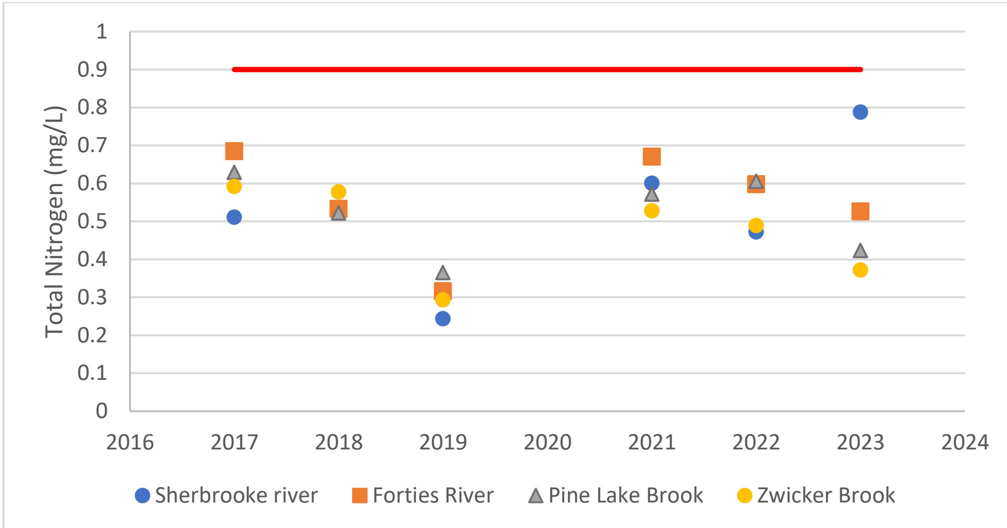

Figure 29. Average annual Total Nitrogen (mg/L) levels from the summer month sampling events at the stream sites. The red line indicates the Dodds and Welch guideline for nitrogen in streams.

During the yearly rainfall-dependent sampling, TN levels ranged from 0.355 mg/L to 0.883 mg/L (Figure 30).

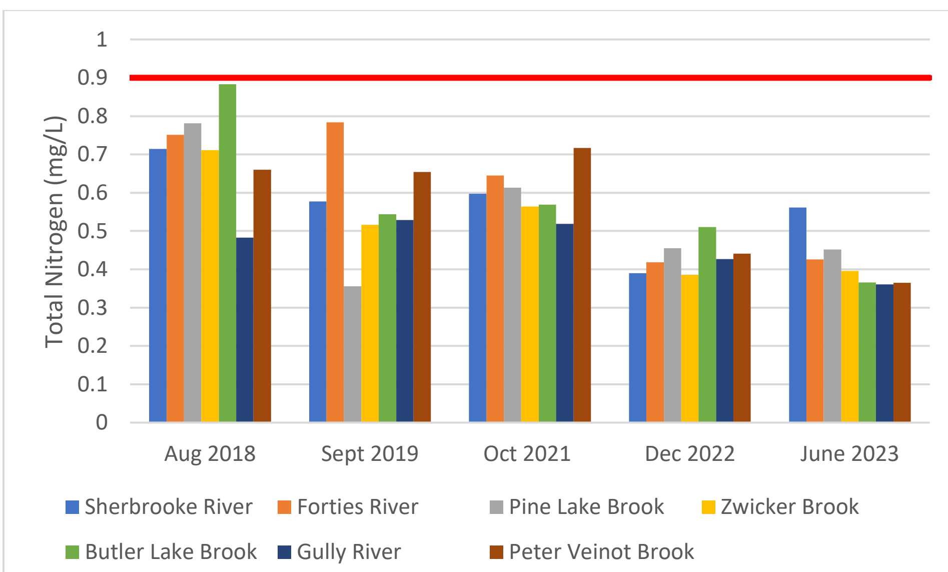

Figure 30. Total Nitrogen (mg/L) readings from the 2022 rainfall-dependent sampling event at the stream sites, including the additional, rainfall-specific sites. The red line indicates the Dodds and Welch guideline for nitrogen in streams.

Total Nitrogen concentrations were measured below the thermocline at Lake 1 and Lake 2 once annually. Lake 2 exceeded the Dodds and Welch guideline of 0.9 mg/L in 2021, while Lake 1 exceeded it in 2022 (Figure 31). Higher nitrogen concentrations below the thermocline in certain years may indicate a possible nutrient-enrichment event during fall turnover, with a potential for eutrophication and algal blooms.

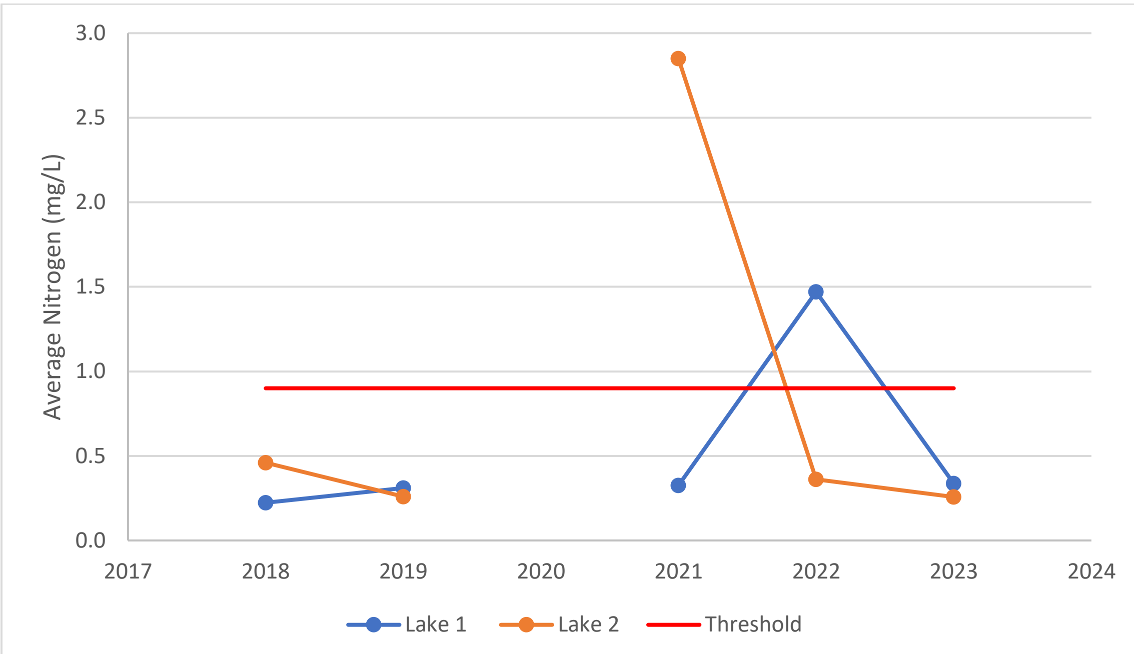

Figure 31. At-depth total nitrogen readings from the once-yearly sampling.

2.3 Biological Water Quality Parameters

2.3.1 Fecal Bacteria

In recreational waters, the presence of fecal pollution poses a risk to the public due to the potential presence of pathogenic microorganisms, which can infect humans and animals and cause serious illnesses. Fecal coliforms are a type of bacteria produced in the intestines of warm-blooded animals, while *E. coli* is a sub-group of fecal coliform. In 2017 and 2018, the bacteria analyzed were fecal coliforms and changed to the more specific *E. coli* readings in 2019. Fecal coliforms were previously used as a proxy for *E. coli*, with the assumption that 90% of fecal coliforms are *E. coli* in freshwater. In 2023, the Health Canada primary contact guideline for *E. coli* changed from ≤400 CFU/100 mL to ≤235 CFU/100 mL, based on new literature on human health and fecal bacteria (Health Canada 2023).

In 2017, fecal coliform at the lake sites was below detection levels (ND = ≤10 CFU/100 mL), and in 2018 ranged from <10 CFU/100 mL to 3.3 CFU/100 mL. From 2019 to 2023, the average yearly *E. coli* readings at the lake sites ranged from not detected (ND) to 30 CFU/100 mL. In July 2023, Lake 3 and 4 had the highest *E. coli* results of any lake site during the program at 60 CFU/100 mL and 90 CFU/100 mL respectively, remaining below Health Canada Guidelines.

The stream sites had consistently higher fecal coliform and *E. coli* results than the lake sites. The average fecal coliform readings from 2018 at the stream sites ranged from 76 CFU/100 mL to 185 CFU/100 mL (Figure 32). The average *E. coli* readings from 2019 to 2023 ranged from 2 CFU/100 mL to 160 CFU/100 mL (Figure 33).

All yearly average readings were below Health Canada's primary and secondary recreational contact guidelines for *E. coli* in freshwaters of ≤235 CFU/100 mL and ≤705 CFU/100 mL (Health Canada 2023). These primary contact activities are activities where the body, face, or trunk are submersed and it is likely water will be swallowed (Health Canada 2012).

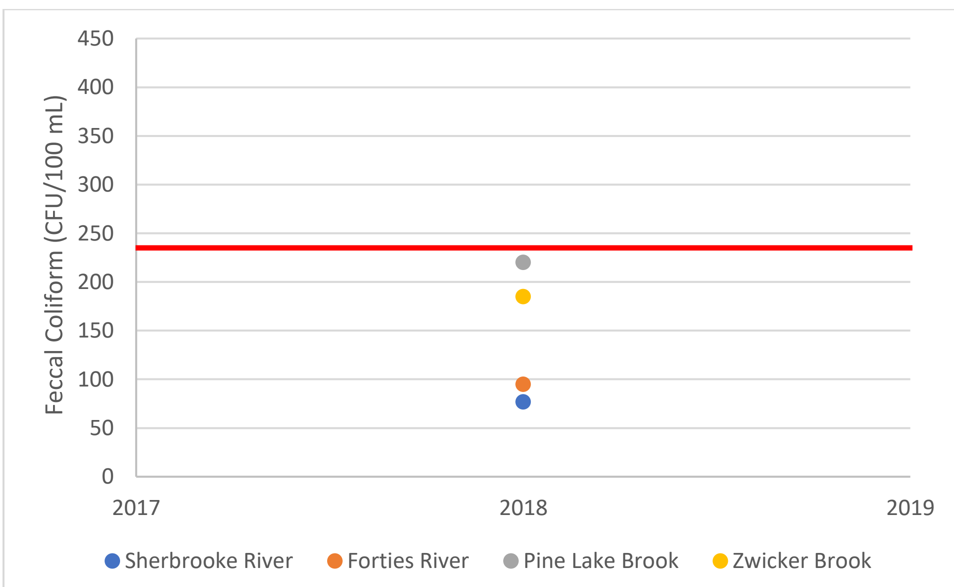

Figure 32. Average annual fecal coliform (CFU/100 mL) readings from the 2018 summer month sampling events at the stream sites. The solid red line indicates Health Canada's primary guideline of 235 CFU/100 mL.

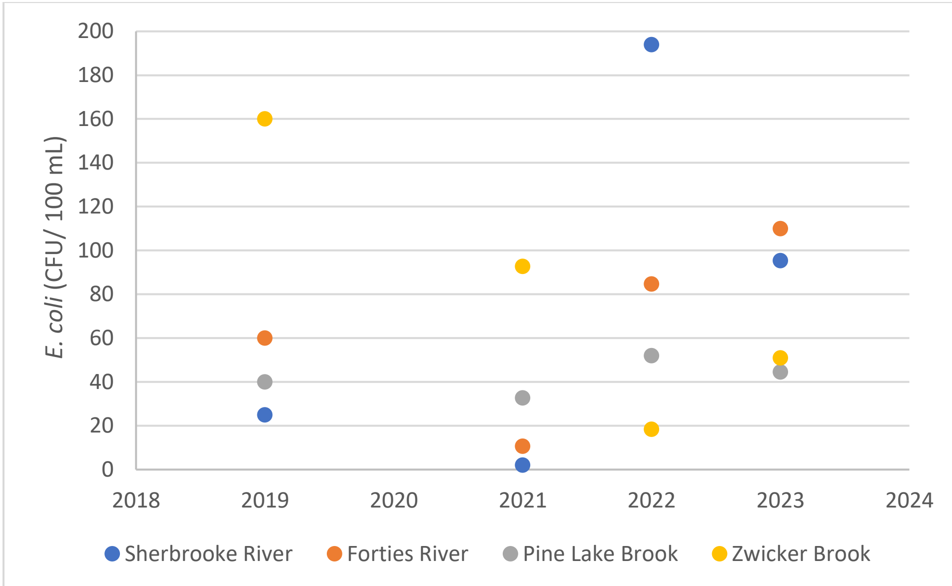

Figure 33. Average annual E. coli (CFU/100 mL) readings from the 2019 - 2023 summer month sampling events at the stream sites.

