

# Sherbrooke Lake 2021 Water Quality Monitoring Report

May 2022

Prepared for:

Municipality of the District of Lunenburg

Municipality of Chester

Sherbrooke Lake Stewardship Committee

# Sherbrooke Lake 2021 Water Quality Monitoring Report

## Contributing Authors

Blake McNeely, Watersheds & Water Quality Team Lead (Coastal Action)

May 2022

## Coastal Action

45 School Street, Suite 403

Mahone Bay, N.S., B0J 2E0

Ph: (902) 634-9977

Email: [info@coastalaction.org](mailto:info@coastalaction.org)

This work was supported by:



## Contents

List of Figures .....	iii
List of Tables .....	vi
1. Introduction .....	1
1.1 Monitoring Program Background.....	2
1.2 Review of the 2019 Sherbrooke Lake Water Quality Monitoring Report.....	2
2. 2021 Water Quality Monitoring Results .....	3
2.1 Water Sampling.....	3
2.1.1. Physical Water Quality Parameters.....	3
2.1.2. Chemical Water Quality Parameters .....	13
2.1.3. Biological Water Quality Parameters.....	19
2.2. Sediment Sampling.....	20
2.2.2. Metals .....	21
2.2.3. Sediment Phosphorus and Orthophosphate .....	24
3. Discussion .....	26
3.1. Algae Blooms in Sherbrooke Lake .....	26
3.2. Trophic State of Sherbrooke Lake .....	26
4. Recommendations.....	29
5. Sherbrooke Lake Algae Pilot Project .....	30
6. References .....	33

## List of Figures

Figure 1. Sherbrooke Lake Water Quality Monitoring Program 2021 monitoring sites. ....	1
Figure 2. Phycocyanin (cells/mL) levels from the 2021 monthly 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. ....	4
Figure 3. Phycocyanin (cells/mL) levels from the 2021 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. ....	4
Figure 4. Phycocyanin (cells/mL) levels from the 2021 rainfall sampling event at the stream sites, 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. ....	5
Figure 5. Temperature (°C) readings from the 2021 monthly sampling events at the lake sites. The red line indicates the 20°C threshold for cold-water fish set by NSSA. ....	6
Figure 6. Temperature (°C) readings from the 2021 sampling events at the stream sites. The red line indicates the 20°C threshold for cold-water fish set by NSSA. ....	6
Figure 7. Temperature (°C) readings from the 2021 rainfall sampling event at the stream sites, including the additional, rainfall-specific sites. ....	7
Figure 8. Dissolved Oxygen (mg/L) readings from the 2021 monthly sampling events at the lake sites. ....	8
Figure 9. Dissolved Oxygen (mg/L) readings from the 2021 sampling events at the stream sites. ....	8
Figure 10. Dissolved Oxygen (mg/L) readings from the 2021 rainfall sampling event at the stream sites, including the additional, rainfall-specific sites. ....	9
Figure 11. pH readings from the 2021 monthly 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. ....	10
Figure 12. pH readings from the 2021 sampling events at the stream sites. The solid red line indicates the 6.5 threshold set by CCME, and the dotted red line indicates the 5 threshold identified by NSSA. ....	10
Figure 13. pH readings from the 2021 rainfall sampling event at the stream sites, including the additional, rainfall-specific sites. ....	11

Figure 14. Total Dissolved Solids (mg/L) readings from the 2021 monthly sampling events at the lake sites..... 11

Figure 15. Total Dissolved Solids (mg/L) readings from the 2021 sampling events at the stream sites. .... 12

Figure 16.Total Dissolved Solids (mg/L) readings from the 2021 rainfall sampling event at the stream sites, including the additional, rainfall-specific sites..... 12

Figure 17. Total Suspended Solids (mg/L) readings from the 2021 monthly sampling events at the lake sites. .... 13

Figure 18. Total Suspended Solids (mg/L) readings from the 2021 sampling events at the stream sites ..... 14

Figure 19. Total Suspended Solids (mg/L) readings from the 2021 rainfall sampling event at the stream sites, including the additional, rainfall-specific sites..... 14

Figure 20. Total Phosphorus (mg/L) levels from Lake 1, 2, and 3 from 2018, 2019, and 2021.... 15

Figure 21. Total Phosphorus (mg/L) readings from the 2021 sampling events at the stream sites. .... 16

Figure 22. Total Phosphorus (mg/L) readings from the 2021 rainfall sampling event at the stream sites, including the additional, rainfall-specific sites..... 16

Figure 23. Total Nitrogen (mg/L) levels from Lake 1, 2, and 3 from 2018, 2019, and 2021. .... 17

Figure 24. Total Nitrogen (mg/L) readings from the 2021 sampling events at the stream sites . 18

Figure 25. Total Nitrogen (mg/L) readings from the 2021 rainfall sampling event at the stream sites, including the additional, rainfall-specific sites ..... 18

Figure 26. E. coli (CFU/100 mL) readings from the 2021 sampling events at the stream sites.... 19

Figure 27. E. coli (CFU/100 mL) readings from the 2021 rainfall sampling event at the stream sites, including the additional, rainfall-specific sites. .... 20

Figure 28. Carlson TSI for Sherbrooke Lake in 2021 using the mean Secchi disk depth (transparency), mean chlorophyll  $\alpha$  concentration and mean total phosphorus concentration. (Carlson, 1977) ..... 27

Figure 29. Comparison of Lake site TSI scores from 2018 to 2021 using the Carlson (1977) trophic equations for total phosphorus, chlorophyll  $\alpha$ , and Secchi disk (2020 excluded)..... 28

Figure 30. Phycocyanin (RFU) depth profile taken on July 23<sup>rd</sup>, 2021. .... 32

## List of Tables

Table 1. Concentrations of metals within Lake site sediment samples. 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. ....	22
Table 2. Concentrations of metals within stream site sediment samples. ....	23
Table 3. Summary of guideline exceedances of 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 .....	24
Table 4. Orthophosphate and Total Phosphorus levels from the annual sediment samples at the Lake and Stream Sites. ....	24
Table 5. TSI values for all lake sites in 2021 for three parameters.....	27
Table 6. Chl-a water sample results compared to the Total Algae Probe results from July 23, 2021. ....	31
Table 7. Chl-a water sample results compared to the Total Algae Probe results from August 25, 2021. ....	31

# 1. Introduction

The following report summarizes the results of the 2021 Sherbrooke Lake Water Quality Monitoring Program. Monitoring activities were conducted at Sherbrooke Lake (SL) by trained volunteers with support from Coastal Action from June to October 2021.

This marks the third year of the monitoring program, which began in 2018. Monitoring activities did not occur in 2020 due to COVID-19 restrictions.

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



Figure 1. Sherbrooke Lake Water Quality Monitoring Program 2021 monitoring sites.

## 1.1 Monitoring Program Background

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 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.

Coastal Action acts as technical support for a group of trained volunteers, who conduct the monthly and rainfall-dependent sampling. Following preliminary ground-truthing activities in 2017, the full Sherbrooke Lake Water Quality Monitoring Program was conducted in 2018 and 2019.

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

## 1.2 Review of the 2019 Sherbrooke Lake Water Quality Monitoring Report

In 2018 and 2019, the overall trophic state of Sherbrooke Lake was oligotrophic-mesotrophic, indicating that the biological productivity of the lake did not change during that period. The monitoring program did not identify any significant issues with the water quality of SL in 2018 and 2019.

Several algae blooms were reported by residents of SL in 2019. Two samples were taken for analysis of Microcystin-LR (a toxin associated with cyanobacteria blooms), but neither displayed a concentration over the Health Canada recreational guideline of 20 µg/L (Health Canada 2012). Algae samples collected from the same blooms were submitted to Dalhousie University to be tested for specific algae species. Both samples identified the presence of green algae, a common type of algae that does not produce harmful toxins.

None of the SL sites exceeded the phosphorus guideline of 0.02 mg/L in 2019; however, Pine Lake Brook exceeded the 0.03 mg/L MOECC stream guideline in July. All other stream sites remained under the MOECC stream guidelines for phosphorus.

Sediment was sampled at Lake sites 1, 2, and 4, and at the mouth of Zwicker Brook to test for metal concentrations. At Lake 1 and 2, arsenic, cadmium, and mercury exceeded the ISQG (Interim Sediment Quality Guidelines). At Lake 4, arsenic and cadmium exceeded the ISQG. Zwicker Brook displayed low concentrations of metals with no parameter exceeding or approaching any of the sediment guidelines.

## **2. 2021 Water Quality Monitoring Results**

### **2.1 Water Sampling**

#### **2.1.1. Physical Water Quality Parameters**

##### ***2.1.1.1. Chlorophyll-a, 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- $\alpha$  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- $\alpha$  is a pigment produced by all types of algae and provides an estimate of total algae production.

Collecting this data over multiple seasons will help determine the baseline concentrations of phycocyanin in SL, which can vary across waterbodies. 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 and build 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). Phycocyanin RFU units were converted to the total number of cells (Genzolia and 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. At no point were the WHO guidelines exceeded, nor were they approached. The data was not collected before, during, or immediately after any known algae blooms.

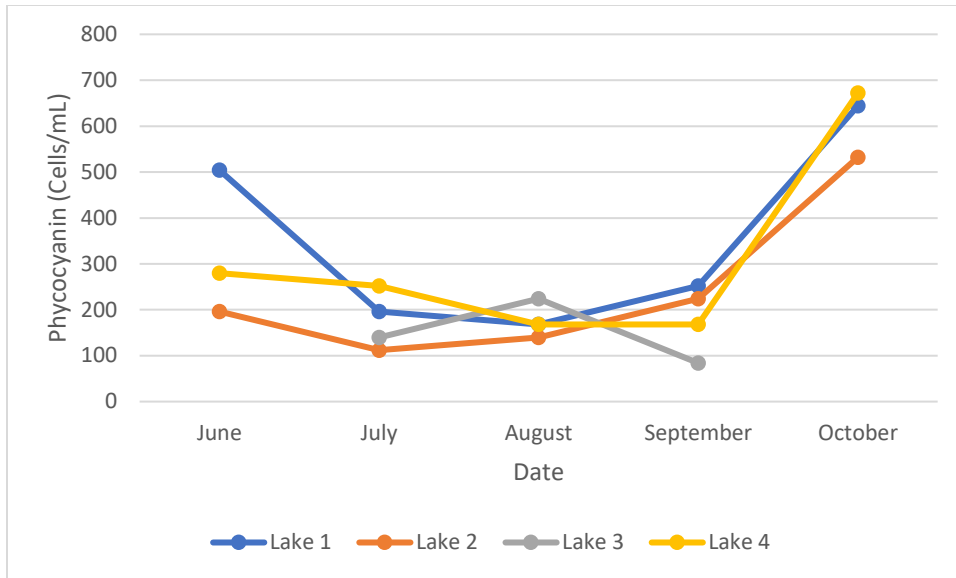


Figure 2. Phycocyanin (cells/mL) levels from the 2021 monthly sampling events at the lake sites. The WHO provides two guidelines; Alert level 1 at 20,000 cells/mL, and Alert level 2 at 100,000 cells/mL.

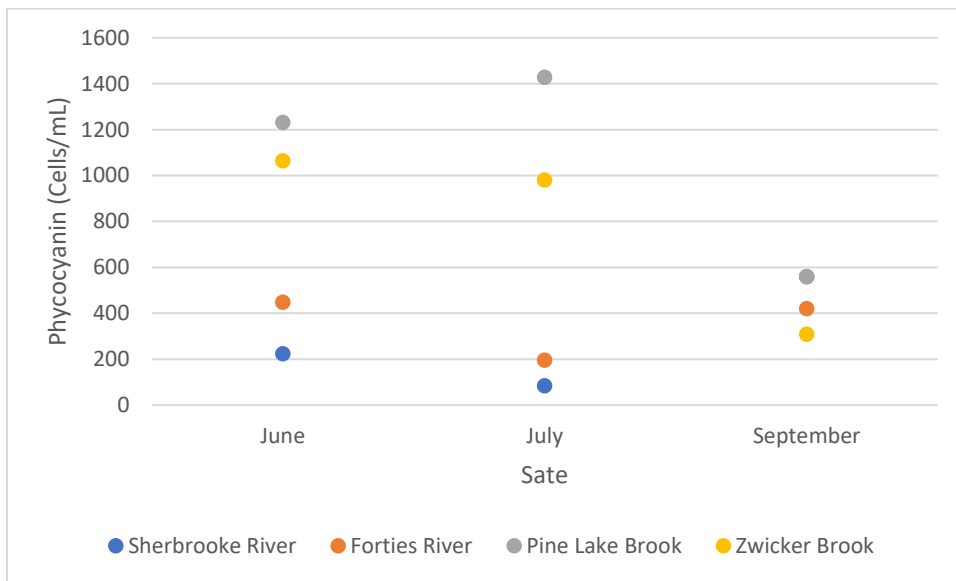


Figure 3. Phycocyanin (cells/mL) levels from the 2021 sampling events at the stream sites. The WHO provides two guidelines; Alert level 1 at 20,000 cells/mL, and Alert level 2 at 100,000 cells/mL.

