2020 - 2024 Lake Monitoring Program Report

Municipality of the County of Kings

Final Version

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COASTAL ACTION

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CONSERVATION AT WORK

2020 - 2024 Lake Monitoring Program Report

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Executive Summary

This report summarizes data collected as part of the 2020 – 2024 Kings County Lake Monitoring Program. The thirteen (13) sampled lakes included in this report are Armstrong Lake, Aylesford Lake, Black River Lake, Gaspereau Lake, Hardwood Lake, Lake George, Lake Torment, Little River Lake, Loon Lake, Lumsden Pond, Murphy Lake, Sunken Lake, and Tupper Lake which are all located within the Municipality of the County of Kings in Nova Scotia, Canada. Water quality samples were taken from 2020 to 2024 during the months of May to October and the analysis of these samples were used to create a Water Quality Index (WQI) for each lake as an indicator of overall lake health. Indicators used to develop the WQI for each lake included Total Phosphorus, Total Nitrogen, temperature, pH, turbidity, and chlorophyll a.

WQI assessments for the thirteen (13) sampled lakes remained between marginal and excellent with none of the lakes indicated to have poor water quality. Further analysis of lake health was done using a Mann-Kendall trend analysis for Total Phosphorus and Total Nitrogen levels within the sample lakes. Little River Lake was omitted due to missing data during the 2020 – 2024 period. Statistically significant increasing trends were observed in Armstrong Lake, Loon Lake, and Murphy Lake while decreasing trends were observed in Gaspereau Lake and Lumsden Pond.

1.0 Introduction

1.1 Background

This report summarizes the 2020 – 2024 field season of the Kings County Lake Monitoring Program. The Kings County Lake Monitoring Program was initiated by citizen scientists from the Municipality of the County of Kings in 1997. It began as a multi-stakeholder group, including three (3) different levels of government and community groups (CARP, 2010). The Kings County Lake Monitoring Program is one of Canada's longest recorded citizen-scientist programs for water quality and lake health and has made valuable contributions to local conservation and limnology research (Table 1). The program was formed to address perceived concerns surrounding the impact of development on lake shorelines in the Municipality of the County of Kings (Municipality).

*Table 1. Examples of longstanding Citizen Science Monitoring Programs in Canada. The Kings County Lake Monitoring Program (**bolded** in table) falls within the top 10. This list may be incomplete and references programs known to the authors at the time of this report.*

Year	Citizen Science Monitoring Program
1962	The Federation of Ontario Cottagers' Association
1969	Canadian Lakes Association
1971	The Manitoba Conservation Districts Association
1991	The Alberta Lake Management Society
1992	British Columbia Lake Stewardship Society
1995	Lake Winnipeg Community-Based Monitoring Network
1996	The Lake Partner Program
1997	**Kings County Lake Monitoring Program**
1998	Quebec's Réseau de surveillance des lacs (Lake Monitoring Network)
2001-2019	Lake Ontario Waterkeeper (merged with Environmental Defence (non-profit) in 2019)
2001-2013	Canadian River Network's Volunteer Programs (merged with Ecology Action Centre in 2013)
2002-2013	Saskatchewan Watershed Authority's Water Quality Monitoring Program (merged with Water Security Agency in 2013)
2003	Lake Simcoe Conservation Foundation (LSCF)

Many lakes in Nova Scotia, including most in the Gaspereau River watershed, are dystrophic, also known as humic or brown water lakes. These lakes are characterized by brown, acidic water with low oxygen levels and support relatively low biodiversity due to high concentrations of dissolved humus, also referred to as soil organic matter. Humic lakes are considered nutrient-poor, but organic-rich (Lund, 1967). They can be found in forested areas, especially in the boreal and Acadian Forest regions (CARP, 2010).

Dystrophic lakes have complex phosphorus dynamics that pose difficulties for predictive phosphorus modelling and traditional water quality indicators. When low oxygen levels are found in non-dystrophic lakes, this is usually an indicator of poor water quality. This cannot be generalized to dystrophic lakes, as they naturally have low oxygen conditions (Kevern, King and Ring, 1996; Cole, 1983). The relationship between phosphorous, chlorophyll a (Chl-a) and Secchi depth in these lakes do not appear to have the same correlation as in clear water lakes (Centre for Water Resources Studies, Dalhousie University, & Stantec, 2009). In clear water lakes, Total Phosphorus, Chl-a, and Secchi depth can be used to determine the trophic state or level of aquatic vegetation (Carlson and Simpson, 1996). Total Nitrogen can also be used for this purpose in some cases. While these indicators are normally related and can predict each other, the relationship is not defined for dystrophic lakes (Marty, 2018).

Because lakes lie in depressions within the land, they are natural traps for particulate materials containing nutrients that enter via their inflows. As a result, all lakes gradually accumulate nutrients and at some point, may become eutrophic (Centre for Water Resources Studies, Dalhousie University, & Stantec, 2009). Eutrophication is defined as the over-enrichment of nutrients in water (Lund, 1967). Eutrophication is a naturally occurring phenomenon, however, humankind has had a hand in altering the frequency and intensity to which it occurs (Reavie et al., 2000; Hasler & Swenson,1967; Henderson Sellers et al., 1987). Cultural eutrophication refers to the phenomenon of eutrophication occurring due to anthropogenic causes. Such anthropogenic causes often include human sewage, industrial wastes, phosphate detergents, drainage from farmlands, and run-off from impervious roadways (Hasler & Swenson, 1967). It can be predicted that increased human presence in areas where bodies of water occur would increase the probability of cultural eutrophication (Marvel, 2015). Common nutrients limiting to aquatic ecosystems are nitrogen and phosphorus, but studies have evaluated that phosphorus is the limiting nutrient for freshwater systems such as lakes (Hasler & Swenson, 1967). Phosphorus loading of a natural system is thought to be negative for various reasons, one of the most important being that it acts as a limiting nutrient for algal growth (Marvel, 2015).

1.2 Project Location

The lakes currently sampled in the Kings County Lake Monitoring Program are located in three (3) different watershed drainage basins, known as the Gaspereau River Watershed, the LaHave River Watershed, and the Cornwallis River Watershed (Figure 1). The surficial geology of the Kings County Lake Monitoring Program area can be seen in Figure 2, where it

can be noted that the most dominant geology of the area is silty and stony till plain, as well as dense areas of bedrock. The watershed boundaries created through changes in topography from the South Mountain Ridge act as barriers to divide the watersheds, keeping them hydrologically separate from one another (Bush & Baldo, 2019). Most of the lakes in the Lake Monitoring Program are found within the Gaspereau River Watershed (Loon Lake, Lake George, Aylesford Lake, Gaspereau Lake, Murphy Lake, Little River Lake, Black River Lake, Lumsden Pond, and Sunken Lake), while the rest of the lakes can be found in the LaHave (Hardwood Lake, Armstrong Lake, and Lake Torment) and the Cornwallis (Tupper Lake) River watershed. Understanding watershed scale hydrology and the connectedness from lake to lake is important for identifying sources of pollution and degradation as lake health can be influenced by watershed scale elements. Upstream sourced pollutants can influence downstream lake health as water flows downstream throughout the watershed.

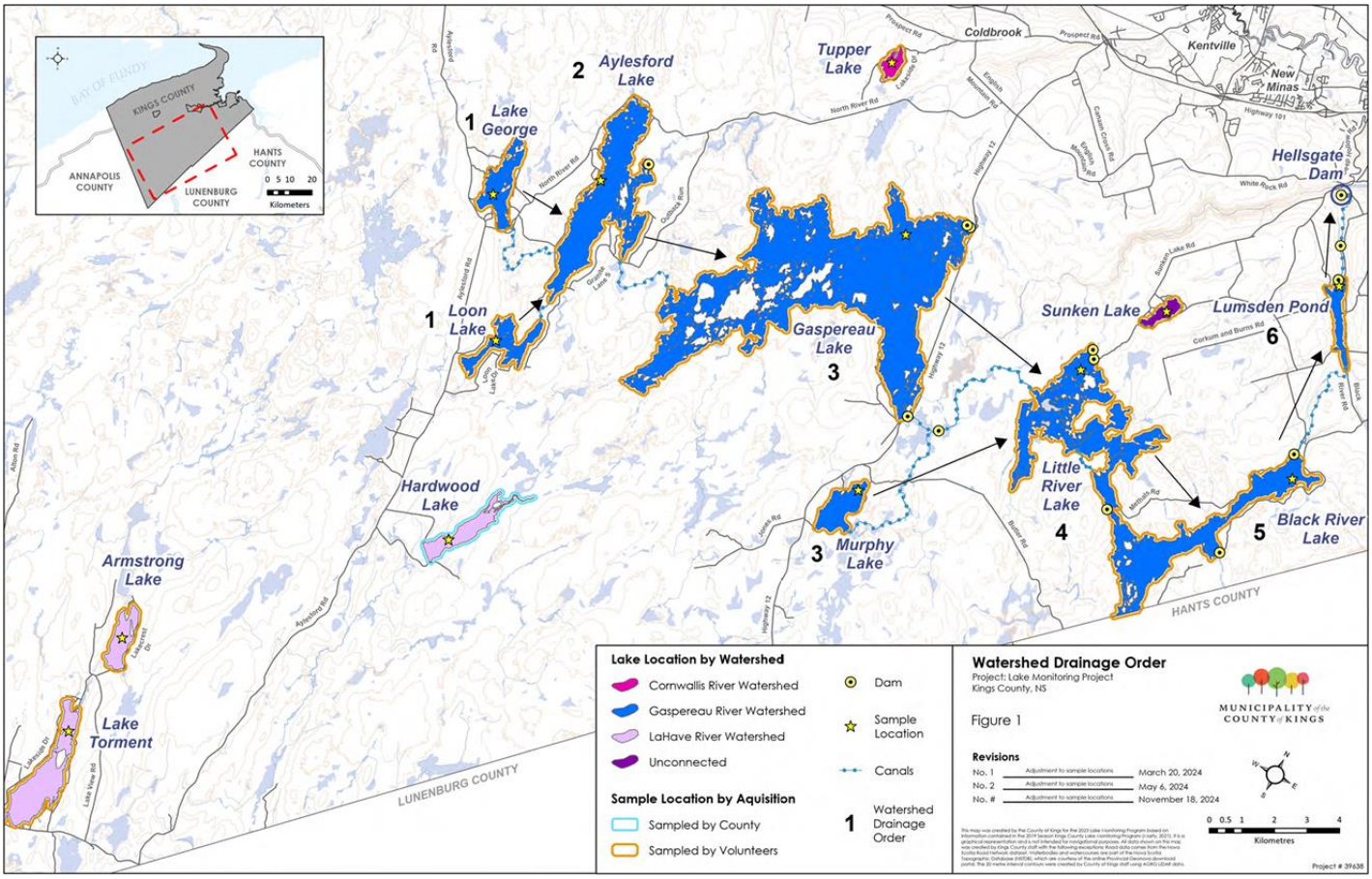


Figure 1. Map of watershed drainage order, sampling locations, and locations of dams in Kings County Lake Sampling Program. Provided by the Municipality of the County of Kings.

1.2.1 Gaspereau River Watershed

Stream order or waterbody order is a numbering system used to indicate the level of branching of water flow and position of a waterbody or watercourse within a watershed. A "first order" waterbody is higher up in the watershed and the water flows from here into the

"second order" lake and so on until it is drained into the ocean. The drainage order of the lakes included in the Lake Monitoring Program found in the Gaspereau River watershed are as follows; Lake George and Loon Lake are first (1st) order lakes located in the headwaters of the watershed, which supply water to Aylesford Lake, a second (2nd) order lake through Loon Lake Channel and Lake George Brook. Gaspereau Lake and Murphy Lake are third (3rd) order lakes, which are followed by the fourth (4th) order Little River Lake, which drains to the fifth (5th) order Black River Lake and then into the sixth (6th) order Lumsden Pond (Figure 1). Although Sunken Lake is located within the Gaspereau River Watershed drainage boundary, it is unique in that it is entirely spring fed and is not supplied by other lakes. From these factors, Sunken Lake has different characteristics than the other lakes involved in the Lake Sampling Program.

Notably, the Gaspereau River Watershed has hydroelectric stations controlled by Nova Scotia Power. The lakes sampled in the Lake Sampling Program where hydroelectric damming systems have been installed are; Aylesford Lake, Gaspereau Lake, Little River Lake, Black River Lake, and Lumsden Pond. The installation of these dams has transformed naturally occurring lakes into reservoirs and naturally occurring rivers into flowage lakes. These flowage lakes are unique as the installation of dams has created areas for water to pool, mimicking how natural depressions retain water. The transition to a reservoir or flowage lake means that regular environmental and seasonal variability of water levels and nutrients can be affected and altered by dam control through drawdowns causing rapid changes in water level. It has been observed that hydroelectric dams can have adverse effects on lake health by decreasing dissolved oxygen levels and increasing temperature (Bunea et al., 2010; Zaidel et al., 2021). It is possible that the dams located within these watershed boundaries can have similar impacts on lake water quality and influence overall lake health. Overall, the installation of these dams resulted in lakes increasing in size to retain more water, and the creation of lakes in areas that were historically rivers. There have also been a number of canals and diversions constructed which impact the natural flow of water throughout the drainage basin, this has resulted in the size of the Gaspereau River Watershed increasing from 384.1 km^2 to 520.1 km^2 (Meade, 2000).

1.2.2 LaHave River Watershed

Armstrong Lake, Lake Torment, and Hardwood Lake are all part of the LaHave River Watershed Drainage Basin. Both Armstrong Lake and Lake Torment are located in the North River sub-watershed where the drainage of Armstrong Lake supplies water to Lake Torment. Hardwood Lake is located in the North Branch sub-watershed and has no interaction with any of the lakes in the Kings County Lake Monitoring Program. Both of these sub-watershed's feed into the main branch sub-watershed of the LaHave system.

1.2.3 Cornwallis River Watershed

Tupper Lake is found in the Cornwallis River Drainage Basin and has no interaction with the other lakes in the Kings County Lake Monitoring Program. This lake drains into Tupper Lake Brook which flows down into the Cornwallis River.

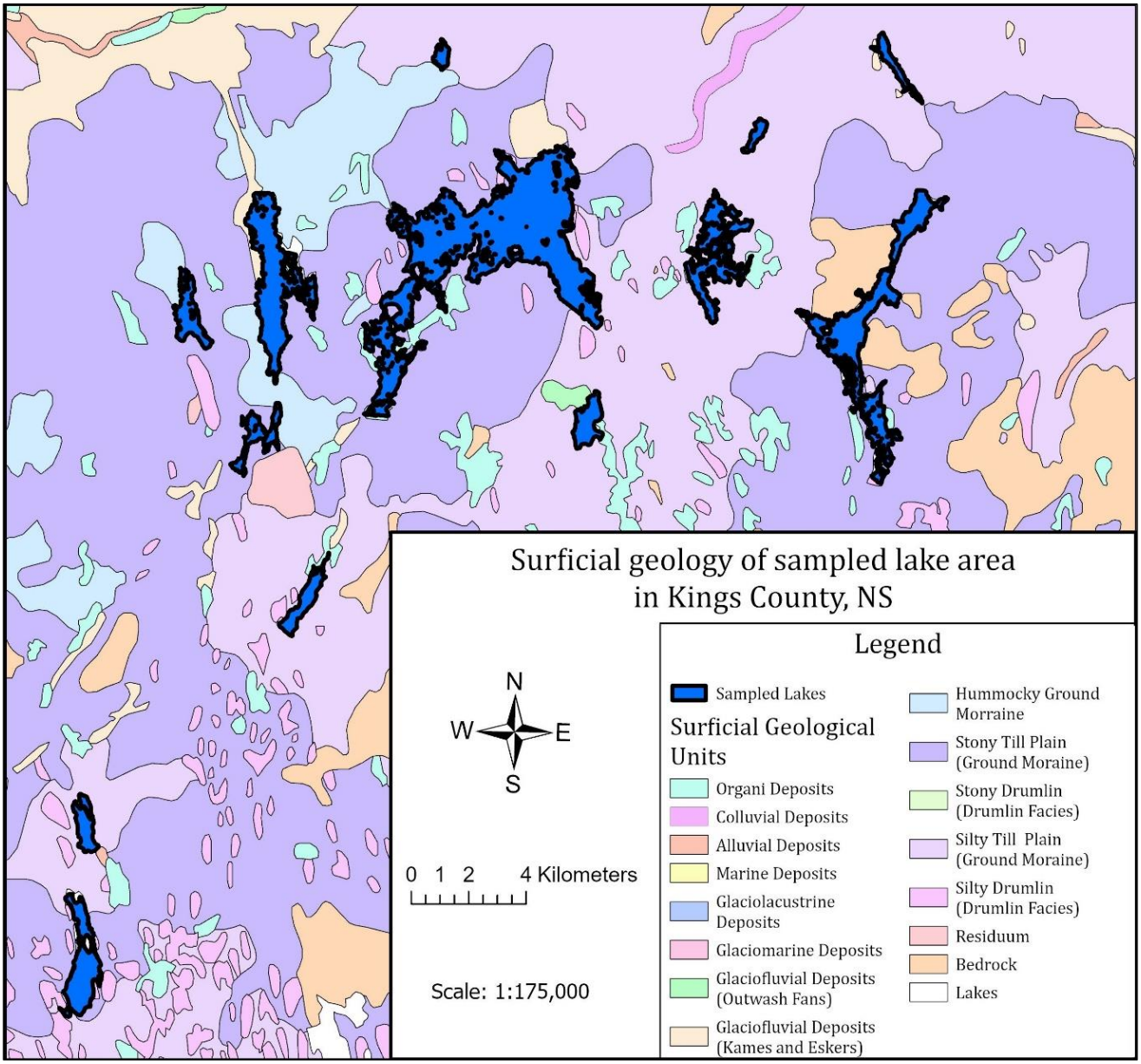


Figure 2. Surficial Geology & Sampled Lakes, Kings County, NS

1.3 Objectives

This report is intended to provide a lake monitoring program overview for the years 2020, 2021, 2022, 2023, and 2024. The goal of the report is to provide an overview of the ongoing lake monitoring protocol, information, and data analysis for each of the thirteen (13) study

lakes. Water Quality Index (WQI) Report Cards and trend analysis are provided for each of the thirteen (13) study lakes to identify changes to lake health from 2020 – 2024.

Coastal Action's goal is to support the Municipality of the County of Kings and its dedicated volunteer group in managing these lakes on a long-term sustainable basis using objectively verifiable indicators so that future generations can continue to enjoy these resources. This report aims to inspire and motivate the community to explore new approaches for improving lake management while offering insights into factors that can contribute to cultural eutrophication. This report aims to give a picture of ecological health for each of the studied lakes based on the collected data provided through the Lake Monitoring Program. A more current picture of lake health for the thirteen (13) lakes is presented throughout this report.

1.4 Scope

This report is intended to create a state of the environment report on the health of the thirteen (13) studied lakes using the best information currently available as gathered during the Lake Monitoring Program. The report utilizes the long-established efforts of the Lake Monitoring Program to analyze trends in nutrients and other important lake health indicators.

2.0 Methodology

2.1 Sampling Analysis

Each year during the beginning of the program, the Municipality holds a meeting in Spring to train volunteers in the procedures for recording data, taking various water quality measurements, and proper collection procedures for sampling. The majority of the sampling for the Kings County Lake Monitoring Program is completed by volunteers as they sample twelve (12) lakes, while the Municipality samples Hardwood Lake as a "control lake" to provide a baseline for comparison of any identified natural variation or external influences that may occur. A map showing the marked sample locations are presented in Figure 1.

Table 2. Kings County Lake Monitoring Program sampling locations. Easting & Northing are formatted in UTM coordinates (Municipality of the County of Kings).

Lake	Northing	Easting
Armstrong Lake	4,959,389.00	362,275.56
Aylesford Lake	4,978,745.84	368,528.15
Black River Lake	4,980,786.04	391,581.20
Gaspereau Lake	4,981,738.20	377,563.82
Hardwood Lake	4,966,811.25	369,664.30
Lake George	4,976,797.86	365,823.21
Lake Torment	4,956,084.06	362,193.47
Little River Lake	4,980,639.16	384,271.13
Loon Lake	4,972,888.56	368,031.27
Lumsden Pond	4,986,676.17	390,034.58
Murphy Lake	4,974,134.46	380,014.15
Sunken Lake	4,983,471.67	385,738.09
Tupper Lake	4,986,183.88	374,674.85

Sampling is generally completed as close to noon as possible on the third (3rd) Sunday of each month from early May to late October weather permitting. The sampling sites are marked with a buoy located at the deepest point of the lakes. The volunteer group uses a boat to access the sampling locations and tie onto the buoy while sampling is completed, the sampling location coordinates can be found in Table 2. Volunteers are instructed to collect samples near the surface and either 1 m from the lake bottom or at twice the Secchi depth, whichever was the shallower measurement, as shown in Figure 3. These two (2) samples are then required to be combined into one (1) bottle prior to being sent to the laboratory.