Fecal coliform concentrations during the 2018 rainfall-dependent sampling ranged from 10 CFU/100 mL to 350 CFU/100 mL (Figure 34). *E. coli* concentrations from the yearly rainfall-dependent sampling ranged from 20 CFU/100 mL to 720 CFU/100 mL (Figure 35). Forties River exceeded the Health Canada secondary recreational guideline in 2019. The primary guideline was exceeded by Sherbrooke River in 2019 and Peter Veinot Brook in 2022.

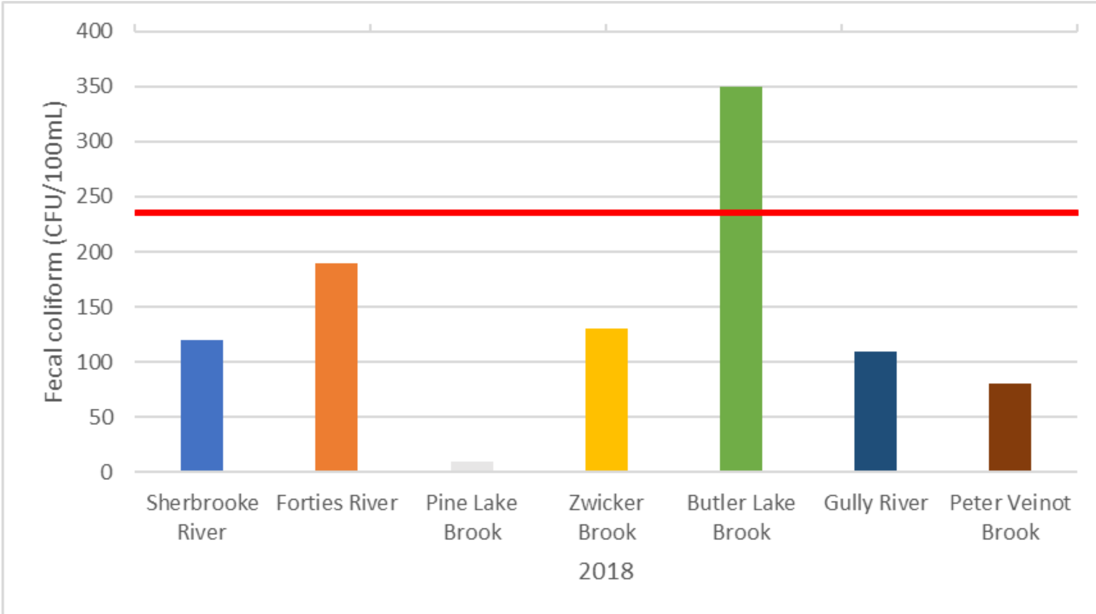

Figure 34. Fecal coliform (CFU/100 mL) readings from the 2018 rainfall-dependent sampling event at the stream sites. The red line indicates Health Canada's primary guideline of 235 CFU/100 mL.

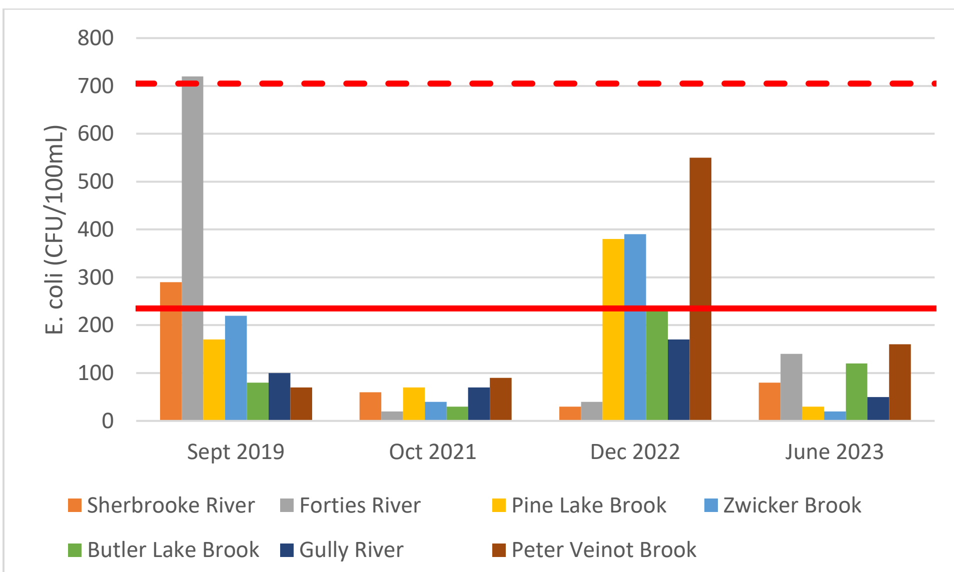

Figure 35. E. coli (CFU/100 mL) readings from the 2019 – 2023 rainfall-dependent sampling events at the stream sites, including the additional, rainfall-specific sites. The solid red line indicates Health Canada's primary recreational guideline of 235 CFU/100 mL and the dashed red line indicates Health Canada's secondary recreational guideline of 705 CFU/100 mL.

2.3.2 Microcystin-LR & Algal Blooms

The recreational guideline for total cyanobacterial toxins – Microcystin-LR is 10 µg/L (Health Canada 2022). This guideline is meant to protect against exposure to microcystins and other toxins that may be present in an algal bloom. The Health Canada guideline of 10 µg/L is for total microcystins, which includes dissolved microcystins present in the water and microcystins within the cyanobacteria cells (Health Canada 2022). Currently, microcystins are the only cyanotoxins with recreational guidelines, as there is a lack of data for the other toxins (Health Canada 2022).

Not all algal blooms are toxic cyanobacteria blooms, and Microcystin-LR is only one of the possible toxins in a cyanobacteria bloom. As well, For this reason, every algal bloom should be treated with caution and reported to the Nova Scotia Department of Environment and Climate Change (NSECC). Following a suspected bloom, recreational activities on the water should be treated with caution, as Microcystin-LR can persist in aquatic environments after a visible bloom has dissipated (Jones & Orr 1994).

During the five years of monitoring for this program, no algal blooms were sampled that contained microcystin.

In 2018, no blooms were reported, in 2019 a total of nine blooms were reported, and two were sampled and sent to Maxxam Analytics (now Bureau Veritas) to be tested, along with an algae sample sent to Dalhousie University to identify the species present. These blooms were below the detection level for microcystin and the dominant algae species in that sample was green algae – a non-toxic species. In 2020, sampling activities were paused due to the COVID-19 pandemic restrictions. A bloom was reported to NSECC in July 2020 but was not tested for microcystins. In 2021, one bloom was reported and sampled but contained no detectable microcystin. There was one potential bloom reported in 2022 and another in 2023 but each dissipated before it could be sampled.

2.4 Sediment Sampling

Sediment sampling at lake and stream sites occurred each year starting in 2018. The bottom substrate was analyzed for metals, phosphorus, and orthophosphate, to assess the risk of internal nutrient loading within the lake and the potential risk from the accumulation of metals within the sediments.

In 2018, Lake 2, Lake 3, and Forties River were sampled. From 2019 to 2023 (excluding 2020) Lake 1, Lake 2, and Lake 4 were sampled. The 2019 stream was Zwicker Brook, the

2021 stream was Sherbrooke River, the 2022 stream was Pine Lake Brook, and the 2023 stream was Zwicker Brook.

2.4.1 Metals

Three guidelines are used for sediment analysis; the CCME's recommended Interim Sediment Quality Guideline (ISQG), the CCME's Probable Effect Levels (PEL), and the Nova Scotia Environmental Quality Standards (NSEQS) contamination threshold.

Arsenic concentrations were noticeably high and exceeded the ISQG guidelines at all lake sites every year except at Lake 1 in 2021. Lake 2 had the highest recorded levels of arsenic, with 2018 and 2023 levels approaching the PEL and NSEQS guidelines. Increased arsenic levels reduce the abundance of benthic invertebrates, the main food source for many aquatic species (CCME 2002). Arsenic levels increased from 2021 to 2023 at Lakes 1 and 2, whereas Lake 4 had a slight decrease of 1.5 mg/kg from 2021 to 2022 and then a further 0.1 mg/kg decrease from 2022 to 2023 (Table 2).

Cadmium levels exceeded the ISQG guidelines at all lake sites in all years except at Lake 1 and Lake 2 in 2021. The highest cadmium concentration recorded was 1.5 mg/kg at Lake 3 in 2018. Like arsenic, cadmium reduces the abundance of benthic invertebrates and damages aquatic species, as exposure can reduce feeding behaviour, reproduction and growth rates, as well as cause mortality (CCME 1999a). However, cadmium levels are generally low at all sites and were not detected at any of the stream sites except Zwicker Brook in 2023. All cadmium readings fell below the probable effect levels. The highest concentration recorded only exceeded the ISQG guidelines by 0.9 mg/kg.

Lead levels exceeded the ISQG guideline in 2018, 2022, and 2023 at Lake 2, and 2023 at Lake 1. At Lake 1 in 2019, the ISQG guideline was approached but not exceeded with a level of 34 mg/kg. Lead levels at the stream sites were very low in all years, except 2023 which saw the highest of all stream sites, 29 mg/kg at Zwicker Brook. Lead can reduce the abundance of benthic invertebrates, and depending on the physicochemical conditions, can be harmful to other aquatic organisms (CCME 2002).

Mercury levels are relatively high at all lake sites. The ISQG guideline was either exceeded or approached at each lake site each year except Lake 4 in 2019. The level of mercury increased at each site from 2021 to 2023. Mercury was not detected at any of the stream sites, except for Zwicker Brook in 2023.

Selenium levels approached the NSEQS guideline at Lake 2 in 2018, 2021, and 2023, and at Lake 4 in 2021 and 2023. Selenium was undetected at any stream sites.

Of the stream sites, Zwicker Brook in 2023 was the only site with metal concentrations above or approaching guidelines (Table 3). Arsenic and cadmium exceeded ISQG guidelines, while mercury and zinc approached them.

See Table 4 for a summary of all exceedances of metals from 2018 to 2023.

Table 2. Concentrations of acid extractable metals within lake site sediment samples. All metals are acid extractable except for Orthophosphate. All units are mg/kg. Light yellow indicates parameters approaching one of the guidelines, orange indicates an exceedance of ISQG, and red indicates an exceedance of either the PEL or NSEQS guidelines.