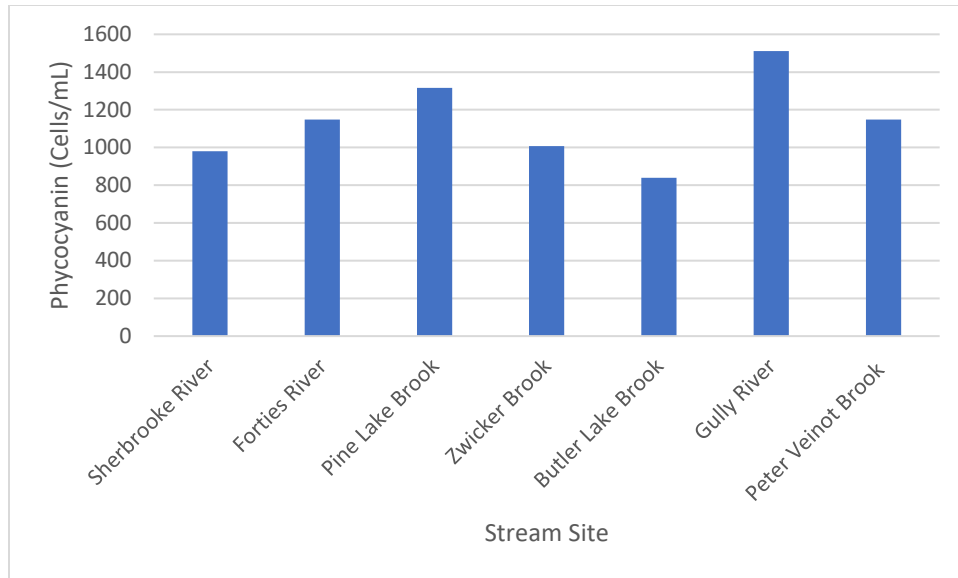


Figure 4. Phycocyanin (cells/mL) levels from the 2021 rainfall sampling event at the stream sites, including the additional, rainfall-specific sites. The WHO provides two guidelines; Alert level 1 at 20,000 cells/mL, and Alert level 2 at 100,000 cells/mL.

### 2.1.1.2. Surface Water Temperatures

Water temperatures were recorded monthly at all lake sites, except Lake 3 which was not sampled in June and October. The stream sites were sampled in June, July, and September. Temperature readings were also taken during a rainfall event in October at all stream sites, including the additional, rainfall-specific sites. Temperatures at the lake sites ranged from 14.9°C to 24.5°C (Figure 5). The highest temperature recorded was at Lake 3 in August, but all other lake sites had similar temperatures during this time. Each lake site exceeded the 20°C temperature threshold for cold-water fish species from June to August (Nova Scotia Salmon Association [NSSA] 2014). Lake 3 and 4 met the guidelines in September, while the temperature of the other sites was recorded just below it.

The stream sites showed cooler temperatures than the lake, ranging from 8.6°C to 23.3°C (Figure 6). The highest temperature recorded was at Sherbrooke River in July. Both Sherbrooke River, and Fortes River exceeded the 20°C temperature threshold for cold-water fish species from June to July. Zwicker Brook also exceeded the threshold in September.

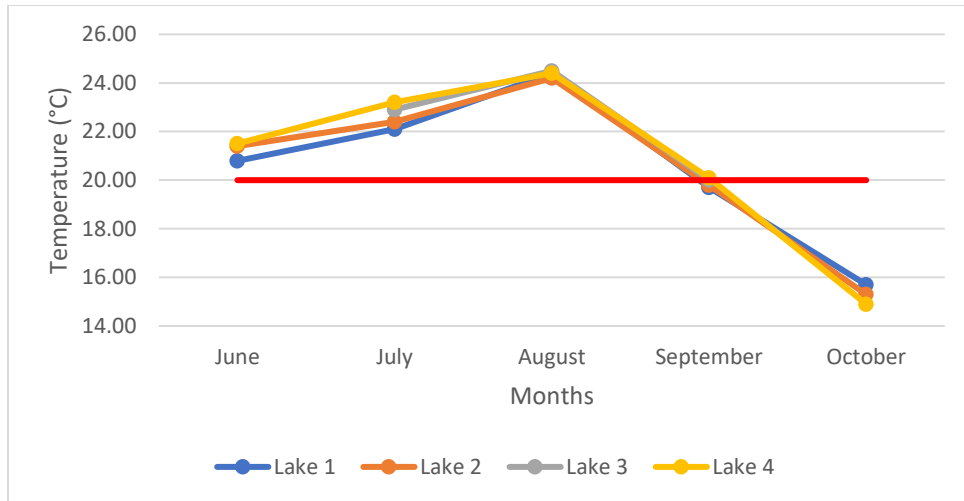


Figure 5. Temperature (°C) readings from the 2021 monthly sampling events at the lake sites. The red line indicates the 20°C threshold for cold-water fish set by NSSA.

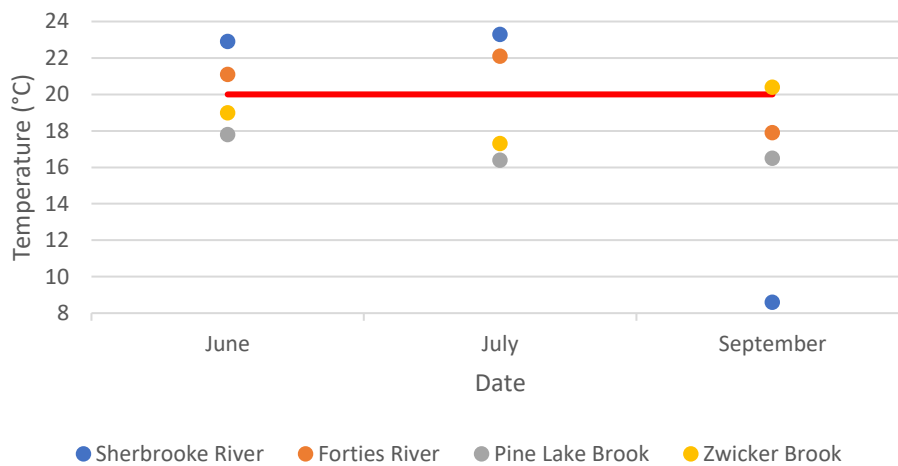


Figure 6. Temperature (°C) readings from the 2021 sampling events at the stream sites. The red line indicates the 20°C threshold for cold-water fish set by NSSA.

Surface water temperature readings were taken during a rainfall event on October 18, 2021, at each of the stream sites, including three additional sites not included in the regular monthly samples. Temperatures range from 11.9°C to 13.4°C (Figure 7).

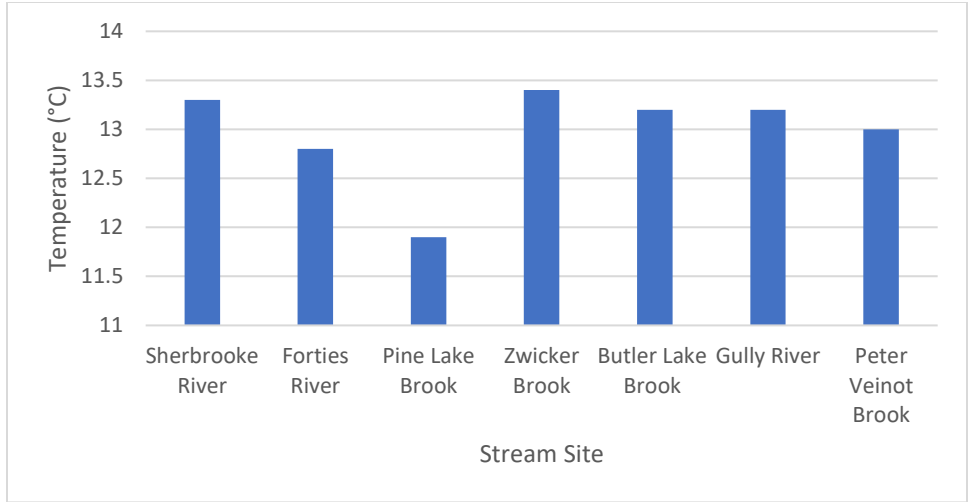


Figure 7. Temperature (°C) readings from the 2021 rainfall sampling event at the stream sites, including the additional, rainfall-specific sites.

### 2.1.1.3. Surface Dissolved Oxygen

Dissolved oxygen (DO) was recorded monthly at all lake sites, except Lake 3 which was not sampled in June and October. The stream sites were sampled in June, July, and September. DO readings were also taken during a rainfall event in October at all stream sites, including the additional rainfall-specific sites. DO readings at the lake sites ranged from 8 mg/L to 9.04 mg/L (Figure 8). The lowest reading was taken at Lake 3 in July. 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 1999). No readings below this threshold were recorded at any regularly monitored lake or stream site in 2021.

DO readings at the stream sites ranged from 6.7 mg/L to 9.15 mg/L (Figure 9). All stream site readings showed DO levels above the 6.5 mg/L threshold. DO concentrations displayed an increase in October after lake turnover

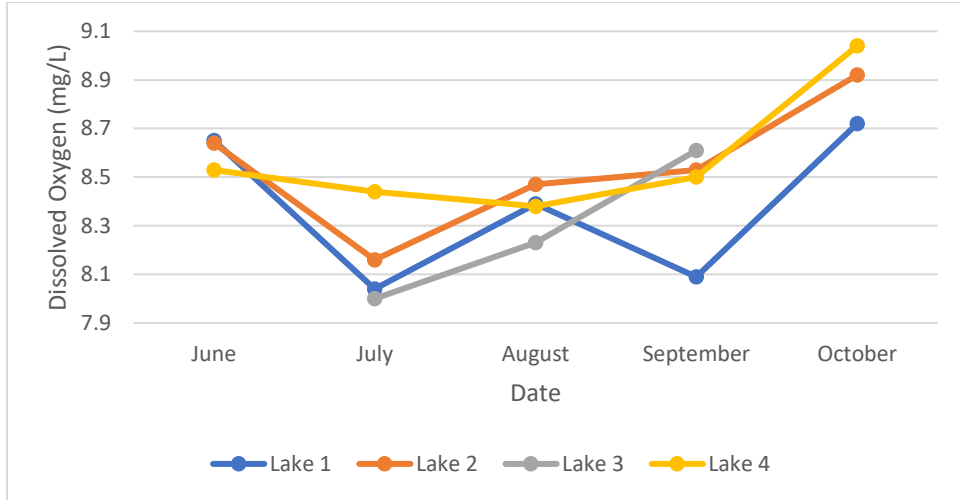


Figure 8. Dissolved Oxygen (mg/L) readings from the 2021 monthly sampling events at the lake sites.

