# KINGS COUNTY

# LAKE MONITORING PROGRAM

2019 SEASON

**Municipality of the County of Kings**

**Final report presented to TAC in November 2021**

Prepared and presented to the TAC by


Jérôme Marty, PhD

Freshwater ecologist.


## EXCECUTIVE SUMMARY

This report provides an assessment of the health of the 13 lakes monitored as part of the Kings County Lakes Monitoring Program (KCVLMP). For 23 years, volunteers have collected detailed information to assess changes in water quality and evaluate the health of the lakes using a water quality index (WQI). This information is valuable because it does allow to understand how the limnology of these lakes have changed over a long period of time. It is also a valuable dataset because there are very few consistent and comprehensive datasets that exists for lakes in Nova Scotia. No comparable programs that are designed and run by citizens volunteering to collect the data.

### Additional information that made it to the report since 2018

Since 2018, the report benefited from the input of two summer interns that helped with sampling and drafting a survey for volunteers to collect additional information on individual lakes. In addition, using the database from the Planning department at the County, maps of each lake were produced, with information on zoning (land use) such as the number of residences along the lakes. This information was added in the results section of the report. Finally, to complement the new maps, the definition of each zone can be found in the land-use bylaw presented in the appendix at the end of the report.

**The unique characteristics of the Kings County Lakes**

Over the years, the Technical Advisory Committee (TAC) has indicated the need to highlight the unique features of the Kings County lakes. Three main facts would be applicable to almost all lakes in this study. First, the amount of ions, measured as conductivity (the sum of constituents, salinity) is extremely low in all of the lakes. This means that the lakes have a low concentration in nutrients, as such, primary production (plant production) is limited. TAC members have observed that the conductivity values observed in the King County lakes are among the lowest in the world.

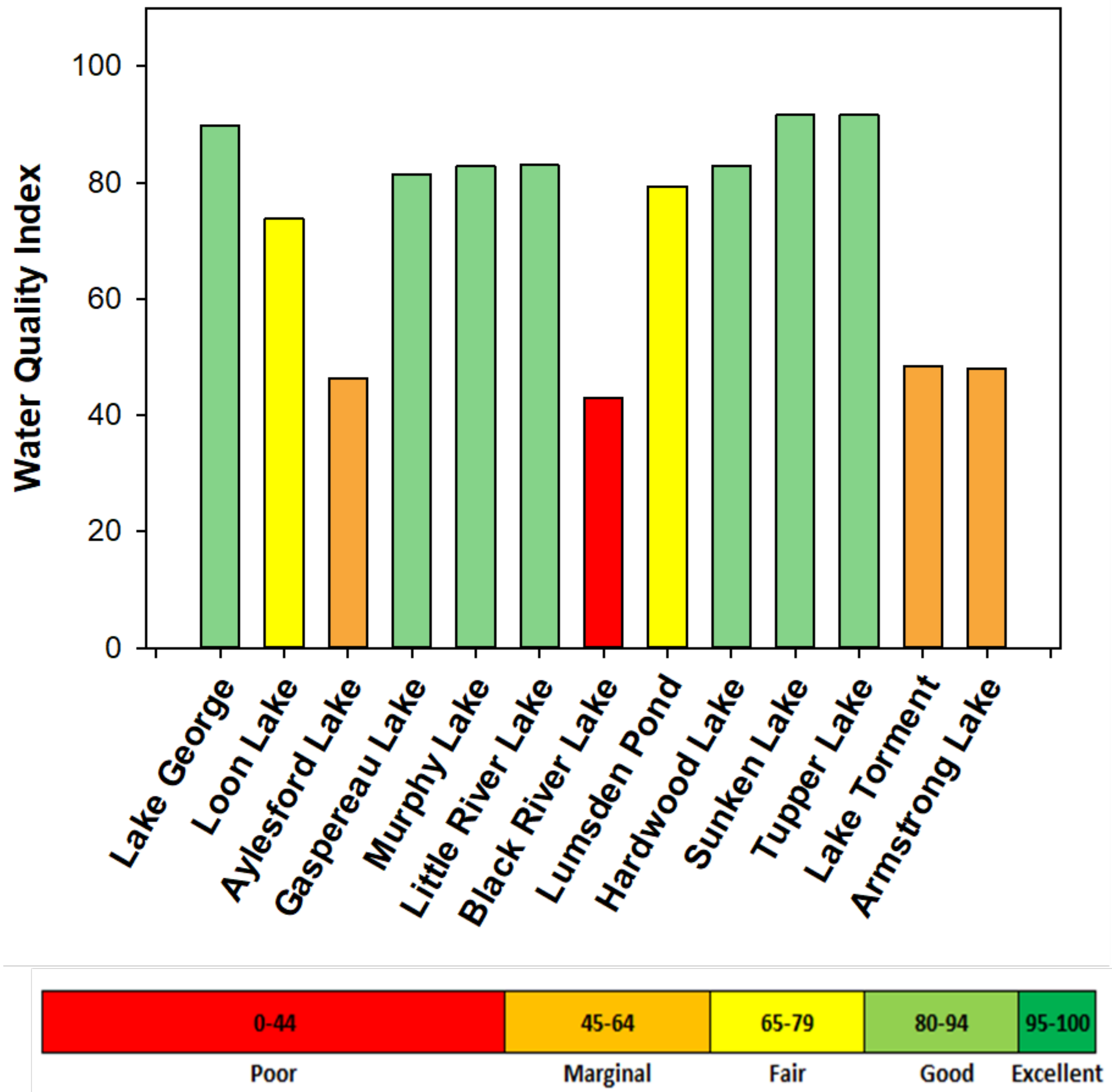
Secondly, the Kings County lakes are characterized by the brown colour of the water, that is due to the high concentration in dissolved organic carbon (DOC). This colour is of natural origin and is not an indication of poor water quality. It is the results of the presence of wetlands in the drainage basin, and in particular Sphagnum bogs that are very common in Atlantic Canada. Only 2 lakes have clear waters (Sunken and Tupper lakes, with a colour value lower than 20); and Lake George is slightly coloured. It is important to note that in coloured lakes, Secchi depth is not a good indicator of trophic state (as it is for clear waters). Variations in colour in the lakes can be observed for year to year and season to season depending on the precipitation driving the flushing rate of the Sphagnum bogs.

Finally, TAC has observed that the concentration in DOC is generally very high in the Kings County lakes. As indicated above, this is a key natural feature of the lakes that is not indicative of poor water quality. In lakes Torment and Armstrong, this concentration exceeds 10 mg/L, a value that is among the highest in the world. In these lakes, the concentrations in DOC exceed that of salinity. As such, there are limitations applying the WQI: Kings County lakes are very different from ‘normal’ lakes, for which the WQI was originally developed. As such, the WQI values presented in this report are the result of a modified calculation that does not include the influence of colour in the water quality rating. WQI values presented in this report are only applicable to Kings County lakes and may not compare well to other values derived from lakes in other regions.

In 2019, most of the lakes showing good water quality rating continue to maintain such rating. The Kings County lakes continue to show nutrient (as total phosphorus and total nitrogen) levels that are most of the time low and below guideline values. Until 2016, the lakes showed an increase in chl.a, a trend that was not observed after 2016. As for the last years, no relationship between nutrient concentrations and algal biomass was observed and this year again, it is not possible to relate the decrease in chl.a to a decrease in nutrients.

**The WQI values for 2019**

The WQI values ranged from poor (Black River Lake) to good (7 of the 13 lakes). In contrast to 2018, no lakes had an excellent water quality rating in 2019. The most frequent reason for the poor and marginal ratings is related to the exceedances in chl.a values, above guidelines.




Although nutrient levels are low in most of the KCVLMP lakes, it is important to note that productivity can be high in some of the lakes and as such local residents should continue and maintain programs aiming at reducing nutrient loading to the lakes. Although most of the WQI rating was good in 2019, it does not mean that the lakes will remain in good health if nutrient loading was to increase in the future or if other variables such as climate change continue to influence lake biological, physical and chemical processes.

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*Acronyms*

| | |
|---|---|
| CCME | Canadian Council of Ministers of the Environment |
| Chl. a | Chlorophyll. a |
| DOC | Dissolved Organic Carbon |
| OECD | Organization for Economic Cooperation and Development |
| pH | Power of Hydrogen ($H^+$) |
| QA/QC | Quality Assurance / Quality Control |
| RPD | Relative Percent Difference |
| SD | Secchi Depth |
| TN | Total Nitrogen |
| TP | Total Phosphorus |
| WQI | Water Quality Index |

*Acknowledgements*

This report receives the feedback and review of the members of the Lake Monitoring Program Technical Steering Committee:

- Emily Lutz– Councillor for District 7
- Kyle Hicks – Nova Scotia Power
- Stephanie Walsh – Nova Scotia Power
- Darrell Taylor – Nova Scotia Environment
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- Joe Kerekes – Scientist Emeritus, Environment Canada
- Reg Newell – Nova Scotia Department of Natural Resources
- Drew Peck – Citizen Member

This project is being managed by Will Robinson-Mushkat, Planner within the land-use planning and inspection services at the Municipality of the County of Kings.

This program would not be successful without its volunteers. The volunteers who sampled the lakes between 1999 and 2019 are as follows:

Mike Armstrong
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Vivian Kent

Ben Raymond
Zack Raymond
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Denise Young

# 1 Introduction

The Kings County Lake Monitoring Program is an initiative begun at the Municipality of the County of Kings in 1997, although early monitoring for some of the lakes started in 1992. The program started as the result of input from a multi-stakeholder group composed of members of all three levels of government and community groups. This group was assembled to address concerns on the impact of development of lake shorelines in Kings County.

Today, the long-term dataset collected by the volunteered group informs on long-term changes in Kings County Lakes. Based on this long-term monitoring, trends are valuable to detect and understand changes that may not be detected using a limited number of sampling years. The Volunteer Water Quality Monitoring program was initiated to help calibrate this model and foster environmental awareness within the community.

There are five overall goals for the program (Municipality of the County of Kings, 2009). These goals are:

- To address citizens' concerns regarding lakeshore development impacts to Kings County lakes by working with lake associations and municipal, provincial and federal departments;
- To put planning tools in place to evaluate the effectiveness of controls on development around lakes and to aid decision making;

- To consider municipal planning and approval activities in the context of predetermined water quality objectives for Kings County lakes;
- To document long-term changes in water quality in the lakes and provide an assessment of the health of the lakes, which in turn can inform on their use.

Water sampling occurs once a month for each lake from May to October and is conducted by volunteers. The monitoring has been conducted every year since 1997 and currently thirteen lakes are sampled regularly as part of the Kings County Lake Monitoring Program. Quality Assurance and Quality Control (QA/QC) sampling was added to the protocols in 2011.  Duplicate samples were collected from ten of the lakes in September 2018 and submitted for laboratory analysis. Two new lakes, Lake Torment and Armstrong Lake, were added to the lake monitoring program in July of 2014. The list of lakes sampled in 2019 is presented in Table 1-1 and Figure 1-1.

The lakes are all located within the boundaries of Kings County, on the South Mountain, south of the Annapolis and Gaspereau valleys. Eight of the thirteen lakes are directly connected via surface flow and eventually drain into the Gaspereau River. Hardwood, Torment, Armstrong, Tupper and Sunken lakes are not part of this system; Hardwood, Torment and Armstrong Lakes are in the LaHave River watershed, Tupper Lake is part of the Cornwallis River watershed and Sunken Lake drains directly into the Gaspereau River without being connected to any of the other lakes (See Figure 1-2).