	Lake 1				Lake 2					Lake 3	Lake 4				Concentration Guidelines		
Metals	**2019**	**2021**	**2022**	**2023**	**2018**	**2019**	**2021**	**2022**	**2023**	**2018**	**2019**	**2021**	**2022**	**2023**	**ISQG**	**PEL**	**NS**
Aluminum (Al)	22000	12000	18000	1900	22000	25000	16000	18000	24000	6700	7200	22000	20000	20000			
Antimony (Sb)	ND	ND	<2 (ND)	<2 (ND)	ND	ND	ND	<2 (ND)	<2 (ND)	ND	ND	ND	<2 (ND)	<2 (ND)			25
Arsenic (As)	8.4	4.8	6.8	8.6	16	12	6.8	12	16	8.3	8.1	9.8	8.3	8.2	5.9	17	17
Barium (Ba)	49	26	42	46	42	50	30	35	44	26	17	35	33	38			
Beryllium (Be)	ND	ND	1.5	1.5	ND	2.1	ND	1.6	2	ND	ND	ND	1.5	1.7			
Bismuth (Bi)	ND	ND	<2 (ND)	<2 (ND)	ND	ND	ND	<2 (ND)	<2 (ND)	ND	ND	ND	<2 (ND)	<2 (ND)			
Boron (B)	ND	ND	<50 (ND)	<50 (ND)	ND	ND	ND	<50 (ND)	<50 (ND)	ND	ND	ND	<50 (ND)	<50 (ND)			
Cadmium (Cd)	0.76	0.31	0.69	0.78	1	0.99	0.46	0.81	1.4	1.5	0.76	0.63	0.66	0.82	0.6	3.5	3.5
Chromium (Cr)	15	8	13	14	14	14	8.7	11	16	4.6	5.1	14	12	13	37.3	90	90
Cobalt (Co)	9	4.3	5.7	7.3	8.8	11	5.2	5.7	7.7	6.8	4.1	6.6	6.2	6			
Copper (Cu)	12	6	9.3	10	15	10	6.1	8.7	13	13	3.1	9.5	8.4	9.4	35.7	197	197
Iron (Fe)	14000	6600	9300	11000	14000	15000	9100	11000	14000	10000	9400	9000	8400	9200			47766
Lead (Pb)	34	8.8	30	37	49	24	8	43	97	13	13	8.9	17	28	35	91.3	91.3
Lithium (Li)	17	8	15	16	10	9.7	4.9	8.9	12	11	14	13	12	14			
Manganese (Mn)	540	230	260	370	480	1300	430	380	460	1000	290	460	420	360			1100
Mercury (Hg)	0.27	0.15	0.25	0.34	0.27	0.2	0.12	0.21	0.35	0.16	ND	0.12	0.14	0.2	0.17	0.486	0.486
Molybdenum (Mo)	ND	ND	<2 (ND)	<2 (ND)	ND	2	ND	<2 (ND)	<2 (ND)	ND	ND	2	<2 (ND)	<2 (ND)			
Nickel (Ni)	10	4.9	8	9.3	7.5	6.9	4.3	5.8	9.4	5.7	4.6	8.7	7.2	8.5			75
Phosphorus (P)	1900		1600	1700	1900	2200		1600	1700	400	490		1700	1600			
Rubidium (Rb)	11	5.9	9.5	11	6.3	6.2	3.5	5.2	7.8	4.7	5.5	7	6.5	7.9			
Selenium (Se)	1.3	0.89	1.2	1.4	1.8	1.8	1.1	1.5	1.9	ND	ND	1.7	1.5	1.6			2

Silver (Ag)	ND	ND	<0.5 (ND)	<0.5 (ND)	ND	ND	ND	<0.5 (ND)	<0.5 (ND)	ND	ND	ND	<0.5 (ND)	<0.5 (ND)			1
Strontium (Sr)	13	6.1	9.3	11	13	13	8.1	9.6	12	ND	ND	8.7	7.8	8.5			
Thallium (Tl)	0.26	0.13	0.18	0.21	0.26	0.24	0.13	0.17	0.23	0.34	0.11	0.31	0.21	0.2			
Tin (Sn)	2.5	ND	2	2.7	3	1.5	ND	2.1	4.5	2	ND	ND	1.1	1.6			
Uranium (U)	4.3	2.6	3.5	3.8	5.7	6.5	3.7	4.3	5.9	1.7	2	7.3	5.7	5.9			
Vanadium (V)	23	12	17	19	30	34	21	25	39	11	12	24	22	24			
Zinc (Zn)	87	46	71	83	93	89	48	70	120	96	66	110	100	110	123	315	315
Orthophosphate (P)	0.15	0.39	0.51	0.11	0.067	0.086	0.27	0.24	0.1	0.26	0.24	0.24	0.26	0.088			

Table 3. Concentrations of metals within stream site sediment samples.

	UNITS	Forties River	Zwicker Brook	Sherbrooke River	Pine Lake Brook	Zwicker Brook	Concentration Guidelines		
Metals		**2018**	**2019**	**2021**	**2022**	**2023**	**ISQG**	**PEL**	**NS**
Acid Extractable Aluminum (Al)	mg/kg	4300	4700	3300	730	1100			
Acid Extractable Antimony (Sb)	mg/kg	ND	ND	ND	ND	<2 (ND)			25
Acid Extractable Arsenic (As)	mg/kg	2.7	ND	ND	ND	9.6	5.9	17	17
Acid Extractable Barium (Ba)	mg/kg	26	18	18	ND	82			
Acid Extractable Beryllium (Be)	mg/kg	ND	ND	ND	ND	1.2			
Acid Extractable Bismuth (Bi)	mg/kg	ND	ND	ND	ND	<2 (ND)			
Acid Extractable Boron (B)	mg/kg	ND	ND	ND	ND	<50 (ND)			
Acid Extractable Cadmium (Cd)	mg/kg	ND	ND	ND	ND	1.3	0.6	3.5	3.5
Acid Extractable Chromium (Cr)	mg/kg	4.7	4	4	ND	9.6	37.3	90	90
Acid Extractable Cobalt (Co)	mg/kg	2.3	2.2	1.9	ND	23			
Acid Extractable Copper (Cu)	mg/kg	ND	4.2	ND	ND	12	35.7	197	197
Acid Extractable Iron (Fe)	mg/kg	8300	6800	5800	1200	15000			47,766
Acid Extractable Lead (Pb)	mg/kg	3.3	3.3	4.2	1	29	35	91.3	91.3
Acid Extractable Lithium (Li)	mg/kg	20	21	16	4.1	25			
Acid Extractable Manganese (Mn)	mg/kg	200	110	150	40	3200			1,100
Acid Extractable Mercury (Hg)	mg/kg	ND	ND	ND	ND	0.15	0.17	0.486	0.486
Acid Extractable Molybdenum (Mo)	mg/kg	ND	ND	ND	ND	<2 (ND)			
Acid Extractable Nickel (Ni)	mg/kg	2.3	3.1	2.2	ND	7.7			75
Acid Extractable Phosphorus (P)	mg/kg	180	190		ND	920			
Acid Extractable Rubidium (Rb)	mg/kg	17	7.8	11	3.1	11			
Acid Extractable Selenium (Se)	mg/kg	ND	ND	ND	ND	0.95			2

Acid Extractable Silver (Ag)	mg/kg	ND	ND	ND	ND	<0.5 (ND)			1
Acid Extractable Strontium (Sr)	mg/kg	ND	ND	ND	ND	31			
Acid Extractable Thallium (Tl)	mg/kg	0.12	ND	ND	ND	0.16			
Acid Extractable Tin (Sn)	mg/kg	ND	ND	ND	ND	1.6			
Acid Extractable Uranium (U)	mg/kg	0.52	0.77	0.46	0.17	8.2			
Acid Extractable Vanadium (V)	mg/kg	11	9	7.3	ND	22			
Acid Extractable Zinc (Zn)	mg/kg	20	34	20	ND	120	123	315	315
Orthophosphate (P)	mg/kg	0.28	0.38	0.36	0.79				

Table 4. Summary of guideline exceedances of acid extractable metals in sediment samples. Light yellow indicates parameters approaching one of the guidelines, orange indicates an exceedance of the ISQG, and red indicates an exceedance of either the PEL or NSEQS guidelines. Units are all mg/kg.

	Lake 1				**Lake 2**					**Lake 3**	**Lake 4**				**Zwicker Brook**
Metals	**2019**	**2021**	**2022**	**2023**	**2018**	**2019**	**2021**	**2022**	**2023**	**2018**	**2019**	**2021**	**2022**	**2023**	**2023**
Arsenic (As)	8.4	4.8	6.8	8.6	16	12	6.8	12	16	8.3	8.1	9.8	8.3	8.2	9.6
Cadmium (Cd)	0.76	0.31	0.69	0.78	1	0.99	0.46	0.81	1.4	1.5	0.76	0.63	0.66	0.82	1.3
Lead (Pb)	34	8.8	30	37	49	24	8	43	97	13	13	8.9	17	28	29
Mercury (Hg)	0.27	0.15	0.25	0.34	0.27	0.2	0.12	0.21	0.35	0.16	ND	0.12	0.14	0.2	0.15
Selenium (Se)	1.3	0.89	1.2	1.4	1.8	1.8	1.1	1.5	1.9	ND	ND	1.7	1.5	1.6	0.95
Zinc (Zn)	87	46	71	83	93	89	48	70	120	96	66	110	100	110	120

2.4.2 Sediment Phosphorus and Orthophosphate

Concentrations of both acid-extractable (total) phosphorus and bioavailable orthophosphate in sediment were analyzed from 2018 to 2023 (Figures 36 and 37). Orthophosphate was not included in the 2023 sample due to a small sample size.

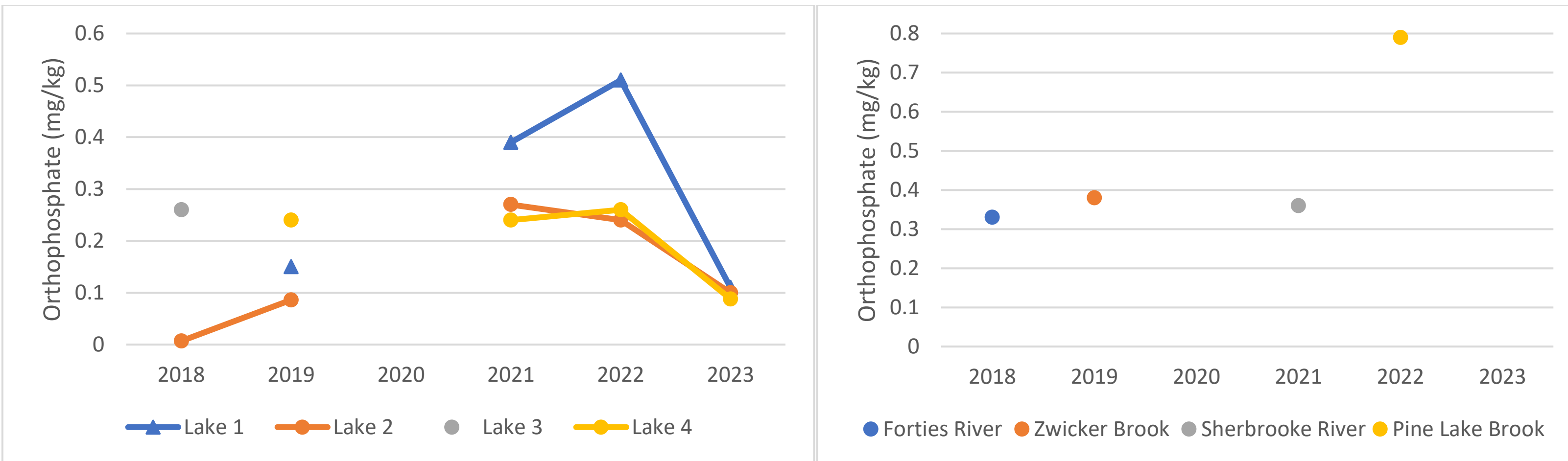

Figure 36. Orthophosphate from sediment samples from 2018 to 2023. 2023 was not included in the stream sites due to the small sample size.

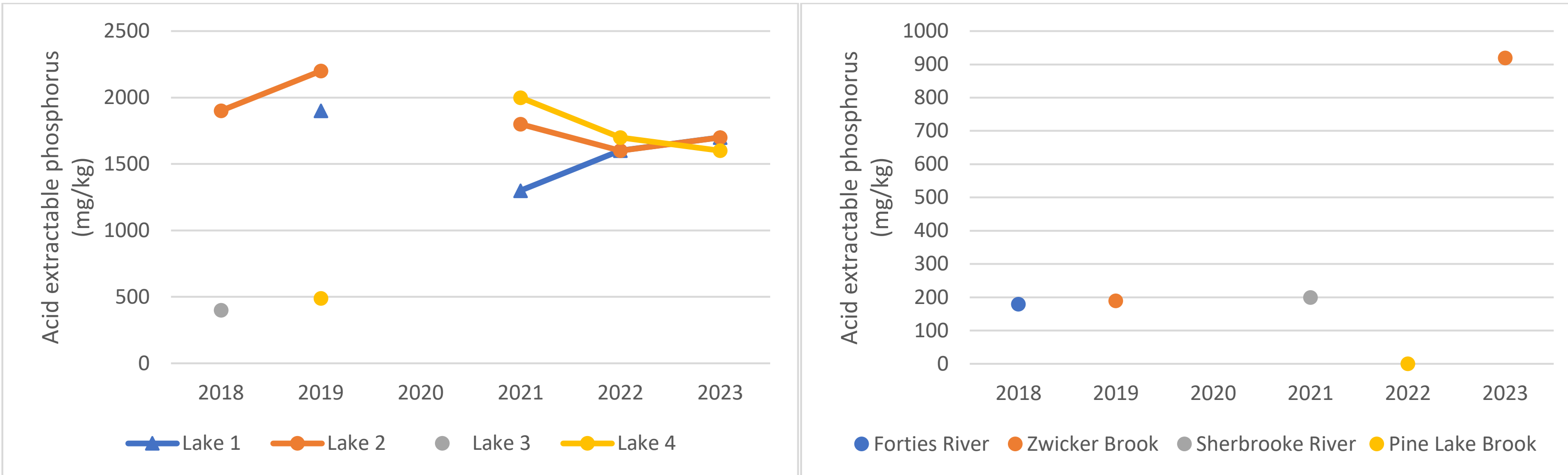

Figure 37. Acid extractable phosphorus (mg/kg) from the 2018 to 2023 sediment samples. 2022 at Pine Lake Brook was below detection levels.