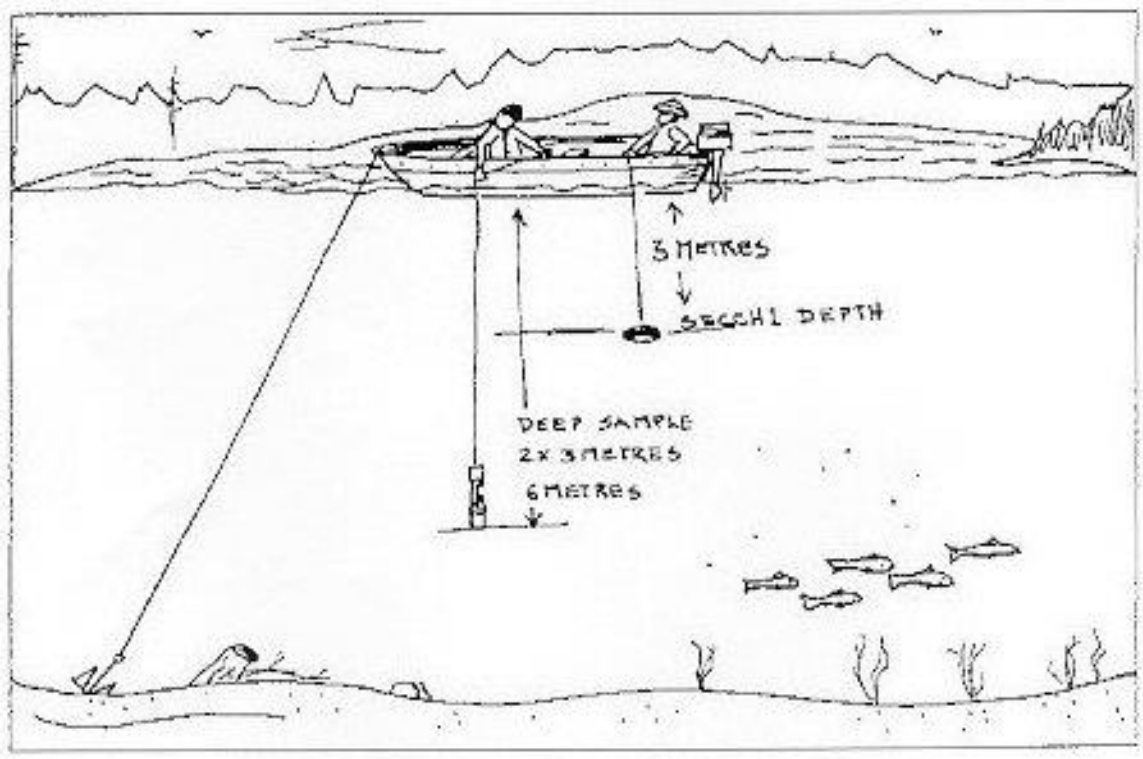


Figure 3. Diagram of sampling technique (Municipality of the County of Kings).

The water samples collected by volunteers at each lake are collected the following day post-sampling by Municipal staff, packaged in a cooler with ice for transportation along with appropriate Chains of Custody, and transported that day to an accredited external laboratory for analysis.

The water samples are laboratory tested for Total Phosphorus, Ortho-phosphorus, Total Nitrogen, Chlorophyll a, Total Organic Carbon, Pheophytin A, pH, and Turbidity. The results from lab analyses are processed through a Water Quality Index (WQI) calculator, which is a tool created by the Canadian Council of Ministers of the Environment (CCME). The value of these measurements as indicators of lake health in dystrophic lakes are presented below in sections 2.1.1. through 2.1.7. to give context for conclusions based on the analysis of collected data.

2.1.1 Total Phosphorus

Phosphorus is a vital element for all living organisms, as it forms the sugar-phosphate backbone of DNA, RNA, and ATP. It is primarily found in the Earth's crust. The phosphorus cycle involves several key steps: the weathering of rocks, absorption by plants, consumption and excretion by animals, decomposition of plant and animal matter, and geologic uplift (Schipanski & Bennett, 2021).

Phosphorus is known to chemically bond with the vast organic molecules, compounds, and various elements in humic materials that are characteristic to dystrophic lakes, therefore

sampling and detection can become complicated. The water quality guideline value for total Phosphorous (TP) can be determined from trigger ranges, which is the desired concentration range for phosphorous to be found in. When this range is exceeded, it indicates a potential environmental problem. A guideline value of <0.02 mg/L has been established which means that lakes found under this guideline can be viewed as either ultra-oligotrophic (TP <0.004 mg/L), oligotrophic (TP 0.004 – 0.01 mg/L), or mesotrophic (TP 0.01 - 0.02 mg/L) (CCME, 2004). When lake TP values exceed the guideline value, they can be considered as meso-eutrophic (TP 0.02 – 0.035 mg/L), eutrophic (TP 0.035 – 0.1 mg/L) or hyper-eutrophic (TP >0.1 mg/L) (CCME, 2004).

2.1.2 Total Nitrogen

There is currently no definitive water quality guideline for total nitrogen (TN) in surface water for Nova Scotia. Eighteen lakes have been monitored by Parks Canada for many years and a guideline of 0.350 mg/L has been established for total nitrogen levels in oligotrophic, brown-water lakes (Parks Canada, 2010). This guideline was used in the analysis of the Lake Monitoring Program data as Kejimkujik lakes are more like the brown water lakes in Kings County than surface water used to establish other guidelines (Marty, J., 2018). As for the two clear water lakes that are monitored in Kings County (Sunken Lake and Tupper Lake), a guideline of 0.9 mg/L is used to better represent the possible nutrient values found in similar systems (Dodds & Welch, 2000).

2.1.3 Chlorophyll a

Chlorophyll is the green pigment found in plants that is responsible for photosynthesis. Chlorophyll a (Chl-a) sampling and analysis is used to observe the abundance of suspended algae in surface waters and is measured in the units µg/L. Algae can have adverse impacts on water quality by causing water coloration when found in high abundance as well as decreasing oxygen levels when algal overgrowth and die off occur (B.C. Ministry of Environment and Climate Change Strategy, 2021). A guideline value of <2.5 µg/L Chl-a is used in this report for analysing lake health where lakes that fall below this guideline are considered to have lower productivity (Vollenweider & Kerekes, 1982).

Blue-green algae (Cyanobacteria) are a public health concern as they can cause harmful algal blooms which have the capacity to release toxins (cyanotoxins) and cause harm to wildlife. A recreational water use guideline value of 33 µg/L for Chlorophyll a is used as an indicator of the potential presence of cyanotoxins (Health Canada, 2024). Although this recreational guideline is important for human awareness, it is worth noting that this value is much higher than that of concern for alterations to lake ecological health and will not be used for interpreting lake health in this report.

2.1.4 Total Organic Carbon

Total Organic Carbon (TOC) is the sum of particulate organic Carbon and dissolved organic Carbon. The TOC of a lake is heavily influenced by the inputs of surrounding terrestrial land

which can be washed in through upstream rivers and tributaries, as well as by heavy rainfall events causing runoff. Dystrophic lakes are characterized by their high content of humic substances and organic matter which gets broken down and causes the distinct dark-colored lake (He et al., 2022). The guideline for TOC is unique to each lake and is based on the TOC historical baseline levels. The Government of British Columbia (1981) has established a guideline of ±20% of the TOC historical mean, which is used in this report to analyze the TOC levels of every lake.

2.1.5 Turbidity

Turbidity is a way of expressing the suspended sediment load of a water body. It is a measurement of the extent to which light will penetrate the water column. Turbidity indicates the number of suspended sediments in the water because light is less likely to penetrate as far in cloudy (i.e. 'turbid') waters. It is measured by passing a beam of light through the water column and measuring the amount of light that is scattered and absorbed. Elevated sediment levels can block light from getting to aquatic plants, impair the functioning of fish gills and interfere with feeding mechanisms of zooplankton. It is measured in nephelometric turbidity units (NTU). The guideline value established for turbidity in lakes is less than 1.3 NTU (Parks Canada, 2010).

2.1.6 Colour

The colour of aquatic systems can be influenced by the fluxes of many factors, causing recurrent changes of the True Colour Value to occur. Colour can be influenced by the type of sediment, the inputs of organic material through heavy rainfall events, the re-suspension of organic matter during lake turnover, the lakes association, and degree of connectivity with wetlands (Moore & Caux, 1997). Colour is measured in True Colour Units (TCU), where low values are associated with clearwater lakes, and high values are associated with dark or brown water lakes. The guideline range for colour is unique to each lake and is based on the lakes specific historical TCU values which must be between the 25^{th} and 75^{th} percentile (Parks Canada, 2010).

2.1.6 Secchi Depth

A Secchi disk is a 20 cm diameter flat disk which usually has alternating black and white quadrants, however when used in marine environments disks are often fully white (NSSA, 2014). This disk is used as a measure of water clarity based on the depth at which the disk disappears when lowering it off the shaded side of a boat. It is important to note that in coloured lakes, Secchi depth is not a good indicator of trophic state or water quality, as the disk is intended for use in clear waters and darker waters would impact how quickly the disk disappears, altering the reliability of readings in darker coloured waters (Marty, J., 2018). The relationship between total Phosphorus, Chl-a, and Secchi depth in coloured lakes does not appear to have the same correlation in dark water lakes as is observed in clear water lakes (Centre for Water Resources Studies and Stantec, 2009).

2.1.7 Temperature

Throughout the Kings County Lake Monitoring Program, temperature has been measured at each lake at two different depths, one reading at the surface, and another reading at double Secchi depth (or 1 meter from bottom when double Secchi depth exceeds maximum lake depth). The guideline value of less than 20°C for lake water temperature was decided based on the effects that temperatures above this can impose on water quality and wildlife. Lake water temperature is an important parameter to monitor as prolonged warm temperatures can lead to increased algal growth in certain conditions, and warm temperatures can negatively impact temperature sensitive species like salmon and trout (MacMillan et al. 2005). Poor land practices around surface waters have been associated with the disturbance of buffer zones that provide shading and bank stabilization which are important for maintaining cooler waters over warm periods (MacMillan et al. 2005).

2.2 Water Quality Index

The Water Quality Index (WQI) is a tool that was developed by the CCME and can be used as a broad and basic indicator of water quality. Data is entered into the system which returns a water quality score from 0 to 100, with 0 indicating the worst water quality and 100 indicating the best. The WQI score is based on three factors: the number of parameters that failed to meet guidelines, the frequency that a parameter failed to meet its guideline, and the magnitude it deviated from the parameter guideline (CCME, 2001).

Validating the CCME WQI score is crucial; even when all the preceding steps have been taken, there is a possibility that the generated CCME WQI score can be an inaccurate assessment of the water quality conditions. In such cases, there are several questions that need to be addressed by the water quality professional to evaluate the validity of the score (CCME, 2001). The water quality parameters used in the WQI of each lake includes Total Phosphorus, Total Nitrogen, temperature, pH, turbidity, and Chl-a.

2.3 Background Lake Data

The background data of each lake was calculated by using the values provided in previous Lake Monitoring Program Reports. To determine the water quality guidelines that depend on background levels (colour, TOC, and Secchi depth), the standard deviation was approximated using data included in previous reports and the data provided to Coastal Action by the Municipality of the County of Kings. The percentiles used for determining each lake's guideline value were estimated using the standard deviation, the calculated average, and Z-scores. The following equation was used to estimate standard deviation:

$$\sigma = (\text{Max. value} - \text{Min. value}) / 4$$

Where ‘Max. value’ is the maximum value observed for the specified parameter and ‘Min. value’ is the minimum value observed for the specified parameter.

The following equation was used to estimate the percentile value for the specified water quality parameter:

$$\text{Percentile value} = (\text{Historical average}) + (Z * \sigma)$$

Where 'Z' is the Z-score value associated with the percentile position amongst the distribution of historical values and 'σ' is the estimated standard deviation. See Appendix A for details on the z-scores used for determining guidelines.

2.4 Mann-Kendall Trend Analysis

The Mann-Kendall trend analysis is a statistical method used to detect monotonic trends (increasing or decreasing patterns) in time series data such as TP or TN concentrations. It is commonly used in hydrology and other fields where analyzing trends over time is important. The purpose of the Mann-Kendall analysis is to determine the statistical significance of the 2020-2024 trends. An alpha value of 0.05 was used resulting in p-values less than 0.05 being accepted as a statistically significant trend. This means that when a trend is accepted as statistically significant, there is a 95% chance that calculated results are correct. All Mann-Kendall trend analyses were done in RStudio.

2.5 Quality Assurance/Quality Control

To ensure accurate observations are made throughout the Report, quality assurance and quality control practices were set in place and held. Coastal Action received data sets from the Municipality of the County of Kings which included data collected by volunteers for the thirteen (13) lakes from 2020 – 2024. Coastal Action completed quality control through cross-examining the lab reports, field sheets, and data compilation to look for any inconsistencies or outlier entries. As a quality control measure, any data that did not have a field sheet or a lab report was excluded from the data analysis to ensure accuracy in the findings provided in the Results presented in Section 3.0 of this Report.

3.0 Results

The 2020 to 2024 Lake Monitoring Program results of each of the thirteen (13) lakes are represented through watershed report cards, the Water Quality Index (WQI), graphing, and Mann-Kendall trend analysis. Results from data analysis, including figures and trends are presented in the following sections for each of the sampled lakes along with written descriptions interpreting the figures and WQI.

3.1 Armstrong Lake

Armstrong Lake is located in the LaHave River Watershed upstream of Lake Torment. Armstrong Lake was not part of the original list of lakes in the Lake Monitoring Program and was added at a later date due to requests from the public.

Data collected from Armstrong Lake between 2020 and 2024 included TP, TN, TOC, colour, and Chl-a. Graphs of these parameters can be seen in Figure 4.

TP levels in Armstrong Lake exceeded the guideline values (0.02 mg/L) twice in 2024 with values of 0.022 mg/L. Values fluctuated between 0.006 mg/L and 0.022 mg/L.

The TN concentrations in Armstrong Lake exceeded guideline values (0.35 mg/L) on 10 samples out of 27 total samples during the period of 2020 – 2024 and had variability in recorded values from year to year and month to month. The annual averages of TN fluctuate around 0.3 mg/L. When looking at the TN concentrations throughout this period, fluctuations between 0.20 mg/L and 0.47 mg/L were observed.

The guideline for TOC is unique for every lake as it is determined from the historical average concentration. In Armstrong Lake, the TOC guideline range is 8.9 - 13.3 mg/L. It was observed that the concentration of TOC was below and above this determined guideline, as values ranged from 5.8 – 17.3 mg/L.

The guideline for colour is determined from the historical average as well, which was found to be 75.8 – 111.9 TCU. For the colour of Armstrong Lake in 2020 – 2024, values ranged from 45.1 – 157.0 TCU, meaning that values were both below and above the guideline range through this period. Values fell below the guidelines on 16 samples and were above the guidelines on 8 samples.

The Chl-a concentrations in Armstrong Lake varied year over year, with the highest values being observed in 2022. The guideline for Chl-a is <2.5 µg/L which was exceeded between 2020 to 2022 with a high maximum of 5.92 µg/L in 2022. The range of Chl-a concentrations observed over 2020-2024 was 0.2 – 5.92 µg/L.

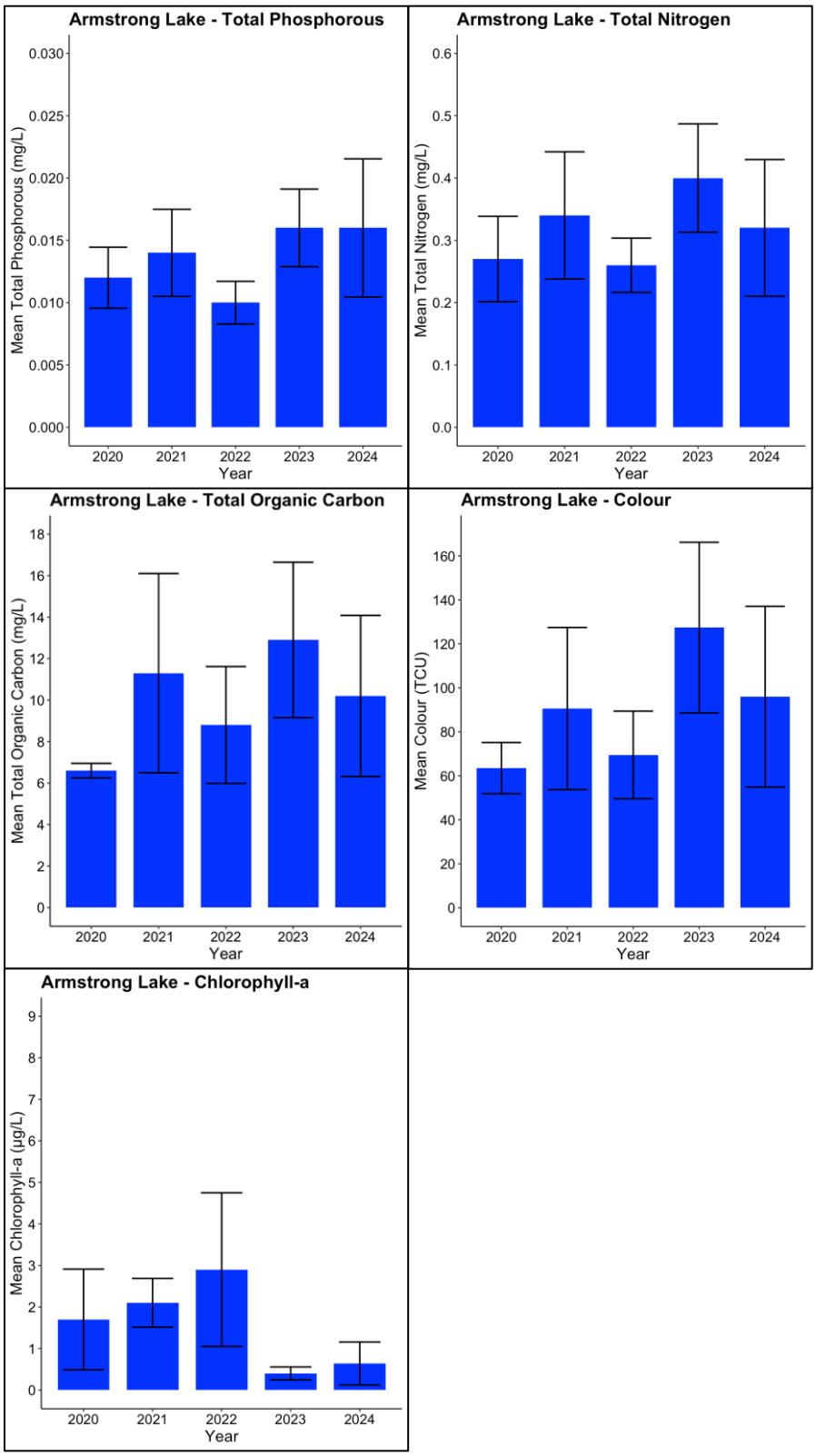


Figure 4. Armstrong Lake Phosphorus, Nitrogen, Organic Carbon, Colour, & Chlorophyll a graphs. Figures represent annual averages from the samples collected in Armstrong Lake between 2020 - 2024 including Total Phosphorous (Top Left), Total Nitrogen (Top Right), Total Organic Carbon (Middle Left), colour (Middle Right), and chlorophyll a (Bottom Left). Standard Deviation indicated by black bars.

3.1.1 Water Quality Index of Armstrong Lake

The WQI of Armstrong Lake was calculated for each year between the period of 2020 - 2024. This is used to give an understanding of the lake's health for each year depending on what water quality parameters have been sampled and where they stand in terms of their guidelines.

In 2020, Armstrong Lake scored a 60.6 which falls into the category of marginal lake health. The results of 2020's WQI exceeded TN, pH, and Chl-a guidelines once per nutrient and the guideline for temperature was exceeded twice over the six sampling events.

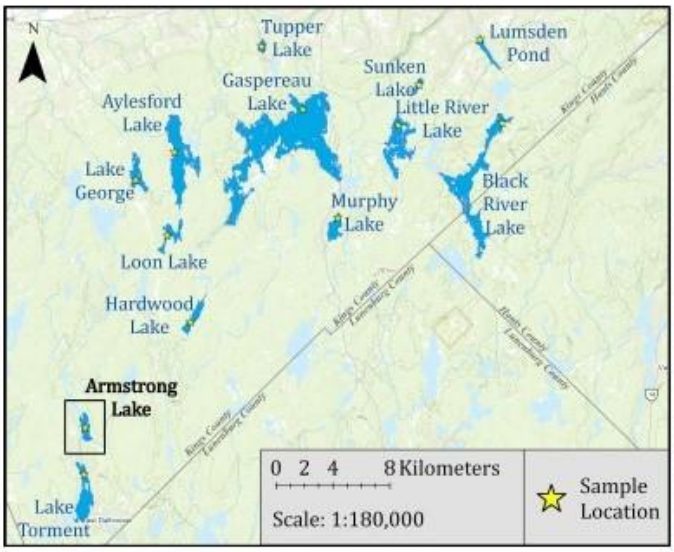
In 2021, the WQI scored a 69.0 which is deemed as fair lake health. The results of this year exceeded the guidelines for Chl-a once, and TN and pH twice each over five sampling events.

In 2022, the WQI scored a 70.0 which is considered fair lake health. The results of this year exceeded the guidelines for pH and turbidity once each, and Chl-a twice over six sampling events.

In 2023, the WQI scored a 76.5 which is considered fair lake health. The results of this year exceeded the guidelines for TN three times and pH four times over five sampling events.

In 2024, the WQI scored a 57.7 which is considered marginal lake health. The guideline for pH was exceeded once, for TP it was exceeded twice, and for TN and temperature guidelines were exceeded 3 times over five sampling events.