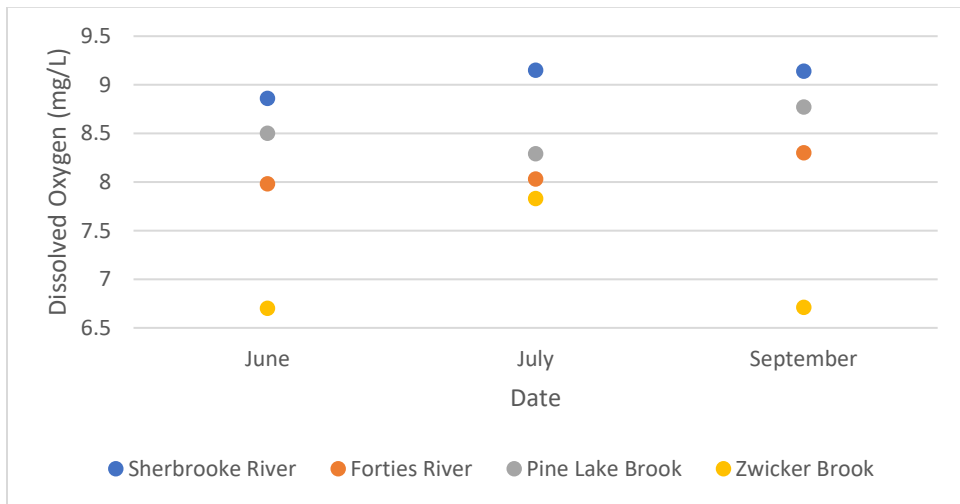


Figure 9. Dissolved Oxygen (mg/L) readings from the 2021 sampling events at the stream sites.

Dissolved oxygen readings were taken during a rainfall event on October 18, 2021, at each of the stream sites, including three additional sites not included in the regular monthly samples. DO levels ranged from 6.1 mg/L to 9.88 mg/L (Figure 10). Only Peter Veinot Brook dipped below the 6.5 mg/L threshold.

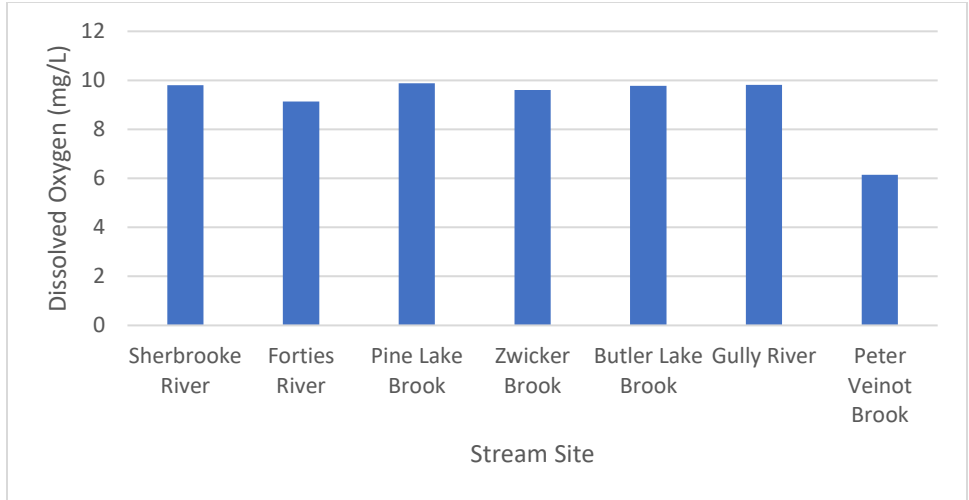


Figure 10. Dissolved Oxygen (mg/L) readings from the 2021 rainfall sampling event at the stream sites, including the additional, rainfall-specific sites.

**2.1.1.4. pH**

pH, a measurement of the acidity of a liquid, was recorded monthly at all lake sites, except Lake 3 which was not sampled in June and October. The stream sites were sampled in June, July, and September. pH readings were also taken during a rainfall event in October at all stream sites, including the additional, rainfall-specific sites. Although the pH measurements for most sites 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. 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 at SL poses minimal threat to organisms, except for some stream sites.

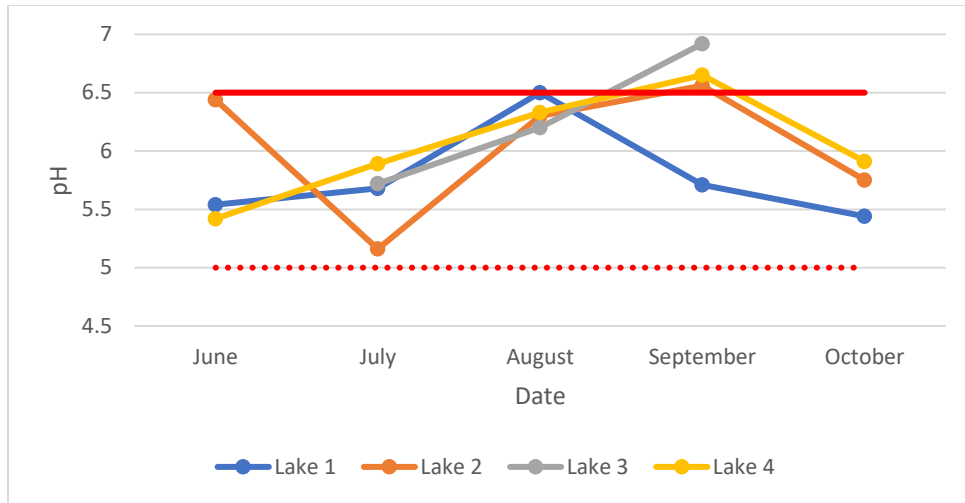


Figure 11. pH readings from the 2021 monthly sampling events at the lake sites. The solid red line indicates the 6.5 pH threshold set by CCME, and the dotted red line indicates the 5.0 pH threshold identified by NSSA.

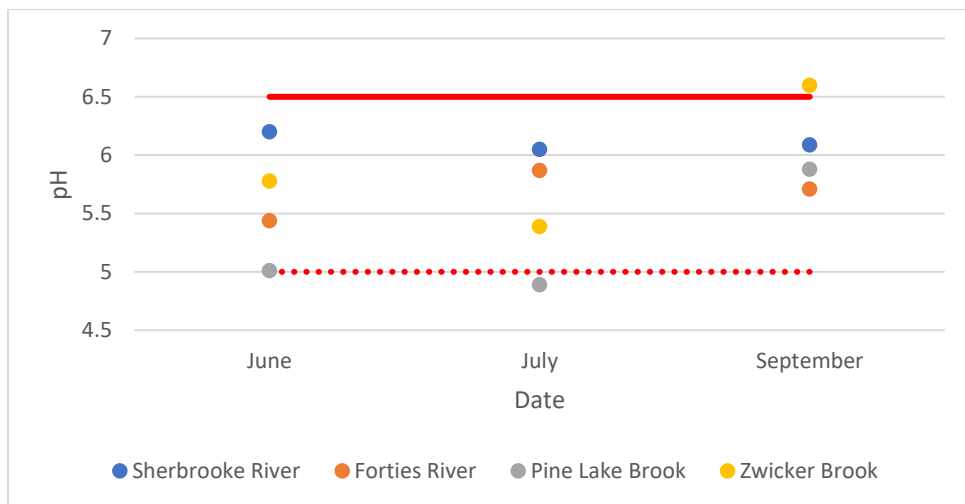


Figure 12. pH readings from the 2021 sampling events at the stream sites. The solid red line indicates the 6.5 threshold set by CCME, and the dotted red line indicates the 5 threshold identified by NSSA.

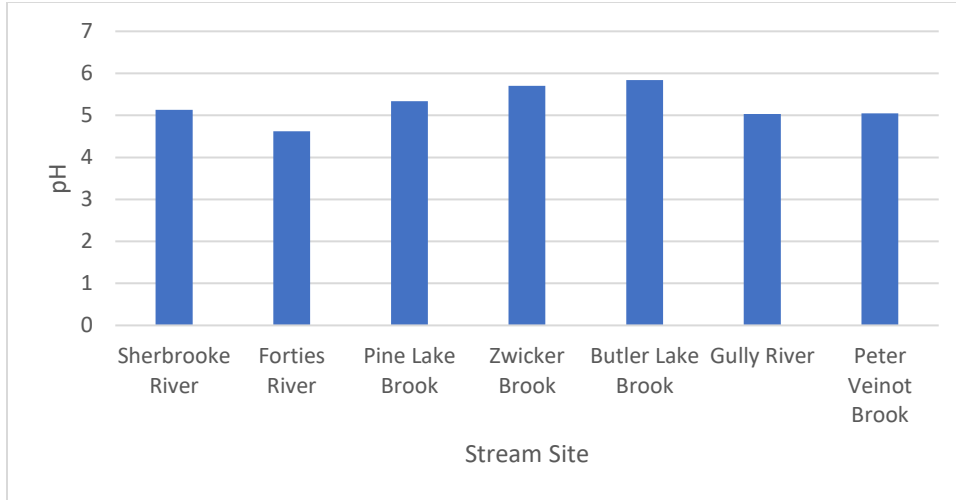


Figure 13. pH readings from the 2021 rainfall sampling event at the stream sites, including the additional, rainfall-specific sites.

### 2.1.1.5. Total Dissolved Solids

Total Dissolved Solids (TDS) were recorded monthly at all lake sites, except Lake 3 which was not sampled in June and October. The stream sites were sampled in June, July, and September. TDS readings were also taken during a rainfall event in October at all stream sites, including the additional, rainfall-specific sites. TDS readings at the lake sites ranged from 17 mg/L to 19 mg/L (Figure 14), and 17 mg/L to 21 mg/L at the stream sites (Figure 15). The highest reading of the lake sites was taken at Lake 1 in August, and the highest reading of the stream sites was taken at the Forties River in June.

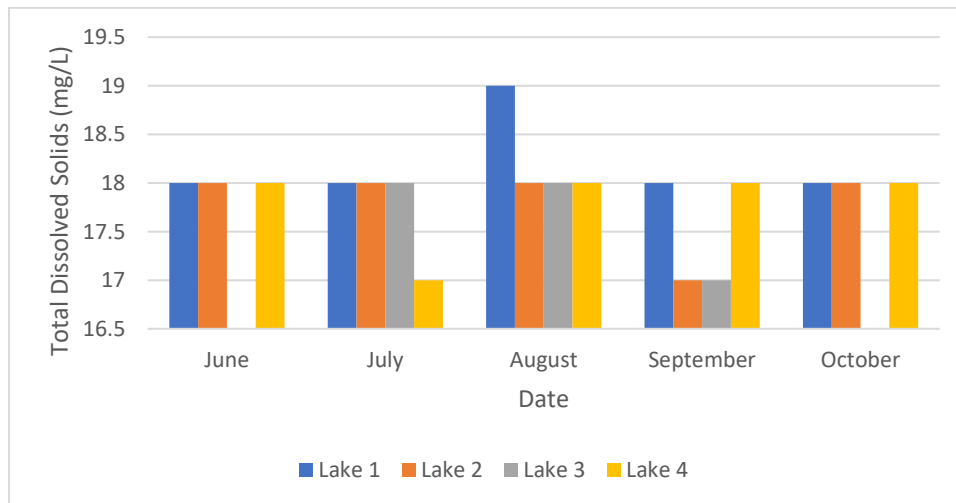


Figure 14. Total Dissolved Solids (mg/L) readings from the 2021 monthly sampling events at the lake sites.

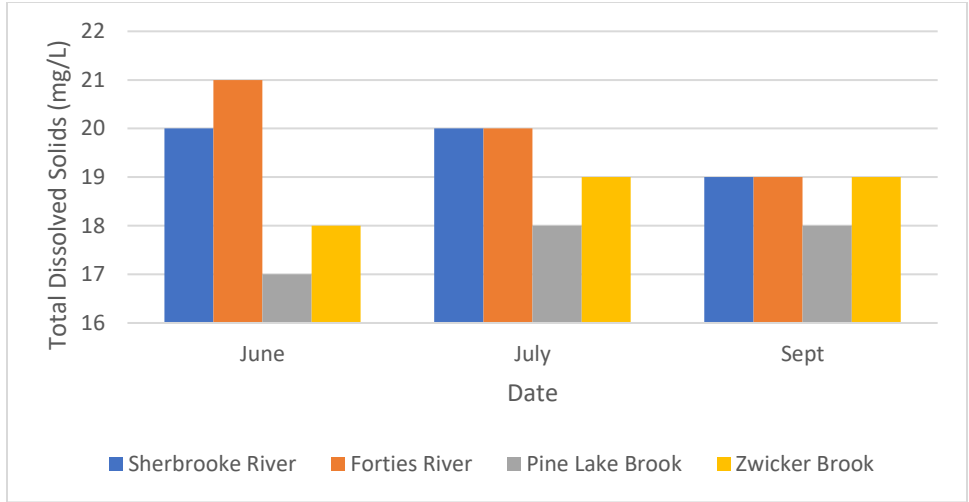


Figure 15. Total Dissolved Solids (mg/L) readings from the 2021 sampling events at the stream sites.