Orthophosphate levels at the lake sites spiked in 2021 and 2022 and then decreased at all sites in 2023. The sample results from Pine Lake Brook showed higher levels of orthophosphate than the three other stream sites. According to Ontario's provincial sediment quality guidelines, pollution can range from clean/marginally polluted ('lowest effect level') at 600 mg/kg of phosphorus to heavily contaminated ('severe effect level') at >2000 mg/kg of phosphorus in sediment (MOE 2008). These guidelines have previously been approached and exceeded at Lake 1, Lake 2, Lake 4, and Zwicker Brook in 2023, but not Lake 3 or other sample sites.

Orthophosphate is a bioavailable form of phosphorus that tends to be in lower concentrations due to high demand by plants; however, as plants decompose, orthophosphate is released back into the environment (CCME 2004). For phosphorus held into complexes with metals, anoxic conditions facilitate the dissolution of complexes and release of phosphorus from sediments (Hayes et al. 1985). Increased levels of phosphorus released from sediments into the water (internal phosphorus loading) can cause nutrient-enrichment and potential eutrophication and algal blooms (Søndergaard et al. 2003). This is particularly susceptible during a turnover when nutrient-rich bottom waters are mixed throughout the lake, providing new food sources for organisms.

3.0 Discussion

3.1 Baseline Data

Baseline studies are often short-term studies used to provide contextual information for environmental assessments or to collect a snapshot of water quality to determine if future activities could be a threat. The objective of this program was to collect baseline information about water quality at Sherbrooke Lake before the development of a public access point. This study provided five years of baseline data from the summer months and does not account for water quality conditions year-round. The additional data from 2017 was also included where relevant, as it was the preliminary baseline data for the study. Sampling times were not consistent in the later years of the program, as changes to the program were made to reflect the data and scientific advice as well as volunteer availability. During this program, several extreme weather events influenced sampling dates and may have influenced water quality results including droughts, hurricanes, tropical storms, and flooding. Due to the limited amount of data collected through the study, only basic statistics were performed for the water quality parameters to avoid skewed and unreliable trends which may not represent the actual conditions within the lake.

3.2 Lake Water Quality

The water quality results did not identify any apparent issues over the five years of this program. Some water quality trends to note include temperature and dissolved oxygen; these are both important for the productivity of an aquatic environment. The average surface temperature at the lake sites shows an upward trend; however, due to the limited dataset collected, robust statistical analyses were not run to avoid skewed or biased results. The time of sample collection can influence parameters such as temperature and dissolved oxygen which are closely related, as water temperature tends to be higher during the day and cooler at night. Sampling during heat waves, which occurred during this project, could also influence the data. Also, the time of year samples were taken could influence temperature (i.e., sampled early June 2018 but late June 2019). Continuous monitoring using in-situ temperature loggers would provide more accurate trend estimates.

Dissolved oxygen concentrations are influenced by water temperature, as oxygen is less soluble in warm water, and during spring and summer, there are increased metabolic rates that affect biochemical oxygen demand (BOD), photosynthesis, and respiration in aquatic plants (MPCA 2009). This is shown in the slight decline of surface dissolved oxygen at the lake sites as temperature increased. In the last three years, the average surface temperatures have surpassed the threshold of 20^0C for coldwater species, like trout and salmon (NSSA 2014). However, surface dissolved oxygen levels at the lake sites remained above the threshold for aquatic life throughout this project.

pH levels had a slight upward trend from 2018 to 2023, at all lake sites except Lake 3. This could be due to regulations that reduced the amount of acid rain Nova Scotia experiences, and the soil beginning to restore base cation concentrations. Between the initial investigative work in 2017 and 2023, the average pH at Lake 1 increased by 0.27, 0.32 at Lake 2, 1.41 at Lake 4, and declined by 0.60 at Lake 3. The average pH at most sites increased to be closer to the CCME threshold of 6.5. This is beneficial for aquatic and human health, as pH can influence the solubility and bioavailability of certain metals. Mercury tends to be more bioavailable in waterbodies with lower pH, resulting in elevated mercury in fish tissues as it biomagnifies in the food web (Jardine et al. 2013). Similarly, aluminum is more soluble at pH 4.0 and can bind to fish gills, impacting respiration and causing mortality (Mani 2003). As aquatic species often have pH thresholds for survival, this increase in pH could improve reproduction of existing sensitive species such as trout, and improve biodiversity in the area (USEPA 2023).

Total phosphorus (TP) is typically the most important nutrient for controlling plant growth, which includes algae. TP concentrations show a slight decline at the lake sites. Nitrogen concentrations have shown a slight increase at the lake sites, but all nutrient concentrations have remained below the thresholds for the duration of this monitoring. The at-depth nutrient concentrations spiked in Lake 2 in 2021 but remained low during all other sampling events. This spike in nutrients is an anomaly in the data and suggests at-depth nutrient enrichment at Lake 2 during this period.

Throughout this monitoring period, the average concentration of smaller particles in the water column (total dissolved solids) had a downward trend, while larger particles (total suspended solids) had an upward trend. These concentrations can be influenced by soil erosion, dead organic material, significant rainfall events, flooding, and runoff. This is an important parameter for monitoring the impacts of future lake-shore development.

The trends of low bacteria and nutrient levels and the oligotrophic-mesotrophic state of the lake suggest that pollution is minimal at Sherbrooke Lake.

Heavy metal concentrations in the sediment may be naturally occurring or due to historic pollution. Uranium and arsenic are naturally occurring pollutants across Nova Scotia, with Sherbrooke Lake being at high risk for contamination for both (Kennedy & Drage 2017; Kennedy & Drage 2020). Uranium is often accompanied by heavy metal pollution, such as cadmium, copper, lead, manganese, and zinc (Zhang et al. 2023). Mercury was also elevated in sediment, which can naturally occur from geologic processes or anthropogenic sources like coal-fired plants, combustion of plant biomass such as fires or biofuel use (Falandysz et al. 2020). Heavy metals in sediment can pose a threat to human and ecological health, as they biomagnify within food webs. For guidelines on fish consumption in Nova Scotia regarding pollutants, visit the consumption advisory at https://novascotia.ca/nse/fish-consumption-advisory.asp. Water depth and slope are associated with increased metal concentrations due to the funnelling of particles towards deeper lake-bottom pockets (Håkanson 1977). This was seen in SL, as Lake 2 is the deepest section of the lake and had the most exceedances for metal guidelines. Generally, sediment in aquatic systems has higher concentrations of heavy metals than the water column itself (Luoma, 1989), but for more information on drinking water visit Nova Scotia Environment at https://novascotia.ca/nse/water/docs/Drop_on_Water_English.pdf .

3.3 Stream Water Quality

No apparent water quality issues were identified at the tributary sites over the five years of the program. Similar trends were observed at the lake and stream sites. The average yearly temperatures show an upward trend at the stream sites; however, unlike the lake, two of the stream sites (Pine Lake Brook and Sherbrooke River) showed a slight increase in average dissolved oxygen. The stream sites showed trends of increasing pH values over the five years. The tributaries had much greater increases in pH than the lake sites, with Sherbrooke River increasing by 0.38, Forties River by 1.77, Pine Lake Brook by 1.97, and Zwicker Brook by

1.44. The increase in pH at the stream sites could improve overall stream health and improve biodiversity (USEPA 2023).

Although bacteria levels were higher at the tributaries than at the lake, test results rarely surpassed the primary recreational guidelines. Despite elevated bacteria at some stream sites, it is unlikely impacting the lake sites as the lake bacteria remained low throughout the program.

During the regular monthly or bi-monthly sampling, the stream sites showed similar water quality results to the lake. This suggests that the tributaries to the lake are not significantly impacting the water quality of the lake.

Rainfall events increased the bacteria levels and total dissolved solids at the tributaries. After the rainfall events, Butler Lake consistently had the highest TDS readings of all the tributary sites, which could be due to land use around the waterbody, as several main roads cross over this brook.

3.4 Cyanobacteria Blooms in Sherbrooke Lake

NS Environment and Climate Change's current system of notifying lake residents of potentially harmful algae blooms is reactive and can be ineffective. NSECC responds to reports of suspected blooms but inspectors are not always able to respond in time to witness the bloom. NSECC rarely collects water samples for analysis and often has to post precautionary advisories based on the appearance of a bloom in photographs provided by residents. Lake closure advisories are posted via Twitter and other online locations.

Microcystin-LR is not the only toxin produced by cyanobacteria. Anatoxins, Cylindrospermopsins, Nodularins, Saxitoxins, Dermatoxtoxins, and other irritant toxins are also produced by cyanobacteria (Health Canada 2022). The majority of commercial labs in Canada do not test for these toxins and there are no recreational guidelines for cyanotoxins other than microcystins (Health Canada 2022). This means that the absence of Microcystin-LR in a water sample does not mean that a bloom does not contain other toxins. Because of this, lake residents should be made aware of all blooms and treat all blooms with the same level of caution. Although the blooms sampled at Sherbrooke Lake throughout this program did not contain detectable levels of microcystin, it is important to be aware of the potential toxins and impacts of cyanobacteria.

As algal blooms can be induced and intensified by increases in nutrients to ecosystems (whether naturally from the mixing of waters or anthropogenically from pollution), trends in algal blooms are hard to predict and can vary spatially. The literature predicts increases in both the size and frequency of blooms, globally, in the future (Michalak et al. 2013). Although the overall nitrogen and phosphorus levels remain low, residents near freshwater should be made aware of algal bloom causes, health effects, precautions to take, and the reporting procedure if a bloom occurs.

In 2021, Coastal Action implemented a pilot study to detect algal blooms through regular monitoring of phycocyanin and chlorophyll-α. Four sampling days were carried out in July, August, and October of 2021. During three of the sampling days, water samples were collected for both microcystin and chlorophyll-α analysis. Water samples were collected on a fourth day in October when an algae bloom was detected by lake residents. Depth profiles using the municipal YSI, and Secchi disk readings were also taken on three of the sampling days.

A total of eight water samples were collected across the four sampling days, seven baseline samples, and one bloom event. All seven baseline days showed no detected microcystin and low levels of chlorophyll-α ranging from 3.01 μg/L to 9.42 μg/L. The bloom event yielded no microcystin but elevated chlorophyll-α levels of 123 μg/L. This result shows that there was indeed a bloom on October 10, 2021, but it likely did not consist of blue-green algae. This pilot study did not yield usable data due to the sporadic water and YSI sampling.