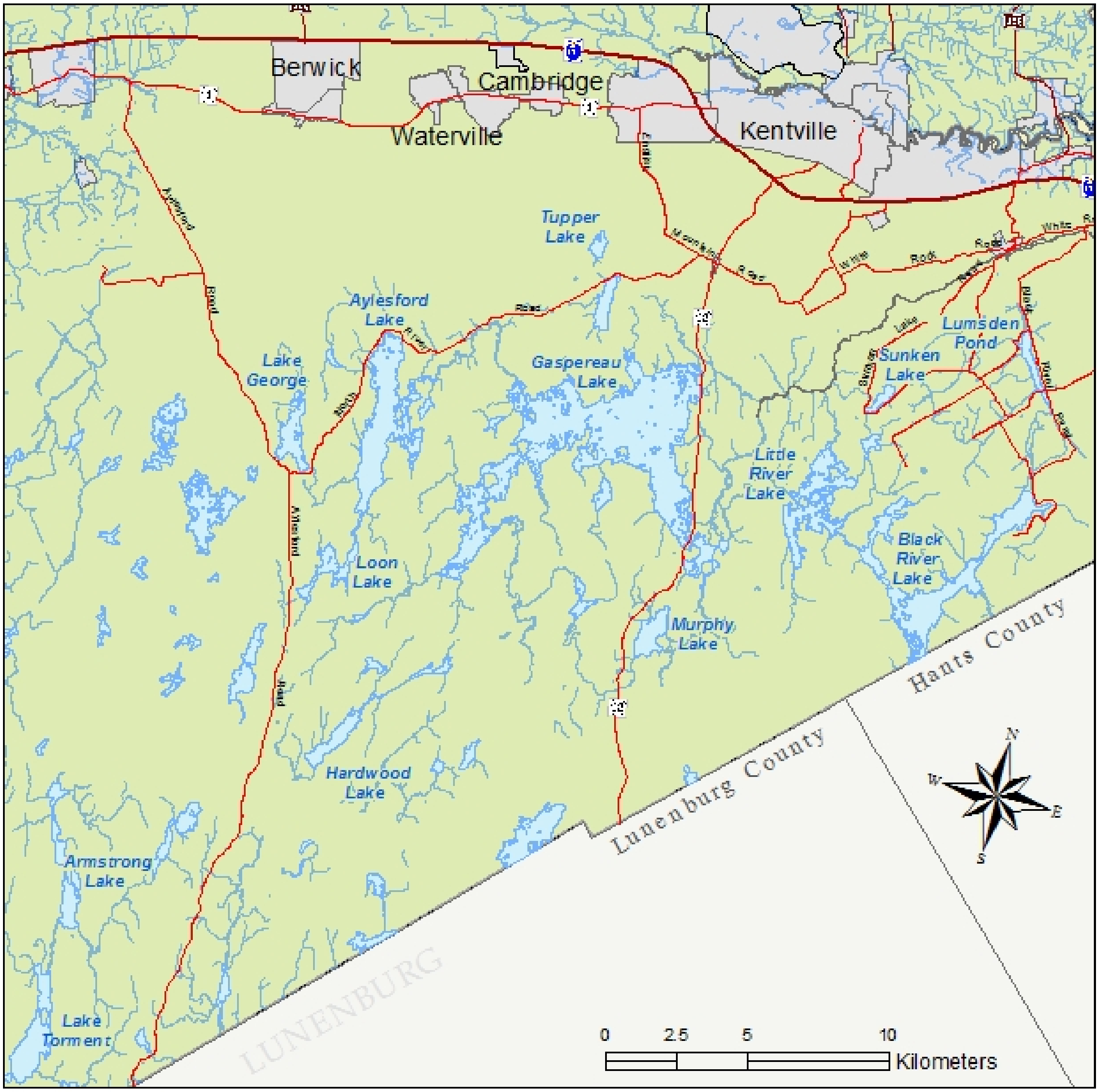



**FIGURE 1-1 LAKES OF THE KINGS COUNTY LAKE MONITORING PROGRAM (SOURCE: MUNICIPALITY OF THE COUNTY OF KINGS)**

The drainage order for the lakes draining to the Gaspereau River is summarized on Table 1-1 and on Figure 1-2. The relative position of each lake is indicated with a number. Since Lake George and Loon Lake both drain into Aylesford Lake, they were both given a 1. The same number is also used for Gaspereau and Murphy Lakes. To facilitate review of potential drainage order trends, data for each lake in this report is presented in the same sequence as their drainage order.

It is important to note that the water flow is regulated in some of the lakes and therefore, systems located on the former Little Black River are not typical lakes due to the presence of a hydroelectric dam. The presence of the dam may affect the quantity of water located downstream as well as the thermal structure of these lakes. Furthermore, it is possible that the water quality of lakes facing flow regulation differs from that of natural lakes, due to different water residence time (flushing) and increased contact with the shoreline (contributing additional particles and nutrient). At this point the report does not provide an analysis of impact of flow regulation but this could be added pending more information on patterns in changes in flow regime from the regulator.

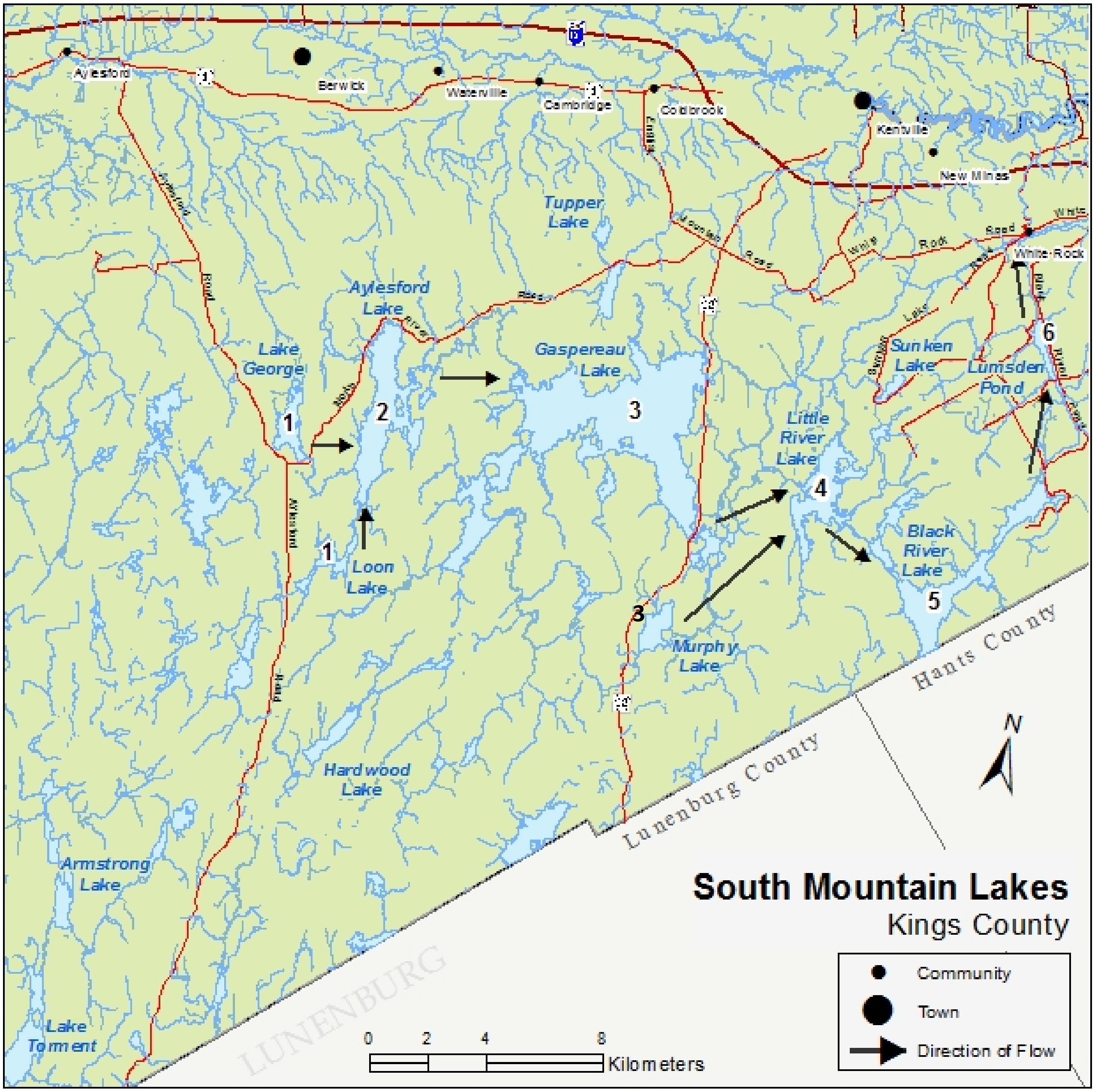



**FIGURE 1-2 DRAINAGE MAP OF THE AYLESFORD LAKES**

### TABLE 1-1 NAMES AND COORDINATES OF THE LAKE MONITORING LOCATIONS

| DRAINAGE | LAKE NAME | LATITUDE | LONGITUDE |
|---|---|---|---|
| 1 | Lake George | 44°56'12"N | 64°41'48"W |
| 1 | Loon Lake | 44°54'0"N | 64°40'0"W |
| 2 | Aylesford Lake | 44°57'00"N | 64°40'00"W |
| 3 | Gaspereau Lake | 44°58'30"N | 64°32'30"W |
| 3 | Murphy Lake | 44°54'30"N | 64°31'0"W |
| 4 | Little River Lake | 44°57'0"N | 64°28'0"W |
| 5 | Black River Lake | 44°58'24"W | 64°27'30"W |
| 6 | Lumsden Pond* | 45°1'30"W | 64°23'45"W |
| - | Hardwood Lake | 44°50'36"N | 64°38'0"W |
| - | Sunken Lake* | 44°59'39.46"N | 64°27'0.30"W |
| - | Tupper Lake* | 45° 1'0.76"N | 64°35'23.71"W |
| - | Lake Torment | 44°43'41.15"N | 64°44'22.18"W |
| - | Armstrong Lake | 44°46'28.84"N | 64°44'26.31"W |

*Coordinates were estimated using Google Earth.

Most of the lakes in this region are dystrophic lakes, also known as humic or brown water lakes. Lakes of this type are common in forested areas, especially in the boreal and Acadian forest regions. Lakes of this nature are characterized by a brownish water colour due to the presence of humic material responsible for acidity. They tend to have low lime (bicarbonate) levels (Cole, 1983; Makie, 2004). The low pH does not necessarily reduce the trophic level of coloured lakes, and productivity can be higher than in clear water lakes under certain conditions (Kerekes and Freedman, 1989).

Humic lakes are typically low in nutrient and therefore have a low productivity. This is due to the low lability of organic matter originating from the watershed. On the other hand, humic lakes are also very sensitive to changes in the watershed as they derived most of their inputs from land. Changes in land-use such as deforestation and residential development are key drivers influencing the trophic status of humic lakes. On the boreal shield, natural drivers also influence water quality of humic lakes: the presence of beaver dam increases flooding which in turn provide additional nutrient in waters (Roy et al., 2007), and finally, fires (and to a high extend clear cutting) are reported to contribute to nutrient loading via export from the soil (Carignan et al. 2000).The cumulative impacts of local disruptions and global changes such as temperature increase has overall raised concerns in many humic lakes. Over the last decade, increasing occurrences of algal blooms (such as cyanobacteria) and abundant growth of vascular plants (macrophytes) are being reported in humic lakes, highlighting the need to better understand their potential impacts.

Several humic lakes are being monitored in Nova Scotia. For example, of the 18 lakes currently monitored in Kejimkujik National Park and National Historic Site, 11 are dystrophic (Parks Canada, 2010). In addition, dystrophic lakes are also found in Yarmouth, Clare and Argyle Counties for which water quality index values are calculated accounting for high dissolved organic matter concentrations (Water Quality Survey of Fourteen Lakes in the Carleton River Watershed Area**,** 2016). The relationship between TP, chl.a and Secchi depth in coloured lakes does not appear to have the same correlation as in clear water lakes (Centre for Water Resources Studies and Stantec, 2009). When low oxygen levels are found in non-dystrophic lakes, this is usually used as an indicator of poor water quality. This cannot be generalized to dystrophic lakes, as they naturally have anoxic conditions at lower depths (Kevern et al., 1996; Cole, 1983). The low colour results for Sunken and Tupper lakes suggest that these lakes are not dystrophic (Parks Canada, 2008).

# 2 Methodology

*The following description of methodology is similar to that described in previous recent years and was updated for 2019 following yearly review comments from the Technical Advisory Committee (TAC).*

Thirteen lakes were sampled during the 2019 field season. Sample collection and field measurements were undertaken by volunteers once per month beginning in May and ending in October.

Sampling was usually completed on the third Sunday of each month at as close to 12:00 pm as possible, weather permitting. If more than 25 mm of rain fell within the previous 24 hours, sampling was delayed several days. This is because rainfall can affect the sample results by increasing turbidity due to the transport of sediments from the watershed into the lake. Taking water samples under these conditions would impair the comparability between samples.  Samples were gathered within the last two weeks of each month.

The samples were taken at the deepest point of the lake, which was marked by a buoy. The coordinates of the site locations are listed in Table 1-1. A boat was anchored or tied to the buoy and the Secchi depth (SD) was measured (Figure 2-1).  Sampling consisted in the collection of 2 samples made of water collected at 2 different depths for each lake: samples were taken near the surface and either 1 m from the bottom or at 2x the Secchi depth (whichever was the shallower measurement). These two samples were then combined into one bottle prior to be sent to the laboratory. This procedure was then repeated to obtain the second sample. Depth samples were not taken closer than 1 metre to the lake bottom. Water temperature readings (surface and bottom), air temperature, weather conditions and station water depth were also documented.

Samples were analyzed for chl.a, total phosphorus (TP), total nitrogen (TN), dissolved organic carbon (DOC), alkalinity, pH, colour, turbidity, conductivity and orthophosphorus (Phosphate). The water samples were sent to the Environmental Services (ES) Lab at the QEII Health Services Centre and the Analytical Services lab of the New Brunswick Department of Environment. All parameters, with the exception of total phosphorus and chl.a, have been analysed at the QEII Centre for the duration of the program from 1997-2011. Phosphorous samples were sent to the ES Lab at the QEII from 1997-2004. The results from 2004 analyzed in this lab displayed high variability, producing anomalies in the data that were difficult to explain (Brylinsky, 2008). A decision was made to change laboratories, and phosphorous samples were then sent to the Analytical Services Lab in New Brunswick from 2005-2011 (Centre for Water Resources Studies and Stantec, 2009). The change in laboratories resulted in a reduction of variability of results, although Brylinsky noted that anomalies remained in the 2007 and 2008 data. The Centre for Water Resources Studies and Stantec (2009) noted that although the phosphorus results produced by the Fredericton lab display more realistic trends, the level of detection at this lab may not be adequate and suggests employing another lab to obtain more accurate results. At the end of 2011 the ES Lab at the QEII updated its equipment and TP testing was resumed at that lab.

From 1997 to 2005, chl.a was also sent to the Environmental Services lab at the QEII and analysed using the fluorometric method. However, because this method was not accredited at this lab, it was discontinued and chl.a samples were sent to the Analytical

Services Lab in New Brunswick.  This lab employed the spectrophotometric method; chl.a results were analysed at this location from 2006-2008. It was found by the Centre for Water Resource Studies and Stantec (2009) that the spectrophotometric method overestimated the results when compared to the fluorometric method. In 2009-2011, chl.a results were once again sent to the QEII for analysis using the fluorometric method (Centre for Water Resources Studies and Stantec, 2009). Since the end of 2011 the ES Lab at the QEII has not offered chl.a testing. Beginning in the 2012 sampling season the ES Lab has filtered all chl.a samples and then forwarded them to the New Brunswick lab for final analysis.