Total Dissolved Solids readings were taken during a rainfall event on October 18, 2021, at each of the stream sites, including three additional sites not included in the regular monthly samples. TDS levels ranged from 17 mg/L to 30 mg/L (Figure 16).

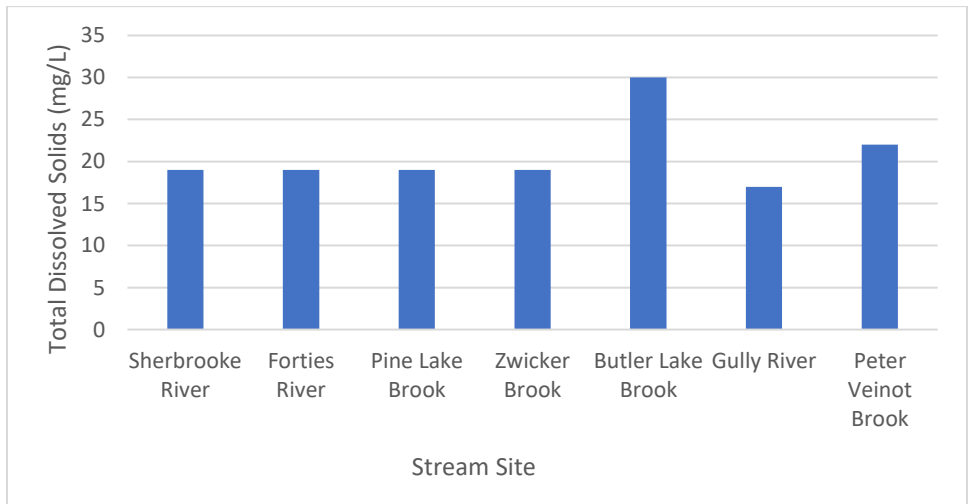


Figure 16. Total Dissolved Solids (mg/L) readings from the 2021 rainfall sampling event at the stream sites, including the additional, rainfall-specific sites.

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.

## 2.1.2. Chemical Water Quality Parameters

### 2.1.2.1. Total Suspended Solids

Total Suspended Solids (TSS) were measured as the value of solids suspended in a water column that do not pass through a 45 µm glass fibre filter. Samples were recorded monthly at all lake sites, except Lake 3 which was not sampled in June and October (Figure 17). The stream sites were sampled in June, July, and September (Figure 18). TSS samples were also taken during a rainfall event in October at all stream sites, including the additional, rainfall-specific sites. In some cases, TSS concentrations were so low that lab results displayed an ‘undetected’ (UD) reading. The TSS samples from the lake sites ranged from UD to 2 mg/L, and from UD to 3.6 mg/L at the stream sites.

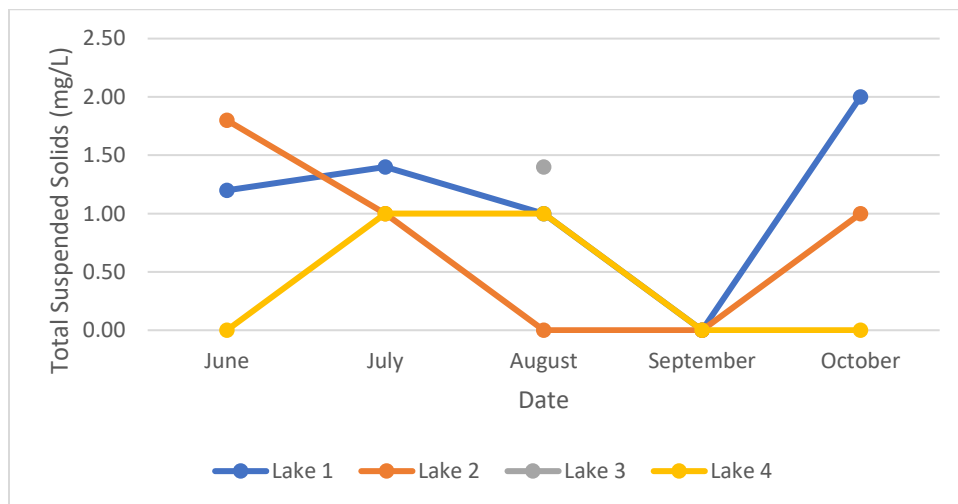


Figure 17. Total Suspended Solids (mg/L) readings from the 2021 monthly sampling events at the lake sites.

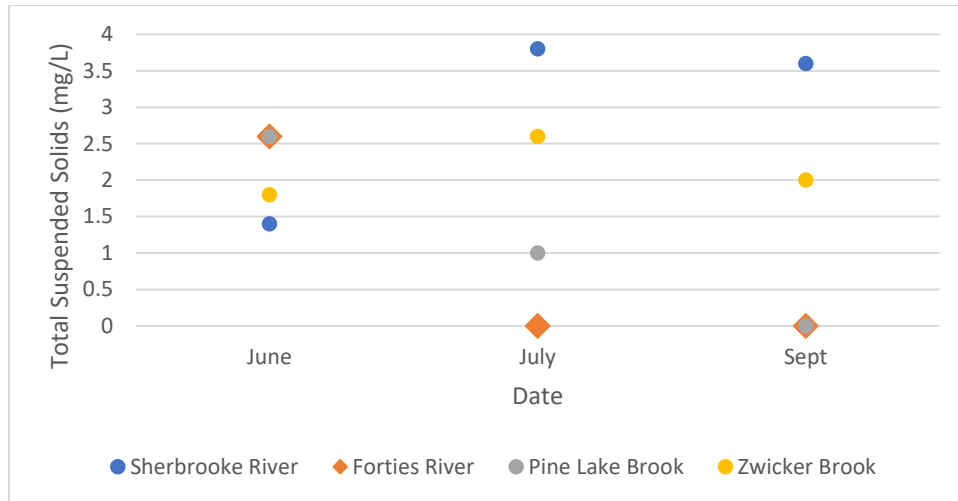


Figure 18. Total Suspended Solids (mg/L) readings from the 2021 sampling events at the stream sites

Total Suspended Solids samples were taken during a rainfall event on October 18, 2021, at each of the stream sites, including three additional sites not included in the regular monthly samples. TSS levels ranged from UD to 2.8 mg/L (Figure 19).

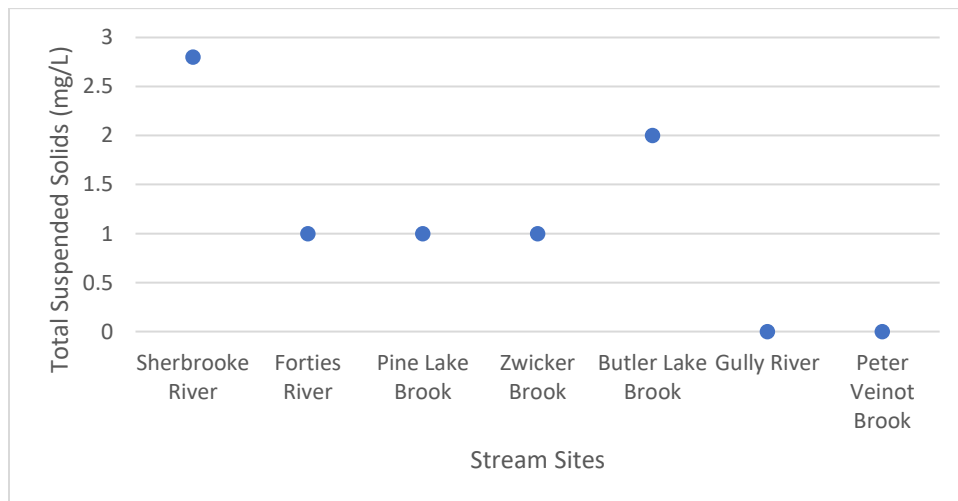


Figure 19. Total Suspended Solids (mg/L) readings from the 2021 rainfall sampling event at the stream sites, including the additional, rainfall-specific sites.

As the CCME has a guideline of a 10 mg/L allowable increase from baseline in waterbodies with TSS  $\leq$  100 mg/L (CCME 2002), the levels observed in 2021 are not a threat to aquatic organisms.

### 2.1.2.2. Total Phosphorus

Total phosphorus (TP) levels were recorded monthly at all lake sites, except Lake 3 which was not sampled in June and October. The stream sites were sampled in June, July, and September. TP readings were also taken during a rainfall event in October at all stream sites, including the additional, rainfall-specific sites. TP readings at the lake sites ranged from 0.004 mg/L to 0.009 mg/L, and 0.014 mg/L to 0.024 mg/L at the stream sites. The highest lake concentration was observed at Lake 1 in September, and the highest concentration of the stream sites was observed at Sherbrooke River in September. Compared to 2018, and 2019, TP levels in the Lake sites have been less varied, and lower in 2021 (Figure 20).

Ontario’s Ministry of Environment and Climate Change (MOECC) has established two guidelines for phosphorus in water bodies:  $\leq 0.02$  mg/L for lakes, and  $\leq 0.03$  mg/L for rivers and streams (Ontario’s Ministry of Environment [MOE] 1979). TP concentrations in the lake and streams did not exceed the MOECC guidelines.

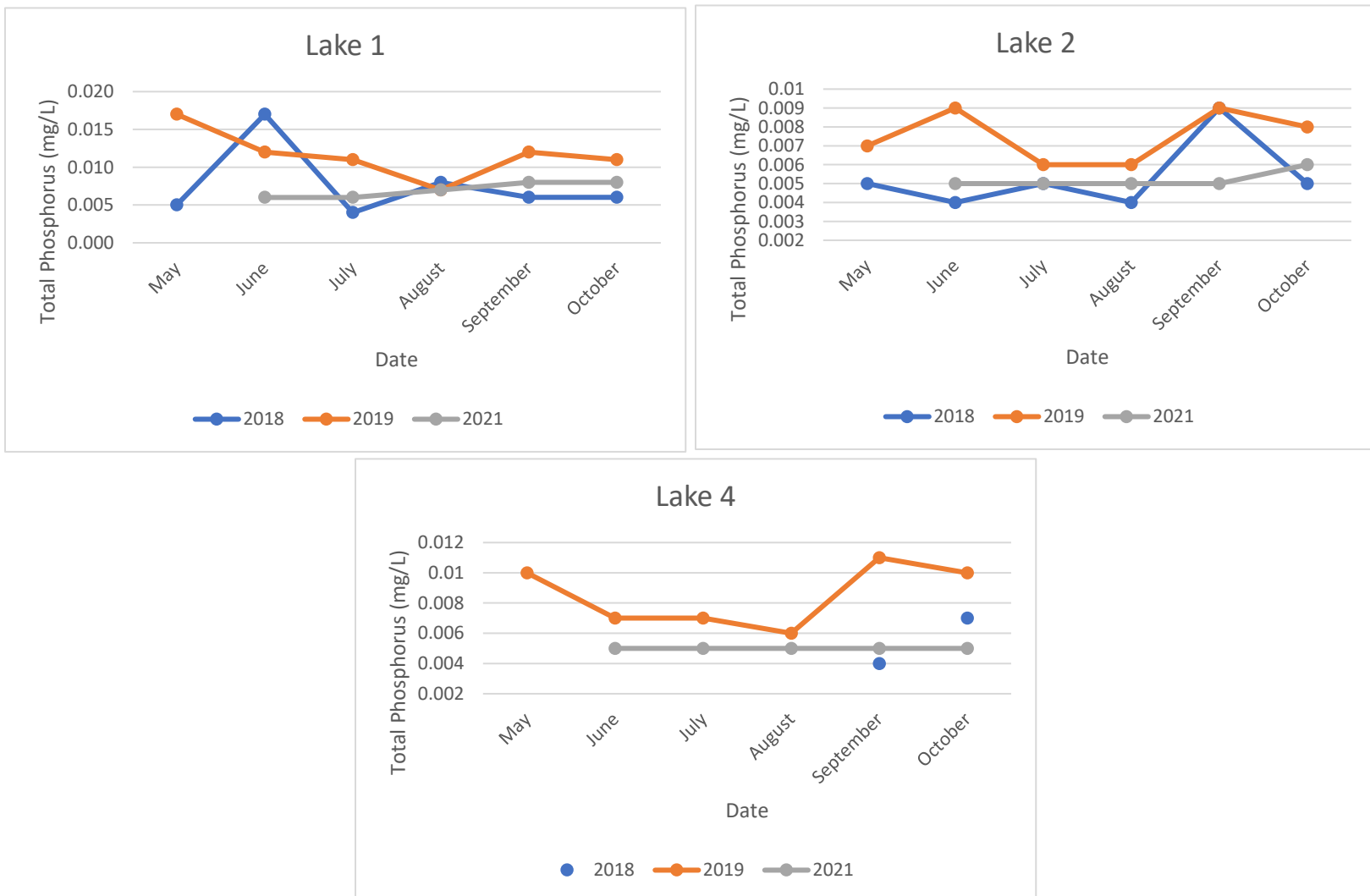


Figure 20. Total Phosphorus (mg/L) levels from Lake 1, 2, and 3 from 2018, 2019, and 2021.