3.1.2 Lake Health Water Quality Report Card - Armstrong Lake



Lake Information

Drainage Order: N/A

Lake Area: 89 ha

Max Depth: 21.0 m

Elevation: 178 m

Year	WQI Score
2020	60.6
2021	69.0
2022	70.0
2023	76.5
2024	57.7

0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Armstrong Lake	Parameter							
	Total Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Organic Carbon (mg/L)	pH	Chlorophyll a (µg/L)	Secchi Depth (m)	Colour (TCU)	Turbidity (NTU)
Guideline	<0.020	<0.350	8.9 - 13.3	6.2 – 9.0	<2.50	>1.3	75.8 – 111.9	<1.30
2020 average	0.012	0.270	6.6	6.4	1.70	1.6	63.5	0.70
2021 average	0.014	0.340	11.3	6.2	2.10	1.5	90.6	0.80
2022 average	0.010	0.260	8.8	6.4	2.90	1.3	69.5	1.00
2023 average	0.016	0.400	12.9	6.0	0.40	0.9	127.4	0.70
2024 average	0.016	0.320	10.2	6.2	0.64	1.1	96.0	1.06
2020-2024 average	0.016	0.311	9.8	6.3	1.56	1.3	87.8	0.87
2011-2018 average	0.018	0.356	11.1	6.3	3.16	1.48	93.8	0.90

Figure 5. Lake Health Water Quality Report Card of Armstrong Lake based on sampling completed from 2020 - 2024.
**Values in red are outside of the guideline range.*
**Cells with 'N/A' have no data collected for that parameter for that year.*

3.2 Lake Torment

Lake Torment is located in the LaHave River watershed directly downstream of Armstrong Lake. Lake Torment was not part of the original lakes included in the Lake Monitoring Program and was added at a later date due to requests from the public.

Data collected from Lake Torment between 2020 and 2024 included TP, TN, TOC, colour, and Chl-a. Graphs of these parameters can be seen in Figure 6.

TP values ranged from 0.006 - 0.024 mg/L between 2020 and 2024. The annual averages over these years were below the guideline value of 0.02 mg/L, however TP did exceed the guideline twice in 2023.

The TN average concentrations in Lake Torment exceeded guideline values (0.35 mg/L) in 2021 and 2023. In total, 9 of the 25 sample events were above the guideline values. The maximum value observed was 0.51 mg/L and a minimum of 0.16 mg/L, the annual averages of TN fluctuate around 0.32 mg/L.

The guideline for TOC is unique for every lake as it is determined from the historical average concentration. In Lake Torment, the TOC guideline range is 7.9 – 11.9 mg/L. Observed TOC concentrations ranged from 5.1 – 18.2 mg/L, both below and above the guideline values. Of the 26 sampling events, 10 fell below the guideline range, while 7 exceeded it.

The guideline for colour is determined from the historical average as well, which was found to be 61.5 – 103.3 TCU. For Lake Torment, between 2020 and 2024, colour values ranged from 35.9 to 172.0 TCU. In 2023, the annual average colour exceeded the guideline, with a value of 138.9 TCU.

The Chl-a concentrations in Lake Torment varied year over year, with the highest values observed in 2022. The guideline for Chl-a is <2.5 µg/L which was exceeded between 2020 - 2022 with a high of 12.5 µg/L in 2022. The range of average Chl-a concentrations observed over 2020-2024 was 0.63 – 12.5 µg/L.

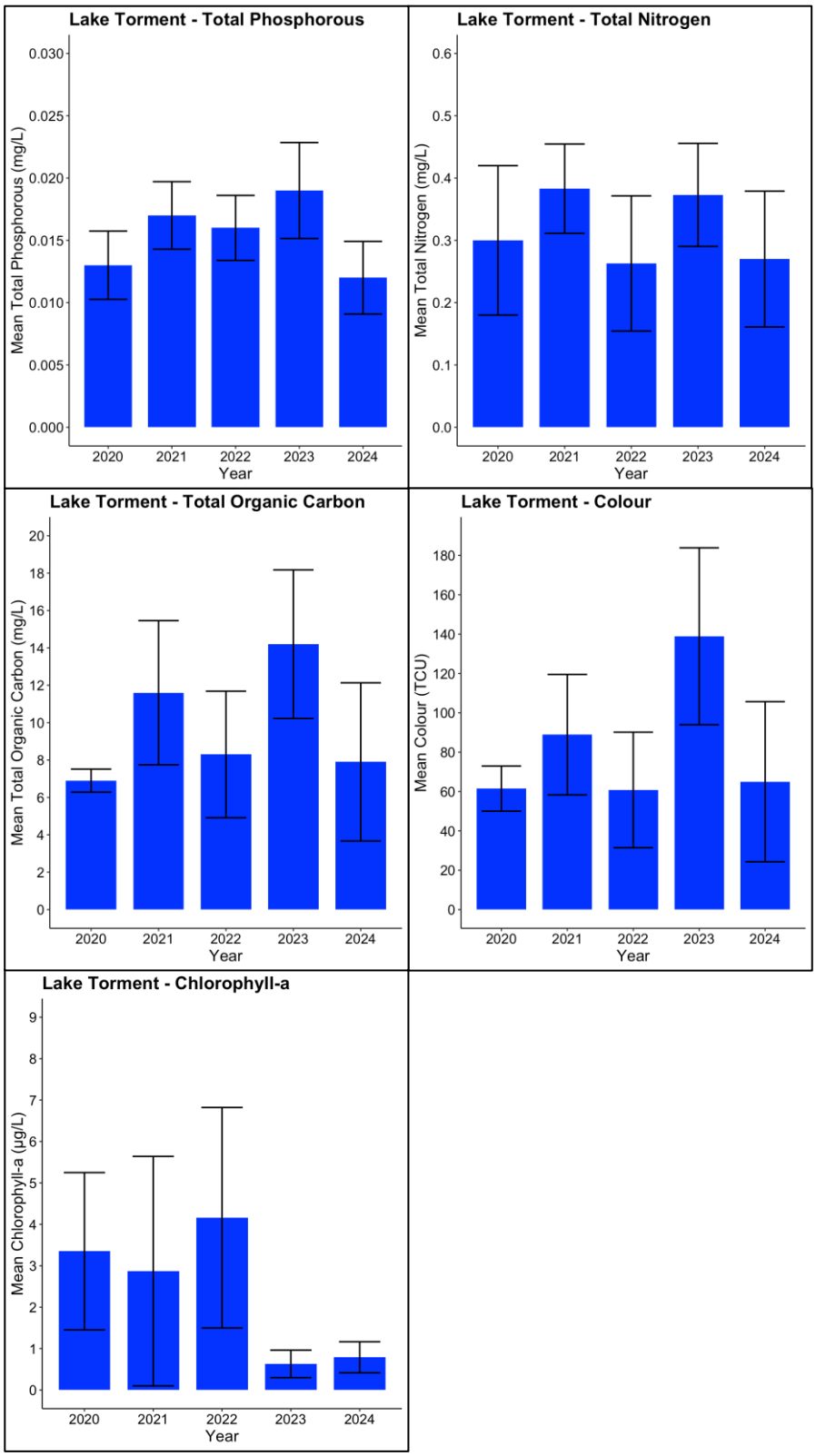


Figure 6. Lake Torment Phosphorus, Nitrogen, Organic Carbon, Colour, & Chlorophyll a graphs. Figures representing annual averages from the samples collected in Lake Torment between 2020 - 2024 including Total Phosphorous (Top Left), Total Nitrogen (Top Right), Total Organic Carbon (Middle Left), colour (Middle Right), and chlorophyll a (Bottom Left). Standard Deviation indicated by black bars.

3.2.1 Water Quality Index of Lake Torment

The WQI of Lake Torment was calculated for each year between the period 2020 - 2024. This is used to give an understanding of the lake's health for each year depending on what water quality parameters have been sampled and where they stand in terms of their guidelines.

In 2020, Lake Torment scored a 58.8 which falls under marginal lake health. The results of this year exceeded the guidelines of TN once and exceeded the guideline for turbidity, temperature, and Chl-a twice over six sampling events.

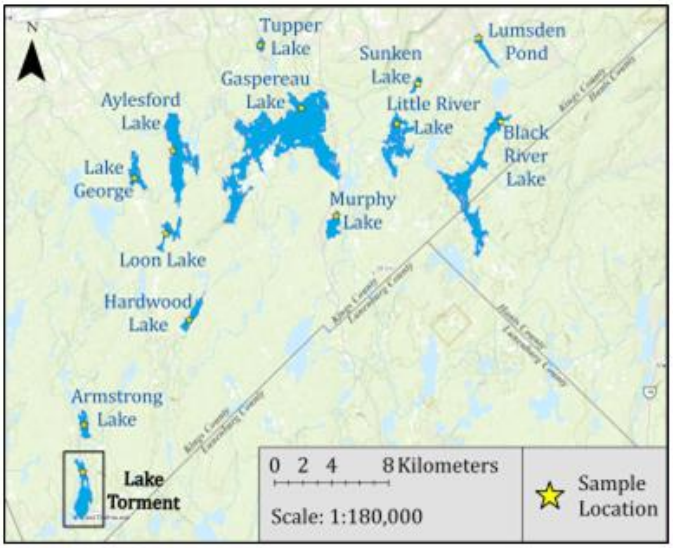
In 2021, the WQI scored a 56.7 which is deemed as marginal lake health. The results of this year exceeded the guideline for Chl-a once, and exceeded the guidelines for TN, turbidity, and pH twice over five sampling events.

In 2022, the WQI scored a 57.2 which is considered marginal lake health. The results of this year exceeded the guideline values for pH once, exceeded the turbidity guideline twice, and exceeded the Chl-a guideline three times over the six months of sampling that occurred.

In 2023, the WQI scored a 55.7 which is considered marginal lake health. The results of this year exceeded the guideline for TP and turbidity twice, exceeded the guideline for TN four times, and fell outside of the pH guideline five times throughout six sampling events that had occurred.

In 2024, the WQI scored a 59.8 which is considered marginal lake health. The guideline for pH, TN, and turbidity was exceeded once, and the guideline for temperature was exceeded three times over five sampling events.

3.2.2 Lake Health Water Quality Report Card - Lake Torment



Lake Information

Drainage Order: N/A

Lake Area: 261 ha

Max Depth: 3.4 m

Elevation: 174 m

Year	WQI Score
2020	58.8
2021	56.7
2022	57.2
2023	55.7
2024	59.8

Lake Torment	Parameter							
	Total Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Organic Carbon (mg/L)	pH	Chlorophyll a (µg/L)	Secchi Depth (m)	Colour (TCU)	Turbidity (NTU)
Guideline	<0.020	<0.350	7.9 - 11.9	6.2 – 9.0	<2.50	>1.0	61.5 - 103.3	<1.30
2020 average	0.013	0.300	6.9	6.5	3.35	1.4	61.5	1.25
2021 average	0.017	0.383	11.6	6.3	2.87	1.1	88.9	1.18
2022 average	0.016	0.263	8.3	6.4	4.16	0.8	60.8	3.00
2023 average	0.019	0.373	14.2	5.9	0.63	1.1	138.9	1.48
2024 average	0.012	0.270	7.9	6.3	0.79	1.9	65.0	0.74
2020-2024 average	0.015	0.320	9.8	6.3	3.57	1.3	84.0	1.53
2011-2018 average	0.016	0.315	9.9	6.5	4.57	1.46	82.4	1.10

Figure 7. Lake Health Water Quality Report Card of Lake Torment based on sampling completed from 2020 - 2024
**Values in red are outside of the guideline range.*
**Cells with 'N/A' have no data collected for that parameter for that year.*

3.3 Hardwood Lake

Hardwood Lake is located in the headwaters of the LaHave River Watershed and does not drain into any of the other lakes in the Lake Sampling Program. Hardwood Lake is sampled by the Municipality as a representative of background conditions or as a control lake for the Lake Sampling Program.

The mean annual TP, TN, TOC, Colour, and Chl-a data collected from Hardwood Lake from 2020-2024 can be observed in Figure 8. Over this period, average annual TP concentrations fluctuated from 0.006 mg/L to 0.008 mg/L. However, a spike in TP was observed in 2024 with a value of 0.014 mg/L causing the annual average to increase to 0.009 mg/L. Overall, the TP concentrations in Hardwood Lake did not exceed the guideline value of 0.02 mg/L.

When looking at the TN concentrations throughout this period, fluctuations between 0.2 mg/L and 0.37 mg/L were observed. The guideline concentration of TN (0.35 mg/L) was exceeded twice throughout the 2020-2024 period with two occurrences of 0.37 mg/L, once in 2023 and once in 2024.

The guideline for TOC is unique for every lake as it is determined from the historical average concentration. In Hardwood Lake, the TOC guideline range is 5.7 – 8.6 mg/L. It was observed that the concentrations of TOC were below and above the determined guideline, as values ranged from 5 – 14 mg/L.

The guideline for colour is also determined from the historical average, which was found to be 32.9 – 61.0 TCU. For the colour of Hardwood Lake in 2020 – 2024, values ranged from 30 – 118 TCU, meaning that values were both below and above the guideline range during this period. It is observed that colour exceeded the guidelines more frequently in 2023 and 2024.

The Chl-a concentrations in Hardwood Lake varied year over year, with the highest values being observed in 2021. The guideline for Chl-a is <2.5 µg/L, which was only exceeded twice, both events occurring in 2021. The range of Chl-a concentrations observed over 2020-2024 was 0.25 – 3.33 µg/L.

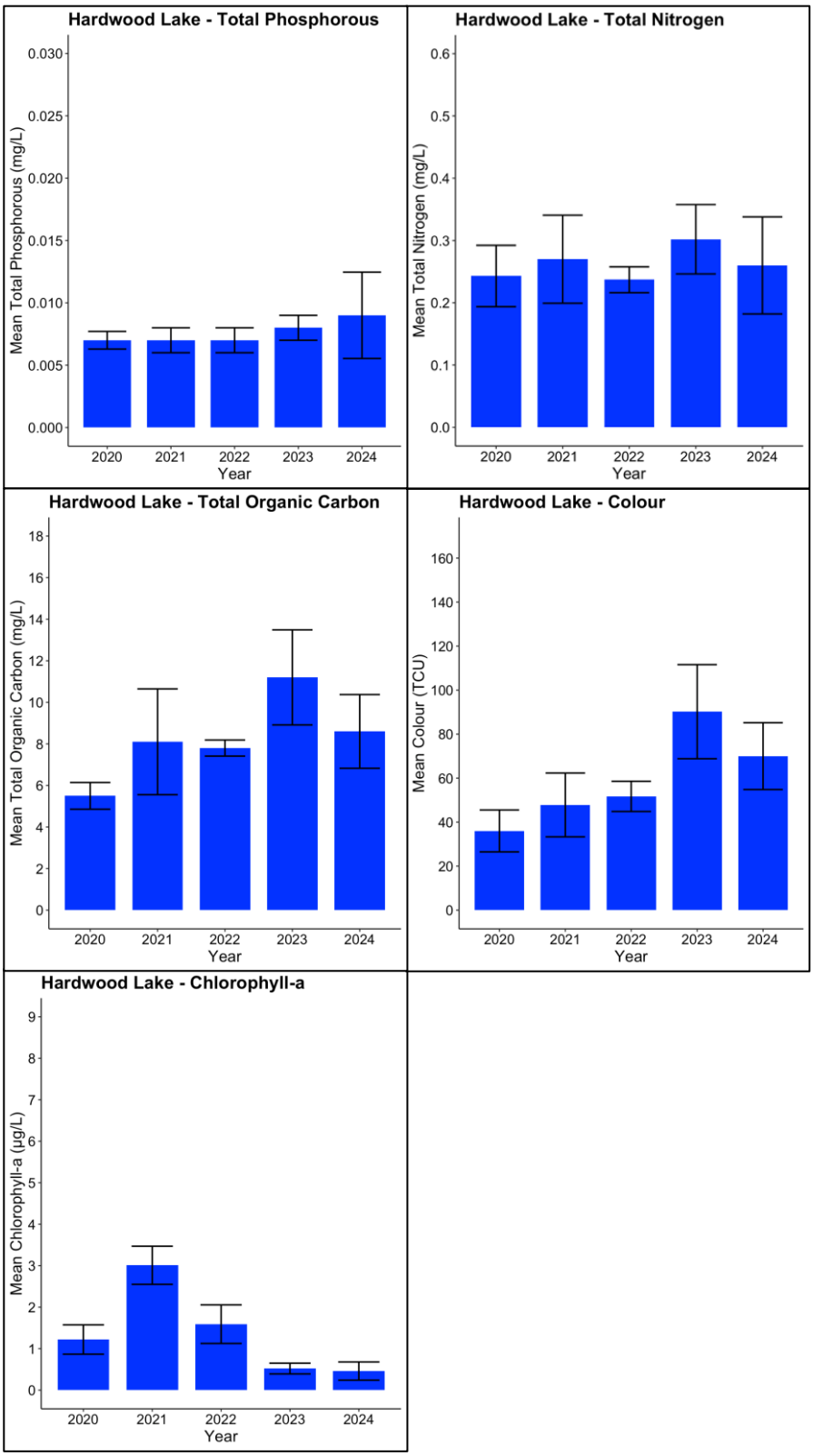


Figure 8. Hardwood Lake Phosphorus, Nitrogen, Organic Carbon, Colour, & Chlorophyll a graphs. Figures representing annual averages from the samples collected in Hardwood Lake between 2020 - 2024 including Total Phosphorous (Top Left), Total Nitrogen (Top Right), Total Organic Carbon (Middle Left), colour (Middle Right), and chlorophyll a (Bottom Left). Standard Deviation indicated by black bars.

3.3.1. Water Quality Index of Hardwood Lake

The WQI of Hardwood Lake was calculated for each year between the period 2020 - 2024. This is used to give an understanding of the lake's health for each year depending on what water quality parameters have been sampled and where they stand in terms of their guidelines.

In 2020, Hardwood Lake scored a 100, which is considered excellent lake health. No guidelines were exceeded during any of the sampling events.

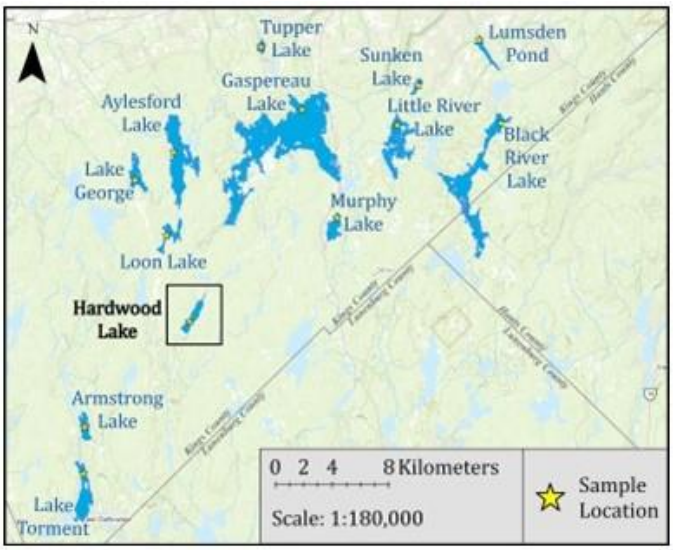
In 2021, the WQI scored an 85.6 which is deemed as good lake health. The results of this year had two Chl-a exceedances across five sampling events.

In 2022, the WQI scored a 90.0 which is considered good lake health. The results of this year had only one pH value outside of the guideline over the six sampling events.

In 2023, the WQI scored a 70.4 which is considered fair lake health. The results of this year exceeded the guideline for TN and temperature once and fell outside of the pH guideline twice over six sampling events.

In 2024, the WQI scored a 70.6 which is considered fair lake health. The results for pH, TN, and temperature were all outside of the guideline once over five sampling events.

3.3.2. Lake Health Water Quality Report Card - Hardwood Lake



Lake Information

Drainage Order: N/A

Lake Area: 120 ha

Max Depth: 7.0 m

Elevation: 208 m

Year	WQI Score
2020	100
2021	85.6
2022	90.0
2023	70.4
2024	70.6

0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Hardwood Lake	Parameter							
	Total Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Organic Carbon (mg/L)	pH	Chlorophyll a (µg/L)	Secchi Depth (m)	Colour (TCU)	Turbidity (NTU)
Guideline	<0.020	<0.350	5.7 - 8.6	6.2 – 9.0	<2.50	>1.6	32.9 – 61.0	<1.30
2020 average	0.007	0.243	5.5	6.6	1.22	2.9	36.0	0.53
2021 average	0.007	0.270	8.1	6.5	3.01	1.8	47.8	1.18
2022 average	0.007	0.237	7.8	6.4	1.59	2.4	51.7	0.75
2023 average	0.008	0.302	11.2	6.2	0.52	1.4	90.2	0.80
2024 average	0.009	0.260	8.6	6.3	0.46	1.6	70.0	0.70
2020-2024 average	0.008	0.260	8.7	6.3	1.07	1.9	65.0	0.76
1993-2018 average	0.012	0.220	7.2	6.3	2.26	2.06	47.0	1.13

Figure 9. Lake Health Water Quality Report Card of Hardwood Lake based on sampling completed from 2020 - 2024.
**Values in red are outside of the guideline range.*
**Cells with 'N/A' have no data collected for that parameter for that year.*

3.4 Lake George

Lake George is one of the most hydrologically upstream lakes in the Gaspereau River Watershed, along with Loon Lake, and is first (1st) order in the watershed drainage system. Aylesford Lake is located downstream of Lake George where it is supplied with water from Lake Georges outflow.

The mean annual TP, TN, TOC, Colour, and Chl-a data collected from Lake George from 2020-2024 can be observed in Figure 10.

When looking at the TN concentrations throughout this period, fluctuations between 0.15 mg/L and 0.3 mg/L were observed. The guideline concentration of TN (0.35 mg/L) was not exceeded throughout the 2020-2024 period.

TP concentrations ranged from 0.004 mg/L - 0.009 mg/L. TP concentrations did not exceed the guideline value of 0.02 mg/L.