**Figure 2-1 A Secchi disk used to take a Secchi depth reading at monitored lakes**

Currently, all samples are sent to the QEII lab for analysis, whereas the chl.a samples are shipped to the ALS laboratory in Winnipeg, ALS (starting in 2016). In 2016, the protocol for laboratory analysis was verified and only frozen filters are sent for analyses, following standard protocols.  Although previous reports have discarded laboratory data from 2004 due to suspected anomalous results in phosphorus, we have included the 2004 data in this report as the trends displayed appear to indicate that these results may not be anomalous.

Quality control/quality assurance sampling was conducted in 2019 through the collection of duplicate samples from ten of the thirteen regularly sampled lakes.

**FIGURE 2-2 SAMPLING DEVICE USED TO COLLECT WATER SAMPLES FROM MONITORED LAKES**

## 2.1 Parameters Measured

### 2.1.1 Total Phosphorus, chl.a, Secchi Depth, Total Nitrogen

In clear water lakes, TP, chl.a and Secchi depth (SD) can be used to determine the trophic state, or level of aquatic vegetation (Carlson and Simpson, 1996). Total nitrogen (TN) can also be used for this purpose in some cases. Although these indicators are normally related and can predict each other, the relationship is not defined for coloured lakes. The Kings County Lakeshore Capacity Model (KCLCM) uses lake characteristics to predict springtime concentrations of TP, which are then used to predict chl.a. Sample data collected from the lakes in the Gaspereau River watershed suggests that the assumed phosphorous-chl.a relationship used in the model does not exist for these lakes and is therefore not appropriate (Centre for Water Resources Studies and Stantec, 2009). Kerekes (1981) found the increase in chl.a in response to increases in phosphorous levels appears to be less in coloured lakes than in clear water lakes, as some of the phosphorous in coloured lakes is chemically bound to humic substances and is therefore less available for algal production. Irrespective of the influence of colour and weaker nutrient/chl.a relationships, phosphorus is still considered the key driver of algal production and chl.a levels in Nova Scotia lakes as well as freshwater lakes generally worldwide (Vollenweider and Kerekes, 1982). TP and TN are measured in mg/L, chl.a is measured in mg/m$^3$ and SD is measured in metres.

### 2.1.2 Dissolved Organic Carbon

Dystrophic lakes are characterized by high levels of humic materials and organic acids, which are generally indicated by DOC content. Lowered productivity and increased susceptibility to acidification and toxic metals can result from changes in DOC levels. Increases can also lower dissolved oxygen by increasing bacteria metabolism (Government of British Columbia, 2001). Elevated DOC levels can be caused by the breakdown of forest materials that have been washed into a lake, such as leaves and evergreen needles. DOC content tends to be inherent to both lake and river systems; thus water quality parameters are generally based on whether or not the levels fluctuate beyond regular background levels. This means water quality parameters will be unique to each system. DOC is measured in mg/L.

### 2.1.3 pH and Alkalinity

pH is a measure of the dissolved hydrogen ion content in the water. The greater the hydrogen ion concentration, the more acidic the system. pH is measured on a scale of 1 to 14. Lower pH is more acidic while higher pH is more alkaline; pH 7 is neutral. The pH scale is logarithmic, meaning every unit decrease represents a tenfold increase in acidity. Levels of pH below 5 have been known to have adverse effects on fish species such as salmon or trout. Alkalinity is a measure of the ability of water to resist lowering pH, also known as its buffering capacity. It is determined by the concentration of carbonates, bicarbonates and hydroxides and is usually a result of the surrounding geology. It can be expressed in terms of equivalents of carbonate or bicarbonate, or in the amount of calcium carbonate present (Mackie, 2004). Dystrophic lakes typically have low calcium content and are more likely to be acidic (Cole, 1983). Therefore, most of the dissolved carbon in humic lakes is under the form of dissolved $CO_2$. There are few established guidelines for alkalinity (Parks Canada, 2008) and it shares many properties with pH, thus alkalinity is not measured in the Kings County Lake Monitoring Program.

### 2.1.4 Turbidity and Colour

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 gives an indication of the amount 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). Lake colour is a parameter that can indicate the types of particulate matter present in the water column (Mackie, 2004). For instance, lakes with a blue colour tend to be clearer, with low amounts of sediments; lakes with a greenish colour likely contain considerable amounts of blue-green algae and if lakes display a reddish-brown colour, this indicates high levels of organic material (Mackie, 2004). Colour is measured in true colour units (TCU).

### 2.1.5 Conductivity

Conductivity is commonly used in water quality assessments as a general indicator of the amount of ions present in the water. It measures the ability of water to conduct an electrical current between two electrodes 1 cm apart. In general, the greater the amount of dissolved solids, the higher the conductivity. Conductivity is measured in milliSiemens per centimetre (mS/cm). Conductivity is not generally used as a water quality parameter as it is dependent on many other parameters (Mackie, 2004): for example, hard waters will have a high conductivity compared to soft waters due to high content in bicarbonates. This being said, conductivity can be a proxy for pollution when a source of nutrient is reaching a water body.

### 2.1.6 Water Temperature

Temperature readings were taken at two different depths for each lake; at the surface and near the lake floor. Water temperatures above 20˚C can be stressful for cold water species such as trout and salmonid species and these species must have a well-oxygenated, cooler hypolimnial layer in the summer to survive (MacMillan et al., 2005). Water stratification occurs when the water above the thermocline does not mix with the water below the thermocline. When the water column is stratified, the deeper layer (the hypolimnion) is isolated from the mixed surface layer and could show low level of oxygen due to respiration. Oxygen depletion, and in particular anoxia (less than 2% oxygen compared to surface water) create an environment that is not favourable for aquatic life. From 1999-2010, dataloggers were installed at two depths (above and below the thermocline) in some of the lakes to determine if stratification exists in those lakes (see past publications for lake stratification results at: http://www.county.kings.ns.ca/residents/lakemon/archives.asp). As of 2011 however, dataloggers were no longer installed at these lakes.

## 2.2 Establishing Water Quality Objectives

Thirteen lakes are monitored as part of the Kings County Lake Monitoring program. Each lake has unique properties and varying levels of shoreline development; thus, each lake is examined separately. The 2019 averages for each parameter were compared against the historical average from 1997 to 2018 (including data from 2004 which was omitted in previous years). Water quality guidelines have been developed for many parameters (i.e. total phosphorus, Secchi depth, and pH) by organizations such as Parks Canada, the British Columbia Ministry of Environment and the Canadian Council of Ministers of the Environment (CCME). These guidelines generally refer to clear water lakes, although Parks Canada has determined guidelines for coloured lakes in Kejimkujik National Park (Parks Canada, 2010). For some parameters within the monitoring program (TP, Secchi depth, pH, colour and dissolved organic carbon), the objectives are determined by deviations from historic values due to lack of specific guidelines for these parameters in coloured lakes.

### 2.2.1 Phosphorus

As per the recommendations of the Centre for Water Resources Studies and Stantec (2009), averages for the values of total phosphorus up to 2019 were calculated for each lake. Although the Kings County Lake Monitoring Program has not yet formally adopted this phosphorus objective, it was used here as an interim measure as no other relevant phosphorus guidelines could be found for dystrophic lakes. The most common provincial guideline for total phosphorus limit is 20 µg/L. In order to capture potential deviation to baseline levels, the total phosphorus water quality objective for each lake was calculated as 150% of the baseline (average) level, not exceeding 20 µg/L. The calculated thresholds for total phosphorus are presented in Table 2-1.

**TABLE 2-1 AVERAGE HISTORIC TOTAL PHOSPHORUS VALUES AND WATER QUALITY OBJECTIVES.**

| LAKE | TOTAL PHOSPHORUS AVERAGE (UP TO 2019) (µG/L) | TOTAL PHOSPHORUS OBJECTIVE (µG/L) |
|---|---|---|
| George | 9 | 13.5 |
| Loon | 12 | 18 |
| Aylesford | 10.3 | 15.4 |
| Gaspereau | 11.5 | 17.3 |
| Murphy | 11.5 | 17.3 |
| Little River | 13.9 | **20** |
| Black River | 10.8 | 16.1 |
| Lumsden | 12.5 | 18.7 |
| Hardwood | 12.3 | 18.4 |
| Sunken | 8.6 | 12.9 |
| Tupper | 10.8 | 16.1 |
| Torment | 16.2 | **20** |
| Armstrong | 15.9 | **20** |

** **BOLD** = 150% of background levels exceeding the maximum 20µg/L guideline value*

### 2.2.2 Chl.a

The guideline for chl.a is 2.5 µg/L (or mg/m$^3$) and was established by the Municipality of Kings in its Municipal Planning Strategy.

### 2.2.3 Secchi Depth, pH and Colour

Guidelines for Secchi depth, colour and pH were determined by analyzing all data from 1997 to 2016 for the 25th and 75th percentile values. These values were used as the lower and upper water quality guidelines. Kejimkujik National Park and National Historic Site used a similar procedure to determine water quality objectives for the brown water lakes within the park (Parks Canada, 2010).

### 2.2.4 Total Nitrogen

There is not a definitive water quality guideline for total nitrogen in surface water in Nova Scotia. Kejimkujik National Park is located in central southern Nova Scotia and contains a number of coloured lakes. Eighteen lakes have been monitored for many years and a guideline of 350 µg/L established for 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 similar to lakes in Kings County than surface water used to establish other guidelines.

### 2.2.5 Dissolved Organic Carbon

Dissolved organic carbon does not have a consistent water quality guideline for the protection of aquatic life. Lake-specific guidelines were used in this report and determined using historical averages and 20% of this average; the lower value was determined using the historical average minus 20% and the upper value by the historical average plus 20%. Ideally, the average is of five samples taken within one month (Government of British Columbia, 2001); however, due to the sample protocol for Kings County, this schedule is not possible. A DOC guideline for brown-water lakes in Kejimkujik National Park and

Historic Site was established as <19 mg/L (Parks Canada, 2010). This value was not used as a guideline in the lake-by-lake analysis as it is not as representative as the lake-determined objectives. Previously, the Parks Canada guideline (19 mg/L) was used in calculating the Water Quality Index score as a definitive cut-off was needed across all lakes, based on the recommendation of the Technical Advisory Committee (TAC), DOC has been removed from the calculation of the WQI from 2013 on to future years.

### 2.2.6 Turbidity

The guideline for turbidity was developed by Parks Canada (2010) for assessing brown-water and clear lakes in Kejimkujik National Park. Acceptable turbidity measurements must be <1.3 NTU.

Guidelines and their sources for parameters measured in the Kings County Lake Monitoring program are in each lake's report cards.

## 2.3 Water Quality Index

The Water Quality Index (WQI) is a tool that was developed by the CCME and can be used as a broad, albeit very basic, indicator of water quality. Data for a series of variables are compared to a guideline value or range using an excel application and a score from 0 to 100 is produced, 0 indicating very poor water quality, 100 indicating excellent water quality. The WQI score is based on three factors: the number of parameters that failed to meet guidelines, the frequency that a particular parameter failed to meet its guideline and the magnitude each value deviated from the parameter guideline (CCME, 2001).

The parameters used in this calculation were pH, TP, total nitrogen, chl.a, and turbidity. Prior to the 2014 report, calculations of WQI also included DOC, Secchi depth, and colour. In previous years' calculation, the inclusion of such variables yielded poor to marginal water quality rating. The WQI was developed as a general tool although humic lakes (ie lakes with high dissolved organic matter content) may not be accurately represented. In humic lakes, DOC concentrations are higher than in clear water lakes due to the high connectivity between water and the watershed. However, it is important to recognize that this DOC has little impact on the trophic state of lakes because it is not providing a nutrient source available for production. In fact, high DOC concentrations (or high colour) will limit algal growth via light limitation in the surface layer of the water column. Therefore, starting in 2014, variables related to humic content of the water were excluded from the WQI calculation to only keep variables related to trophic state. As a consequence, current calculations cannot be directly compared to those reported in years prior to 2014. Prior to the 2011 report, the guideline for total nitrogen was 900 µg/L. This guideline has been lowered to 350 µg/L which is the cut-off used by Parks Canada for brown-water lakes in Kejimkujik National Park (2010). The results of the water quality index are shown in each report card with a corresponding colour associated with a water quality rating.

### 2.4 Quality Assurance / Quality Control

Various duplicate and blank samples have been collected since 2011 for quality assurance and quality control purposes. When analyzing the data received each year, a review of observations exceeding the normal range of variation for each variable is conducted. When an unusual value is found, a review of the original data entry and questions to the laboratory are asked before deciding to keep or exclude the value from the analysis.

# 3 Results

The following section present for each lake, a report card summarizing the 2019 data as well as an interpretation and recommendation for lakes showing a poor rating in water quality.

The Water Quality index (WQI) developed by the CCME was calculated using the following variables: chl.a, Total Phosphorus, Total Nitrogen, pH and turbidity. As indicated earlier, other variables were considered in the past but were removed from the calculations because of the limitations of the WQI in coloured waters. For example, the WQI is designed to use colour or DOC as a parameter defining water quality. Although high DOC values may be observed for high trophic status lakes, it is generally not DOC associated with a humic content. Therefore, variables such as colour and DOC, which are naturally high in humic, coloured lakes were not considered in the WQI, but are still presented in the lake summary table, and compared to guidelines values.

The following section provides includes an interpretation of the data collected for each lake sampled as part of this study including and illustrated with a summary table of all water quality parameters, histograms of the trends in WQI between 2013 to 2019, histograms of the concentration in chl.a, TP and estimates of colour.

## 3.1 Land use associated with each lake

Since 2018, data on land use was added to the report to provide a better understanding of the number of residences and activities (dams, agriculture, aquaculture) occurring within the boundaries of the lakes. The number of civic points correspond to the number of lots around the lake, and most have a property built on them (Residential Civic point). The residences are shown in individual maps for each lake below. The number of industrial properties is very low in the area, with Transportation, Transmissions and Storage (TR Civic Pt) being the most common. These sites are dams. The Table 3.1 below provides the detailed land use metrics for each lake.