Total phosphorus samples were taken during a rainfall event on October 18, 2021, at each of the stream sites, including three additional sites not included in the regular monthly samples. TP levels ranged from 0.015 mg/L to 0.019 mg/L (Figure 22).

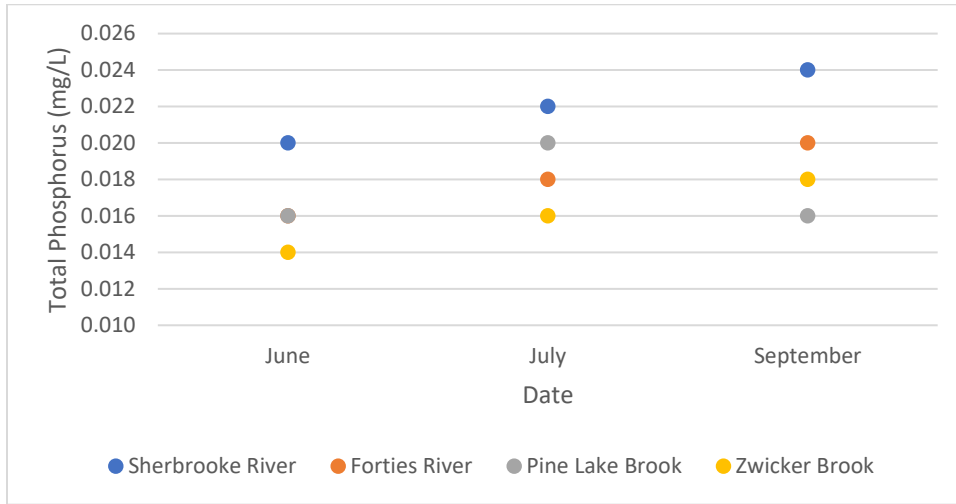


Figure 21. Total Phosphorus (mg/L) readings from the 2021 sampling events at the stream sites.

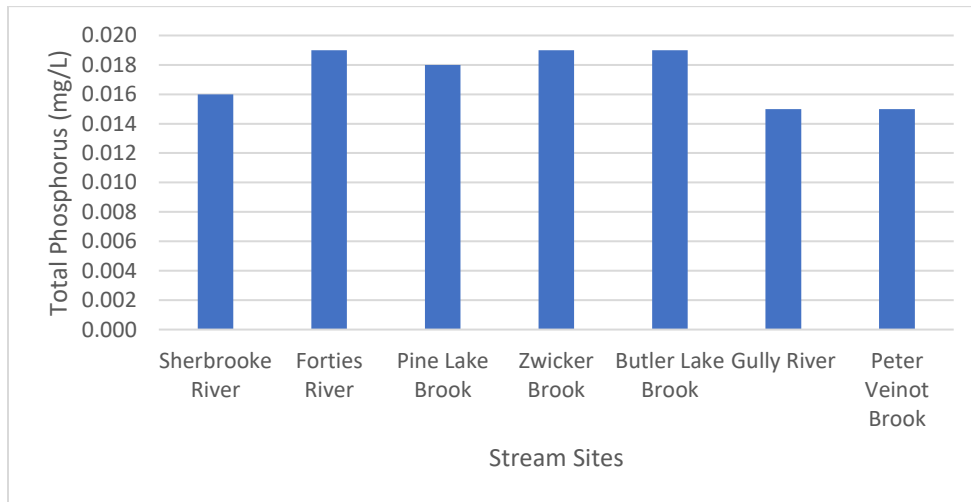


Figure 22. Total Phosphorus (mg/L) readings from the 2021 rainfall sampling event at the stream sites, including the additional, rainfall-specific sites.

In September, Total Phosphorus samples were taken below the thermocline at Lake 1 and Lake 2. Results show 0.014 mg/L Lake 1, and 0.43 mg/L at Lake 2. The results from Lake 2 did exceed the MOECC guidelines. Higher phosphorus concentrations below the thermocline may indicate a possible nutrient-enrichment event during fall turnover, with a potential for eutrophication and algal blooms. In SL, at-depth phosphorus concentrations were equal to

or higher than surface concentrations, indicating that the deeper lake waters are nutrient-enriched.

### 2.1.2.3. Total Nitrogen

Total Nitrogen (TN) levels were recorded monthly at all lake sites, and at the stream sites in June, July, and September. TN readings were also taken during a rainfall event in October at all stream sites, including the additional, rainfall-specific sites. TN readings at the lake sites ranged from 0.207 mg/L to 0.375 mg/L (Figure 23), and 0.389 mg/L to 0.832 mg/L at the stream sites (Figure 24). The highest concentration at the lake sites occurred at Lake 1 in September, and the highest stream concentration occurred at Sherbrooke River in September.

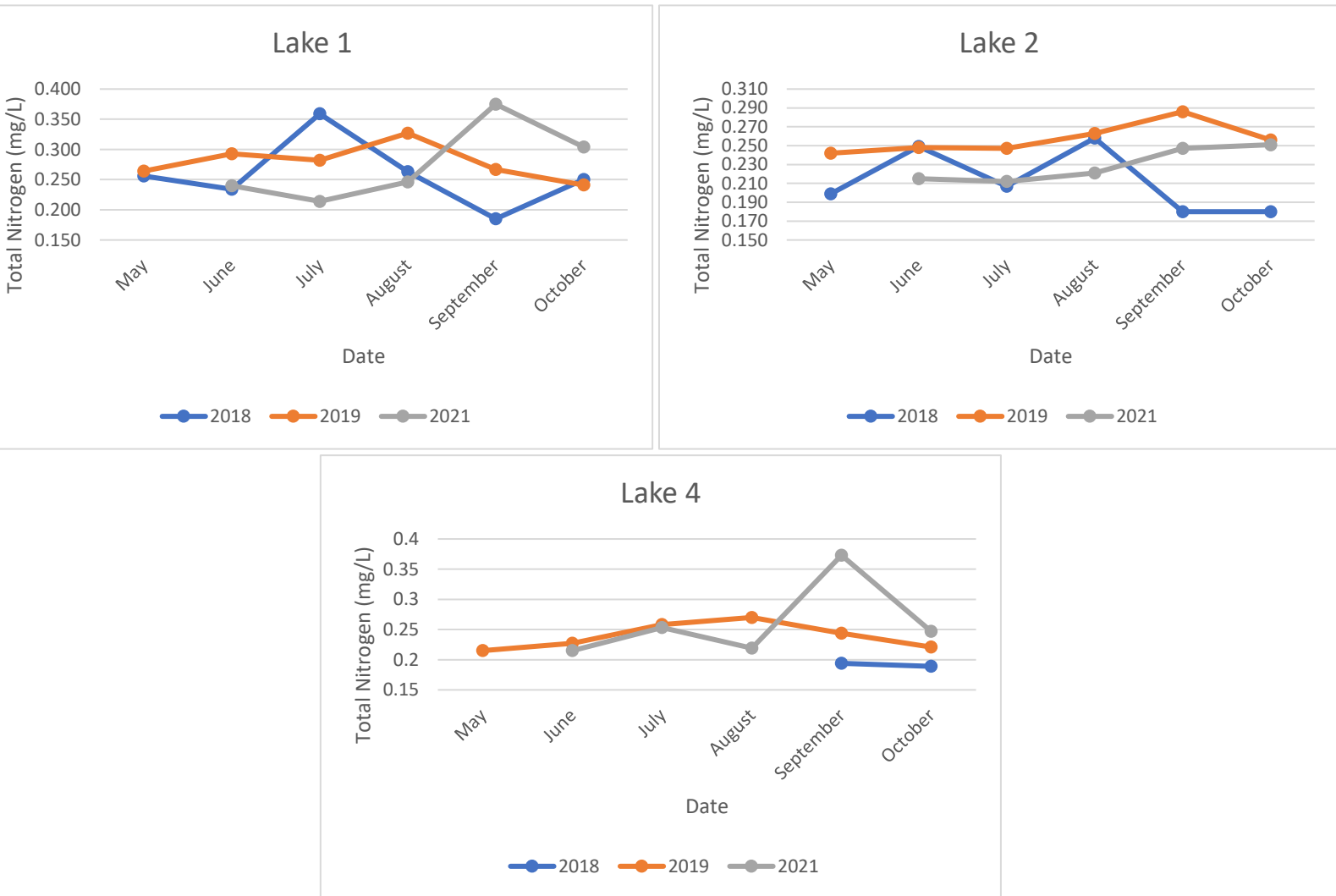


Figure 23. Total Nitrogen (mg/L) levels from Lake 1, 2, and 3 from 2018, 2019, and 2021.

Total Nitrogen samples were taken during a rainfall event on October 18, 2021, at each of the stream sites, including three additional sites not included in the regular monthly samples. TN levels ranged from 0.519 mg/L to 0.717 mg/L (Figure 25). Dodds and Welch have established a guideline for nitrogen in waterbodies of 0.9 mg/L. This guideline was approached at Sherbrooke River in September, but not exceeded by any other site.

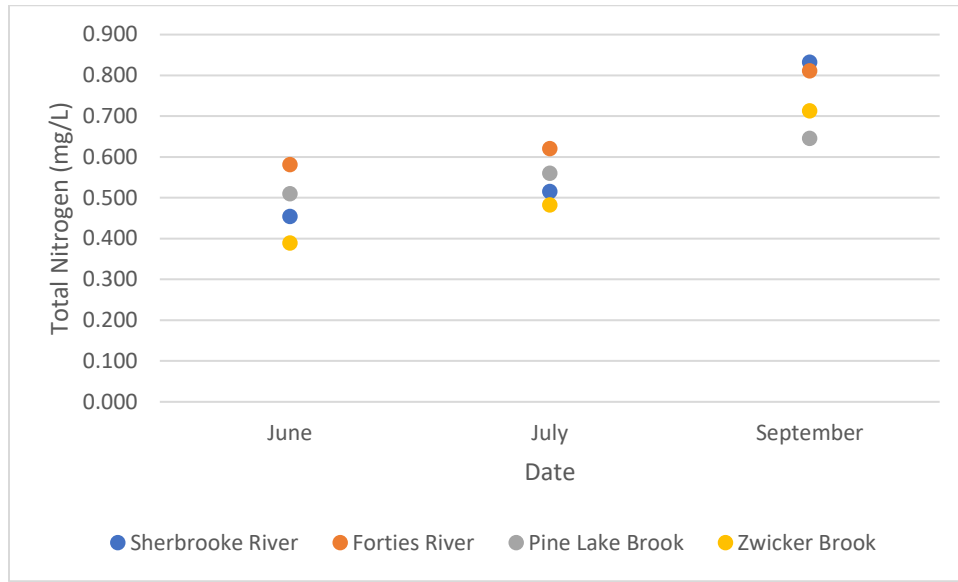


Figure 24. Total Nitrogen (mg/L) readings from the 2021 sampling events at the stream sites

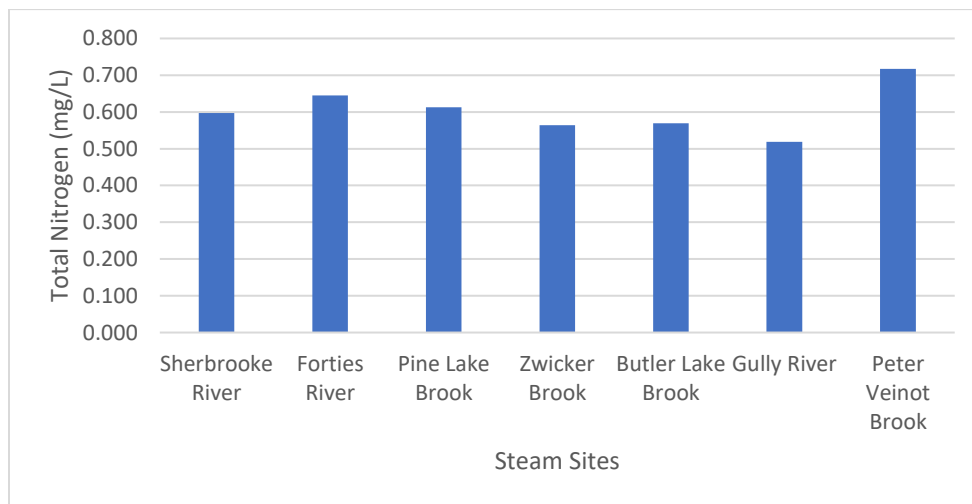


Figure 25. Total Nitrogen (mg/L) readings from the 2021 rainfall sampling event at the stream sites, including the additional, rainfall-specific sites

Total Nitrogen concentrations were measured below the thermocline at Lake 1 and Lake 2. Lake Results show 0.326 mg/L at Lake 1, and 2.85 mg/L at Lake 2. The results from Lake 2 exceeded the Dodds and Welch guideline of 0.9 mg/L. Higher nitrogen concentrations below the thermocline may indicate a possible nutrient-enrichment event during fall turnover, with a potential for eutrophication and algal blooms.