TOC concentrations ranged from 3.5 – 7.1 mg/L. The guideline for TOC is unique for every lake as it is determined from the historical average concentration. In Lake George, the TOC guideline range is 3.5 – 5.3 mg/L. Values exceeded guidelines four times in 2023 and three times in 2024 with exceedance values ranging from 5.4 mg/L to 7.1mg/L.

Colour values ranged from 11.7 - 43.9 TCU. The guideline for colour is determined from the historical average as well, which was found to be 21.5- 26.7 TCU. Between 2020 – 2024, Colour values in Lake George were both below and above the guideline range. It was observed that colour exceeded the guidelines more frequently in 2023 and 2024 and was below the guidelines more frequently in 2020-2022.

Chl-a values ranged from 0.39 – 5.0 µg/L. The guideline for Chl-a is <2.5 µg/L. The value exceeded guidelines twice in 2020, and three times in 2022. The highest value of 5.0 µg/L was observed in October 2022.

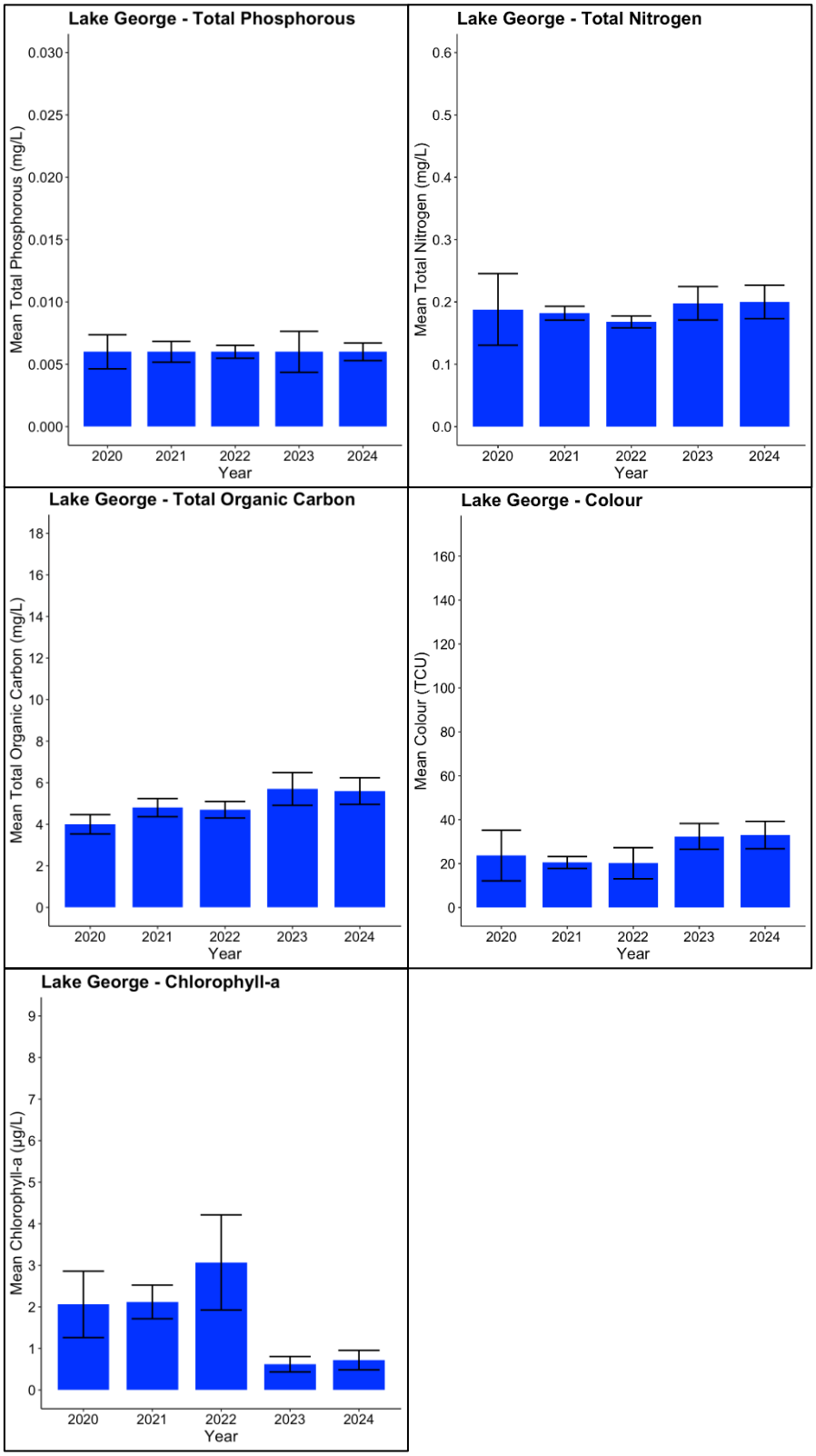


Figure 10. Lake George Phosphorus, Nitrogen, Organic Carbon, Colour, & Chlorophyll a graphs. Figures representing annual averages from the samples collected in Lake George between 2020 - 2024 including Total Phosphorous (Top Left), Total Nitrogen (Top Right), Total Organic Carbon (Middle Left), colour (Middle Right), and chlorophyll a (Bottom Left). Standard Deviation indicated by black bars.

3.4.1. Water Quality Index of Lake George

The WQI of Lake George was calculated for each year between the period 2020 - 2024. This is used to give an understanding of the lake's health for each year depending on what water quality parameters have been sampled and where they stand in terms of their guidelines.

In 2020, Lake George scored a 79.7 which is considered fair lake health. The results of this year exceeded the guidelines of Chl-a and turbidity twice each over six sampling events.

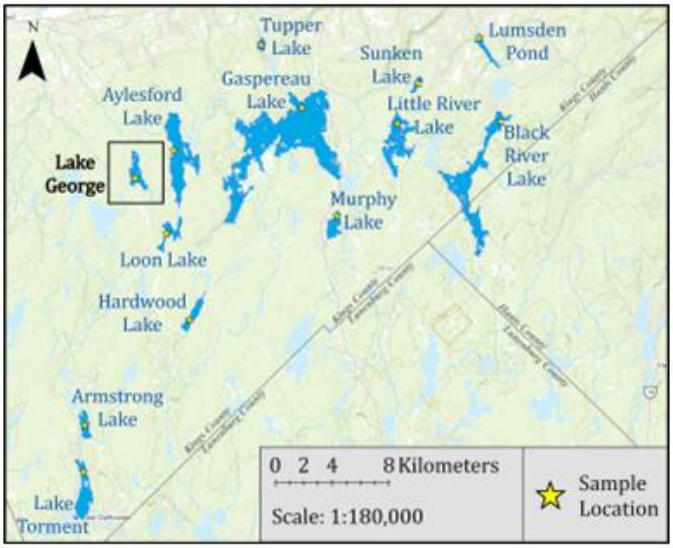
In 2021, the WQI scored a 100 which is considered excellent lake health, and no guidelines were exceeded over five sampling events.

In 2022, the WQI scored a 69.3 which is considered fair lake health. The results of this year exceeded the guideline for Chl-a three times, the guideline for pH twice, and the guideline for turbidity once over six sampling events.

In 2023, the WQI scored a 79.2 which is considered fair lake health. The results of this year exceeded the guideline for temperature once over five sampling events.

In 2024, the WQI scored a 79.4 which is considered fair lake health. The results of this year exceeded the guideline for temperature once, and the guideline for turbidity twice over five sampling events.

3.4.2. Lake Health Water Quality Report Card - Lake George



Lake Information

Drainage Order: 1

Lake Area: 153 ha

Max Depth: 9.5 m

Elevation: 231 m

Year	WQI Score
2020	79.7
2021	100
2022	69.3
2023	90.2
2024	79.4

0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Lake George	Parameter							
	Total Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Organic Carbon (mg/L)	pH	Chlorophyll a (µg/L)	Secchi Depth (m)	Colour (TCU)	Turbidity (NTU)
Guideline	<0.020	<0.350	3.5 - 5.3	6.2 – 9.0	<2.50	>3.0	21.5 - 26.7	<1.30
2020 average	0.006	0.188	4.0	6.8	2.06	3.4	23.7	0.75
2021 average	0.006	0.182	4.8	6.7	2.12	3.5	20.5	0.58
2022 average	0.006	0.168	4.7	6.5	3.07	3.5	20.2	0.88
2023 average	0.006	0.198	5.7	6.6	0.62	2.1	32.4	0.82
2024 average	0.006	0.200	5.6	6.7	0.72	2.5	33.0	1.66
2020-2024 average	0.006	0.190	4.9	6.7	1.73	3.0	26.0	0.93
1997-2018 average	0.009	0.165	4.4	6.5	2.44	3.51	24.1	0.69

Figure 11. Lake Health Water Quality Report Card of Lake George based on sampling completed from 2020 – 2024.
**Values in red are outside of the guideline range.*
**Cells with 'N/A' have no data collected for that parameter for that year.*

3.5 Loon Lake

Loon Lake is one of the most hydrologically upstream lakes in the Gaspereau River Watershed, along with Lake George, and is first (1st) in the watershed drainage system. Aylesford Lake is located downstream of Loon Lake where it is supplied with water from Loon Lakes outflow.

The mean annual TP, TN, TOC, Colour and Chl-a data collected from Loon Lake from 2020-2024 can be observed in Figure 12. Over this period, TP concentrations range from 0.006 mg/L to 0.026 mg/L. Overall, annual average TP concentrations at Loon Lake remained below the guideline limit of 0.02 mg/L.

TN annual averages at Loon Lake ranged from 0.203 mg/L to 0.298 mg/L, which fall below the guideline limit of 0.35 mg/L. Although a value of 0.480 mg/L was recorded in 2024, this was the only recorded TN exceedance in Loon Lake over the sampling period.

Mean annual concentrations of TOC at Loon Lake ranged between 4.9 mg/L and 8 mg/L. In both 2023 and 2024 TOC concentrations fell out of the guideline limit for Loon Lake with 4.4 mg/L and 6.6 mg/L respectively.

Annual average colour values ranged from 30.4 – 74.6 TCU. The guideline for colour is determined from the historical average as well, which was found to be 18.6 – 51.9 TCU. Colour exceeded guidelines in 2023 with an average of 66.2 TCU and in 2024 with an average value of 74.6 TCU.

Chl-a values ranged from 0.49 – 3.39 µg/L and the guideline for Chl-a is <2.5 µg/L. The guideline value was exceeded in 2020 with an average value of 2.72 µg/L and in 2021 with an average value of 3.39 µg/L.

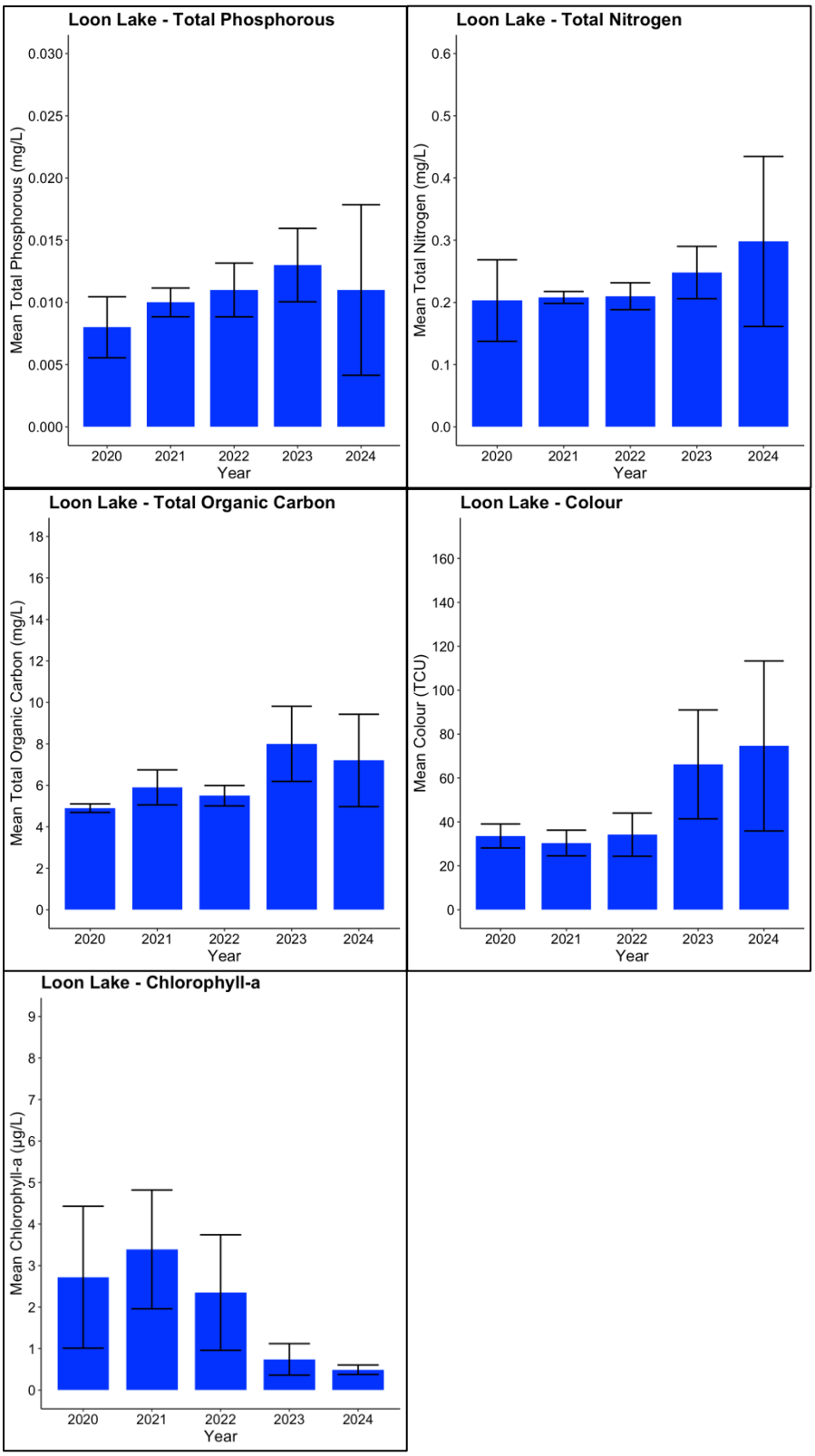


Figure 12. Loon Lake Phosphorus, Nitrogen, Organic Carbon, Colour, & Chlorophyll a graphs. Figures representing annual averages from the samples collected in Loon Lake between 2020 - 2024 including Total Phosphorous (Top Left), Total Nitrogen (Top Right), Total Organic Carbon (Middle Left), colour (Middle Right), and chlorophyll a (Bottom Left). Standard Deviation indicated by black bars.

3.5.1. Water Quality Index of Loon Lake

The WQI of Loon Lake was calculated for each year between the period 2020 - 2024. This is used to give an understanding of the lake's health for each year depending on what water quality parameters have been sampled and where they stand in terms of their guidelines.

In 2020, Loon Lake scored a 69.2 which is considered fair lake health. The results of this year exceeded the guidelines of temperature once over three sampling events, as well as Chl-a twice and turbidity once over four sampling events.

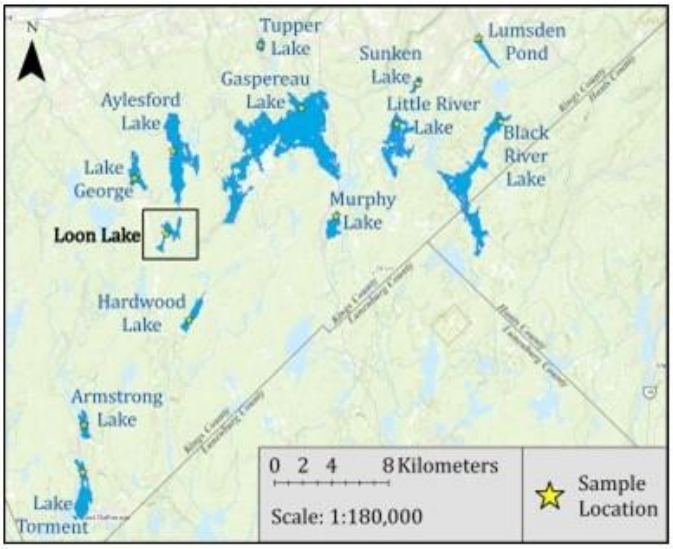
In 2021, the WQI scored a 76.2 which is considered fair lake. The results of this year exceeded the guidelines for Chl-a three times, temperature twice, and TOC once over four sampling events.

In 2022, the WQI scored a 78.4 which is considered fair lake health. The results of this year exceeded the guidelines for Chl-a and temperature twice each over four sampling events.

In 2023, the WQI scored a 78.8 which is considered fair lake health. The results of this year exceeded the guidelines for colour and TOC four times each, temperature once, and turbidity twice over the 5 sampling events.

In 2024, the WQI scored a 65.5 which is considered fair lake health. The results of this year exceeded the guidelines for TP, colour, TOC, and turbidity twice each, and TN once over four sampling events.

3.5.2. Lake Health Water Quality Report Card - Loon Lake



Lake Information

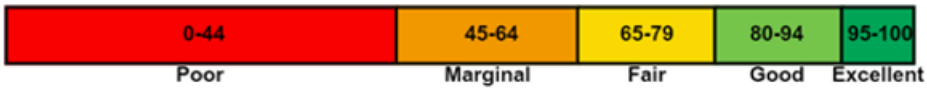
Drainage Order: 1

Lake Area: 90 ha

Max Depth: 8.1 m

Elevation: 206 m

Year	WQI Score
2020	69.2
2021	76.2
2022	78.4
2023	78.8
2024	65.5



Loon Lake	Parameter							
	Total Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Organic Carbon (mg/L)	pH	Chlorophyll a (µg/L)	Secchi Depth (m)	Colour (TCU)	Turbidity (NTU)
Guideline	<0.020	<0.350	4.4 - 6.6	6.2 – 9.0	<2.50	>2.3	18.6 - 51.9	<1.30
2020 average	0.008	0.203	4.9	6.5	2.72	2.2	33.6	0.89
2021 average	0.010	0.208	5.9	6.4	3.39	2.1	30.4	0.71
2022 average	0.011	0.210	5.5	6.5	2.35	2.0	34.2	0.68
2023 average	0.013	0.248	8.0	6.4	0.74	1.7	66.2	1.98
2024 average	0.011	0.298	7.2	6.6	0.49	1.9	74.6	3.50
2020-2024 average	0.012	0.234	6.4	6.5	1.88	2.0	48.6	1.57
1997-2018 average	0.012	0.192	5.5	6.2	3.36	2.52	35.2	1.10

Figure 13. Lake Health Water Quality Report Card of Loon Lake based on sampling completed from 2020 – 2024.
**Values in red are outside of the guideline range.*
**Cells with 'N/A' have no data collected for that parameter for that year.*

3.6 Aylesford Lake

Aylesford Lake is located in the Gaspereau River Watershed situated downstream of both Lake George and Loon Lake, and upstream of Gaspereau Lake. Aylesford Lake is second (2^{nd}) in the watershed drainage and a dam is installed at the outflow for the production of hydropower.

The mean annual TP, TN, TOC, Colour, and Chl-a data collected from Aylesford Lake from 2020-2024 can be observed in Figure 14. Over this period, TP concentrations fluctuated from 0.006 mg/L to 0.027 mg/L. TP concentration only exceeded the guideline value of 0.02 mg/L twice over the 5 years which occurred in 2021 when concentrations of 0.027 and 0.023 mg/L were observed.

When looking at the TN concentrations throughout this period, fluctuations between 0.16 mg/L and 0.25 mg/L were observed. The guideline concentration of TN (0.35 mg/L) was not exceeded during the 2020-2024 sampling period.

The guideline for TOC is unique for every lake as it is determined from the historical average concentration. In Aylesford Lake, the TOC guideline range is 4.4 – 6.6 mg/L. It was observed that the concentration of TOC exceeded the guideline once in 2020, once in 2023, and three times in 2024 with the highest value observed being 9 mg/L in 2020.

The guideline for colour is also determined from the historical average, which was found to be 26.9 – 40.5 TCU. The range of colour values observed in Aylesford Lake over 2020 – 2024 were 22 – 61.3 TCU, meaning that values were both below and above the guideline range. It was observed that colour exceeded the guideline more frequently than it fell below, with 13 of 25 sampling events exceeding the guideline, with the highest annual averages being in 2023 and 2024.

The Chl-a concentrations in Aylesford Lake varied year over year, with the highest values being observed in 2021. The guideline for Chl-a is <2.5 µg/L which was exceeded in sampling events in 2020, 2021, and 2022 with a total of 11 samples being over the guidelines in those years. The range of Chl-a concentrations observed over the 2020-2024 sampling period was 0.29 – 4.31 µg/L.