**TABLE 3-1 NUMBER OF RESIDENCES AND MAIN INDUSTRIAL ACTIVITIES THE KINGS COUNTY SAMPLED LAKES.**

| Name | Civic Points | Rs Civic Pt | TR Civic Pt** | AG Civic Pt | MA Civic Pt** |
|---|---|---|---|---|---|
| Armstrong Lake | 65 | 65 | 0 | 0 | 0 |
| Aylesford Lake | 240 | 223 | 3 | 0 | 2 |
| Black River Lake | 76 | 65 | 3 | 1* | 4 |
| Gaspereau Lake | 59 | 53 | 3 | 0 | 0 |
| Hardwood Lake | 3 | 3 | 0 | 0 | 0 |
| Lake George | 145 | 141 | 0 | 0 | 0 |
| Lake Torment | 285 | 278 | 1 | 0 | 0 |
| Little River Lake | 22 | 21 | 0 | 0 | 1 |
| Loon Lake | 48 | 46 | 1 | 0 | 0 |
| Lumsden Pond | 50 | 46 | 3 | 0 | 0 |
| Murphy Lake | 108 | 106 | 1 | 0 | 0 |
| Sunken Lake | 86 | 84 | 0 | 0 | 0 |
| Tupper Lake | 57 | 54 | 1 | 0 | 0 |

* This would be the fish hatchery

** These are the dams

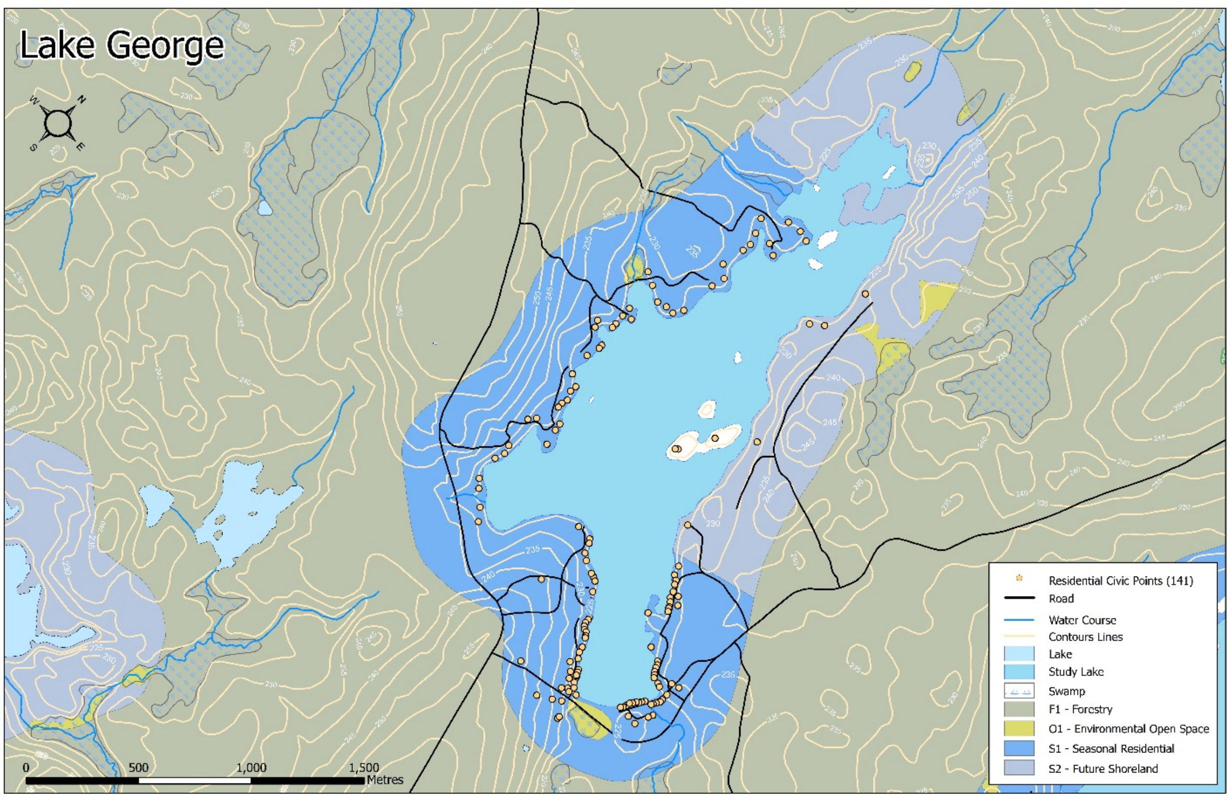
| Term | Description |
|---|---|
| AG | Agriculture |
| MA | Manufacturing |
| RS | Residential |
| TR | Transportation, Transmissions and Storage |

Statistical analyses (correlations and multiple regressions) were conducted using on one hand the number of residences and development, the proportion of the land occupied by these development and activities and, on the other hand all variables used to calculate the WQI values. The hypothesis was that a higher number of properties (and activities) may explain the differences in nutrients and chl.a concentration between lakes. These calculations were done using the 2019 data as well as with the last 5 years averages.

Similar to 2018, the results from these analyses are showing that none of the land use metrics had a significant influence on nutrient and chl.a concentrations. Furthermore, no significant relationship was found between land use data and WQI values. As noted for each lake, the concentrations in nutrient have been stable for many years (in particular for TP).

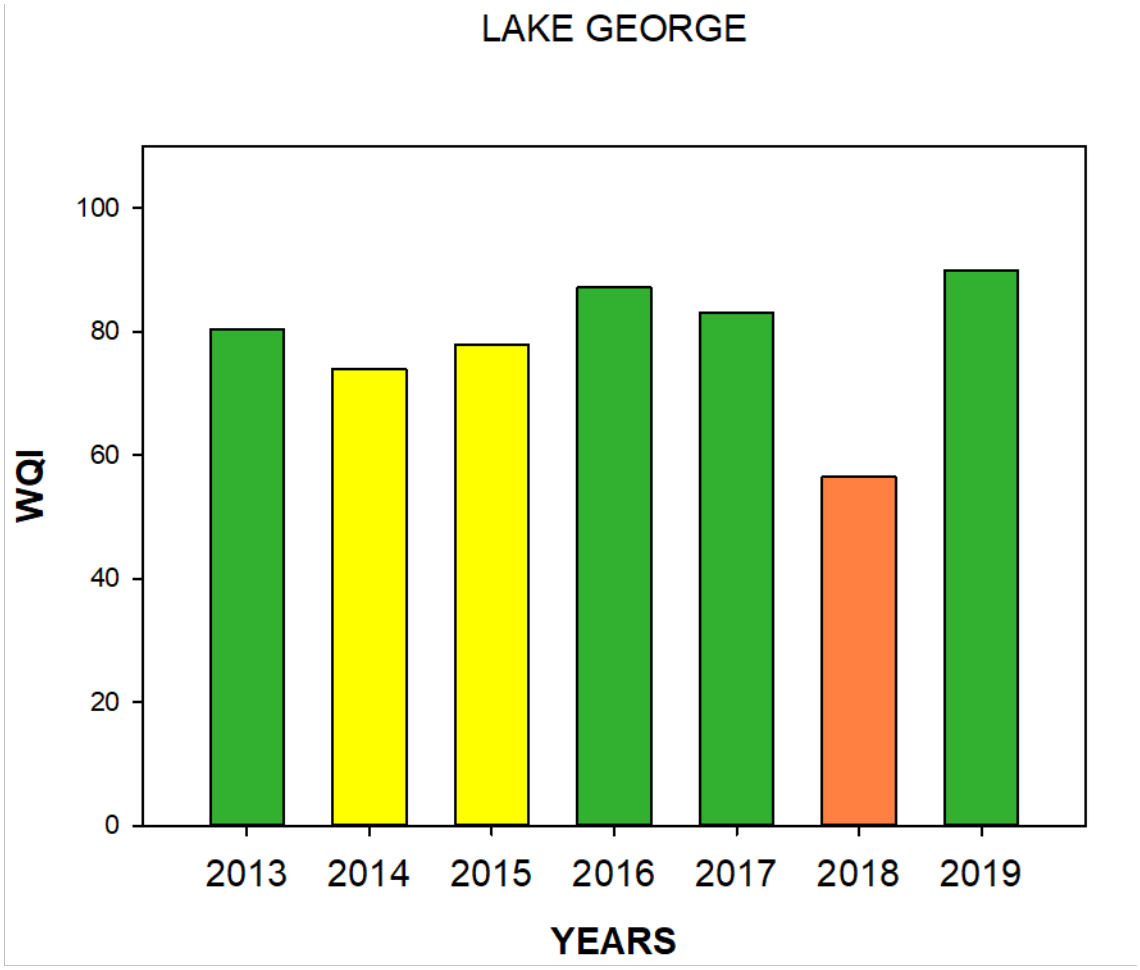
## 3.2 Lake George

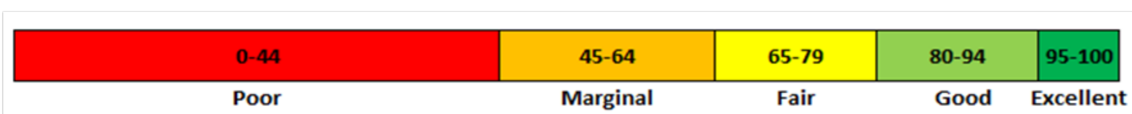
Among the Kings County lakes, Lake George is the first lake in term of drainage. It is a fairly small lake (Lake surface area about 153 ha) and fairly shallow, with a maximum depth of 9 meters. Around the lake, there are 2 main zone types, with most of the properties located in the seasonal residential zone. The zones are equally distributed around the lake. This lake has been sampled as early as 1993, which is one of the longest time series for the Kings County lakes monitoring program.




**Water Quality Index (WQI):**

The water quality value for Lake George was 89.9, corresponding to a good water quality rating. This value is similar to that observed in 2016 and 2017.



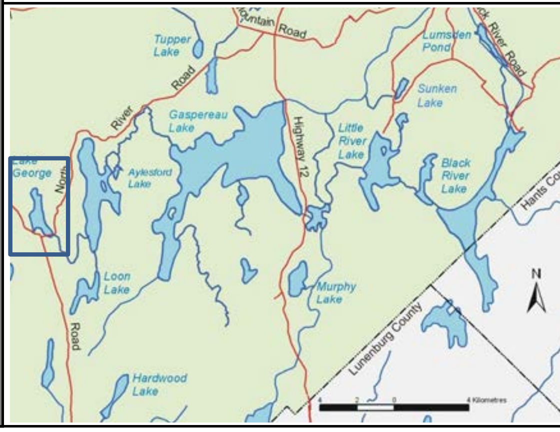




**Summary report card:**

In 2019, Lake George showed only 4 exceedances (4/42), with all of them for chl.a concentration. The maximum chl.a concentration was 3.1µg/L which was slightly higher compared to guideline at 2.5µg/L. No other parameters used in WQI were above guideline values.

# LAKE GEORGE

**89.9**




Drainage Order = 1

Elevation = 231 m

Lake Area = 153 ha

Max Depth = 9.5 m

**1997-2019 Trends:**

**WQI change (1Y and 5Y):** +59 and +18%

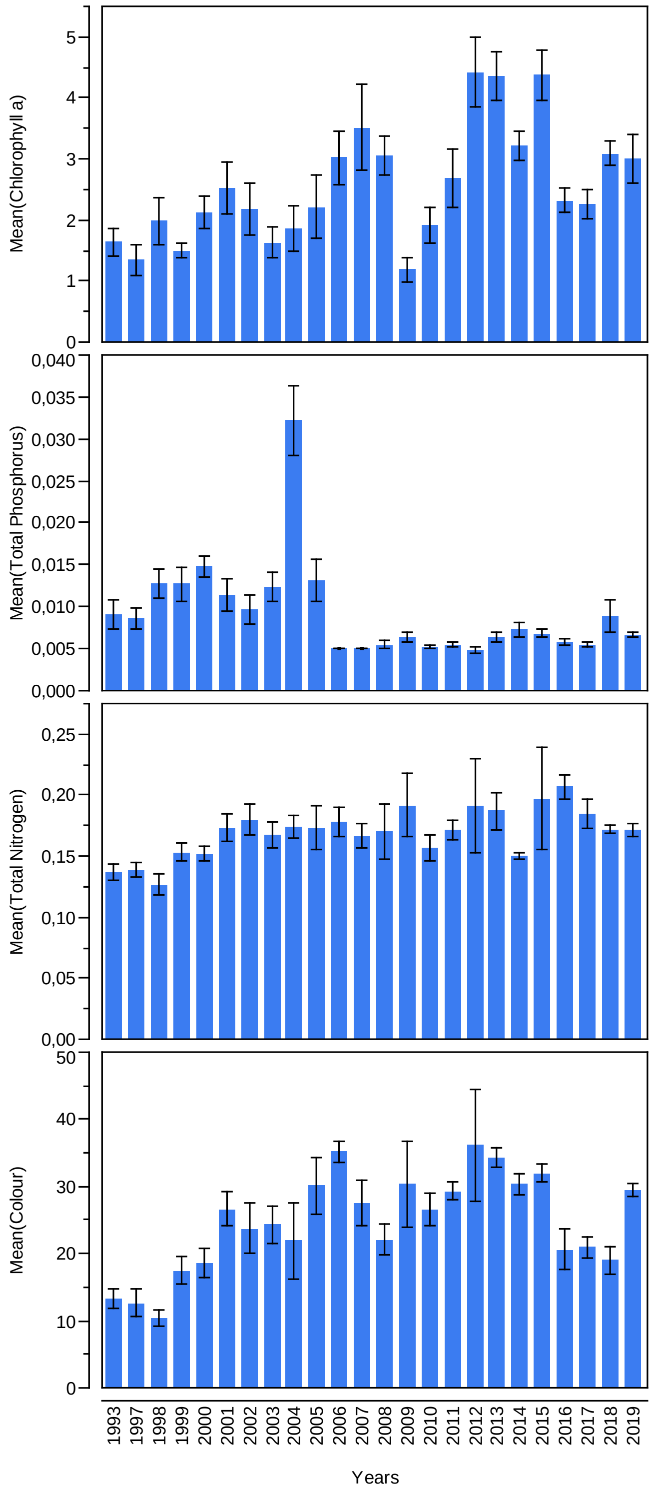
| | Parameter | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | TP (µg/L) | Chl A (mg/m$^3$) | DOC (mg/L) | pH | Secchi Depth (m) | Colour (TCU) | TN (µg/L) | Turbidity (NTU) |
| **Guideline** | 13.5 | 2,5 | 3.6-5.3 | 6.3-6.7 | 2.9-4.1 | 17-31 | 350 | 1,3 |
| **2019 average** | 6,7 | 2,2 | 4,2 | 6,6 | 3 | 20,9 | 185 | 0,8 |
| **2019 (min - max)** | (6 - 10) | (1.4-3.1) | (4-4.4) | (6.6-6.7) | (2.4-3.5) | (17-25.7) | (150-230) | (0.5-1.3) |
| **1997-2018 average** | 9.1 | 2.5 | 4.4 | 6.5 | 3,56 | 24.3 | 168 | 0.7 |