### 2.1.3. Biological Water Quality Parameters

#### 2.1.3.1. Fecal Bacteria

*E. coli* samples were taken monthly at all lake sites, and at the stream sites in June, July, and September. Readings were also taken during a rainfall event in October at all stream sites, including the additional, rainfall-specific sites. *E. coli* readings at the lake sites ranged from undetected to 2 CFU/100 mL, and undetected to 190 CFU/100 mL at the stream sites (Figure 27). Of the 17 total *E. coli* samples taken at the lake sites, only three showed any detected concentrations. The samples collected in July at Lake 1, August at Lake 2, and October at Lake 4 all showed 2 CFU/100 mL. All other samples did not detect any *E. coli*. The highest concentration was observed at Zwicker Brook in June (Figure 26).

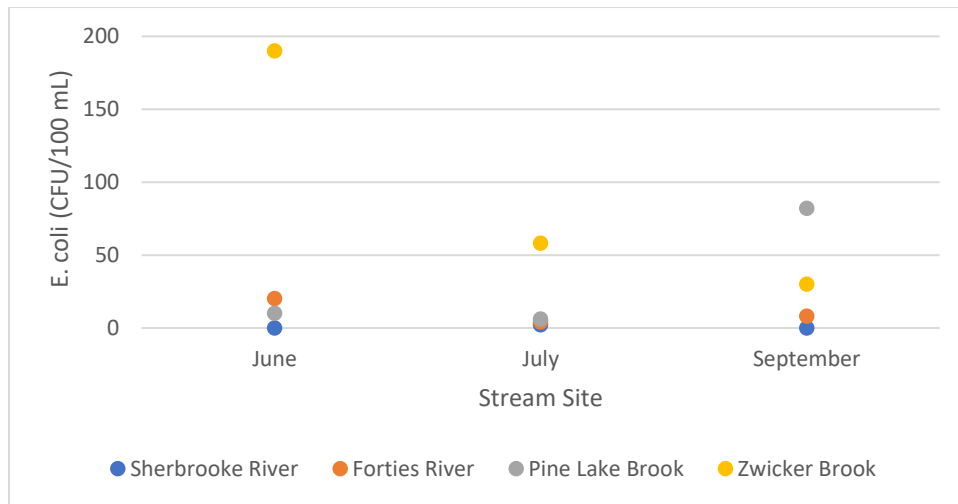


Figure 26. *E. coli* (CFU/100 mL) readings from the 2021 sampling events at the stream sites

*E. coli* samples were taken during a rainfall event on October 18, 2021, at each of the stream sites, including three additional sites not included in the regular monthly samples. *E. coli* concentrations ranged from 20 CFU/100 mL to 90 CFU/100 mL (Figure 27).

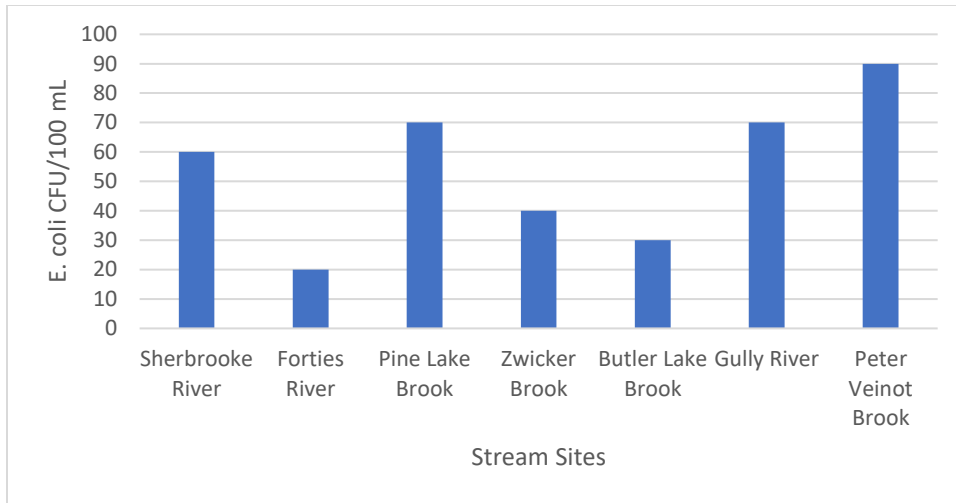


Figure 27. *E. coli* (CFU/100 mL) readings from the 2021 rainfall sampling event at the stream sites, including the additional, rainfall-specific sites.

Health Canada has set primary and secondary recreational contact guidelines for *E. coli* in freshwaters,  $\leq 400$  CFU/100 mL and  $\leq 1000$  CFU/100 mL, respectively (Health Canada 2012). At no point did any sample display concentrations that approached the primary or secondary guideline.

### 2.1.3.2. Microcystin-LR & Algal Blooms

The recreational guideline for cyanobacterial toxins – Microcystin-LR is 10  $\mu\text{g/L}$  (Health Canada 2012). This guideline is meant to protect against exposure to microcystins and other toxins that may be present in an algal bloom. Microcystin-LR can persist in aquatic environments after a visible bloom has dissipated (Federal-Provincial-Territorial Committee on Drinking Water 2002).

Not all algal blooms are toxic cyanobacteria blooms, and Microcystin-LR is only one of the possible toxins in a cyanobacteria bloom. For this reason, every algal bloom should be treated with caution and reported to Nova Scotia Environment (NSE).

An algal bloom was detected at the outlet to Gully Lake on July 7, 2021. Volunteers collected and submitted a water sample to BV Labs. No Microcystin-LR was detected in the sample.

## 2.2. Sediment Sampling

Sediment sampling at sites Lake 1, 2, and 4 have occurred each year since 2018. Sediment samples are collected from one stream each year. In 2021, the bottom substrate was analyzed for metals, phosphorus (except 2021), 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.

### **2.2.2. 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. Sediment samples are collected annually from the lake sites and one stream site. In 2018, Lake 2, Lake 3, and Forties River were sampled. In 2019, Lake 1, Lake 2, Lake 4, and Zwicker Brook were sampled. The same lake sites were sampled in 2021 as 2019, with the stream sample being collected from Sherbrooke River.

Arsenic concentrations were noticeably high and have exceeded the ISQG guidelines at all lake sites every year except at Lake 1 in 2021. In 2018 and 2019, Lake 2 had the highest recorded levels of arsenic, with 2018 levels approaching the PEL & NSEQS guidelines. Increased arsenic levels reduce the abundance of benthic invertebrates, the main food source for many aquatic species (CCME 2002). Of the three-stream sites sampled, none have arsenic levels of concern, and no metal concentrations show levels approaching any of the guidelines. Arsenic levels appear to be decreasing at the three lake sites, except Lake 4 where there was a slight increase of 1.7 mg/kg from 2019 to 2021.

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. However, cadmium levels are generally low at all sites and were not detected at any of the stream sites. The highest concentration recorded only exceeded the ISQG guidelines by 0.9 mg/kg.

Lead levels were low at all sites each year, with only the ISQG guideline being exceeded in 2018 at Lake 2. 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. Lead can reduce the abundance of benthic invertebrates, and depending on the physicochemical conditions, can be harmful to other aquatic organisms (CCME 2002). Lead levels at the lake sites in 2021 are the lowest recorded to date.

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. However, the level appears to be decreasing at each site. Mercury was not detected at any of the stream sites.

Selenium levels approached the NSEQ guideline at Lake 2 in 2018 and 2021, and at Lake 4 in 2021. Selenium was undetected at all stream sites.

Table 1. Concentrations of metals within Lake site sediment samples. 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.

Metals	UNITS	Lake 1		Lake 2			Lake 3	Lake 4		Concentration Guidelines		
		2019	2021	2018	2019	2021	2018	2019	2021	ISQG	PEL	NS
Acid Extractable Aluminum (Al)	mg/kg	22000	12000	22000	25000	16000	6700	7200	22000			
Acid Extractable Antimony (Sb)	mg/kg	ND	ND	ND	ND	ND	ND	ND	ND			25
Acid Extractable Arsenic (As)	mg/kg	8.4	4.8	16	12	6.8	8.3	8.1	9.8	5.9	17	17
Acid Extractable Barium (Ba)	mg/kg	49	26	42	50	30	26	17	35			
Acid Extractable Beryllium (Be)	mg/kg	ND	ND	ND	2.1	ND	ND	ND	ND			
Acid Extractable Bismuth (Bi)	mg/kg	ND	ND	ND	ND	ND	ND	ND	ND			
Acid Extractable Boron (B)	mg/kg	ND	ND	ND	ND	ND	ND	ND	ND			
Acid Extractable Cadmium (Cd)	mg/kg	0.76	0.31	1	0.99	0.46	1.5	0.76	0.63	0.6	3.5	3.5
Acid Extractable Chromium (Cr)	mg/kg	15	8	14	14	8.7	4.6	5.1	14	37.3	90	90
Acid Extractable Cobalt (Co)	mg/kg	9	4.3	8.8	11	5.2	6.8	4.1	6.6			
Acid Extractable Copper (Cu)	mg/kg	12	6	15	10	6.1	13	3.1	9.5	35.7	197	197
Acid Extractable Iron (Fe)	mg/kg	14000	6600	14000	15000	9100	10000	9400	9000			47,766
Acid Extractable Lead (Pb)	mg/kg	34	8.8	49	24	8	13	13	8.9	35	91.3	91.3
Acid Extractable Lithium (Li)	mg/kg	17	8	10	9.7	4.9	11	14	13			
Acid Extractable Manganese (Mn)	mg/kg	540	230	480	1300	430	1000	290	460			1,100
Acid Extractable Mercury (Hg)	mg/kg	0.27	0.15	0.27	0.2	0.12	0.16	ND	0.12	0.17	0.486	0.486
Acid Extractable Molybdenum (Mo)	mg/kg	ND	ND	ND	2	ND	ND	ND	2			
Acid Extractable Nickel (Ni)	mg/kg	10	4.9	7.5	6.9	4.3	5.7	4.6	8.7			75
Acid Extractable Phosphorus (P)	mg/kg	1900		1900	2200		400	490				
Acid Extractable Rubidium (Rb)	mg/kg	11	5.9	6.3	6.2	3.5	4.7	5.5	7			
Acid Extractable Selenium (Se)	mg/kg	1.3	0.89	1.8	1.8	1.1	ND	ND	1.7			2
Acid Extractable Silver (Ag)	mg/kg	ND	ND	ND	ND	ND	ND	ND	ND			1
Acid Extractable Strontium (Sr)	mg/kg	13	6.1	13	13	8.1	ND	ND	8.7			
Acid Extractable Thallium (Tl)	mg/kg	0.26	0.13	0.26	0.24	0.13	0.34	0.11	0.31			
Acid Extractable Tin (Sn)	mg/kg	2.5	ND	3	1.5	ND	2	ND	ND			
Acid Extractable Uranium (U)	mg/kg	4.3	2.6	5.7	6.5	3.7	1.7	2	7.3			
Acid Extractable Vanadium (V)	mg/kg	23	12	30	34	21	11	12	24			
Acid Extractable Zinc (Zn)	mg/kg	87	46	93	89	48	96	66	110	123	315	315
Orthophosphate (P)	mg/kg	0.15	0.39	0.067	0.086	0.27	0.26	0.24	0.24			

Table 2. Concentrations of metals within stream site sediment samples.