3.5 Trophic State of Sherbrooke Lake

The biological productivity of SL has been assessed and monitored for changes over time by identifying its trophic state annually. Based on the mean depth of transparency (Secchi disk), and mean concentrations of chlorophyll-α and phosphorus, a Trophic State Index (TSI) score can be calculated using the Carlson (1977) equations (Equations 1, 2, and 3). Trophic states range from oligotrophic (low productivity and minimal biomass) to hypereutrophic (high productivity and maximum biomass).

$$\textit{Equation 1:}\ TSI\ (Secchi\ disk) = 60 - 14.41 \times ln(Mean\ Secchi\ disk\ [m])$$

$$\textit{Equation 2:}\ TSI\ (Chlorophyll\ a) = 30.6 + 9.81 \times ln(Mean\ Chlorophyll\ a\ \left[\frac{\mu g}{L}\right])$$

$$\textit{Equation 3:}\ TSI\ (Total\ Phosphorus) = 4.15 + 14.42 \times ln(Mean\ Total\ Phosphorus\ \left[\frac{\mu g}{L}\right])$$

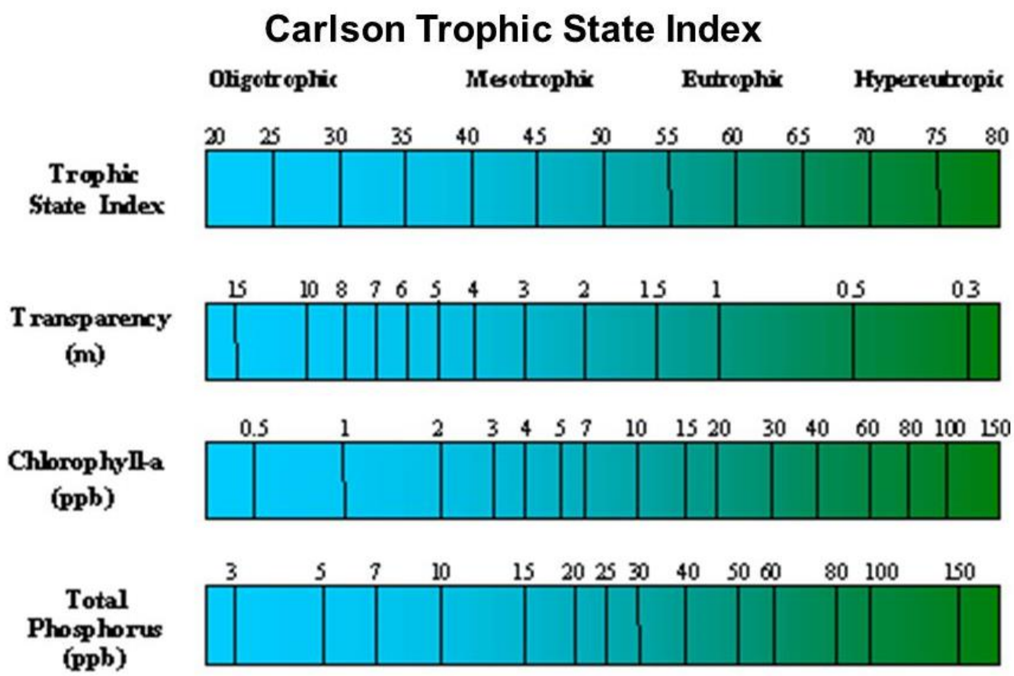

Figure 38. Carlson Trophic State Index parameters (Carlson 1977).

The trophic state of SL has remained oligotrophic-mesotrophic from 2018 to 2023; ranging from 39.11 to 42.44. SL appears to be maintaining a steady TSI score over the five years this data has been collected (Figure 39). The oligotrophic-mesotrophic state of SL indicates moderate biological productivity. A slight increase in TSI in 2023 could be the result of lower Secchi disk readings. The average total suspended solids and chlorophyll-α readings were higher in 2023 compared to previous years, which correlates with reduced visibility for Secchi disk readings. Secchi depth readings are highly influenced by several factors; therefore, the TSI score for Total Phosphorus should be considered the most accurate reflection of biological productivity in SL.

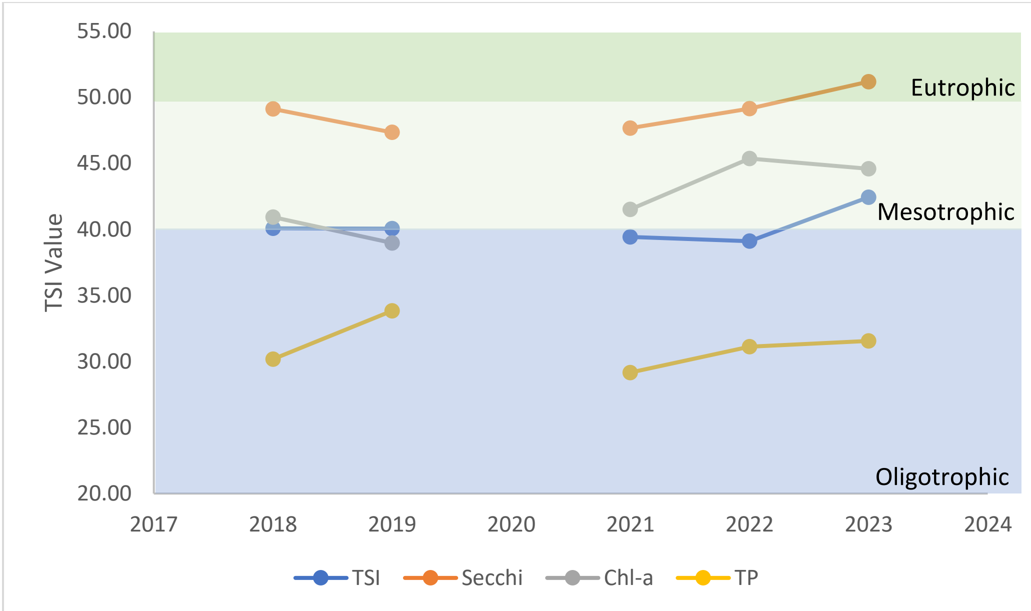

Figure 39. Comparison of Lake site TSI scores from 2018 to 2023 using the Carlson (1977) trophic equations for total phosphorus, chlorophyll-α, and Secchi disk (2020 excluded).

4.0 Conclusions

Overall, the water quality at Sherbrooke Lake and its tributaries showed no apparent issues over the five years of this project, but trends should continue to be monitored. This baseline study provides information on the current water quality trends of the lake, that could be used to assess the impacts of future developments.

Although the upward trend of temperature at the lake sites could be attributed to other factors, the temperature of the lake and its tributaries should continue to be monitored. Factors that can influence temperature include weather conditions, time of sampling, and consistency of sampling (i.e., the same months and time of day sampled). Continuous monitoring using in-situ temperature loggers would provide more accurate trend estimates for the lake surface temperature. If water temperatures are increasing, this could make the lake’s ecosystem more vulnerable to other changes, as many organisms have sensitive temperature thresholds which dictate their survival. Increasing temperatures could also contribute to cyanobacteria blooms, as they tend to grow in warm, slow-moving waters with high levels of nutrients (Nova Scotia 2023).

pH levels show a slight increasing trend over the years. This could be showing that the soils are beginning to recover from acid rain deposition, and increasing their buffering capacity.

If this trend continues, it could benefit aquatic species such as trout, and improve biodiversity in the area (USEPA 2023).

Metals concentrations in sediment from most of the lake sites exceeded guidelines. Heavy metals can biomagnify within food webs, which can impact human health if contaminated fish are consumed. For consumption guidelines of fish visit https://novascotia.ca/nse/fish-consumption-advisory.asp. For information on drinking water guidelines visit Nova Scotia Environment at https://novascotia.ca/nse/water/docs/Drop_on_Water_English.pdf.

While microcystins were not detected in algae blooms tested at Sherbrooke Lake from 2017 to 2023, residents should continue to be diligent in monitoring for cyanobacteria blooms and exercise caution with water-based recreation when there is a suspected bloom. Suspected blooms should be reported to the local Nova Scotia Environment and Climate Change (NSECC) office, or at the general NSECC phone number 1-877-936-8476.

Parameters that are commonly impacted by development (i.e., temperature, dissolved oxygen, total suspended and dissolved solids, nutrients, and bacteria) should be monitored in the future to determine if increased residential development on the lake shores and tributaries is impacting water quality. MOC has a by-law of 20m vegetated buffer from the high-water mark for waterbodies, while MODL has no current standardized vegetative buffer regulations.

Additional risks to Sherbrooke Lake include invasive species. Invasive species can be transported on watercraft or other gear, so it is important to always clean, drain, and dry equipment before entering a new water body. To learn more about aquatic invasive species or to report invasive species sightings, visit the Nova Scotia Invasive Species Council website https://nsinvasives.ca/. Increased boat traffic on the lake could increase the risk of invasive species transport, as well as an increased risk of pollutants from fuel spills. A spill kit should be carried on any motorized watercraft.

While this study showed no apparent water quality issues, residents should be aware of how land-use practices impact water quality and the occurrence of cyanobacteria blooms. Implementing good land-use practices can help to maintain or improve the water quality trends observed in this baseline study.

5.0 Call to Action

Sherbrooke Lake is considered generally healthy but vulnerable to change. Human activities such as fertilizing lawns, removing vegetative buffers between lawns and the lake, and improper management of septic fields can all impact the lake's water quality. Currently, Sherbrooke Lake's nutrient status is at the low end for freshwater lakes. This is encouraging news, but only through continued vigilance will that situation continue in the face of increasing development and alteration of the lake's shoreline and surrounding watershed.

Some good land-use practices to maintain healthy waterways include leaving or implementing a natural vegetative buffer strip between the waterway and development. Native plants along the shoreline can help stabilize the soil to prevent erosion, reduce runoff from rainfall, and reduce the amount of nutrients entering the waterway; all of which improve the health of the ecosystem. This buffer strip can also provide habitat for songbirds, provide temperature control of the water, and benefit pollinator species. For a list of native plants in Nova Scotia visit the Nova Scotia Invasive Species Council "Plant Wise" page at https://nsinvasives.ca/wp-content/uploads/2023/07/CCIS-NSISC-Grow-Me-Instead-Guide_2023_EN_web.pdf. For additional information on sustainable and resilient shoreline management, visit the TransCoastal Adaptations webpage on GreenShores, https://www.transcoastaladaptations.com/green-shores.

To reduce nutrients entering waterways, homeowners can reduce or eliminate fertilizing lawns. Ensuring your septic system is regularly maintained and pumped can also help reduce the amount of bacteria and nutrients entering waterways. Similarly, properly storing or disposing of manure or waste piles from animals including pets and livestock can reduce the amount of nutrients and bacteria in the water.

Motorized watercraft can also impact local waterways. Carry a spill kit on motorized watercraft to contain and clean up any unexpected fuel spills. To reduce the spread of aquatic invasive species, ensure that you are properly cleaning, draining, and drying any equipment (watercraft, waders, etc.) before entering a new water body.

Discuss with your neighbours and friends what you're doing to promote healthy freshwater ecosystems, as protecting and conserving our freshwater is a community effort.

Table 5. What homeowners can do to reduce the occurrence of cyanobacteria blooms and maintain healthy waterways.

WHAT YOU CAN DO

N = Nitrogen P = Phosphorus S = Sediment

Action	Benefits	What is reduced
Leave a natural vegetative buffer along lake, stream, ditch, or other waterway.	Grass or wood buffers help filter pollutants and reduce flood damage. This can also help to reduce occurrences of algae blooms.	N P S
Remember to inspect and pump your septic every 3-5 years.	A properly maintained septic system prevents costly repairs and untreated sewage discharge into our streams.	N P S
Plant a rain garden or install a rain barrel.	Rain gardens and rain barrels help reduce stormwater runoff and can cut down on landscaping costs.	N P S
Follow the 4 Rs of fertilizer use: right source, right amount, right place and right time.	The 4 Rs approach promotes the wise use of fertilizer by farmers, residents, and landscapers to reduce costly nutrient loss that pollutes our streams.	N P
Plant cover crops.	Cover crops build healthy soils that help hold back nutrients and water and increase crop yields.	N P S
Install a drainage management system.	Managing field drainage reduces nutrient loss while saving water for when your crops need it most.	N P
Properly manage livestock and pet waste.	Properly storing and disposing of animal waste reduces nutrients and prevents harmful bacteria from entering local waters.	N P
Help your community develop a plan that supports low impact development.	Smart development fosters growth and protects the local resources and character of the community.	N P S

This table is adapted from the March 2014 Mills Creek Report Card, Erie Soil and Water Conservation District

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5.1 Homeowner Resources

Nova Scotia Drinking Water Guidelines:

- https://novascotia.ca/nse/water/docs/Drop_on_Water_English.pdf

Nova Scotia Fish Consumption Guidelines:

- https://novascotia.ca/nse/fish-consumption-advisory.asp

Best Land-use Practices and Information:

- https://nsinvasives.ca/plant-wise/
- https://nsinvasives.ca/wp-content/uploads/2023/07/CCIS-NSISC-Grow-Me-Instead-Guide_2023_EN_web.pdf
- https://www.transcoastaladaptations.com/green-shores
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- https://www.countyofkings.ca/upload/All_Uploads/Living/services/permits/lakeshore/Lake%20Development%20Brochure.pdf
- https://loveyourlake.ca/project/responsible-shoreline-development/
- https://novascotia.ca/nse/wastewater/docs/homeowners.guide.to.septic.systems.pdf
- https://www.speciesatrisk.ca/stewardshipguide/

6.0 Acknowledgements

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Figure 40. Volunteers and Coastal Action staff.