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

## Long-term trends:

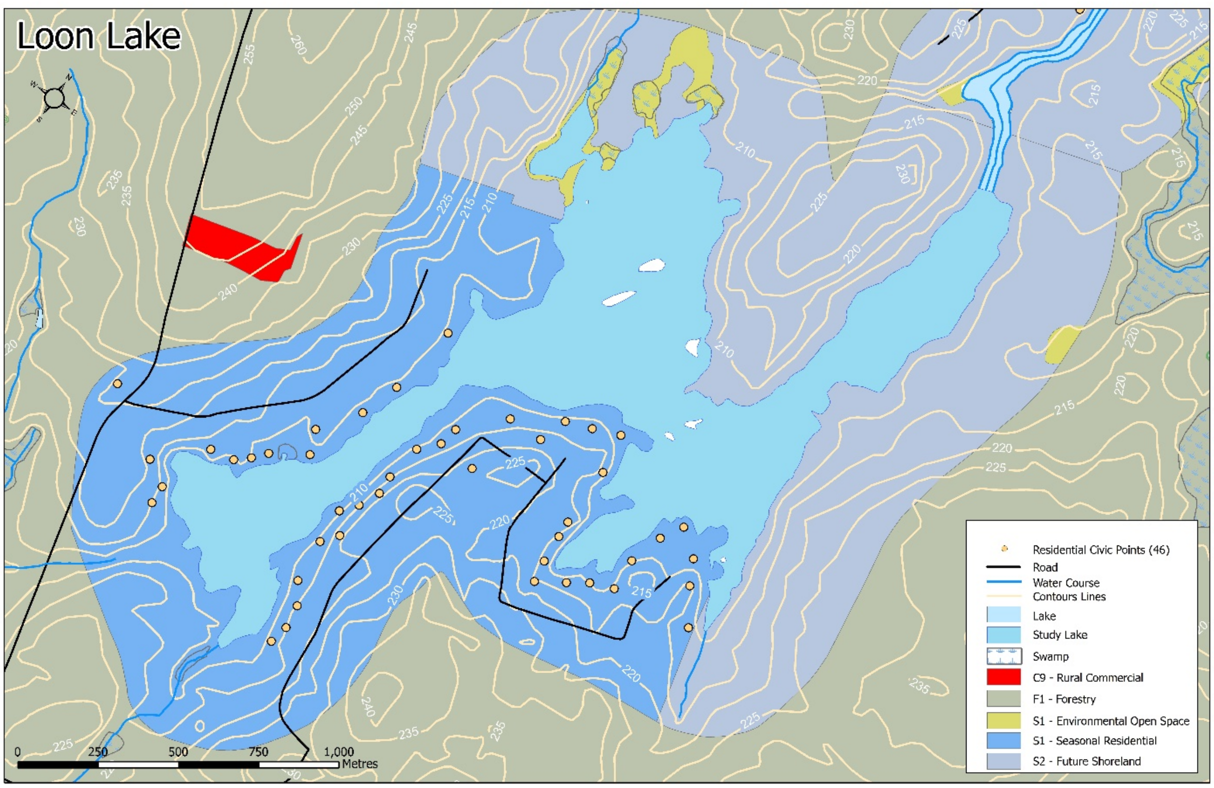
In 2019, mean chl.a concentration was similar to that observed in 2018. The mean concentration in both TP and TN have been stable for the last 10 years.

**Lake George: Histograms of the long-term values in chl.a, TP, total nitrogen concentrations and colour**



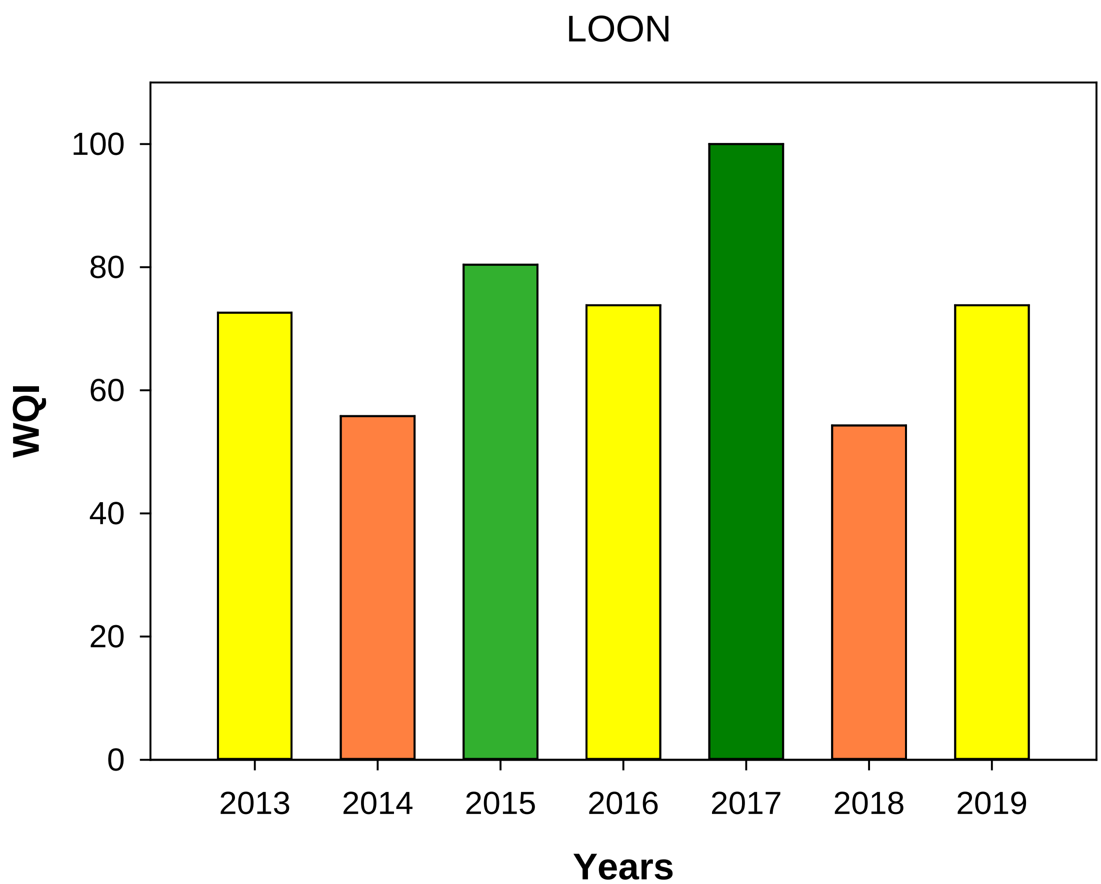
## 3.3 Loon Lake

Loon Lake is a small (90 ha), shallow (max depth 8.1m) Lake which is connected to the much larger Lake Aylesford. With Lake George, Loon Lake are the most upstream lakes of chain of lakes sampled in this study. Based on satellite imagery, the watershed of Loon Lake is mostly forested, although clear cutting activities may have occurred in the past. There is a mature riparian zone around the lake There are less than 50 residences on Lake loon, all located in the southern section of the lake.



**Water Quality Index (WQI):**

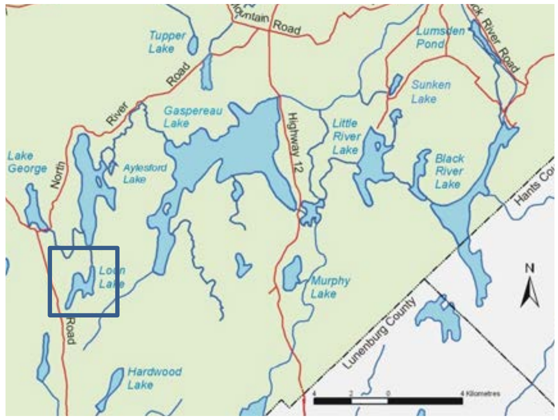
The Water Quality Index value for Lake Loon increased from 53 to 74 in 2019. The water quality rating was Fair in 2019. The rating for this lake fluctuates considerably from year to year. This year fair rating was due to exceedances in chl.a values.




**Summary report card:**

In 2019, Lake Loon showed 5 exceedances (5/35); 2 for chl.a, 2 for turbidity and one for pH. Other variables not entered in WQI calculations showed exceedances as well: colour values were all above guidelines as well as some values for DOC and secchi depth.

# LOON LAKE




**73.8**

Drainage Order = 1

Elevation = ~206 m

Lake Area = ~90 ha

Max Depth = 8.1 m

**1997-2019 Trends:**

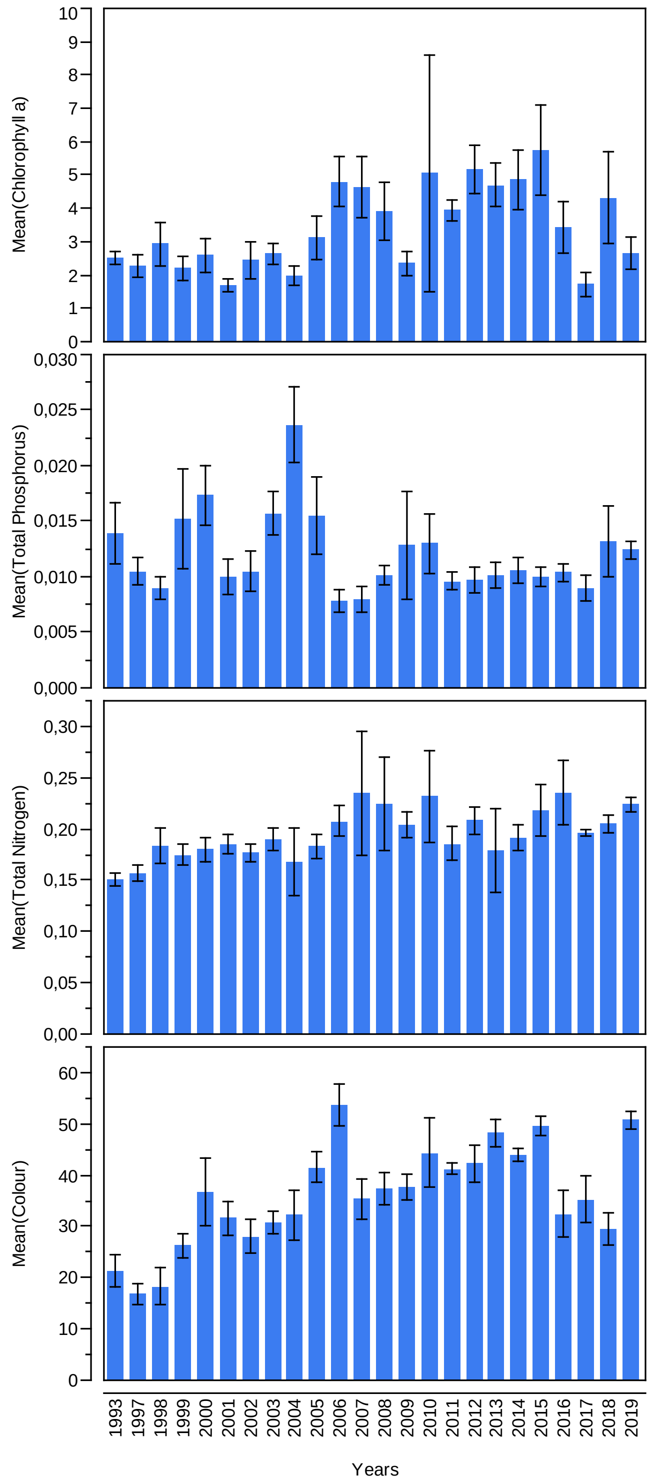
**WQI change (1Y and 5Y):** +36 and +1%

| | Parameter | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | TP (µg/L) | Chl A (mg/m$^3$) | DOC (mg/L) | pH | Secchi Depth (m) | Colour (TCU) | TN (µg/L) | Turbidity (NTU) |
| **Guideline** | 18.1 | 2,5 | 4.4-6.6 | 6-6.4 | 2.1-2.8 | 26-44 | 350 | 1,3 |
| **2019 average** | 12.4 | **2.6** | **7.0** | 6.3 | 2,7 | **50.7** | 224 | 1.3 |
| **2019 (min - max)** | (11-15) | (1.6-**4.0**) | (6.4-**8.2**) | (6.1-6.4) | (2.5-**2.9**) | (**46.7-55.4**) | (210-250) | (0.7-**2.2**) |
| **1997-2018 average** | 12.0 | **3.4** | 5.5 | 6.2 | 2,50 | 35.1 | 193 | 1.1 |