	UNITS	Forties River	Zwicker Brook	Sherbrooke River	Concentration Guidelines		
					ISQG	PEL	NS
<b>Metals</b>		2018	2019	2021			
Acid Extractable Aluminum (Al)	mg/kg	4300	4700	3300			
Acid Extractable Antimony (Sb)	mg/kg	ND	ND	ND			25
Acid Extractable Arsenic (As)	mg/kg	2.7	ND	ND	5.9	17	17
Acid Extractable Barium (Ba)	mg/kg	26	18	18			
Acid Extractable Beryllium (Be)	mg/kg	ND	ND	ND			
Acid Extractable Bismuth (Bi)	mg/kg	ND	ND	ND			
Acid Extractable Boron (B)	mg/kg	ND	ND	ND			
Acid Extractable Cadmium (Cd)	mg/kg	ND	ND	ND	0.6	3.5	3.5
Acid Extractable Chromium (Cr)	mg/kg	4.7	4	4	37.3	90	90
Acid Extractable Cobalt (Co)	mg/kg	2.3	2.2	1.9			
Acid Extractable Copper (Cu)	mg/kg	ND	4.2	ND	35.7	197	197
Acid Extractable Iron (Fe)	mg/kg	8300	6800	5800			47,766
Acid Extractable Lead (Pb)	mg/kg	3.3	3.3	4.2	35	91.3	91.3
Acid Extractable Lithium (Li)	mg/kg	20	21	16			
Acid Extractable Manganese (Mn)	mg/kg	200	110	150			1,100
Acid Extractable Mercury (Hg)	mg/kg	ND	ND	ND	0.17	0.486	0.486
Acid Extractable Molybdenum (Mo)	mg/kg	ND	ND	ND			
Acid Extractable Nickel (Ni)	mg/kg	2.3	3.1	2.2			75
Acid Extractable Phosphorus (P)	mg/kg	180	190				
Acid Extractable Rubidium (Rb)	mg/kg	17	7.8	11			
Acid Extractable Selenium (Se)	mg/kg	ND	ND	ND			2
Acid Extractable Silver (Ag)	mg/kg	ND	ND	ND			1
Acid Extractable Strontium (Sr)	mg/kg	ND	ND	ND			
Acid Extractable Thallium (Tl)	mg/kg	0.12	ND	ND			
Acid Extractable Tin (Sn)	mg/kg	ND	ND	ND			
Acid Extractable Uranium (U)	mg/kg	0.52	0.77	0.46			
Acid Extractable Vanadium (V)	mg/kg	11	9	7.3			
Acid Extractable Zinc (Zn)	mg/kg	20	34	20	123	315	315
Orthophosphate (P)	mg/kg	0.28	0.38	0.36			

Table 3. Summary of guideline exceedances of 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

Metals	UNITS	Lake 1		Lake 2			Lake 3	Lake 4	
		2019	2021	2018	2019	2021	2018	2019	2021
Acid Extractable Arsenic (As)	mg/kg	8.4	4.8	16	12	6.8	8.3	8.1	9.8
Acid Extractable Cadmium (Cd)	mg/kg	0.76	0.31	1	0.99	0.46	1.5	0.76	0.63
Acid Extractable Lead (Pb)	mg/kg	34	8.8	49	24	8	13	13	8.9
Acid Extractable Mercury (Hg)	mg/kg	0.27	0.15	0.27	0.2	0.12	0.16	ND	0.12

### 2.2.3. Sediment Phosphorus and Orthophosphate

Concentrations of both acid extractable (total) phosphorus and bioavailable orthophosphate in sediment were analyzed from 2018 to 2021, with total phosphorus being excluded from the 2021 sample.

Table 4. Orthophosphate and Total Phosphorus levels from the annual sediment samples at the Lake and Stream Sites.

	Lake 1		Lake 2			Lake 3	Lake 4		Forties River	Zwicker Brook	Sherbrooke River
	2019	2021	2018	2019	2021	2018	2019	2021	2018	2019	2021
Orthophosphate in sediment (mg/kg)	0.15	0.39	0.0067	0.086	0.27	0.26	0.24	0.24	0.33	0.38	0.36
Acid extractable phosphorus in sediment (mg/kg)	1900		1900	2200		400	490		180	190	

Orthophosphate levels increased at all sites in 2021, except for Lake 4, which remained at the same level as in 2019. Sherbrooke River showed similar levels of orthophosphate as the two other stream sites sampled in 2018 and 2019. 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 (Ontario MOE 2008). These guidelines have previously been approached and exceeded at Lake 1 and Lake 2, but not Lake 3 or Lake 4.

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, Reid, and Cameron, 1985). Increased levels

of phosphorus released from sediments into the water (internal phosphorus loading) can cause nutrient-enrichment and potential eutrophication and algal blooms (Sondergaard, Jensen, and Jeppesen, 2003) – this is particularly susceptible during turnover when nutrient-rich bottom waters are mixed throughout the lake, providing new food sources for organisms.

### **3. Discussion**

Similar to the 2018 and 2019 monitoring results, the water quality of Sherbrooke Lake and its tributaries did not identify any significant water quality issues in 2021. Several algal blooms were reported in SL in 2021; however, sampling blooms and determining their toxicity remains a challenge. All visible blooms should be treated with caution and ongoing efforts will continue to improve the reporting and advisory process.

#### **3.1. Algae Blooms in Sherbrooke Lake**

NS Environment's current system of notifying lake residents of potentially harmful algae blooms is reactive and can be ineffective. NSE responds to reports of suspected blooms but inspectors are not always able to respond in time to witness the bloom. NSE rarely collects water samples for analysis and often has to post precautionary advisories based on the appearance of a bloom in photographs from 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, Dermatotoxins, and other irritant toxins are also produced by cyanobacteria (Health Canada 2012). The majority of commercial labs in Canada do not test for these toxins. 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.

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 size and frequency of blooms, globally, in the future (Michalak et al. 2013). Although nitrogen and phosphorus levels remain low, algal blooms should continue to be monitored and tested within Sherbrooke Lake, with residents made aware of algal bloom causes, health effects, precautions to take, and the reporting procedure if a bloom occurs.

#### **3.2. 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- $\alpha$  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). The following information was based on data collected from Lake sites 1,2, and 4 from June to October of 2021.

Four Secchi disk readings were missed due to inclement weather conditions during sample days. This included Secchi readings from all sites in August, and from Lake 2 in September. The calculations below omitted the four missing data points.

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

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

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

Table 5. TSI values for all lake sites in 2021 for three parameters.

Parameter	Calculated TSI Value
Secchi disk (transparency)	47.66
Chlorophyll-α	41.50
Total Phosphorus	29.16
<b>TSI Value</b>	<b>39.45</b>

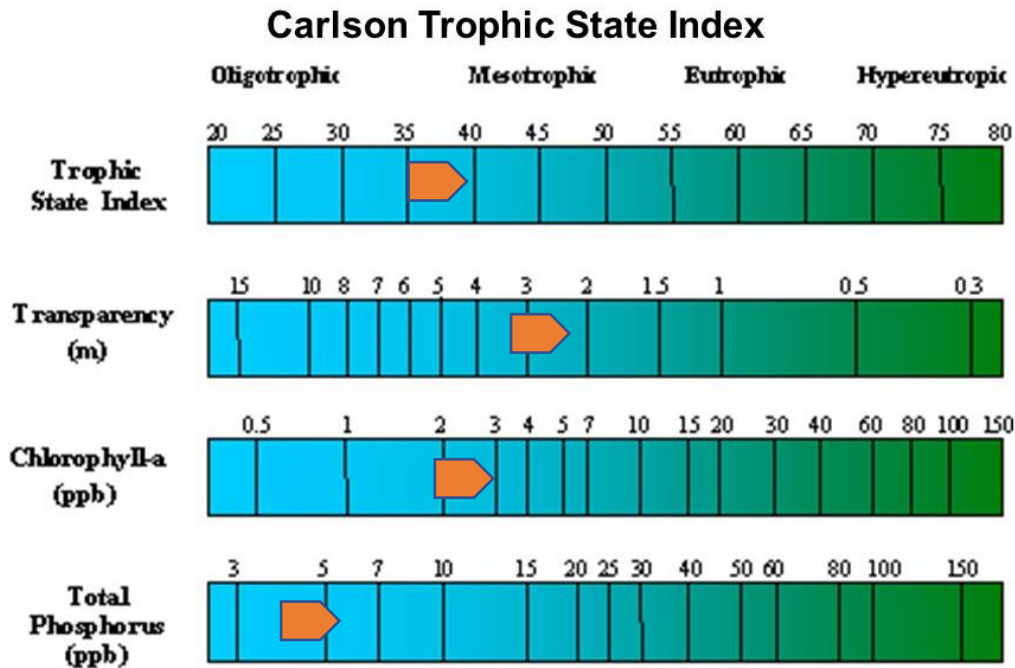


Figure 28. Carlson TSI for Sherbrooke Lake in 2021 using the mean Secchi disk depth (transparency), mean chlorophyll a concentration and mean total phosphorus concentration. (Carlson, 1977)

The trophic state of SL in 2018 and 2019 was oligotrophic-mesotrophic. The transition from oligotrophic to mesotrophic is a TSI score of 40. In 2018 and 2019, the TSI was less than a 10<sup>th</sup> of a decimal over 40, therefore classifying the lake as mesotrophic. In 2021, the TSI score was 39.4, putting the lake into an oligotrophic state. SL appears to be maintaining a steady TSI score over the three years this data has been collected (Figure 29). The Total Phosphorus remains the lowest of all TSI scores every year, while the Secchi TSI score is the highest. 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, resulting in an oligotrophic status.

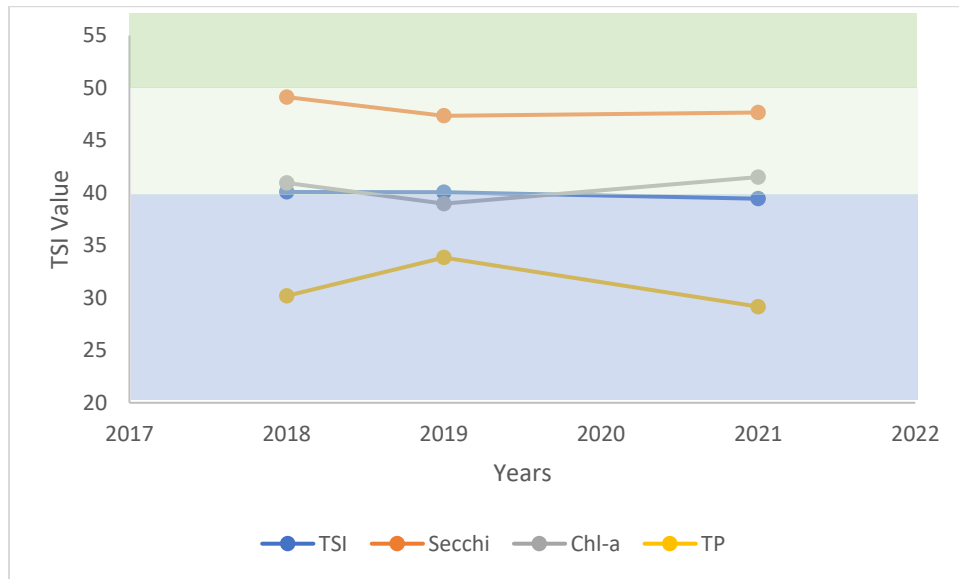


Figure 29. Comparison of Lake site TSI scores from 2018 to 2021 using the Carlson (1977) trophic equations for total phosphorus, chlorophyll  $\alpha$ , and Secchi disk (2020 excluded).