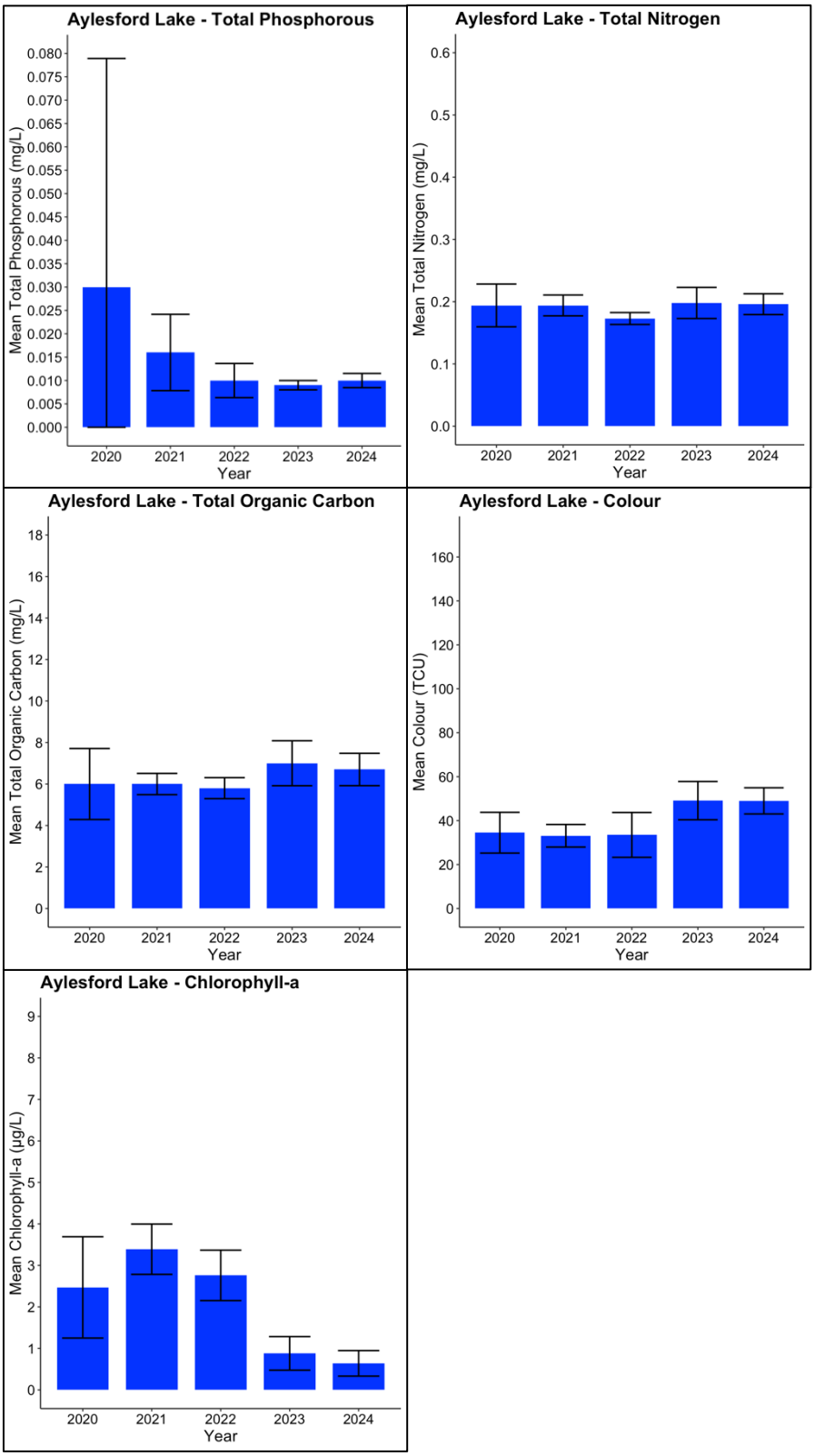


Figure 14. Aylesford Lake Phosphorus, Nitrogen, Organic Carbon, Colour, & Chlorophyll a graphs. Figures representing annual averages from the samples collected in Aylesford Lake between 2020 - 2024 including Total Phosphorous (Top Left), Total Nitrogen (Top Right), Total Organic Carbon (Middle Left), colour (Middle Right), and chlorophyll a (Bottom Left). Standard Deviation indicated by black bars.

3.6.1. Water Quality Index of Aylesford Lake

The WQI of Aylesford Lake was calculated for each year between the period 2020 - 2024. This is used to give an understanding of the lake's health for each year depending on what water quality parameters have been sampled and where they stand in terms of their guidelines.

In 2020, Aylesford Lake scored a 56.7 which is considered marginal lake health. The results of this year exceeded the guidelines of TP, pH, and turbidity once each and the guideline for Chl-a twice over five sampling events.

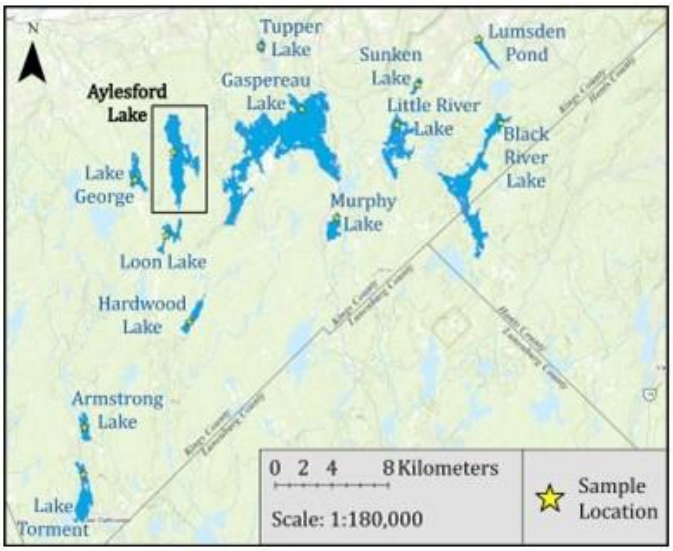
In 2021, the WQI scored a 54.4 which is considered marginal lake health. The results of this year exceeded Chl-a five times, the guideline for turbidity three times, the guideline for TP twice over five sampling events, and the guideline for temperature once over four sampling events.

In 2022, the WQI scored a 57.3 which is considered marginal lake health. The results of this year exceeded the guideline for Chl-a four times over five sampling events, the guideline for pH three times, and the guideline for turbidity and temperature twice each over six sampling events.

In 2023, the WQI scored a 70.2 which is considered fair lake health. The results of this year exceeded the guideline for temperature once over five sampling events.

In 2024, the WQI scored a 79.3 which is considered fair lake health. The results of this year exceeded the guidelines for temperature three times and turbidity once over five sampling events.

3.6.2. Lake Health Water Quality Report Card – Aylesford Lake



Lake Information

Drainage Order: 2

Lake Area: 532 ha

Max Depth: 12.0m

Elevation: 216 m

Year	WQI Score
2020	56.7
2021	54.4
2022	57.3
2023	70.2
2024	79.3

0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Aylesford Lake	Parameter							
	Total Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Organic Carbon (mg/L)	pH	Chlorophyll a (µg/L)	Secchi Depth (m)	Colour (TCU)	Turbidity (NTU)
Guideline	<0.020	<0.350	4.4 - 6.6	6.2 – 9.0	<2.50	>2.3	26.9 - 40.5	<1.30
2020 average	0.030	0.194	6.0	6.3	2.47	2.4	34.5	2.57
2021 average	0.016	0.194	6.0	6.2	3.39	2.4	33.1	2.23
2022 average	0.010	0.173	5.8	6.1	2.76	2.3	33.5	1.20
2023 average	0.009	0.198	7.0	6.2	0.88	2.0	49.1	1.15
2024 average	0.010	0.196	6.7	6.2	0.64	2.2	49.0	0.74
2020-2024 average	0.015	0.191	6.3	6.2	2.08	2.2	39.2	1.58
1997-2018 average	0.010	0.178	5.5	6.2	2.96	2.68	33.7	0.66

Figure 15. Lake Health Water Quality Report Card of Aylesford Lake based on sampling completed from 2020 - 2024.
**Values in red are outside of the guideline range.*
**Cells with 'N/A' have no data collected for that parameter for that year.*

3.7 Gaspereau Lake

Gaspereau Lake is the largest lake is the Gaspereau River Watershed, and it is used for the production of hydropower through damming. The lake is located downstream from Aylesford Lake and upstream of Little River Lake making it third (3rd) in watershed drainage.

The mean annual TP, TN, TOC, Colour, and Chl-a data collected from Gaspereau Lake from 2020-2024 can be observed in Figure 16. Over this period, TP concentrations fluctuated from 0.006 mg/L to 0.014 mg/L, not exceeding the 0.02 mg/L guideline.

When looking at the TN concentrations throughout this period, fluctuations between 0.18 mg/L and 0.3 mg/L were observed. The guideline concentration of TN (0.35 mg/L) was not exceeded during the 2020-2024 sampling period.

The guideline for TOC is unique for every lake as it is determined from the historical average concentration. In Gaspereau Lake, the TOC guideline range is 4.6 – 6.9 mg/L. It was observed that the concentration of TOC fell below the guideline with the lowest value being 4 mg/L and no exceedances of the guideline occurred as the highest value observed was 6.6 mg/L.

The guideline for colour is also determined from the historical average, which was found to be 34.7 – 46.3 TCU. The range of colour values observed in Gaspereau Lake from 2020 – 2024 was 13.6 – 50.4 TCU, meaning that values were both below and above the guideline range. It is observed that colour was below the guideline more frequently than exceeding the guideline, with the lowest annual averages being in 2021 and 2022.

The Chl-a concentrations in Gaspereau Lake varied year after year, with the highest values being observed in 2022. The <2.5 µg/L Chl-a guideline was exceeded every year except for 2023 and 2024. The range of Chl-a concentrations observed over the 2020-2024 sampling period was 0.5 – 5.16 µg/L.

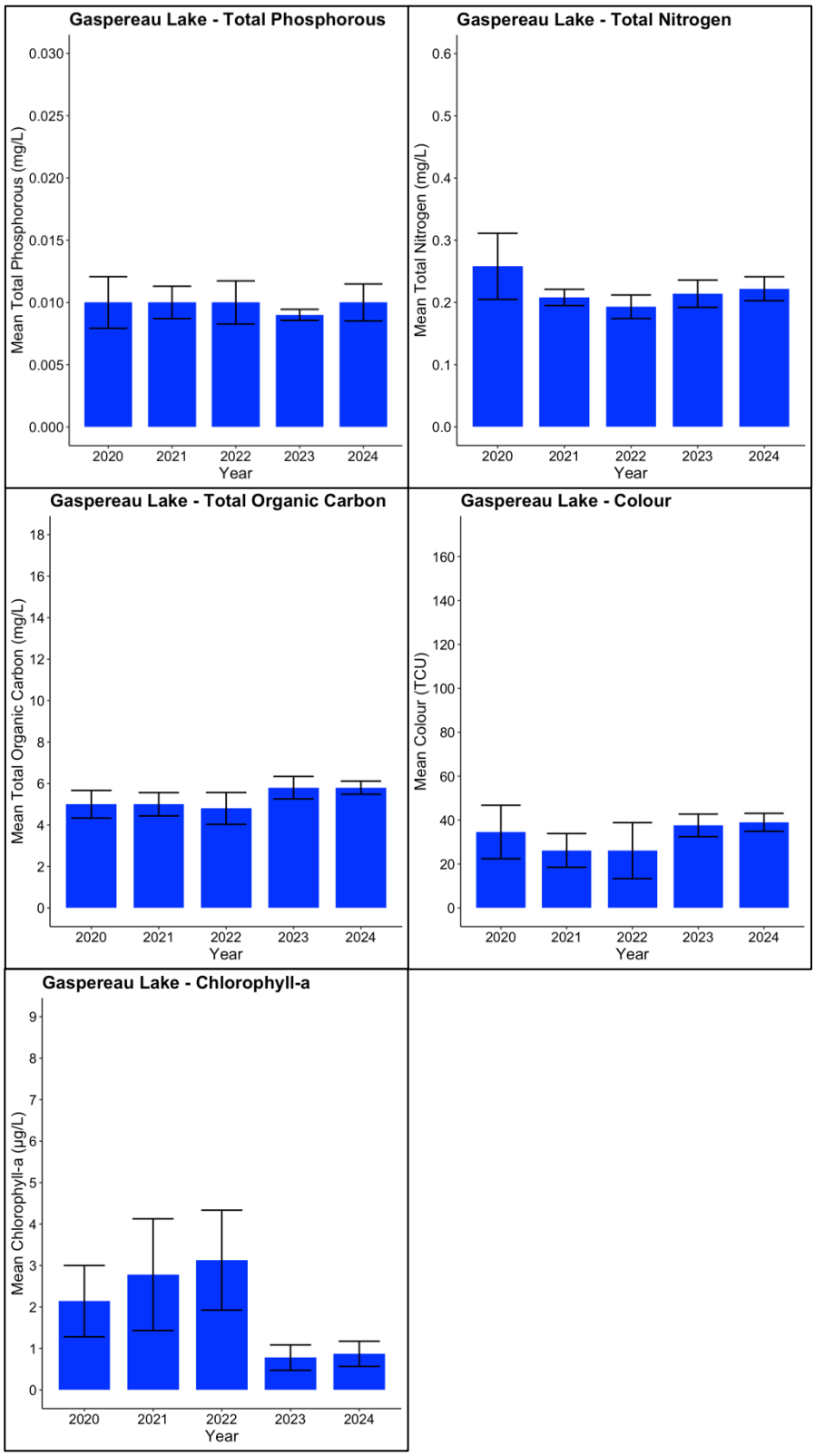


Figure 16. Gaspereau Lake Phosphorus, Nitrogen, Organic Carbon, Colour, & Chlorophyll a graphs. Figures representing annual averages from the samples collected in Gaspereau Lake between 2020 - 2024 including Total Phosphorous (Top Left), Total Nitrogen (Top Right), Total Organic Carbon (Middle Left), colour (Middle Right), and chlorophyll a (Bottom Left). Standard Deviation indicated by black bars.

3.7.1. Water Quality Index of Gaspereau Lake

The WQI of Gaspereau Lake was calculated for each year between the period 2020 - 2024. This is used to give an understanding of the lake's health for each year depending on what water quality parameters have been sampled and where they stand in terms of their guidelines.

In 2020, Gaspereau Lake scored a 79.9 which is considered fair lake health. The results of this year exceeded the guidelines of temperature once and the guideline for Chl-a twice over five sampling events.

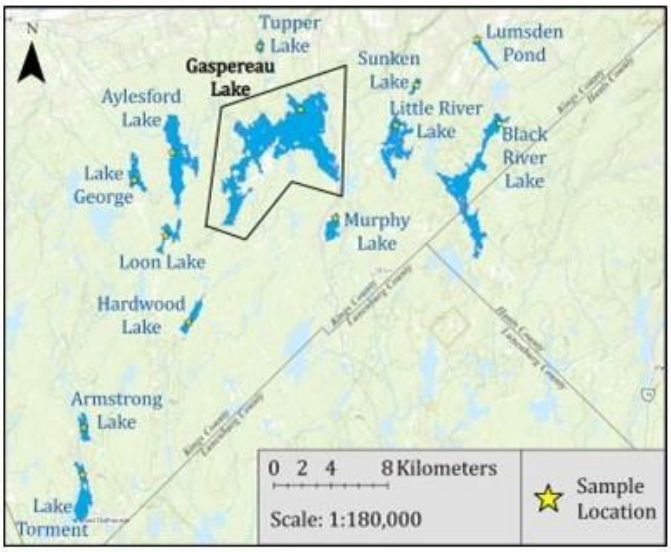
In 2021, the WQI scored a 79.1 which is considered fair lake health. The results of this year exceeded the guidelines of temperature once and the guideline for Chl-a three times over five sampling events.

In 2022, the WQI scored a 59.1 which is considered marginal lake health. The results of this year exceeded the guideline for Chl-a three times over five sampling events, the guideline for pH and temperature twice each, and the guideline for turbidity once over six sampling events.

In 2023, the WQI scored a 90.2 which is considered good lake health. The results of this year exceeded the guidelines for temperature once over five sampling events.

In 2024, the WQI scored a 79.2 which is considered fair lake health. The results of this year exceeded the guidelines for temperature and pH twice each over five sampling events.

3.7.2. Lake Health Water Quality Report Card - Gaspereau Lake



Lake Information

Drainage Order: 3

Lake Area: 2200 ha

Max Depth: 10.9 m

Elevation: 175 m

Year	WQI Score
2020	79.9
2021	79.1
2022	59.1
2023	90.2
2024	79.2

0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Gaspereau Lake	Parameter							
	Total Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Organic Carbon (mg/L)	pH	Chlorophyll a (µg/L)	Secchi Depth (m)	Colour (TCU)	Turbidity (NTU)
Guideline	<0.020	<0.350	4.6 - 6.9	6.2 – 9.0	<2.50	>1.8	34.7 - 46.3	<1.30
2020 average	0.010	0.258	5.0	6.3	2.14	2.3	34.6	0.88
2021 average	0.010	0.208	5.0	6.3	2.78	2.4	26.2	0.67
2022 average	0.010	0.193	4.8	6.1	3.13	2.5	26.1	1.03
2023 average	0.009	0.214	5.8	6.4	0.78	2.2	37.6	0.84
2024 average	0.010	0.222	5.8	6.3	0.87	2.2	39.0	1.04
2020-2024 average	0.010	0.220	5.3	6.3	1.94	2.3	33.0	0.90
1997-2018 average	0.012	0.226	5.7	6.3	3.47	2.02	40.5	0.97

Figure 17. Lake Health Water Quality Report Card of Gaspereau Lake based on sampling completed from 2020 - 2024.
**Values in red are outside of the guideline range.*
**Cells with 'N/A' have no data collected for that parameter for that year.*

3.8 Murphy Lake

Murphy Lake is located in the Gaspereau River Watershed upstream of Little River Lake and is third (3rd) in lake drainage order.

The mean annual TP, TN, TOC, Colour, and Chl-a data collected from Murphy Lake from 2020-2024 can be observed in Figure 18. Over this period, TP concentrations fluctuated from 0.006 mg/L to 0.015 mg/L. Overall, the TP concentrations in Murphy Lake did not exceed the guideline value of 0.02 mg/L.

When looking at the TN concentrations throughout this period, fluctuations between 0.21 mg/L and 0.33 mg/L were observed. The guideline concentration of TN (0.35 mg/L) was not exceeded throughout the 2020-2024 period.

The guideline for TOC is unique for every lake as it is determined from the historical average concentration. In Murphy Lake, the TOC guideline range is 5.0 – 7.4 mg/L. It was observed that the average concentration of TOC exceeded guidelines in 2023 and 2024, with average values of 8.3 and 7.5 mg/L respectively. In total, 7 of the 25 samples were above guidelines and five of these samples occurred in 2023 and 2024.

The guideline for colour is also determined from the historical average, which was found to be 24.8 – 42.7 TCU. For the colour of Murphy Lake in 2020 – 2024, average values ranged from 25.3 – 49.0 TCU, with values exceeding the guidelines in 2023 and 2024, with values between 45.9 TCU and 68.8 TCU.

The Chl-a concentrations in Murphy Lake varied year over year, with the highest average values being observed in 2021 at 1.93 µg/L and the lowest average values being observed in 2024 at 0.33 µg/L. The guideline for Chl-a is <2.5 µg/L was exceeded twice in 2021, with values of 2.89 µg/L and 3.16 µg/L, and once in 2022, with a value of 2.88 µg/L.

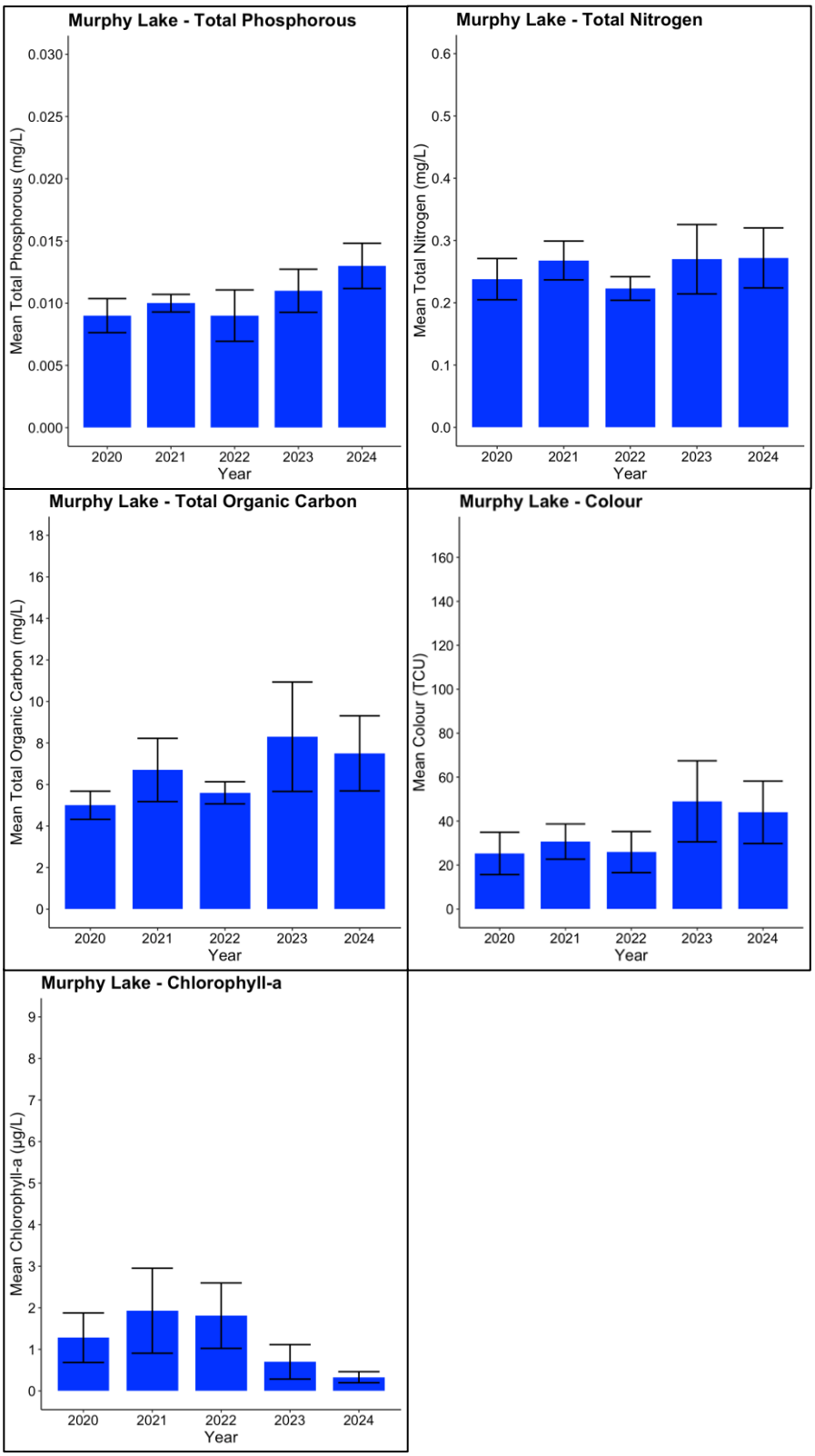


Figure 18. Murphy Lake Phosphorus, Nitrogen, Organic Carbon, Colour, & Chlorophyll a graphs. Figures representing annual averages from the samples collected in Murphy Lake between 2020 - 2024 including Total Phosphorous (Top Left), Total Nitrogen (Top Right), Total Organic Carbon (Middle Left), colour (Middle Right), and chlorophyll a (Bottom Left). Standard Deviation indicated by black bars.