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

## Long-term trends:

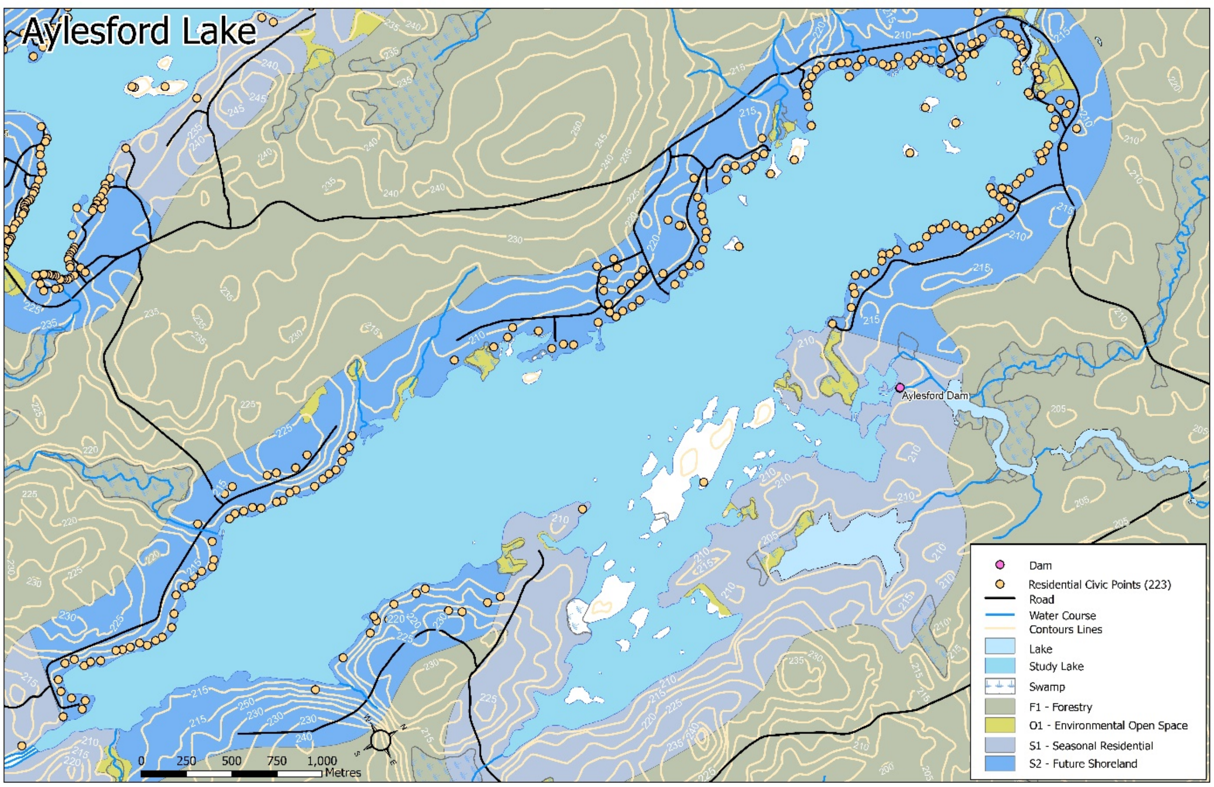
The mean concentration in both TP and TN have been stable for the last 10 years in Loon Lake. The value for colour has significantly increased (50.7 TCU) compared to the past 3 years.




**Lake George: Histograms of the long-term values in chl.a, TP, total nitrogen concentrations and colour**

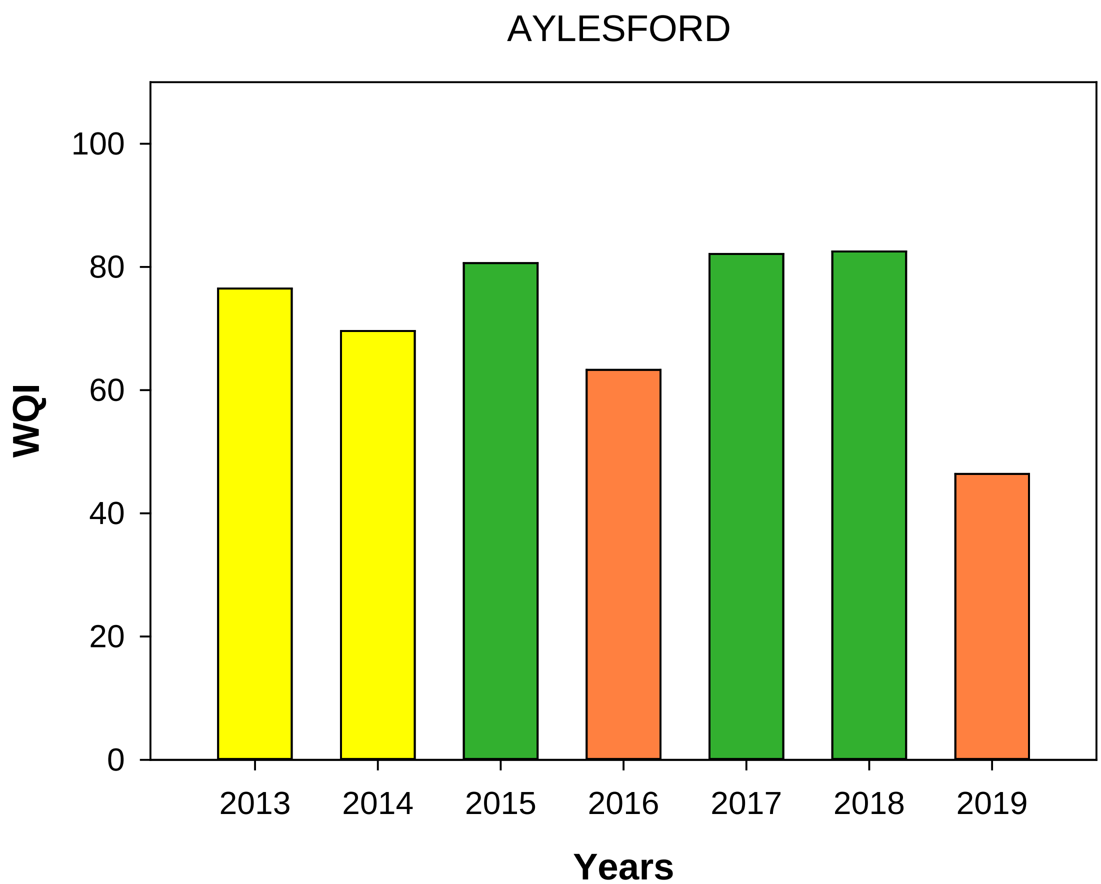
## 3.4 Aylesford Lake

Aylesford Lake is the third largest lake in this study with a surface area of 532 ha. It is a fairly shallow lake (given its size) with maximum depth of 12m. The lake is part of chain of several lakes, and is positioned as second order in drainage. The water of Aylesford Lake flows into the largest lake, Gaspereau. As for the other lakes in the area, Lake Aylesford is surrounded by forested areas. The majority of the lakes nearshore is developed with a dense number of residences.



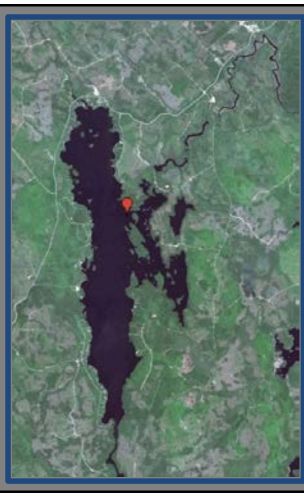
**Water Quality Index (WQI):**

The Water Quality Index for Lakes Aylesford was 46.4 (marginal rating) in 2019. This value is significantly lower compared to the last 2 years (about 44% lower). The WQI value observed in 2019 is the lowest observed in the last 7 years.

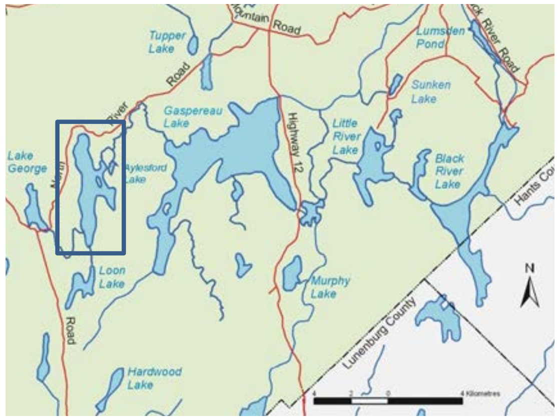



**Summary report card:**

Exceedances were observed in several parameters in 2019: overall, 13/42 exceedances were observed, mostly for chl.a and total phosphorous concentrations. In addition, high turbidity values were recorded. These high values likely correspond to the high number of particles as algal matter.



## AYLESFORD LAKE




**46.4**

Drainage Order = 2

Elevation = 216 m

Lake Area = 532 ha

Max Depth = 12 m

**1997-2019 Trends:**

**WQI change (1Y and 5Y):**
-44 and -39%

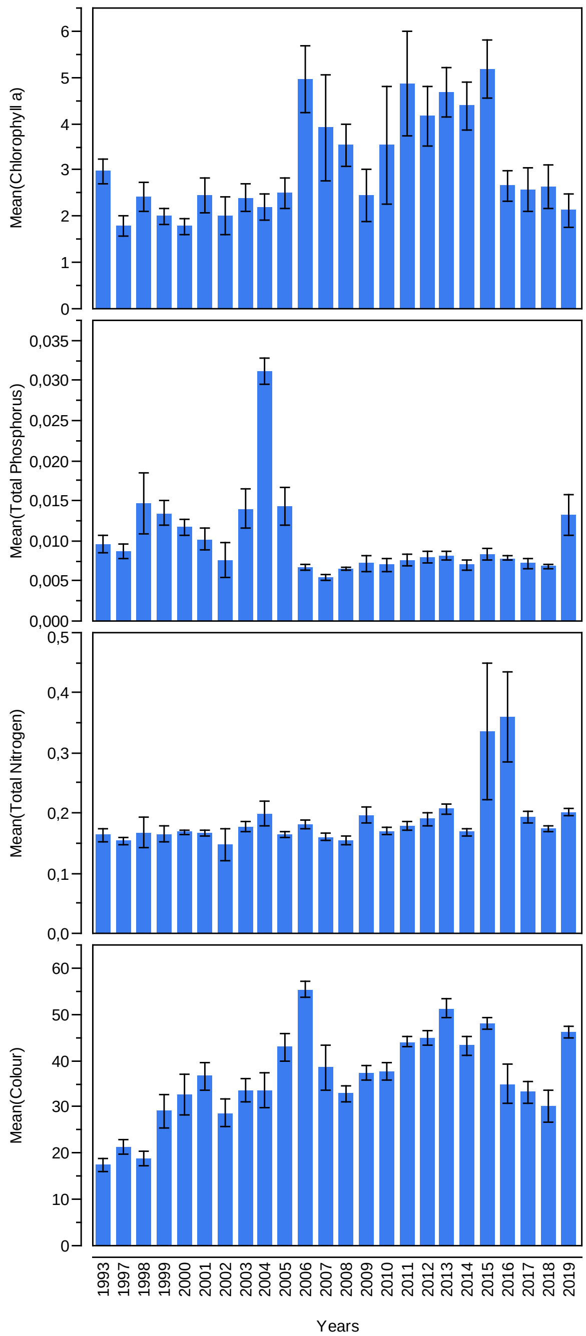
| | Parameter | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **TP (µg/L)** | **Chl A (mg/m$^3$)** | **DOC (mg/L)** | **pH** | **Secchi Depth (m)** | **Colour (TCU)** | **TN (µg/L)** | **Turbidity (NTU)** |
| **Guideline** | 15.4 | 2,5 | 4.4-6.6 | 6-6.3 | 2.2-3.2 | 24-45 | 350 | 1,3 |
| **2019 average** | 13.1 | 2,10 | 6.5 | 6,10 | 2,50 | **46.2** | 201 | **2.3** |
| **2019 (min - max)** | (8-**22**) | (1-**3.5**) | (6.2-**7**) | (5.9 - 6.2) | (**1.7-3.9**) | (41-**49**) | (180-220) | (0.6-**8.1**) |
| **1997-2018 average** | 10.2 | **2.9** | 5.5 | 6.2 | 2,70 | 33.8 | 185 | 0.7 |