## 4. Recommendations

The following recommendations are suggested for the Sherbrooke Lake Water Quality Monitoring Program:

1. The Sherbrooke Lake Water Quality Monitoring Program should continue in 2022 as this program was developed to establish a water quality baseline to aid in evidence-based decisions concerning the development of the public access property acquired by MODL for public use. Development at this site has yet to begin, meaning that further monitoring will continue to establish a baseline understanding of SL water quality before the potential impacts of this development start.
2. A meeting should be arranged between SLSC members and the public access site planning committee to discuss current and future planning activities at the public access site and how they may relate to the water quality of SL.
3. Attempts should be made to identify a lake resident willing and able to host the SL weather station. The station should be installed as early as possible in the monitoring season and checked monthly to ensure it is working properly.
4. Monitoring of the seven inlet streams should continue during rainfall-dependent events, to determine how rainfall is affecting inlet streams.
5. Volunteer monitors should continue to be supplied with bottles for Microcystin-LR sample collection.
6. Algae blooms should continue to be monitored, recorded, and reported to Nova Scotia Environment. Efforts should continue to improve the reporting and advisory process between the NS Department of Environment and Climate Change, municipal units, and SL cottage associations.
7. Depth profiles & Secchi disk readings should be taken during periods of low wind to ensure accurate data is collected. Depth profiles at all lake sites should be added as a monthly monitoring activity given the varying strength and depth of the thermocline observed at these sites in previous years and considering the elevated nutrient concentrations observed in deeper waters.
8. Sediment total phosphorus should be included in the 2022 sample. BV labs now require a separate analysis for this parameter.

## 5. Sherbrooke Lake Algae Pilot Project

During the summer of 2020, there were several reports of potential algal blooms along the shoreline of Sherbrooke Lake. NS Environment did not collect samples to confirm cyanobacteria (blue-green algae) but determined through observations that it was a risk. This resulted in an alert for the public to avoid water contact in the lake for the remainder of the summer; however, that advisory did not reach all residents and property owners on the lake. This indiscriminate response is not ideal as it affected the entire lake for an indeterminate length of time.

This bloom event led to the discussion of the need for a more targeted and pre-emptive approach to cyanobacteria blooms on Sherbrooke Lake. With climate change contributing to increased water temperatures and longer periods of thermal stratification, the chances of a bloom increase. Having real-time data on algal conditions could allow for a more proactive response by residents of the lake and NS Environment to any potential blooms. Cyanobacteria testing is currently included in the Sherbrooke Lake Water Quality Monitoring Program; however, it is infrequent and limited. Program volunteers are equipped with the appropriate bottles and sampling procedures to respond to potential blooms that get reported by lake residents. A water sample is collected for the analysis of microcystin, a toxin associated with cyanobacteria. This reactive approach is not ideal because algal blooms are sudden events and tend not to last long, making it challenging to find and sample a bloom before it dissipates. Furthermore, cyanobacteria blooms can produce other harmful toxins which can not currently be analyzed at commercial laboratories. For these reasons, NSE must take an extremely precautionary approach to lake closures and advisories following the report of a potential bloom.

This pilot project involved monitoring multiple locations at multiple depths as well as conducting surface water transects using a YSI multiparameter water meter outfitted with a ProDSS Total Algae probe, which measures chlorophyll- $\alpha$  as well as phycocyanin, which is a pigment found in blue-green algae. If phycocyanin readings on the YSI increased beyond a pre-determined threshold a water sample was to be taken and submitted to Bureau Veritas laboratory for an analysis of microcystin. The intent was to use these two sampling methods to determine a relationship between phycocyanin readings on the YSI and the microcystin results from the lab. This way the probe could be used to provide real-time estimates of microcystin present in the lake. Funding for this pilot project was provided by the Plum Foundation and MODL. The YSI Total Algae probe was purchased by MODL.

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- $\alpha$  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 sample days, seven baseline samples, and one bloom event. All seven baseline days showed no detected microcystin and low levels of chlorophyll- $\alpha$  ranging from 3.01  $\mu\text{g/L}$  to 9.42  $\mu\text{g/L}$ . The bloom event yielded no microcystin but elevated chlorophyll- $\alpha$  levels of 123  $\mu\text{g/L}$ . This result shows that there was indeed a bloom on October 10<sup>th</sup>, but it likely did not consist of blue-green algae.

The chlorophyll- $\alpha$  levels from the baseline water samples to the algae probe were put through a Pearson's r statistical test to check for statistical significance between the two datasets. The test determined that there is no statistical significance between the two data sets, meaning that one reading cannot be used to predict the other. This test could not be performed on the phycocyanin levels given that all of the water samples did not yield any results.

Wong and Hobbs (2019) performed the same analysis with the intent to discover a statistical significance between phycocyanin RFU values from a YSI EXO Sonde, fixed with a Total Algae Probe, and phycocyanin  $\mu\text{g/L}$  values from a water sample. They discovered a statistically significant relationship between the results they collected from their Sonde and water samples.

Notable differences between these two projects were that Coastal Action's analysis was testing chlorophyll-a, while Wong and Hobbs were testing for phycocyanin. The two projects also used different probes and sampling intervals. Coastal Action used a ProDSS Total Algae probe, with which a single data point was taken, while Wong and Hobbs used a YSI EXO 3 Total Algae probe which was attached to a dock and took hourly readings.

Table 6. Chl-a water sample results compared to the Total Algae Probe results from July 23, 2021.

Site	Probe (RFU)	Sample ( $\mu\text{g/L}$ )
Bangay 3	0.89	3.29
Bangay 3a	n/a	4.13
Deep Cove 1	0.75	3.55
Inlet 4	0.88	3.01
Municipal 2	0.8	3.41

Table 7. Chl-a water sample results compared to the Total Algae Probe results from August 25, 2021.

Site	Probe (RFU)	Sample (Chl-a $\mu\text{g/L}$ )
Forties	0.72	9.42
Algae Bay	0.71	3.48

Depth profiles were also performed during the July, August, and October sampling days. The only notable increase in phycocyanin (RFU) occurred at the Deep Cove site during the

July samples. The levels of phycocyanin increased from 0.1 RFU at 8m depth, to 0.71 RFU at 16m depth (Figure 30). Temperature data taken at the same time show that phycocyanin levels start to increase below the thermocline. YSI readings were taken at 2-m intervals at this site. All other depth profiles showed low and consistent chlorophyll- $\alpha$  and phycocyanin RFU values.

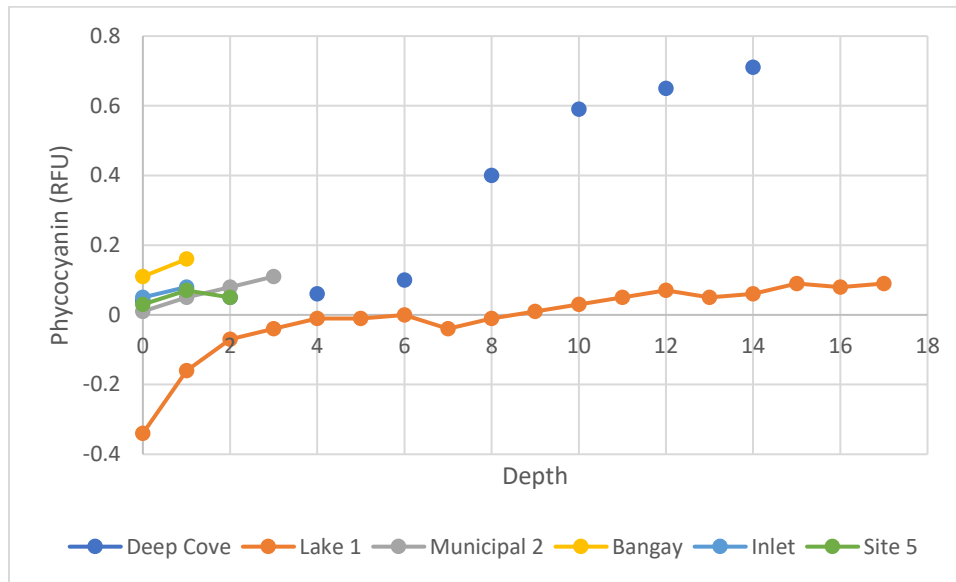


Figure 30. Phycocyanin (RFU) depth profile taken on July 23<sup>rd</sup>, 2021.

Coastal Action does not recommend replicating the same sampling activities in 2022. The current method of sporadic water and YSI readings has shown not to yield useable data. A change to project methods, similar to the ones used by Wong and Hobbs, may be required to achieve the goal of real-time algae warnings. However, given the size of Sherbrooke Lake, several permanent sampling stations would need to be set up at various locations on the lake with a satellite system that provides real-time YSI readings. This comes with several logistical and resourcing challenges such as station security, maintenance, and staff hours/availability for on-demand water sampling. The cost of a project and stations such as this would be considerable and would likely need to run for several years to gather enough data to predict algae bloom events. The Sherbrooke Lake Stewardship Committee has recommended that a literature review be conducted to review current algae bloom identification and notification practices.

## 6. References

- Canadian Council of Ministers of the Environment (CCME). (1999). Canadian water quality guidelines for the protection of aquatic life: Dissolved oxygen (Freshwater). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.
- Canadian Council of Ministers of the Environment (CCME). 2002. Canadian water quality guidelines for the protection of aquatic life: Total particulate matter. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.
- Carlson, R. E. (1977). A trophic state index for lakes. *Limnology and oceanography*, 22(2), 361-369.
- Dodds, W.K. and Welch, E.B. (2000). Establishing nutrient criteria in streams. *J.N.Am.Benthol.Soc.*19(1), 186-196.
- Genzoli, L. & Kann, J. (2016). Evaluation of phycocyanin probes as a monitoring tool for toxigenic cyanobacteria in the Klamath River below Iron Gate Dam. 10.13140/RG.2.2.23897.31841.
- Hayes, F.R., Reid, B.L, & Cameron, M.L. (1985). Lake Water and Sediment. *Limnology and Oceanography*, 3, 308-317.
- Health Canada. (2012). Guidelines for Canadian Recreational Water Quality, Third Edition. Water Air, and Climate Change Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. (Catalogue No H129-15/2012E).
- Hinch, P.R. and Underwood, J.K. 1985. A study of aquatic conditions in Lake Echo during 1984. N.S. Dept. Env. Lib. L192.1 85/00 C2. 38 p.
- Michalak, A.M., Anderson, E.J., Beletsky, D., Boland, S., Bosch, N.S., Bridgeman, T.B., Chaffin, J.D., Cho, K., Confesor, R., Daloğlu, I. and DePinto, J.V. (2013). Record-setting algal bloom in Lake Erie caused by agricultural and meteorological trends consistent with expected future conditions. *Proceedings of the National Academy of Sciences*, 201216006.
- Nova Scotia Environment (NSE). (2014). Environmental Quality Standards for Contaminated Sites, Rationale and Guidance Document. Version 1.0, April 2014. 57 p.
- Nova Scotia Salmon Association (NSSA) NSLC Adopt-A-Stream Program. (2014). Walking the River: A Citizen's Guide to Interpreting Water Quality Data. 43 p.
- Nova Scotia Salmon Association (NSSA) NSLC Adopt-a-Stream Program. (2015). Acid Rain. [<http://www.nssalmon.ca/issues/acid-rain>].
- Ontario Ministry of the Environment (MOE). (1979). Rationale for the establishment of Ontario's Provincial Water Quality Objectives. Queen's Printer for Ontario. 236 p.
- Ontario Ministry of the Environment (MOE). (2008). Guidelines for Identifying, Assessing and Managing Contaminated Sediments in Ontario. Queen's Printer for Ontario. 112 p.
- Søndergaard, M., Jensen, J. P., & Jeppesen, E. (2003). Role of sediment and internal loading of phosphorus in shallow lakes. *Hydrobiologia*, 506(1-3), 135-145.

Wong, S. and W.O. Hobbs. 2019. Exploring the Use of Fluorometric Sensors to Monitor Harmful Algal Blooms in Lakes. Publication 20-03-010. Washington State Department of Ecology, Olympia.  
<https://fortress.wa.gov/ecy/publications/SummaryPages/2003010.html>.