Figure 41. Volunteers ready for sampling.

Figure 42. Volunteers with sampling gear.

Figure 43. Volunteers sampling.

7.0 References

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8.0 Appendix

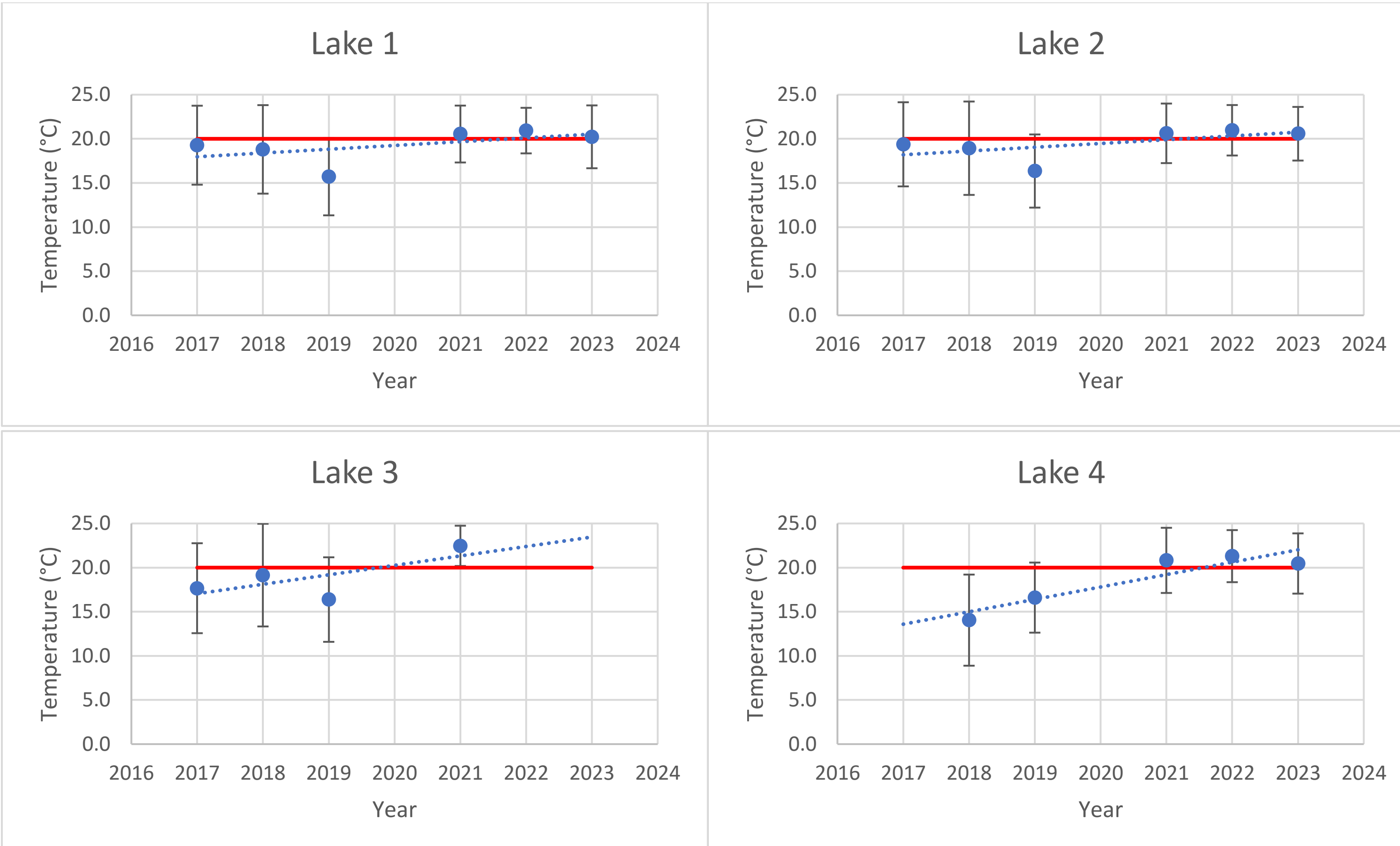

Figure 44. Average annual temperature (°C) readings from the 2017 to 2023 summer month sampling events at the lake sites. The red line indicates the 20°C threshold for cold-water fish set by NSSA. The black error bars indicate standard error. The blue dotted line indicates the trendline.

Table 6. Surface temperature (°C) readings from the 2017 to 2023 summer sampling events at the lake sites.

	Lake 1 Surface temperature (°C)					
	2017	**2018**	**2019**	**2021**	**2022**	**2023**
May		15.7	9			
June		18.6	13.9	20.8	19.2	16.4
July	22.6	25.6	17.2	22.1		24.8
Aug	20.4	23	22.4	24.4	23.9	
Sept	21.4	18.2	15.8	19.7	19.7	19.8
Oct		11.6	15.1	15.7		

	Lake 2 Surface temperature (°C)					
	2017	**2018**	**2019**	**2021**	**2022**	**2023**
May		16	10.1			
June		19.4	14.7	21.4	20.3	17.5
July	23.5	26.1	17.4	22.4		24
Aug	20.5	23.1	22.4	24.2	24.1	
Sept	21	17.9	18.5	19.8	18.5	20.4
Oct		11.1	15	15.3		

	Lake 3 Surface temperature (°C)					
	2017	**2018**	**2019**	**2021**	**2022**	**2023**
May		16.2	11			
June		20.2	14.6			
July		26.7		22.9		
Aug	20.2	23.7	23.2	24.5		
Sept	21	17.9	19.1	20		
Oct		10.2	14			

	Lake 4 Surface temperature (°C)					
	2017	**2018**	**2019**	**2021**	**2022**	**2023**
May			11.3			
June			14.8	21.5	21.4	18.3
July			17	23.2		24.4
Aug			22.8	24.4	24.2	
Sept		17.7	18.9	20.1	18.3	18.7
Oct		10.4	14.7	14.9		

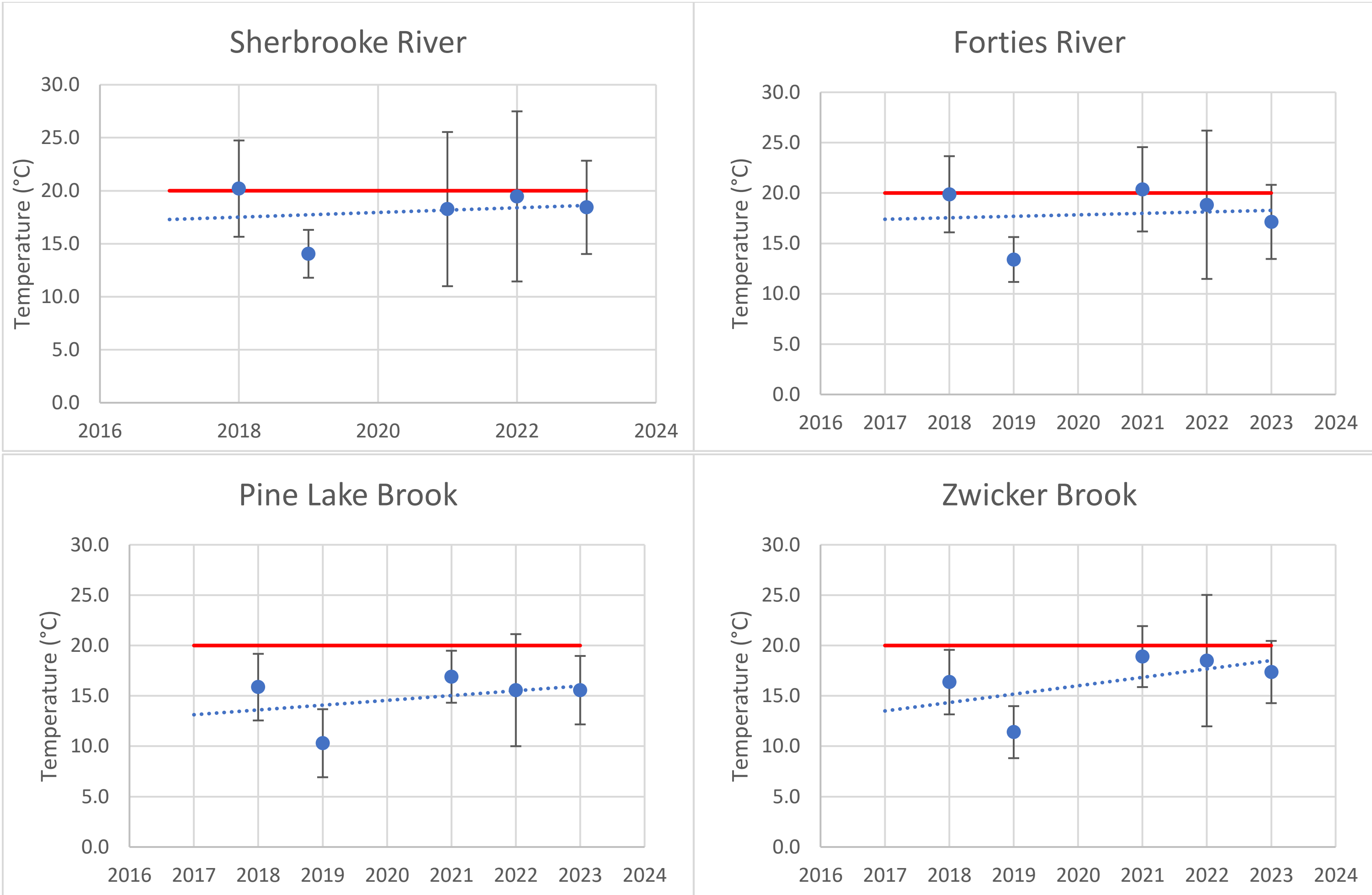

Figure 45. Average annual temperature (°C) readings from the 2017 to 2023 summer month sampling events at the stream sites. The red line indicates the 20°C threshold for cold-water fish set by NSSA. The black error bars indicate standard error. The blue dotted line indicates the trendline.