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

### Long-term trends:

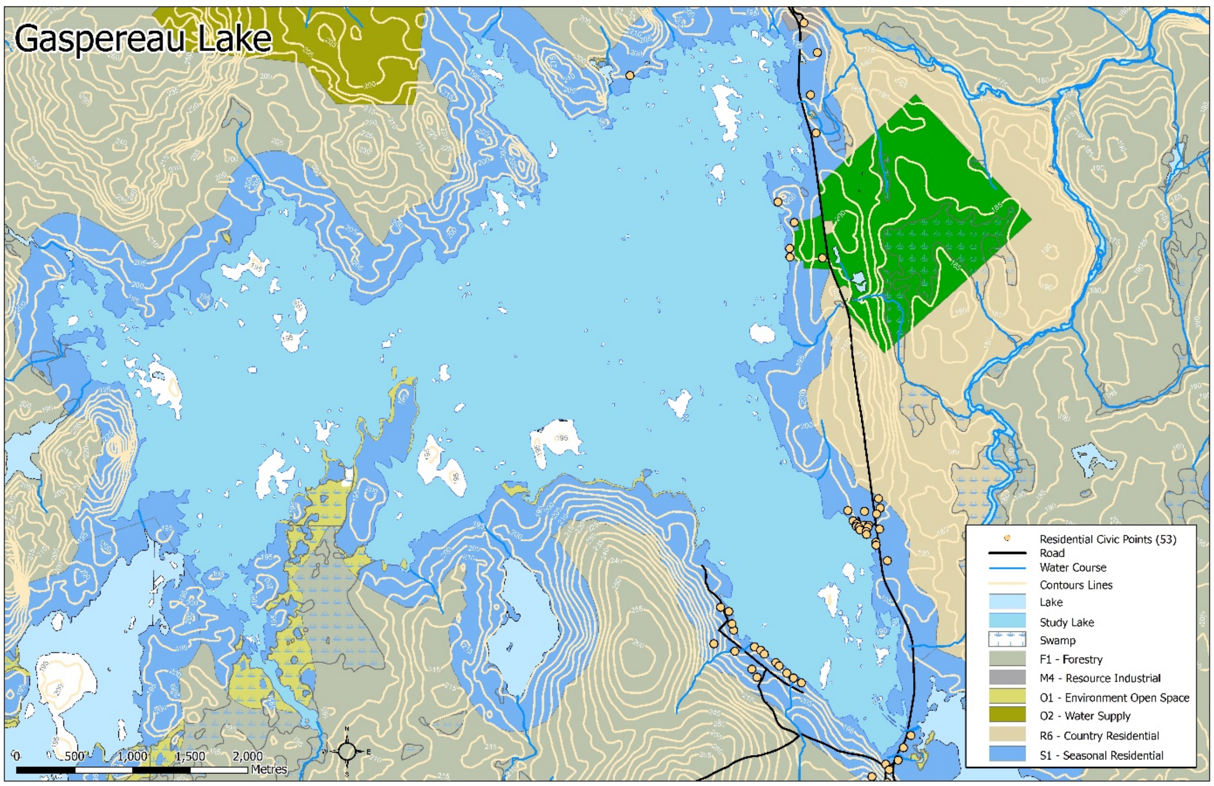
In the 2019, total phosporous and colour values increased compared to the last 3 years. No long-term trends were observed. The meand contentrations in chl.a and in total nitrogen were similar the last 4 years and 3 years respectively. The increase in colour may be related to the lower precipitation in 2019, associated with lower run-off and less dilution.

**Aylesford Lake: Histograms of the long-term values in chl.a, TP, total nitrogen concentrations and colour**



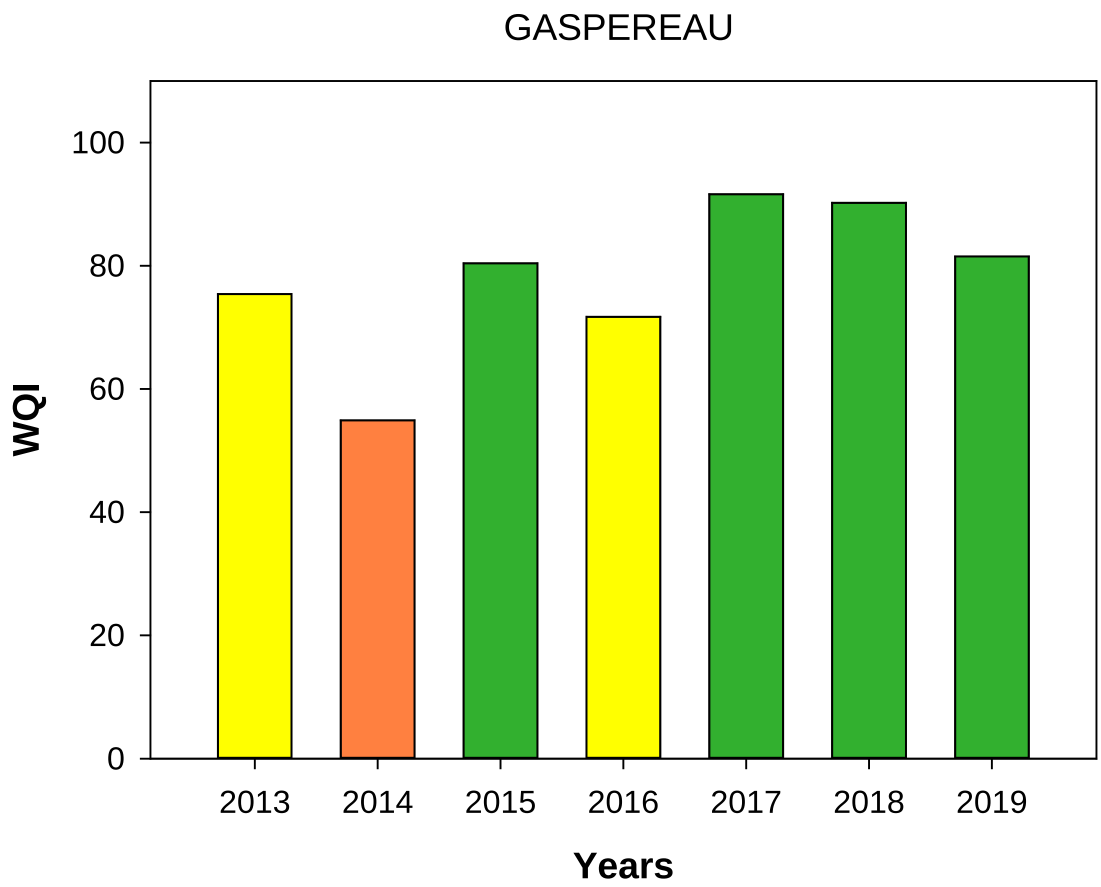
## 3.5 Gaspereau Lake

Gaspereau Lake is the largest lake in this study, with a surface area of 2,200 ha. For its size, it is fairly shallow, with a maximum depth of 10.9 m. Gaspereau Lake receives some of its water from Lake Aylesford (upstream), which shares similar water quality. Gaspereau Lake has a complex morphology and has a watershed mostly forested. Based on satellite imagery, this lake has little residential development in its watershed.




**Water Quality Index (WQI):**

In 2019, the WQI in Gaspereau Lake was 81.5, a good rating. This value is similar to that measured in past 3 years and explained with similar water quality parameters.

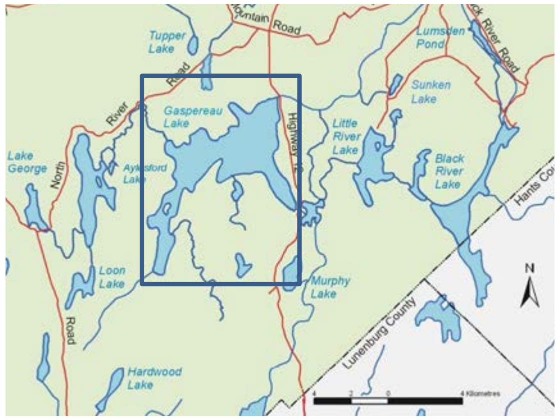



**Summary report card:**

Overall, minor exceedances were observed in 2019 for Lake Gaspereau. The concentration in chl.a exceeded guideline frequently (4/6) and but the mean chl.a concentration remained below guideline (1.6 µg/L). Concentrations in chl.a were not related to nutrient concentration (TP and TN) which have remained fairly constant over the last 10 years.

# GASPEREAU LAKE

**81.5**




Drainage Order = 3

Elevation = 175 m

Lake Area = 2200 ha

Max Depth = 10.9 m

**1997-2019 Trends:**

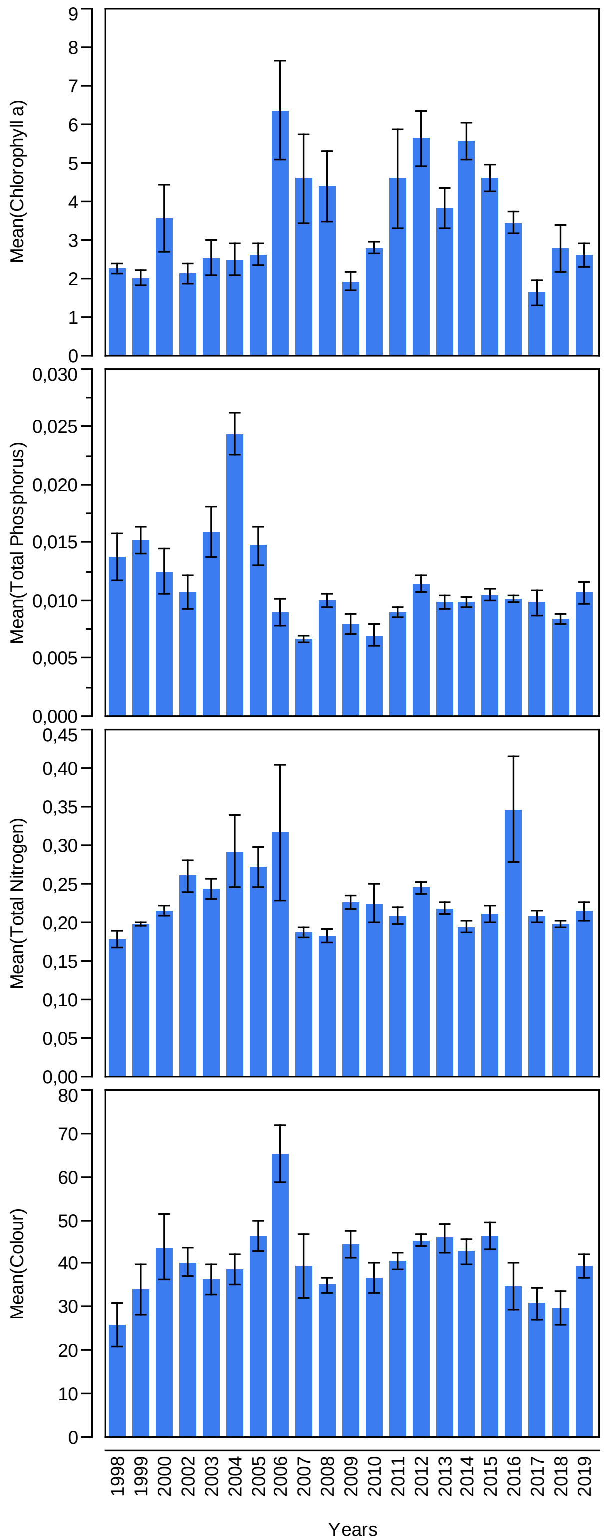
**WQI change (1Y and 5Y):** -10 and 5%

| | **Parameter** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **TP (µg/L)** | **Chl A ($mg/m^3$)** | **DOC (mg/L)** | **pH** | **Secchi Depth (m)** | **Colour (TCU)** | **TN (µg/L)** | **Turbidity (NTU)** |
| **Guideline** | 17,3 | 2,5 | 4.5-6.8 | 6.1-6.4 | 1.7-2.2 | 36-46 | 350 | 1,3 |
| **2019 average** | 10,00 | 1,60 | 4,90 | 6,30 | **2,60** | 30,80 | 208 | 0,83 |
| **2019 (min - max)** | (10 - 10) | (0.9-**2.8**) | (4.4-5.2) | (6.2 - 6.4) | (2.2-**2.9**) | (**24.5**-43.4) | (180-220) | (0.75-1.0) |
| **1997-2018 average** | 11.6 | **3.49** | 5.6 | 6.2 | 1,96 | 39.9 | 232 | 1.0 |

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

## Long-term trends:

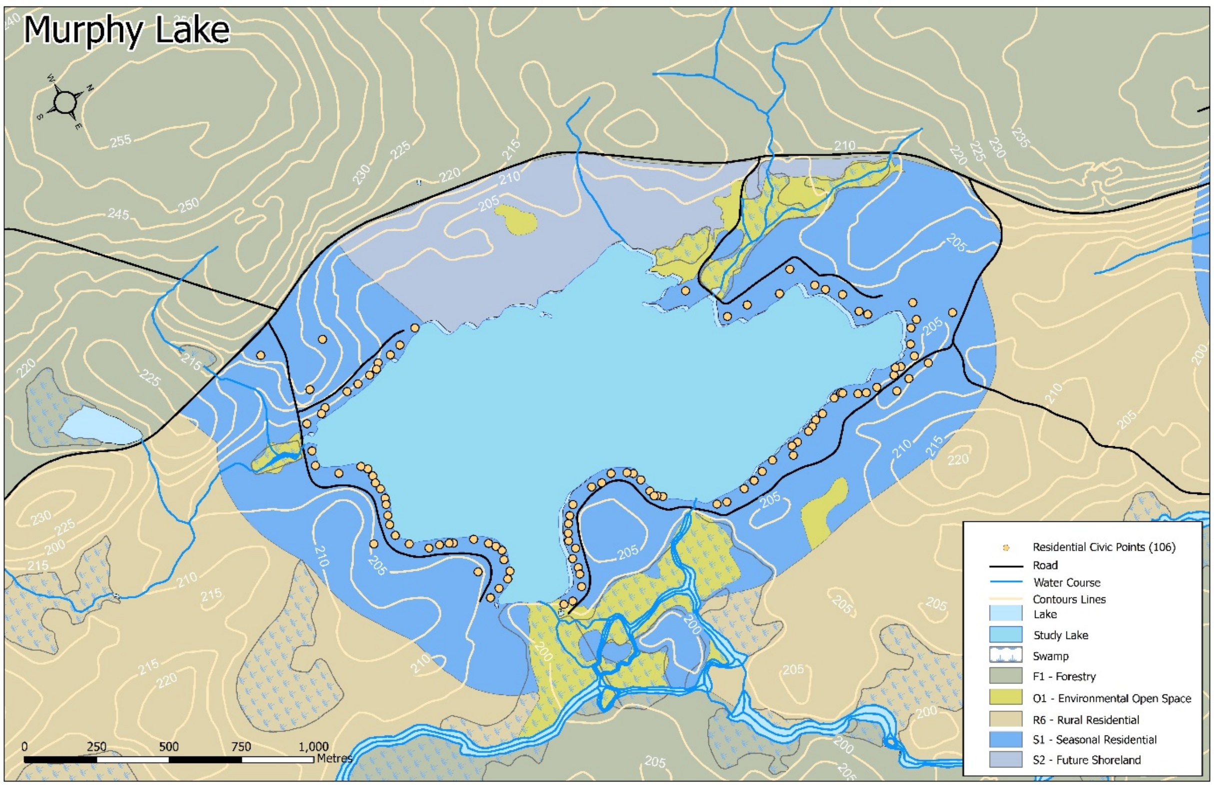
Long-term trends for Lake Gaspereau show that chl.a concentration has increased in the last 2 years compared to 2017 but remains lower compared to past 10 years. Nutrients levels (TP and TN) have remained constant over the last decade. The mean value for colour has increased from 30 NTU (last 3 years) to about 40 NTU in 2019. This increase in colour is consistent with that observed in several lakes in 2019.