3.8.1. Water Quality Index of Murphy Lake

The WQI of Murphy Lake was calculated for each year between the period 2020 - 2024. This is used to give an understanding of the lake's health for each year depending on what water quality parameters have been sampled and where they stand in terms of their guidelines.

In 2020, Murphy Lake scored an 89.8 which is considered good lake health. The results of this year exceeded the guidelines for TOC four times, colour three times, and temperature once over five sampling events.

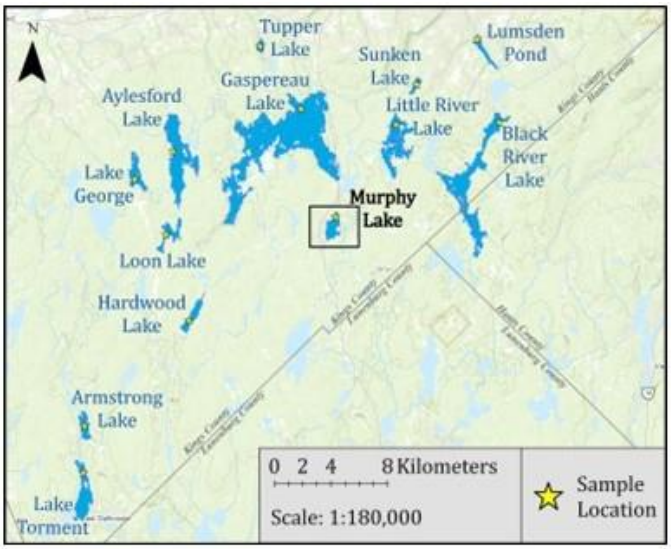
In 2021, the WQI scored a 78.4 which is considered fair lake health. The results of this year exceeded the guidelines for temperature and TOC three times each, as well as Chl-a and colour twice each over five sampling events.

In 2022, the WQI scored a 70.4 which is considered fair lake health. The results of this year exceeded the guidelines for colour three times, temperature twice, as well as Chl-a and pH once each over five sampling events.

In 2023, the WQI scored a 78.6 which is considered fair lake health. The results of this year exceeded the guidelines for temperature once over four sampling events as well as colour, turbidity, and TOC twice each over three sampling events.

In 2024, the WQI scored an 88.8 which is considered good lake health. The results of this year exceeded the guidelines for temperature and TOC three times each, and colour twice over five sampling events.

3.8.2. Lake Health Water Quality Report Card - Murphy Lake



Lake Information

Drainage Order: 3

Lake Area: 121 ha

Max Depth: 6.8 m

Elevation: 207 m

Year	WQI Score
2020	89.8
2021	78.4
2022	70.4
2023	78.6
2024	88.8

0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Murphy Lake	Parameter							
	Total Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Organic Carbon (mg/L)	pH	Chlorophyll a (µg/L)	Secchi Depth (m)	Colour (TCU)	Turbidity (NTU)
Guideline	<0.020	<0.350	5.0 - 7.4	6.2 – 9.0	<2.50	>1.7	24.8 - 42.7	<1.30
2020 average	0.009	0.238	5.0	6.9	1.28	2.3	25.3	0.61
2021 average	0.010	0.268	6.7	6.8	1.93	1.9	30.7	0.88
2022 average	0.009	0.223	5.6	6.7	1.81	2.3	25.9	0.98
2023 average	0.011	0.270	8.3	6.8	0.70	1.7	49.0	1.33
2024 average	0.013	0.272	7.5	6.9	0.33	1.9	44.0	0.76
2020-2024 average	0.010	0.253	6.4	6.8	1.24	2.0	33.0	0.88
1997-2018 average	0.012	0.239	6.2	6.7	2.30	1.97	33.8	1.37

Figure 19. Lake Health Water Quality Report Card of Murphy Lake based on sampling completed from 2020 - 2024.
**Values in red are outside of the guideline range.*
**Cells with 'N/A' have no data collected for that parameter for that year.*

3.9 Little River Lake

Little River Lake is located in the Gaspereau River Watershed downstream from Gaspereau Lake and Murphy Lake. It is the fourth (4^{th}) in drainage order and flows into the downstream Black River Lake. The water must flow past a dam that was installed at the inflow of Black River Lake.

The mean annual TP, TN, TOC, Colour, and Chl-a data collected from Little River Lake from 2020-2024 can be observed in Figure 20. No data was collected for the year 2023 at this waterbody.

TP concentrations ranged from 0.006 mg/L - 0.016 mg/L and did not exceed the guideline value of 0.02 mg/L.

When looking at the annual average TN concentrations throughout this period, fluctuations between 0.28 mg/L and 0.364 mg/L were observed. The guideline concentration of TN (0.35 mg/L) exceeded the upper limit twice in 2020 with concentrations of 0.40 mg/L and 0.68 mg/L.

The guideline for TOC is unique for every lake as it is determined from the historical average concentration. In Little River Lake, the TOC guideline range is 5.2 – 7.8 mg/L. Of the 19 samples taken, the guideline value for TOC exceeded the upper limit five times and the lower limit twice.

The guideline for colour is also determined from the historical average, which was found to be 38.6 – 59.4 TCU. Colour values in Little River Lake exceeded guidelines twice in 2024 with values of 87.1 TCU and 79.8 TCU.

The guideline for Chl-a is <2.5 µg/L and was exceeded four times with two samples exceeding guidelines in 2022. The minimum value was 0.58 µg/L in 2024, and the maximum value was 3.7 µg/L in 2022.

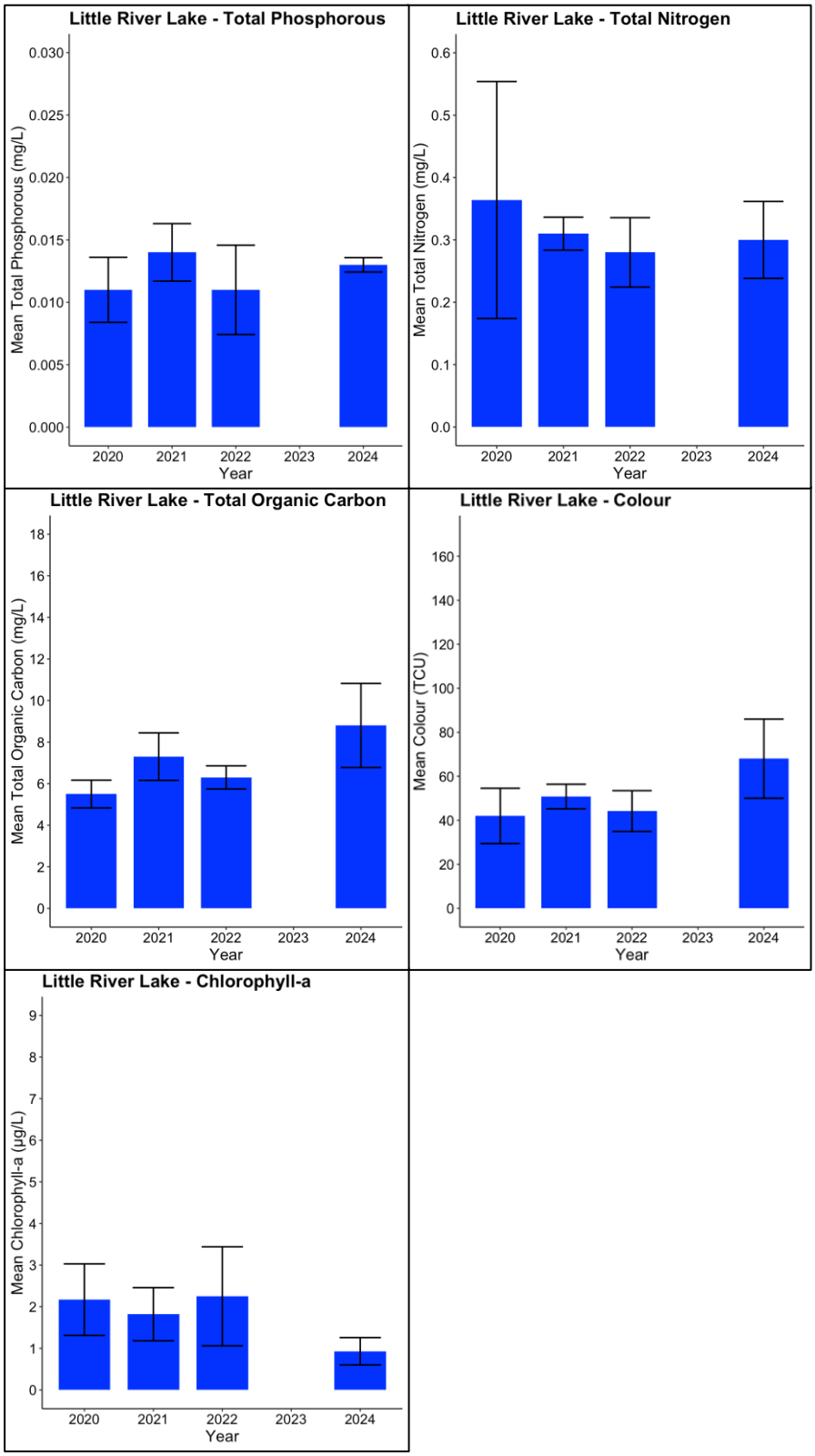


Figure 20. Little River Lake Phosphorus, Nitrogen, Organic Carbon, Colour, & Chlorophyll a graphs. Figures representing annual averages from the samples collected in Little River Lake between 2020 - 2024 including Total Phosphorous (Top Left), Total Nitrogen (Top Right), Total Organic Carbon (Middle Left), colour (Middle Right), and chlorophyll a (Bottom Left). Standard Deviation indicated by black bars.

3.9.1. Water Quality Index of Little River Lake

The WQI of Little River Lake was calculated for each year between the period 2020 - 2024. This is used to give an understanding of the lake's health for each year depending on what water quality parameters have been sampled and where they stand in terms of their guidelines.

In 2020, Little River Lake scored a 70 which is considered fair lake health. The results of this year exceeded the guidelines of temperature and Chl-a once each, and the guideline for TN twice over five sampling events.

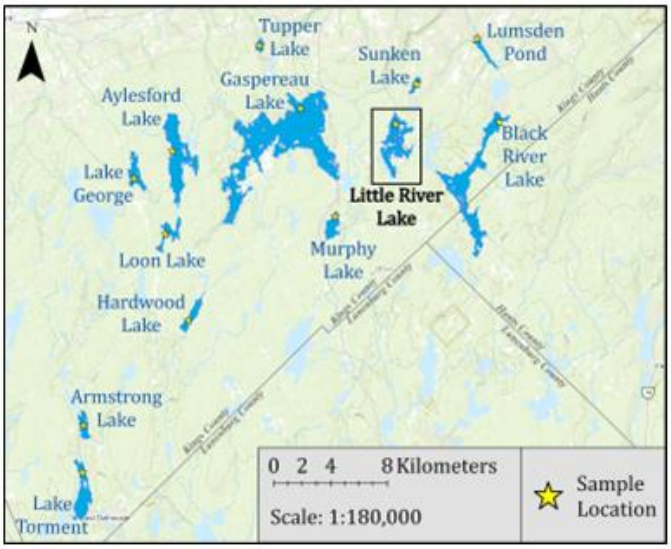
In 2021, the WQI scored a 79.3 which is considered fair lake health. The results of this year exceeded the guidelines of temperature three times and the guideline for Chl-a once over five sampling events.

In 2022, the WQI scored a 69.4 which is considered fair lake health. The results of this year exceeded the guideline for Chl-a twice over four sampling events. They exceeded the guideline for pH twice, and the guideline for temperature once over five sampling events.

In 2023, there was no data for Little River Lake as the lake was understood to have been drained by Nova Scotia Power for dam servicing (Municipality of the County of Kings, personal communication, January 17, 2025).

In 2024, the WQI scored a 78.5 which is considered fair lake health. The results of this year exceeded the guidelines for temperature three times and turbidity once over four sampling events.

3.9.2. Lake Health Water Quality Report Card - Little River Lake



Lake Information

Drainage Order: 4

Lake Area: 520 ha

Max Depth: 6.6 m

Elevation: 189 m

Year	WQI Score
2020	70
2021	79.3
2022	69.4
2023	N/A
2024	78.5

Little River Lake	Parameter							
	Total Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Organic Carbon (mg/L)	pH	Chlorophyll a (µg/L)	Secchi Depth (m)	Colour (TCU)	Turbidity (NTU)
Guideline	<0.020	<0.350	5.2 - 7.8	6.2 – 9.0	<2.50	>1.9	38.6 - 59.4	<1.30
2020 average	0.011	0.364	5.5	6.5	2.17	2.4	42.0	0.80
2021 average	0.014	0.310	7.3	6.4	1.82	2.4	50.8	0.67
2022 average	0.011	0.280	6.3	6.3	2.25	2.4	44.2	0.78
2023 average	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2024 average	0.013	0.300	8.8	6.5	0.93	2.0	68.0	1.08
2020-2024 average	0.012	0.318	6.9	6.4	1.81	2.3	50.0	0.82
1998-2018 average	0.014	0.265	6.5	6.4	3.13	2.11	49.5	1.01

Figure 21. Lake Health Water Quality Report Card of Little River Lake based on sampling completed from 2020 - 2024.
**Values in red are outside of the guideline range.*
**Cells with 'N/A' have no data collected for that parameter for that year.*

3.10 Black River Lake

Black River Lake is located in the Gaspereau River Watershed downstream of Little River Lake and upstream of Lumsden Pond. Black River Lake is fifth (5^{th}) in drainage order and a dam has been installed at the lake's outlet.

The mean annual TP, TN, TOC, Colour, and Chl-a data collected from Black River Lake from 2020-2024 can be observed in Figure 22.

TP concentrations ranged from 0.006 mg/L - 0.026 mg/L from 2020 to 2024. The guideline value of 0.02 mg/L was exceeded once over this sampling period.

When looking at the TN concentrations throughout this period, fluctuations between 0.19 mg/L and 0.42 mg/L were observed. The guideline concentration of TN (0.35 mg/L) was exceeded once with a value of 0.42 mg/L in 2024.

The guideline for TOC is unique for every lake as it is determined from the historical average concentration. In Black River Lake, the TOC guideline range is 5.3 – 7.9 mg/L. The guideline value for TOC was exceeded 4 times out of 23 sampling events between 2020 and 2024. Average annual values varied between 5.7 mg/L and 8.1 mg/L.

The guideline for colour is also determined from the historical average, which was found to be 43.5 – 61.3 TCU. Colour values in Black River Lake exceeded guidelines in 2023 with an average value of 65.6 TCU. Values ranged from 31.9 – 84.7 TCU during this study period.

The guideline for Chl-a is <2.5 µg/L, which was exceeded in 2021 with an average value of 2.84 µg/L and in 2022 with an average value of 3.16 µg/L. In total, there were five exceedances of the guidelines. The minimum value was 0.45 µg/L in 2024, and the maximum value was 5.20 µg/L in 2022.

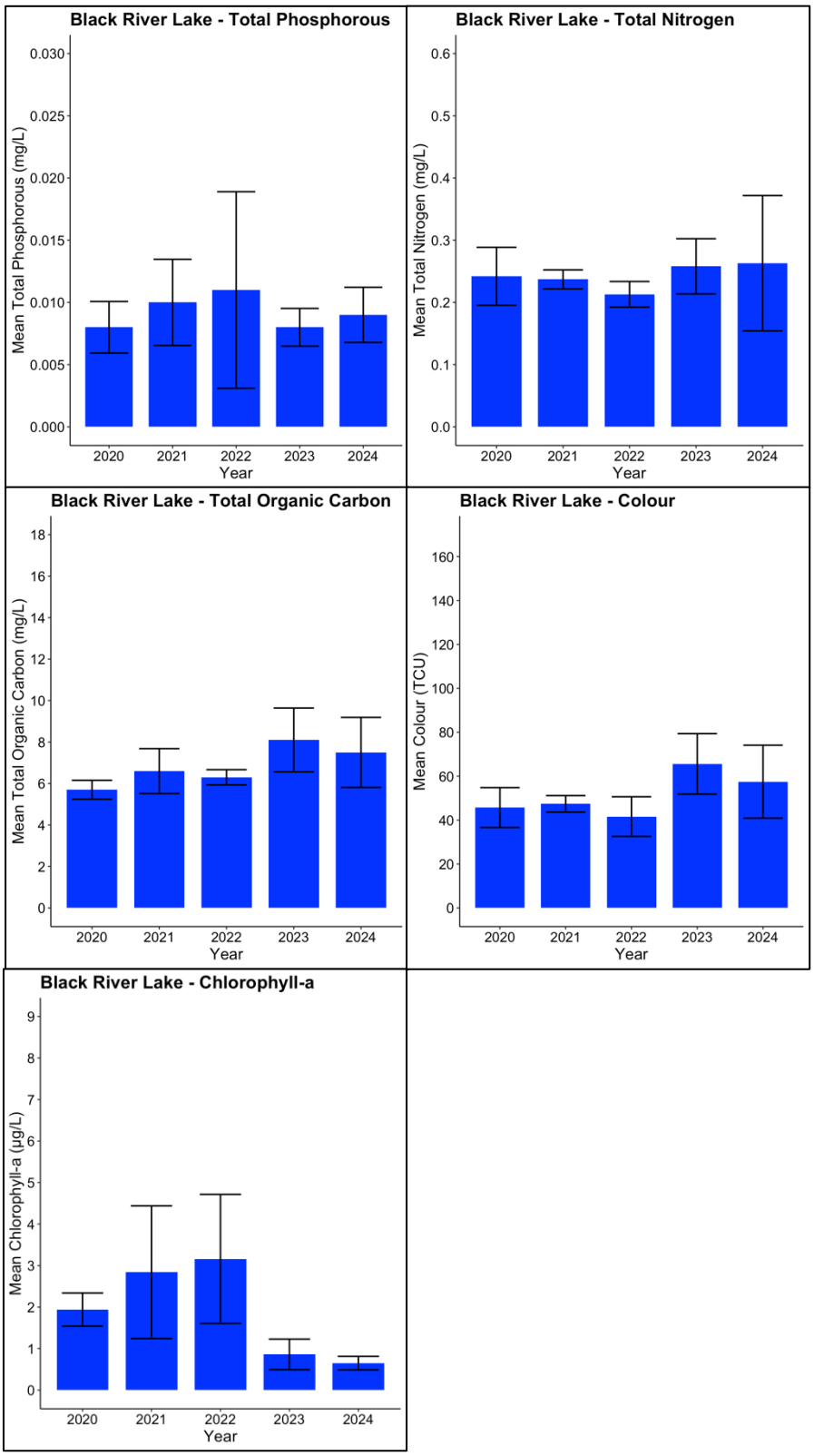


Figure 22. Black River Lake Phosphorus, Nitrogen, Organic Carbon, Colour, & Chlorophyll a graphs. Figures representing annual averages from the samples collected in Black River Lake between 2020 - 2024 including Total Phosphorous (Top Left), Total Nitrogen (Top Right), Total Organic Carbon (Middle Left), colour (Middle Right), and Chlorophyll-A (Bottom Left). Standard Deviation indicated by black bars.

3.10.1. Water Quality Index of Black River Lake

The WQI of Black River Lake was calculated for each year between the period 2020 - 2024. This is used to give an understanding of the lake's health for each year depending on what water quality parameters have been sampled and where they stand in terms of their guidelines.

In 2020, Black River Lake scored a 70.6 which falls under fair lake health. The results of this year exceeded the guidelines for temperature, pH, and Chl-a once over six sampling events.

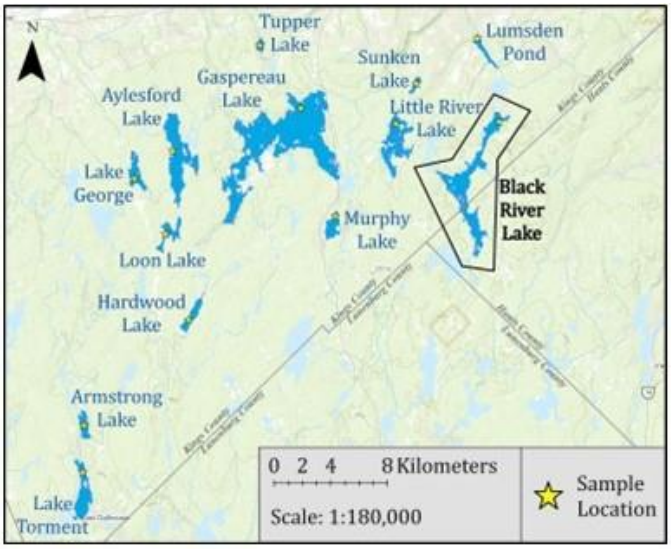
In 2021, the WQI scored a 78.1 which is deemed fair lake health. The results of this year exceeded the guideline for Chl-a once and exceeded the guideline for temperature twice over five sampling events.