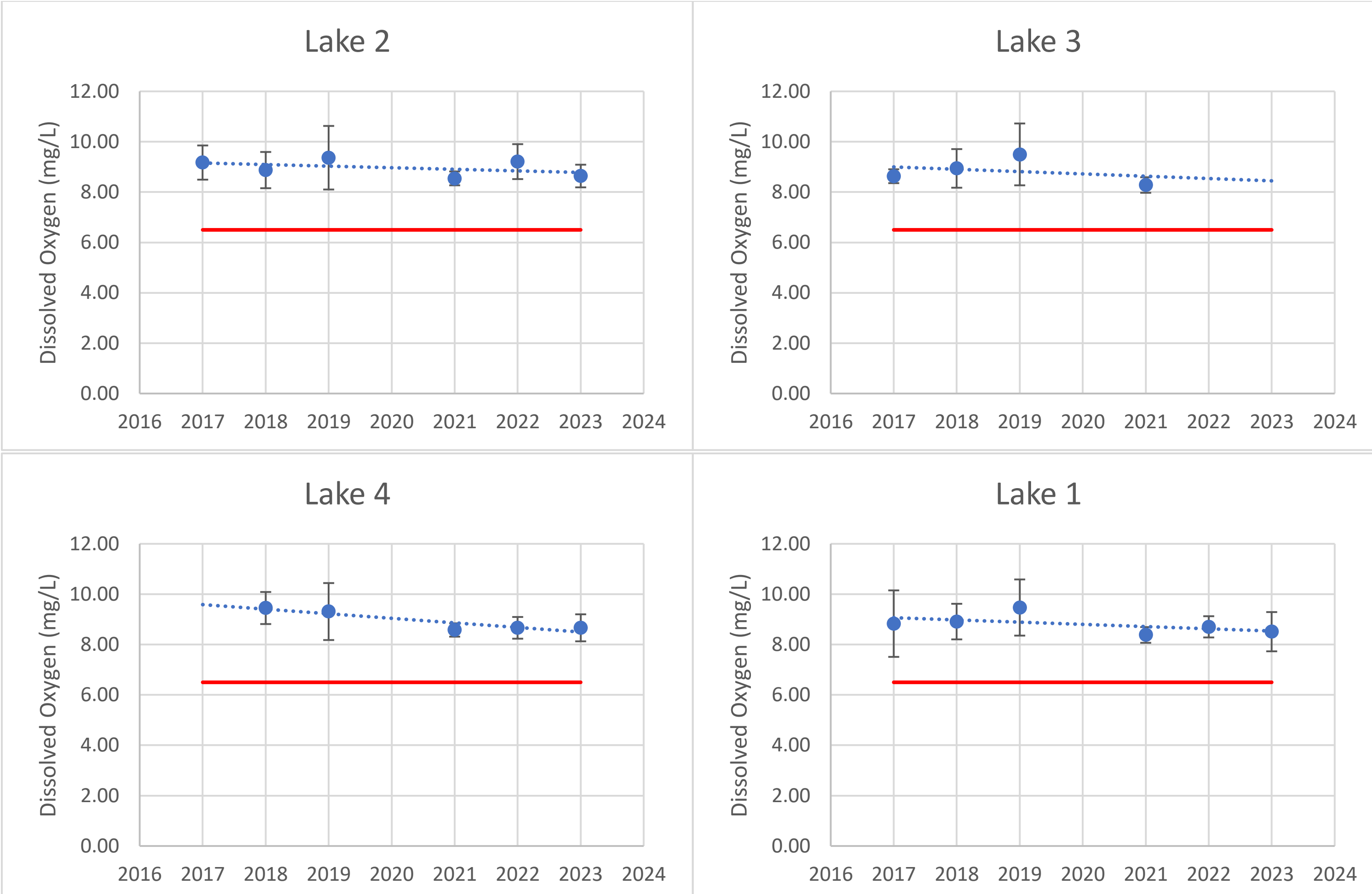

Figure 46. Average annual dissolved oxygen (mg/L) readings from the 2017 to 2023 summer month sampling events at the lake sites. The solid red line indicates the CCME threshold of 6.5 mg/L. The black error bars indicate standard error. The blue dotted line indicates the trendline.

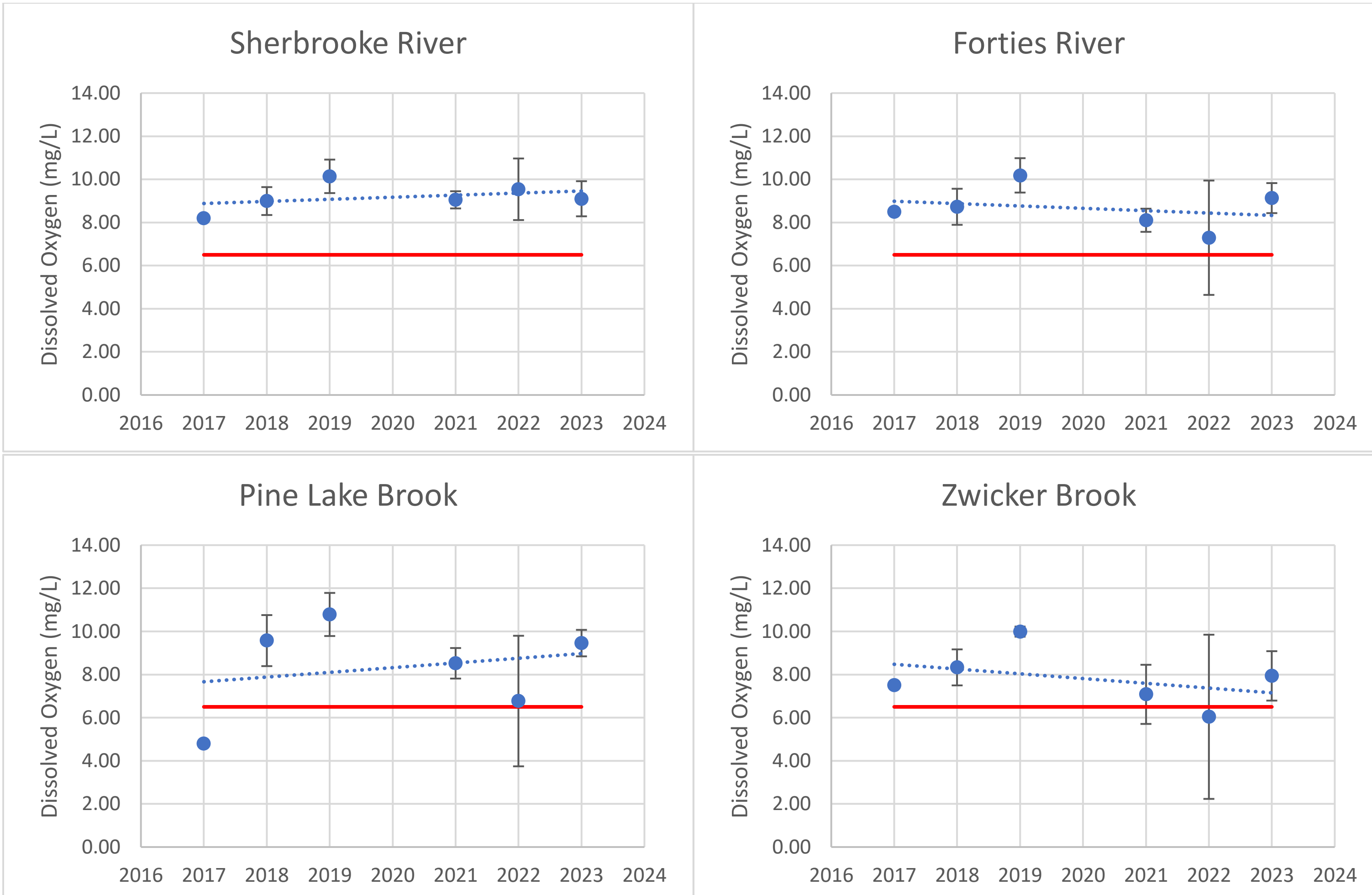

Figure 47. Average annual dissolved oxygen (mg/L) readings from the 2017 to 2023 summer month sampling events at the stream sites. The solid red line indicates the CCME threshold of 6.5 mg/L. The black error bars indicate standard error. The blue dotted line indicates the trendline.

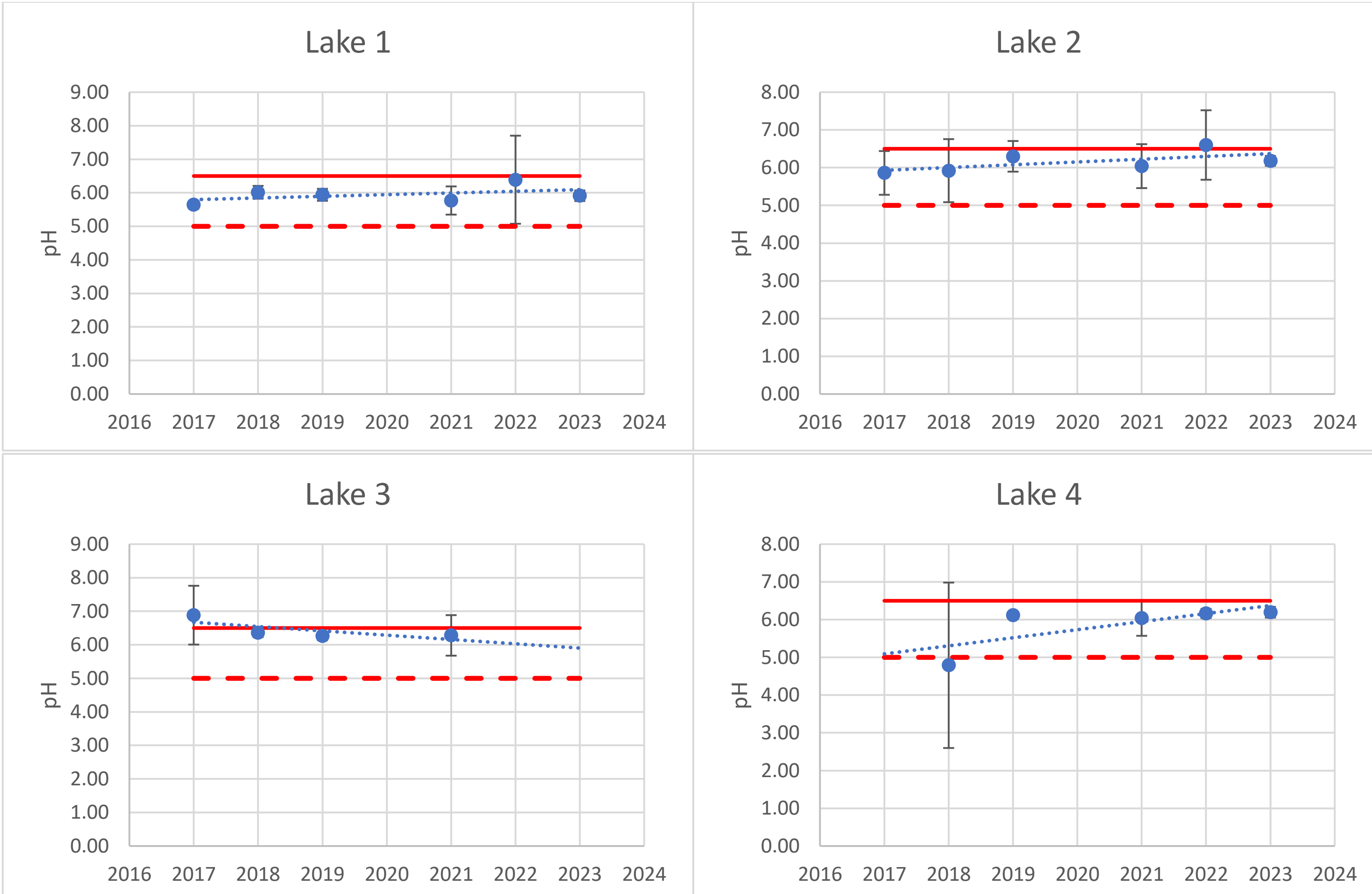

Figure 48. Average annual pH readings from the 2017 - 2023 summer month sampling events at the lake sites. The solid red line indicates the 6.5 pH threshold set by CCME, and the dotted red line indicates the 5.0 pH threshold identified by NSSA. The black error bars indicate the standard error. The blue dotted line indicates the trendline.

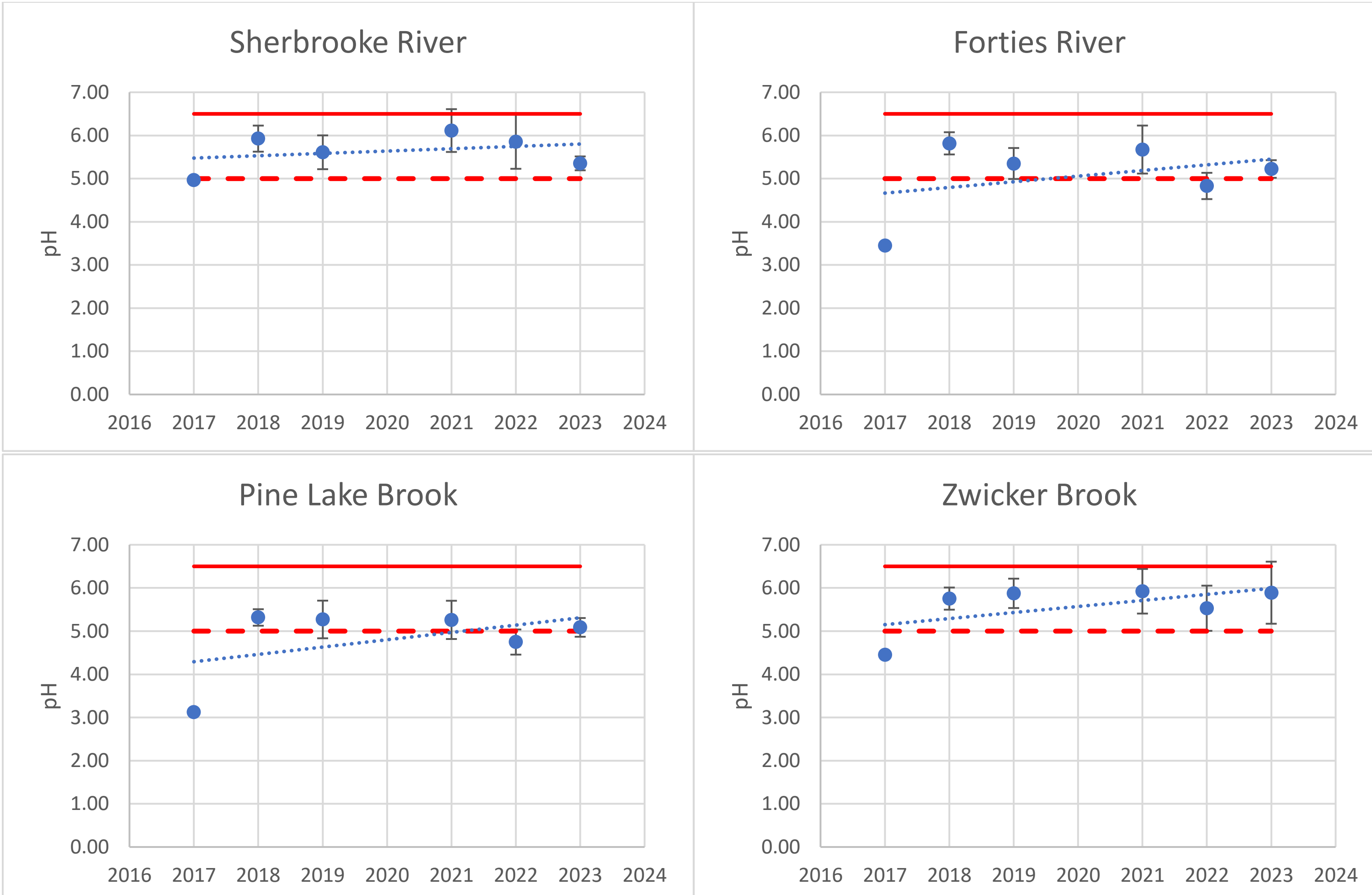

Figure 49. Average annual pH readings from the 2017 to 2023 summer month sampling events at the stream sites. The solid red line indicates the 6.5 pH threshold set by CCME, and the dotted red line indicates the 5.0 pH threshold identified by NSSA. The black error bars indicate the standard error. The blue dotted line indicates the trendline.

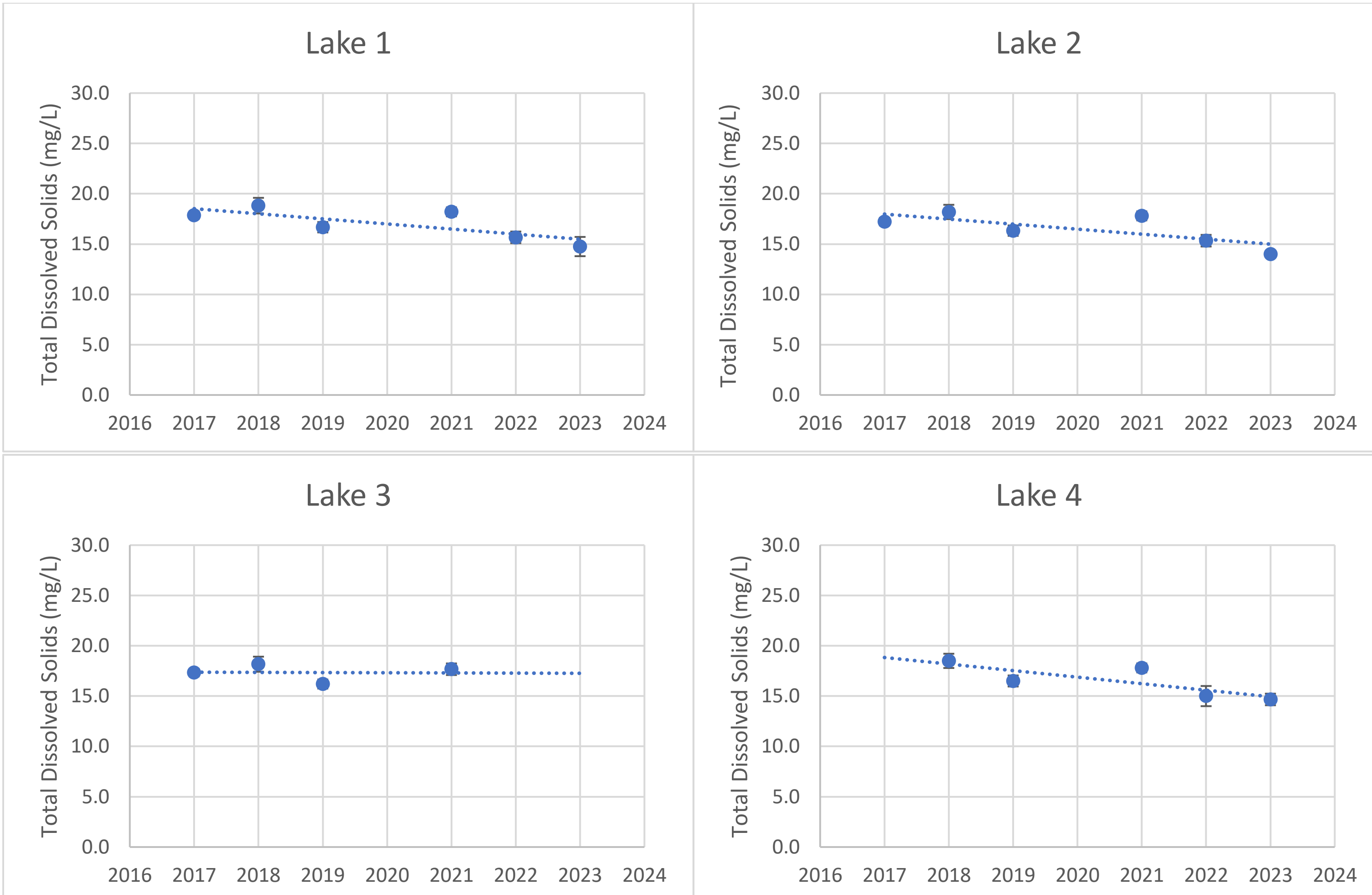

Figure 50. Average annual Total Dissolved Solids (mg/L) readings from the 2017 to 2023 summer month sampling events at the lake sites. The blue dotted line indicates the trendline.

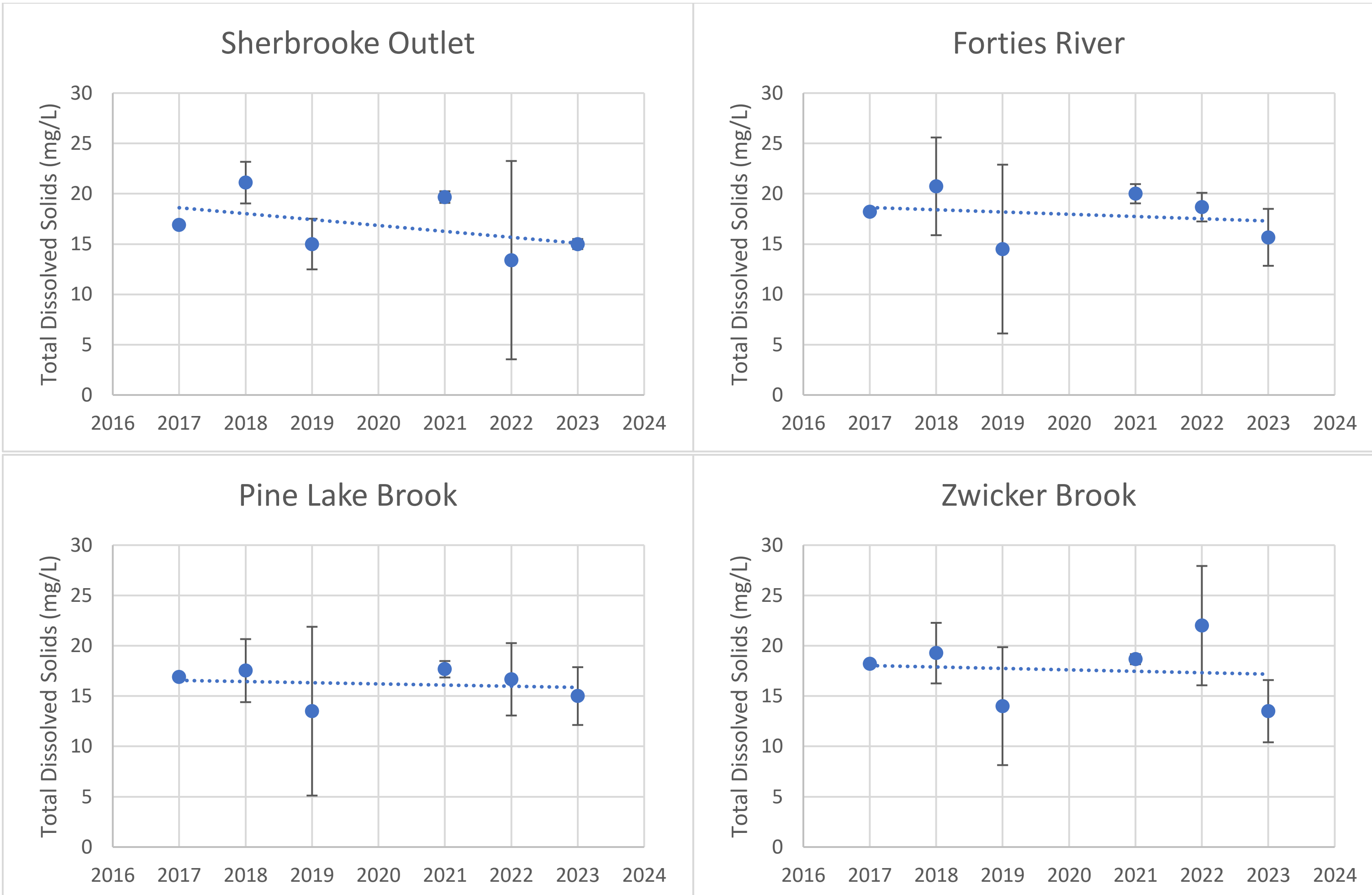

Figure 51. Average annual Total Dissolved Solids (mg/L) readings from the 2017 to 2023 summer month sampling events at the stream sites. The blue dotted line indicates the trendline.

Table 7. Orthophosphate and Total Phosphorus levels from the annual sediment samples at the Lake and Stream Sites. FR = Forties River; ZB = Zwicker Brook; SR = Sherbrooke River; PLB = Pine Lake Brook. ND = less than the detectable limit. Orthophosphate was not able to be completed for ZB in 2023.

	Lake 1				**Lake 2**					**Lake 3**	**Lake 4**				**FR**	**ZB**	**SR**	**PLB**	**ZB**
Parameter (Units)	**2019**	**2021**	**2022**	**2023**	**2018**	**2019**	**2021**	**2022**	**2023**	**2018**	**2019**	**2021**	**2022**	**2023**	**2018**	**2019**	**2021**	**2022**	**2023**
Orthophosphate in sediment (mg/kg)	0.15	0.39	0.51	0.11	0.0067	0.086	0.27	0.24	0.1	0.26	0.24	0.24	0.26	0.09	0.33	0.38	0.36	0.79	
Acid extractable phosphorus in sediment (mg/kg)	1900	1300	1600	1700	1900	2200	1800	1600	1700	400	490	2000	1700	1600	180	190	200	ND	920