In 2022, the WQI scored a 59.1 which is considered marginal lake health. The results of this year exceeded the guidelines for TP once, exceeded the guidelines for temperature and pH twice, and exceeded the Chl-a guideline three times over the 6 sampling events.

In 2023, the WQI scored a 79.2 which is considered fair lake health. The results of this year exceeded the guideline for temperature three times and the guideline for turbidity once over the 5 sampling events.

In 2024, the WQI scored a 79.4 which is considered fair lake health. The results of this year exceeded the guideline for TN once, and the guideline for temperature twice over four sampling events.

3.10.2. Lake Health Water Quality Report Card - Black River Lake



Lake Information

Drainage Order: 5

Lake Area: 668 ha

Max Depth: 15.0m

Elevation: 170 m

Year	WQI Score
2020	70.6
2021	78.1
2022	59.1
2023	79.2
2024	79.4

0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Black River Lake	Parameter							
	Total Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Organic Carbon (mg/L)	pH	Chlorophyll a (µg/L)	Secchi Depth (m)	Colour (TCU)	Turbidity (NTU)
Guideline	<0.020	<0.350	5.3 - 7.9	6.2 – 9.0	<2.50	>1.6	43.5 - 61.3	<1.30
2020 average	0.008	0.242	5.7	6.4	1.94	2.7	45.7	0.84
2021 average	0.010	0.237	6.6	6.4	2.84	2.4	47.4	0.66
2022 average	0.011	0.213	6.3	6.2	3.16	2.2	41.6	0.66
2023 average	0.008	0.258	8.1	6.4	0.86	1.9	65.6	0.86
2024 average	0.009	0.263	7.5	6.3	0.65	1.8	57.5	0.93
2020-2024 average	0.009	0.243	6.8	6.3	1.86	2.2	51.2	0.80
1997-2018 average	0.011	0.249	6.6	6.3	3.07	1.97	52.4	1.00

Figure 23. Lake Health Water Quality Report Card of Black River Lake based on sampling completed from 2020 - 2024.
**Values in red are outside of the guideline range.*
**Cells with 'N/A' have no data collected for that parameter for that year.*

3.11 Lumsden Pond

Lumsden Pond is located in the Gaspereau River Watershed downstream of Black River Lake and is sixth (6^{th}) in drainage order. Lumsden Pond is hydrologically the furthest downstream lake in the watershed. This lake has a dam located at its outflow which is used to generate hydropower.

The mean annual TP, TN, TOC, Colour, and Chl-a data collected from Lumsden Pond from 2020-2024 can be observed in Figure 24.

TP concentrations ranged from 0.007 mg/L - 0.041 mg/L. The TP concentration guideline was exceeded once with a value of 0.041 mg/L in October 2022.

TN concentrations ranged from 0.19 - 0.37 mg/L. The TN concentration guideline was only exceeded once with a value of 0.37 mg/L in September 2023.

TOC concentrations ranged from 5.3 – 10.1 mg/L. The guideline for TOC is unique for every lake as it is determined from the historical average concentration. In Lumsden Pond, the TOC guideline range is 5.0 – 7.6 mg/L. The upper guideline was exceeded five times with values between 7.8 mg/L and 10.1 mg/L.

Colour values ranged from 32.8 - 78.2 TCU. The guideline for colour is also determined by the historical average, which was found to be 39.3 - 54.5 TCU. Between 2020 – 2024, colour values in Lumsden Pond were below the guideline range seven times and above seven times with a total of 27 sampling events. It was observed that colour exceeded the guideline more frequently in 2023 and 2024.

Chl-a values ranged from 0.75 - 8.66 µg/L. The guideline for Chl-a is <2.5 µg/L. The guideline value was exceeded twice over nine sampling events. It was observed that Chl-a exceeded the guideline more frequently between 2020-2022.

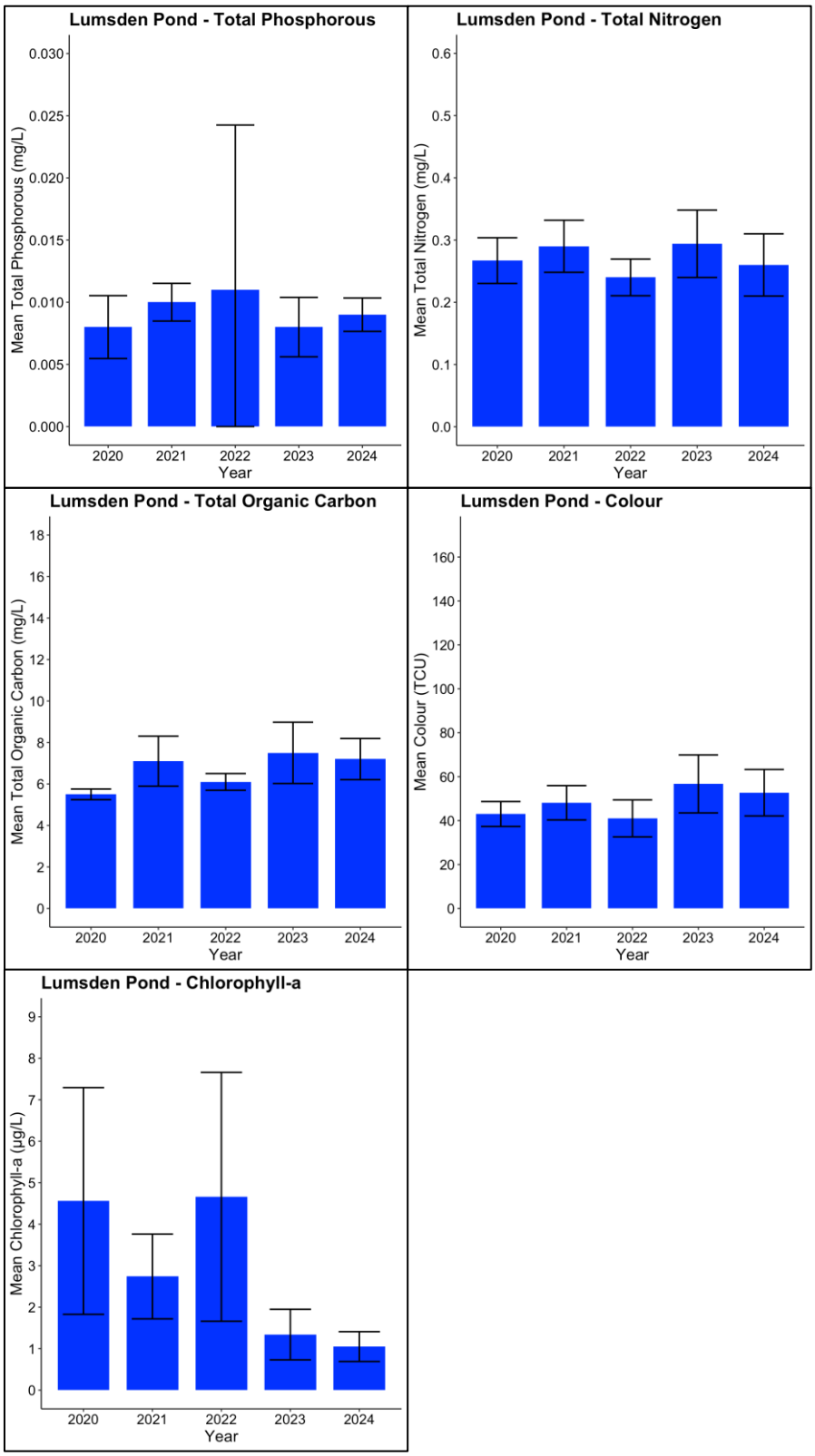


Figure 24. Lumsden Pond Phosphorus, Nitrogen, Organic Carbon, Colour, & Chlorophyll a graphs. Figures representing annual averages from the samples collected in Lumsden Pond between 2020 - 2024 including Total Phosphorous (Top Left), Total Nitrogen (Top Right), Total Organic Carbon (Middle Left), colour (Middle Right), and chlorophyll a (Bottom Left). Standard Deviation indicated by black bars.

3.11.1. Water Quality Index of Lumsden Pond

The WQI of Lumsden Pond was calculated for each year between the period 2020 - 2024. This is used to give an understanding of the lake's health for each year depending on what water quality parameters have been sampled and where they stand in terms of their guidelines.

In 2020, Lumsden Pond scored a 67.1 which falls under fair lake health. The results of this year exceeded the guidelines of temperature and Chl-a three times each and exceeded the guideline for turbidity once over six sampling events.

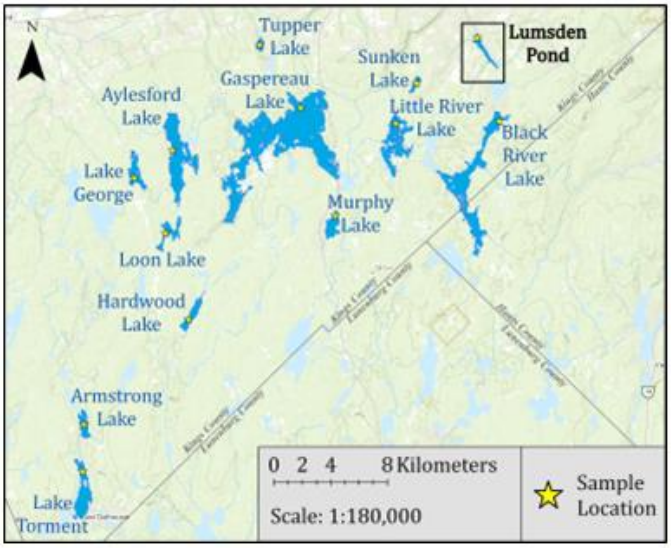
In 2021, the WQI scored a 68.0 which is deemed as fair lake health. The results of this year exceeded the guidelines of temperature and Chl-a three times each and exceeded the guideline for turbidity once over six sampling events.

In 2022, the WQI scored a 48.1 which is considered marginal lake health. The results of this year exceeded the guideline values for total phosphorous once, exceeded the temperature and turbidity guidelines twice each, and exceeded the Chl-a guideline three times over six sampling events.

In 2023, the WQI scored a 69.6 which is considered fair lake health. The results of this year exceeded the guideline for temperature once and exceeded the total nitrogen and turbidity guidelines once each over six sampling events.

In 2024, the WQI scored a 79.2 which is considered fair lake health. The guideline for temperature was exceeded three times, and the guideline for turbidity was exceeded once over five sampling events.

3.11.2. Lake Health Water Quality Report Card - Lumsden Pond



Lake Information

Drainage Order: 6

Lake Area: 88 ha

Max Depth: 19.0m

Elevation: 126 m

Year	WQI Score
2020	67.1
2021	68.0
2022	48.1
2023	69.6
2024	79.2

Lumsden Pond	Parameter							
	Total Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Organic Carbon (mg/L)	pH	Chlorophyll a (µg/L)	Secchi Depth (m)	Colour (TCU)	Turbidity (NTU)
Guideline	<0.020	<0.350	5.0 - 7.6	6.2 – 9.0	<2.50	>1.7	39.3 - 54.5	<1.30
2020 average	0.011	0.267	5.5	6.6	4.56	1.8	43.0	1.59
2021 average	0.010	0.290	7.1	6.5	2.74	2.1	48.1	0.88
2022 average	0.016	0.240	6.1	6.4	4.66	1.8	41.0	1.23
2023 average	0.010	0.294	7.5	6.6	1.34	1.7	56.7	1.06
2024 average	0.009	0.260	7.2	6.5	1.05	1.6	52.7	1.14
2020-2024 average	0.011	0.271	6.6	6.5	2.94	1.8	48.0	1.20
1997-2018 average	0.012	0.271	6.3	6.4	4.41	1.85	46.9	1.02

Figure 25. Lake Health Water Quality Report Card of Lumsden Pond based on sampling completed from 2020 - 2024.
**Values in red are outside of the guideline range.*
**Cells with 'N/A' have no data collected for that parameter for that year.*

3.12 Sunken Lake

Sunken Lake is located within the Gaspereau River Watershed catchment; however, it is hydrologically disconnected from all lakes in the Lake Sampling Program as it is supplied by spring water.

The mean annual TP, TN, TOC, Colour, and Chl-a data collected from Sunken Lake from 2020-2024 can be observed in Figure 26.

TP concentrations ranged from 0.003 mg/L - 0.024 mg/L and did exceed the guideline value of 0.02 mg/L once in 2024.

When looking at the TN concentrations throughout this period, fluctuations between 0.13 mg/L and 0.46 mg/L were observed. The guideline concentration of TN (0.9 mg/L) was not exceeded during the entire sampling period.

The guideline for TOC is unique for every lake as it is determined from the historical average concentration. In Sunken Lake, the TOC guideline range is 2.2 – 3.3 mg/L. The guideline value for TOC exceeded the upper limit seven times and the lower limit once with values ranging from 2.1 – 4.1 mg/L.

The guideline for colour is determined from the historical average as well, which was found to be 9.8 – 11.6 TCU, which is significantly lower than other waterbodies in the study area as Sunken Lake is a clearwater lake. Average colour values in Sunken Lake were below guidelines between 2020 and 2024 with a range of annual averages between 5.6 – 8.4 TCU.

The guideline for Chl-a is <2.5 µg/L, which was not exceeded during the study period. The minimum average value was 0.29 µg/L in 2024, and the maximum average value was 1.40 µg/L in 2022.

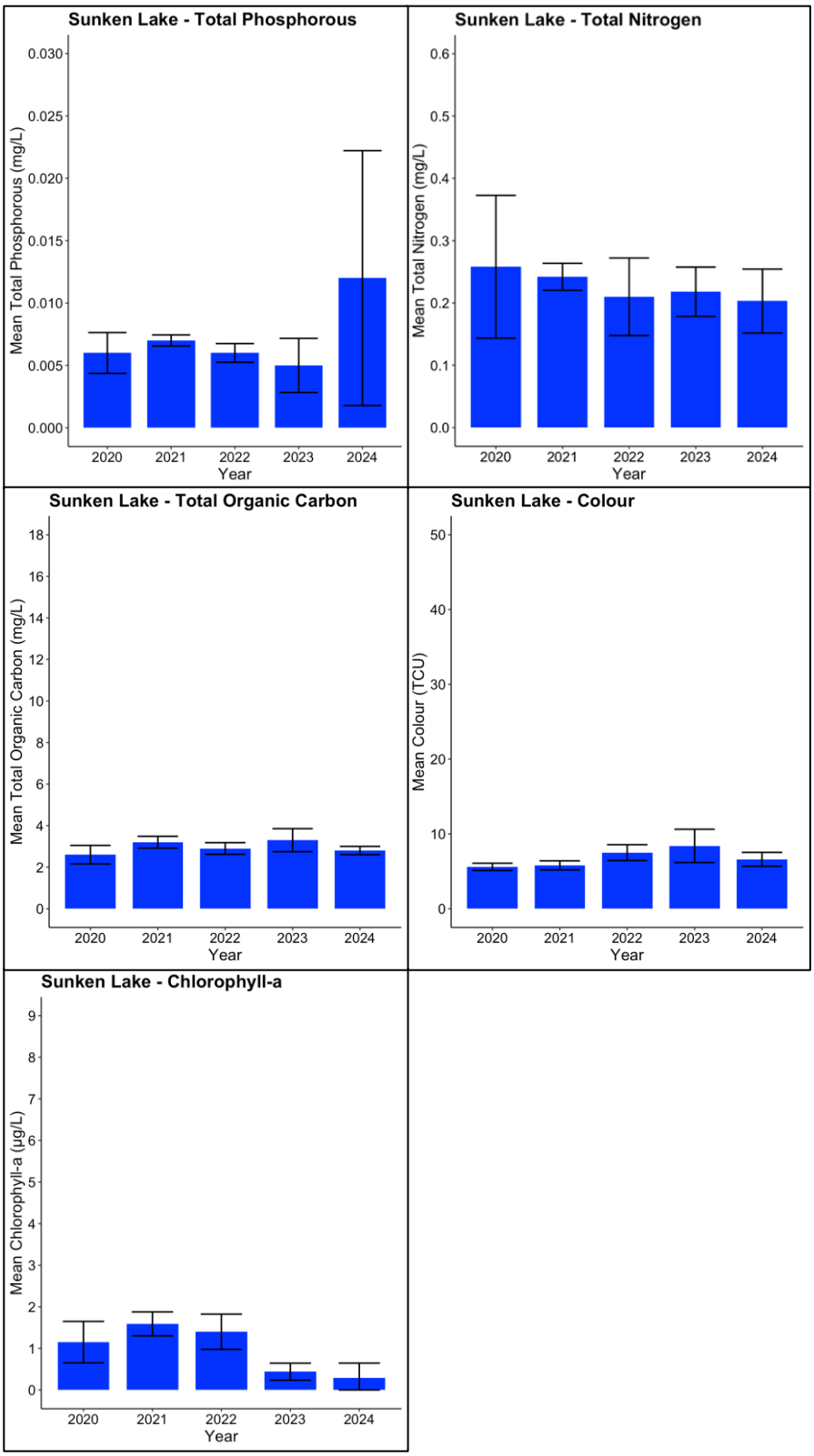


Figure 26. Sunken Lake Phosphorus, Nitrogen, Organic Carbon, Colour, & Chlorophyll a graphs. Figures representing annual averages from the samples collected in Sunken Lake between 2020 - 2024 including Total Phosphorous (Top Left), Total Nitrogen (Top Right), Total Organic Carbon (Middle Left), colour (Middle Right), and chlorophyll a (Bottom Left). Standard Deviation indicated by black bars.

3.12.1 Water Quality Index of Sunken Lake

The WQI of Sunken Lake was calculated for each year between the period 2020 - 2024. This is used to give an understanding of the lake's health for each year depending on what water quality parameters have been sampled and where they stand in terms of their guidelines.

In 2020, Sunken Lake scored a 90.2 which is considered good lake health. The results of this year exceeded the guideline for temperature over five sampling events.

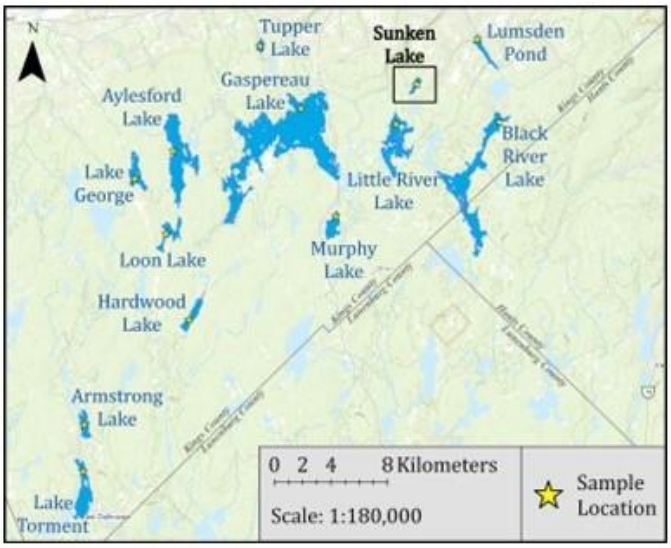
In 2021, the WQI scored an 88.7 which is considered good lake health. The results of this year exceeded the guideline for temperature three times over five sampling events.

In 2022, the WQI scored a 79.6 which is considered fair lake health. The results of this year exceeded the guidelines of temperature three times and turbidity once over six sampling events.

In 2023, the WQI scored a 90.2 which is considered good lake health. The results of this year exceeded the guideline for turbidity once over five sampling events.

In 2024, the WQI scored a 77.7 which is considered fair lake health. The results of this year exceeded the guidelines for TP and turbidity once each over three sampling events.

3.12.2 Lake Health Water Quality Report Card - Sunken Lake



Lake Information

Drainage Order: N/A

Lake Area: 22.2 ha

Max Depth: 6.9 m

Elevation: 209 m

Year	WQI Score
2020	90.2
2021	88.7
2022	79.6
2023	90.2
2024	77.7

0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Sunken Lake	Parameter							
	Total Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Organic Carbon (mg/L)	pH	Chlorophyll a (µg/L)	Secchi Depth (m)	Colour (TCU)	Turbidity (NTU)
Guideline	<0.020	<0.900	2.2 - 3.3	>5.3	<2.50	>2.6	9.8 - 11.6	<1.30
2020 average	0.006	0.258	2.6	7.1	1.15	4.6	5.6	0.77
2021 average	0.007	0.242	3.2	7.1	1.59	4.1	5.8	0.72
2022 average	0.006	0.210	2.9	6.9	1.40	4.2	7.5	0.90
2023 average	0.005	0.218	3.3	7.2	0.44	3.8	8.4	0.90
2024 average	0.012	0.203	2.8	7.2	0.29	1.7	6.6	2.00
2020-2024 average	0.007	0.230	3.0	7.1	1.04	3.9	6.8	0.96
2006-2018 average	0.009	0.201	2.8	7.1	3.10	3.28	10.7	1.10

Figure 27. Lake Health Water Quality Report Card of Sunken Lake based on sampling completed from 2020 - 2024.
**Values in red are outside of the guideline range.*
**Cells with 'N/A' have no data collected for that parameter for that year.*

3.13 Tupper Lake

Tupper Lake is located in the Cornwallis River Watershed and is hydrologically separate from the other lakes in the Lake Sampling Program.

The mean annual TP, TN, TOC, Colour, and Chl-a data collected from Tupper Lake from 2020-2024 can be observed in Figure 28.

TP concentrations ranged from 0.004 mg/L - 0.019 mg/L and did not exceed the guideline value of 0.02 mg/L.

When looking at the TN concentrations throughout this period, fluctuations between 0.15 mg/L and 0.28 mg/L were observed. The guideline concentration of TN (0.9 mg/L) was not exceeded during the entire sampling period.

The guideline for TOC is unique for every lake as it is determined from the historical average concentration. In Tupper Lake, the TOC guideline range is 3.6 – 5.5 mg/L. The average values for TOC were below guidelines in 2020 with values between 3.2 – 3.8 mg/L and above guidelines in 2023 and 2024 with values between 3.6 – 8.0 mg/L. Average annual values between 2020 – 2024 varied between 3.5 mg/L and 5.5 mg/L.

The guideline for colour is also determined from the historical average, which was found to be 11.2 – 25.6 TCU, which is significantly lower than other waterbodies in the study area as Tupper Lake is a clearwater lake. Colour values in Tupper Lake ranged between 5.6 TCU and 42.6 TCU. Average values fell below guidelines in 2020 and 2022 with 9.1 TCU and 8.3 TCU respectively. Values exceeded the upper limit of the guidelines twice in 2023, with values of 42.6 TCU and 28.8 TCU, and once in 2024 with a value of 29.9 TCU.

The guideline for Chl-a is <2.5 µg/L. Of the 25 samples taken, 4 samples were in exceedance of the guideline value. These exceedances occurred twice in 2021, with values of 2.96 µg/L and 2.98 µg/L, and twice in 2022, with values of 4.28 µg/L and 10.7 µg/L. Values ranged between 0.24- 10.70 µg/L during this study period.

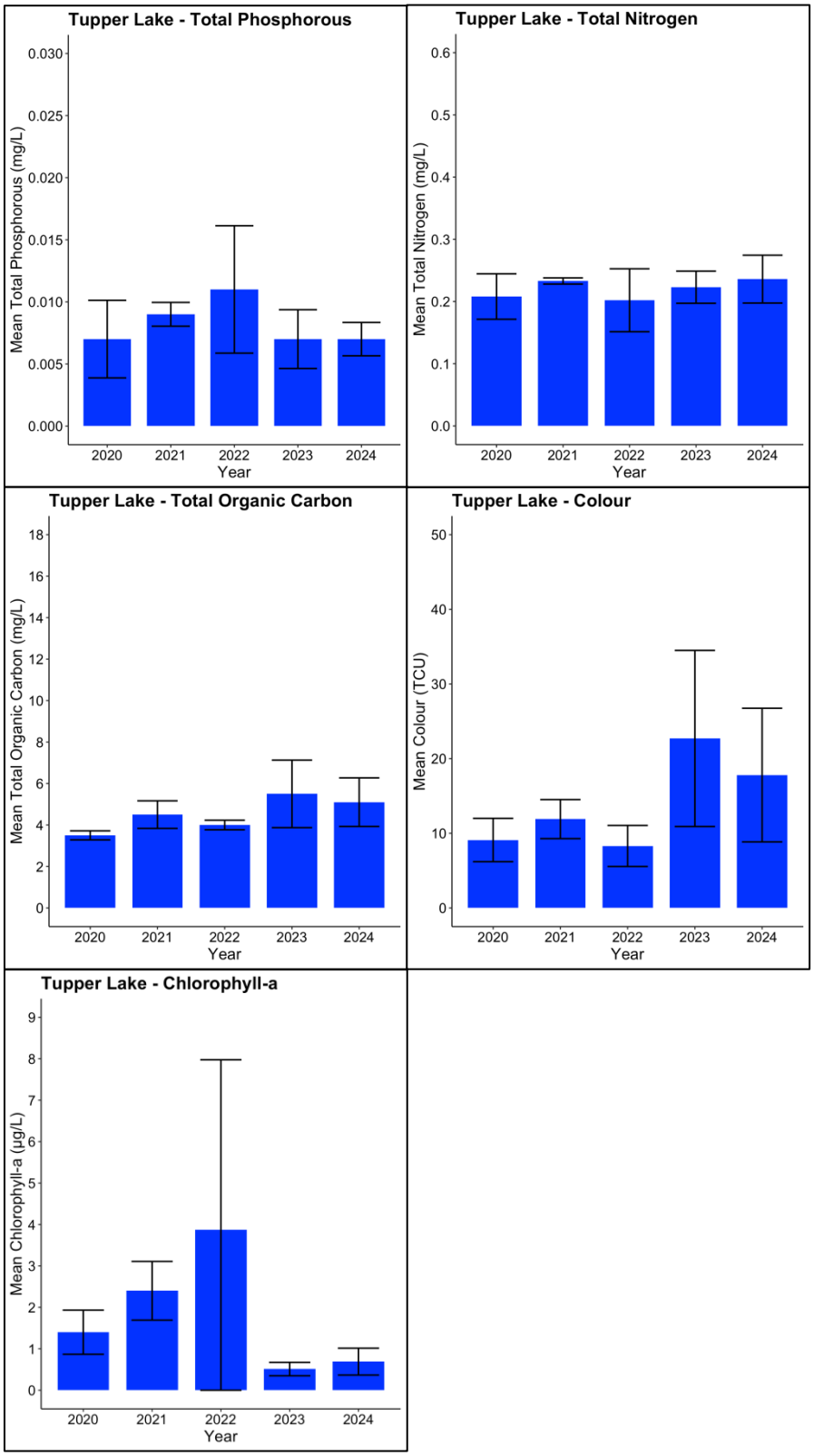


Figure 28. Tupper Lake Phosphorus, Nitrogen, Organic Carbon, Colour, & Chlorophyll a graphs. Figures representing annual averages from the samples collected in Tupper Lake between 2020 - 2024 including Total Phosphorous (Top Left), Total Nitrogen (Top Right), Total Organic Carbon (Middle Left), colour (Middle Right), and chlorophyll a (Bottom Left). Standard Deviation indicated by black bars.

3.13.1. Water Quality Index of Tupper Lake

The WQI of Tupper Lake was calculated for each year between the period 2020 - 2024. This is used to give an understanding of the lake's health for each year depending on what water quality parameters have been sampled and where they stand in terms of their guidelines.

In 2020, Tupper Lake scored an 89.2 which is considered good lake health. The results of this year exceeded the guideline for temperature three times over six sampling events.

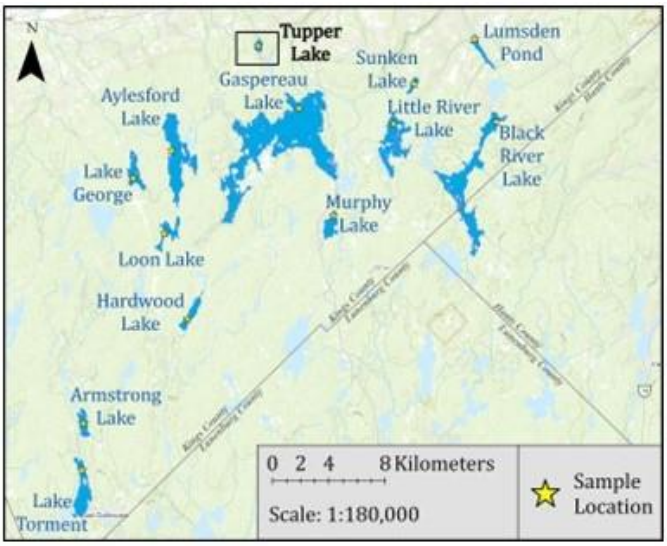
In 2021, the WQI scored a 67.5 which is considered fair lake health. The results of this year exceeded the guidelines for temperature three times, Chl-a twice, and turbidity once over four sampling events.

In 2022, the WQI scored a 67.5 which is considered fair lake health. The results of this year exceeded the guideline for Chl-a twice over four sampling events; and guidelines for temperature twice, and turbidity once over five sampling events.

In 2023, the WQI scored an 80.1 which is considered good lake health. The results of this year exceeded the guidelines for temperature twice and turbidity once over six sampling events.

In 2024, the WQI scored a 78.2 which is considered fair lake health. The results of this year exceeded the guidelines for temperature four times and turbidity once over five sampling events.

3.13.2. Lake Health Water Quality Report Card - Tupper Lake



Lake Information

Drainage Order: N/A

Lake Area: 36 ha

Max Depth: 3.0 m

Elevation: 201 m

Year	WQI Score
2020	89.2
2021	67.5
2022	67.5
2023	80.1
2024	78.2

Tupper Lake	Parameter							
	Total Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Organic Carbon (mg/L)	pH	Chlorophyll a (µg/L)	Secchi Depth (m)	Colour (TCU)	Turbidity (NTU)
Guideline	<0.020	<0.900	3.6 - 5.5	>5.3	<2.50	N/A	11.2 - 25.6	<1.30
2020 average	0.007	0.208	3.5	7.0	1.40	N/A	9.10	0.62
2021 average	0.009	0.233	4.5	7.0	2.40	N/A	11.9	1.30
2022 average	0.011	0.202	4.0	6.9	3.87	N/A	8.30	1.64
2023 average	0.007	0.223	5.5	7.0	0.51	N/A	22.7	1.02
2024 average	0.007	0.236	5.1	7.1	0.69	N/A	17.8	1.44
2020-2024 average	0.008	0.221	4.5	7.0	1.74	N/A	14.2	1.19
2003-2018 average	0.011	0.225	4.5	6.8	2.49	2.6	18.4	0.91

Figure 29. Lake Health Water Quality Report Card of Tupper Lake based on sampling completed from 2020 - 2024.
**Values in red are outside of the guideline range.*
**Cells with 'N/A' have no data collected for that parameter for that year.*

3.14 Lake Health Comparison

Overall, the WQI analysis of the thirteen sampled lakes in Kings County, as seen in Figure 30, determined scoring most frequently fell in the 65 – 79 range, which is considered fair lake health. This indicates that during the 2020 – 2024 sampling period, most of the lake's water quality was generally protected, with occasional conditions outside of desirable levels. Notably, no lake recorded very low WQI scores (0 – 44), meaning none exhibited poor water quality health during the sampling period. Furthermore, there was a total of two excellent scores, one at Hardwood Lake and one at Lake George, as well as ten good scores.

Many lakes displayed year to year variability in their scoring, with the most variable lakes being Hardwood Lake, Lake George, and Gaspereau Lake, all of which fell into three different scoring categories over five years. In contrast, three lakes—Lake Torment, Loon Lake, and Little River Lake—remained consistent, staying within a single scoring category over five years. Loon Lake and Little River Lake scored in the fair lake health range (65 – 79) every year. Lake Torment remained in the marginal range (45 – 64), while also exhibiting the least amount of variability in it's score across the sampling period.

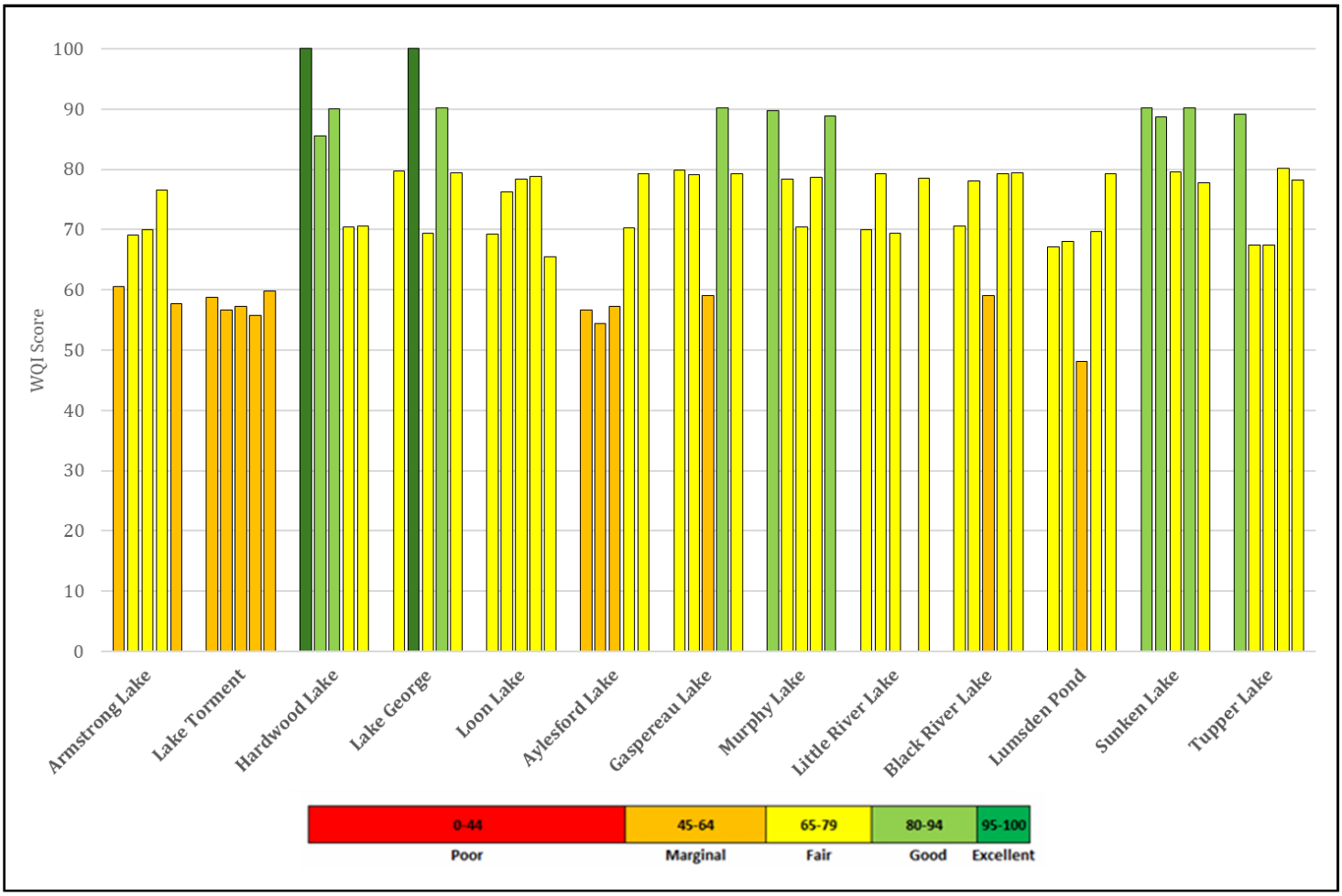


Figure 30. WQI score of each lake for each year over the 2020 – 2024 Kings County Lake Monitoring Program sampling period. Bars are coloured based on their WQI scoring, where 0-44 is poor (Red), 45 – 64 is Marginal (Orange), 65 – 79 is fair (yellow), 80 – 94 is good (Light green), and 95 – 100 is excellent (dark green).

3.15 Mann-Kendall Trend Test Results

The Mann-Kendall trend test was completed for every lake in the Kings County Lake Monitoring Program, to determine whether TP and TN concentrations had increasing, decreasing, or no trend at all over the 2020-2024 sampling period. These observations are illustrated in Tables 2 and 3 below, where the column "Mann-Kendall Trend" displays the trend direction for each lake, and column "p-value" displays the statistical significance of this trend. It is worth noting that these trends are not in comparison to the historical average and that these values can be below the TP guideline values even if increasing trends are observed. These trends provide insight into the likely trajectories of the lakes based on their statistical significance (p-value).

The TP trend analysis, as shown in Table 2, indicates that most lakes had increasing concentrations of TP, to varying degrees, between 2020 and 2024. It is observed that out of the thirteen (13) lakes sampled, only two (2) lakes (Gaspereau Lake and Lumsden Pond) experienced a decrease, while ten (10) lakes experienced increases. Little River Lake was given "N/A" due to the lack of data available during this period to run the Mann-Kendall trend analysis. From determined trends, three (3) lakes (Armstrong Lake, Loon Lake, and Murphy Lake) had statistically significant increasing trends.

Table 3. Total Phosphorus Mann-Kendall trend analysis for 13 lakes sampled from 2020 – 2024 in Kings County, Nova Scotia.
**__Bolded values__ are statistically significant trends.*

Total Phosphorous Mann-Kendall Trend Analysis			
Lake	**Mann-Kendall Trend**	**p-value (<0.05 is statistically significant)**	**Number of observed guideline exceedances**
Armstrong Lake	**Increase**	**0.0320569**	**3**
Lake Torment	Increase	0.8138497	4
Hardwood Lake	Increase	0.1275501	0
Lake George	Increase	0.4963372	0
Loon Lake	**Increase**	**0.0004405**	**2**
Aylesford Lake	No trend	1	3
Gaspereau Lake	Decrease	0.6975752	0
Murphy Lake	**Increase**	**0.0032458**	**0**
Little River Lake	N/A	N/A	0
Black River Lake	Increase	0.541093	1
Lumsden Pond	Decrease	0.7376943	1
Sunken Lake	Increase	0.3716929	1
Tupper Lake	Increase	0.8752891	0

The TN trend analysis, as shown in Table 3, indicates that most lakes had increasing concentrations of TN between 2020 and 2024. Of the thirteen (13) lakes sampled over the period, only two (2) lakes (Gaspereau Lake and Sunken Lake) experienced decreases, while ten (10) lakes experienced increases. Little River Lake was given "N/A" due to the lack of data available during this period to run the Mann-Kendall trend analysis. From these determined trends, two (2) lakes (Lake George and Loon Lake) had statistically significant increasing trends. Armstrong Lake and Lake Torment had the most exceedances for TN of the thirteen sampled lakes from 2020 – 2024.

Table 4. Total Nitrogen Mann-Kendall trend analysis for 13 lakes sampled from 2020 – 2024 in Kings County, Nova Scotia.
**__Bolded values__ are statistically significant trends.*

Total Nitrogen Mann-Kendall Trend Analysis			
Lake	**Mann-Kendall Trend**	**p-value (<0.05 is statistically significant)**	**Number of observed guideline exceedances**
Armstrong Lake	Increase	0.0675726	10
Lake Torment	Increase	0.5512716	9
Hardwood Lake	Increase	0.203562	2
Lake George	**Increase**	**0.0219809**	**0**
Loon Lake	**Increase**	**0.0090739**	**1**
Aylesford Lake	Increase	0.5020955	0
Gaspereau Lake	Decrease	0.840444	0
Murphy Lake	Increase	0.1482347	0
Little River Lake	N/A	N/A	3
Black River Lake	Increase	0.4445632	1
Lumsden Pond	Increase	0.8691905	1
Sunken Lake	Decrease	0.4728467	0
Tupper Lake	Increase	0.1187316	0

4.0 Conclusion

The lake analysis results from the Kings County Lake Monitoring Program revealed health ratings ranging from marginal to excellent, with no lakes showing "poor" health according to WQI. The most common WQI rating was "fair", while a score of "excellent" was recorded only twice across the lakes analyzed over the years. The WQI scores for each lake showed a strong correlation with the concentrations of TN and Chl-a, as these parameters were most frequently found to exceed acceptable levels.

A limitation encountered during the calculation of WQI was how lake health scoring can be influenced by absent data. The absence of data points was observed to introduce bias, affecting WQI scoring as lakes can be assigned health rankings from an incomplete representation of the lakes water quality. This issue was evident in the WQI scoring for Hardwood Lake in 2020, which received a score of 100 (Excellent), despite missing a significant amount of sampling data. The years following 2020 had no missing samples and scored lower, which categorized the lake as "fair" lake health. The WQI for each year of each lake is generated based on a series of tests where if less sample data is collected, fewer tests are completed, and a score is generated without considering the missing sample values. Although in the example of 2020 Hardwood Lake it inflated the scoring, it can also have the reverse effect and denote a lake as having poor health. This is important to consider as it can have effects on comparing these WQI scores from year to year, lake to lake, and with previous Kings County Lake Monitoring Program Reports.

It was observed that the lake guideline values for TOC and colour were frequently outside of their recommended range, however, this is not necessarily an indicator of poor lake health for dystrophic lakes. In these lakes, sphagnum moss naturally releases organic acids, including tannic acids, which can contribute to elevated levels of TOC and colour (Marty, J., 2018). Ongoing monitoring of TOC levels over time will provide insight into how the County of Kings' dystrophic lakes function as carbon sinks.

Lakes are dynamic ecosystems that constantly evolve due to various natural and anthropogenic factors, yet they can still maintain a stable condition over time. This concept is known as dynamic equilibrium and suggests while lakes experience changes in water quality, nutrient levels, and biodiversity, they can still adjust and stabilize in response to these fluctuations.

To understand how a lake may change over time is a complex task that requires time and resources. Lakes can act as great sinks because over time, nutrients naturally settle in these waterbodies; however, these nutrients may accumulate at accelerated rates which can raise concerns for the lake's ecological health. By collecting water quality data over long periods of time, a lake's stable dynamic equilibrium can be observed and used to determine if rapid changes are occurring. This data along with established guidelines offers valuable insights into a lake's condition and its changes over time. Adopting an initiative-taking approach to understand nutrient trends can help inspire communities to implement measures to benefit lake health. The Kings County Lake Monitoring Program is an essential initiative, providing critical information that plays a role in safeguarding the area's freshwater systems for the future.

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Appendix A

The z-score values show in the table on the right were used in calculations to determine guideline values of water quality parameters that are lake specific. The z-score values allow for an understanding of how far a point is away from the mean. Using the z-scores associated with the percentile value, the guideline range values were determined to understand each lakes health.

Percentile	Z-score
20	-0.842
25	-0.674
50	0
75	0.674
80	0.842