**Gaspereau Lake: Histograms of the long-term values in chl.a, TP, total nitrogen concentrations and colour**

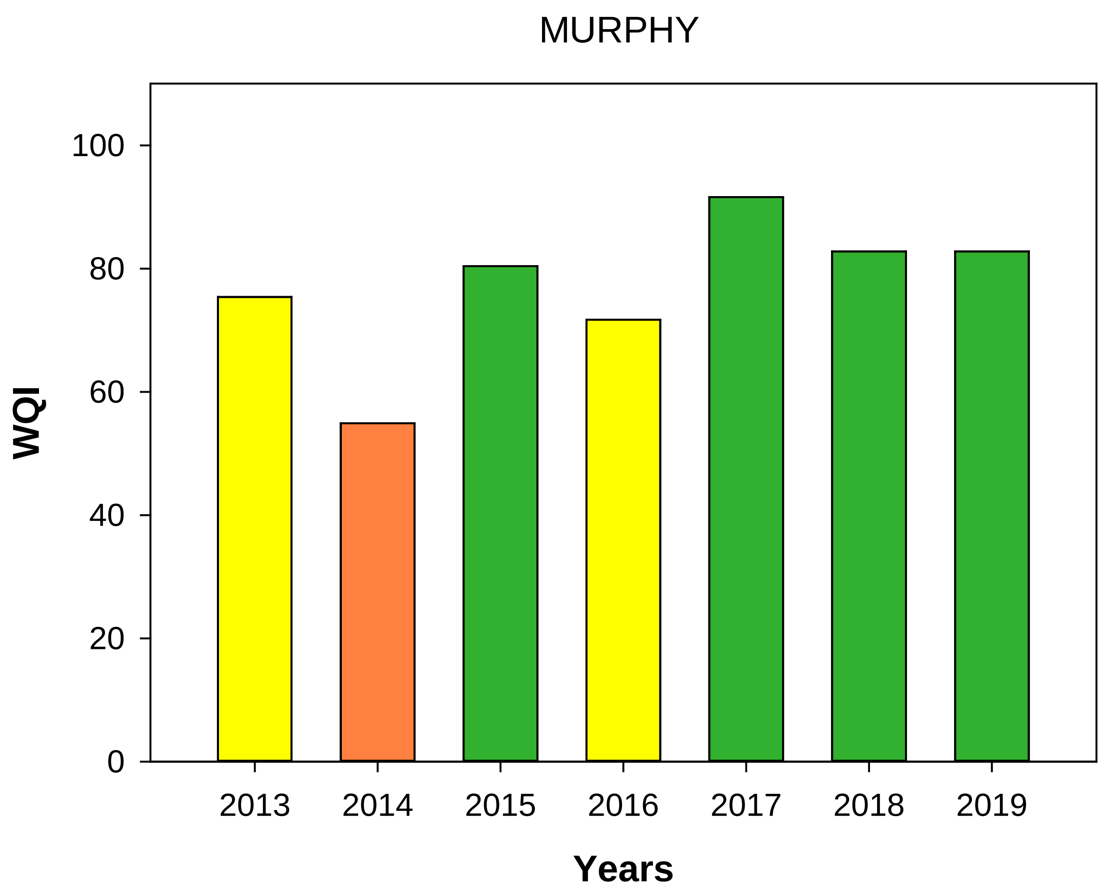
## 3.6 Murphy Lake

Murphy Lake is a fairly small (121 ha), and shallow (max depth: 6.8 m) lake. Its watershed is surrounded by a forested area on the western side. Residential development occupies most of the contour of the lake.




**Water Quality Index (WQI):**

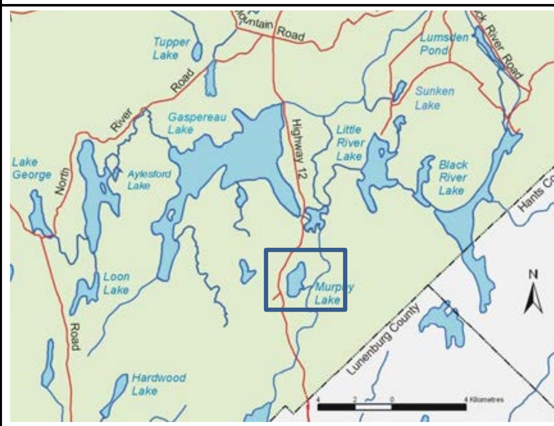
The Water Quality Index of Murphy Lake was 82.8 in 2019, which is rated as a good water quality. This rating is similar to that recorded in 2017 and 2018 and is among the highest values observed in the last 6 years. This good rating is explained by an overall low frequency of values above guidelines.




**Summary report card:**

The results observed in 2019 are similar to those reported in 2017 and 2018. Exceedances were observed only 3 times over the sampling season: twice with chl.a and once with total nitrogen (TN). The lake has low phosphorous concentrations, close to 10 µg/L. Both TP and TN concentrations remains low and without significant positive (or negative) trends for the last decade.

# MURPHY LAKE




**82.8**

Drainage Order = 3

Elevation = 207 m

Lake Area = 121 ha

Max Depth = 6.8 m

**1997-2019 Trends:**

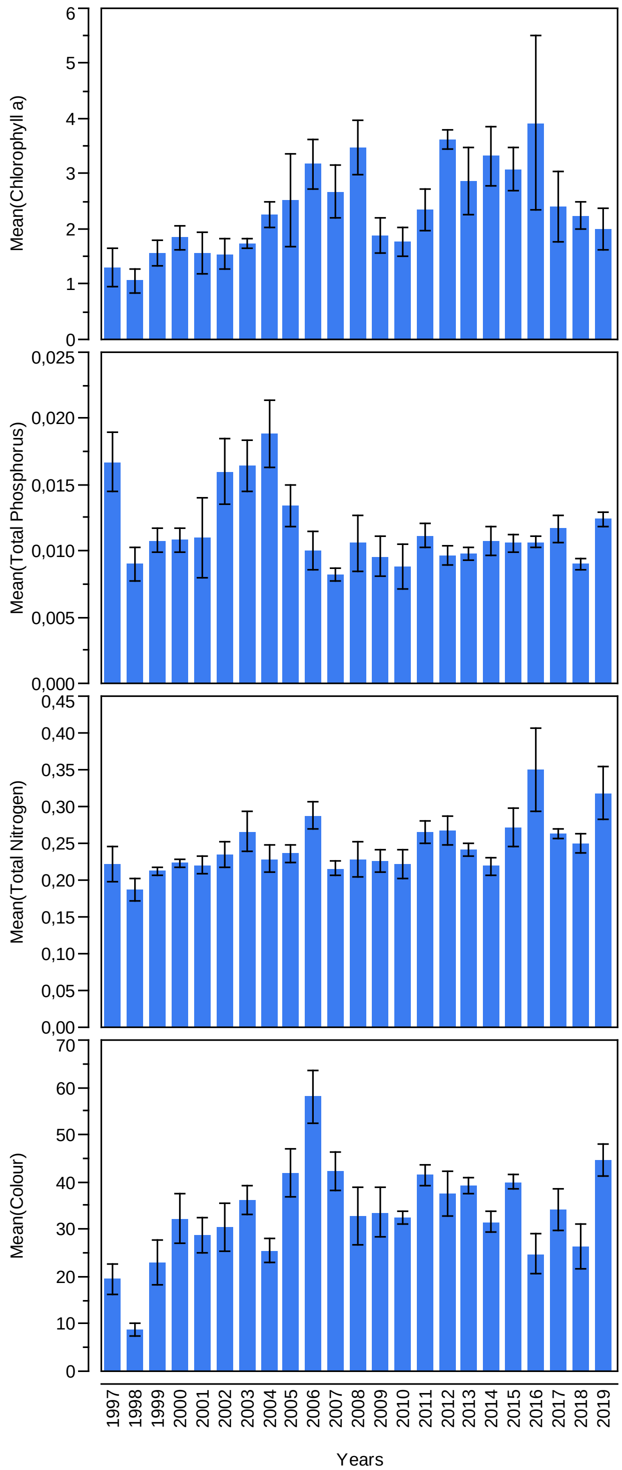
**WQI change (1Y and 5Y):**
0 and 14%

| | **Parameter** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **TP (µg/L)** | **Chl A (mg/m³)** | **DOC (mg/L)** | **pH** | **Secchi Depth (m)** | **Colour (TCU)** | **TN (µg/L)** | **Turbidity (NTU)** |
| **Guideline** | 17.3 | 2.5 | 5.0-7.5 | 6.5-6.9 | 1.7-2.3 | 25-42 | 350 | 1,3 |
| **2019 average** | 12.4 | 2.0 | **7.8** | 6.8 | 1,70 | **44.5** | 318 | 1,00 |
| **2019 (min - max)** | (11-14) | (0.8-2.9) | (7-**8.4**) | (6.7-**7**) | (1.2-2.1) | (37.7-**55**) | (270-**460**) | (0.8-1.1) |
| **1997-2018 average** | 11.5 | 2.4 | 6.2 | 6.7 | 2,00 | 33.3 | 244 | **1.3** |

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

## Long-term trends:

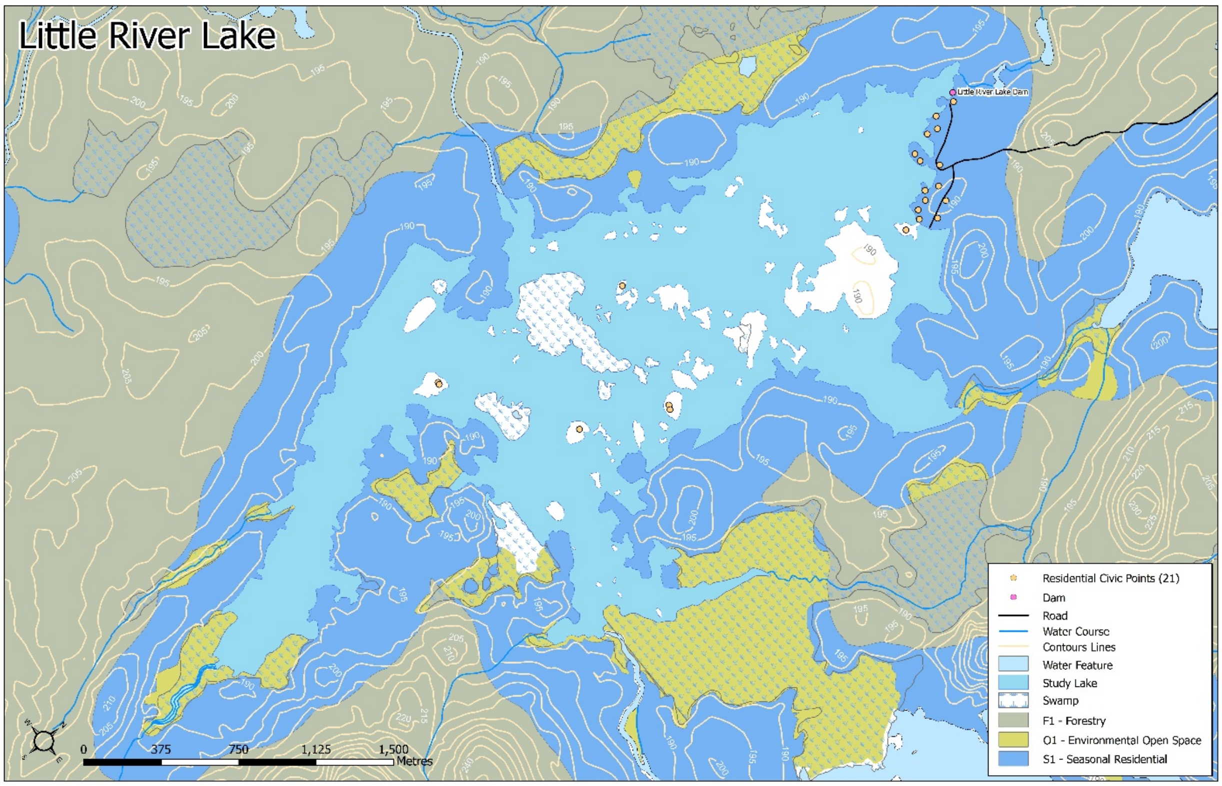
The long-term trends in chl. a concentration shows a continued decrease since 2016. This decline in chl.a is about 50% compared to 2016. No significant long-term trend was observed for nutrients (TP and TN), as well as for colour.




**Murphy Lake: Histograms of the long-term values in chl.a, TP, total nitrogen concentrations and colour**

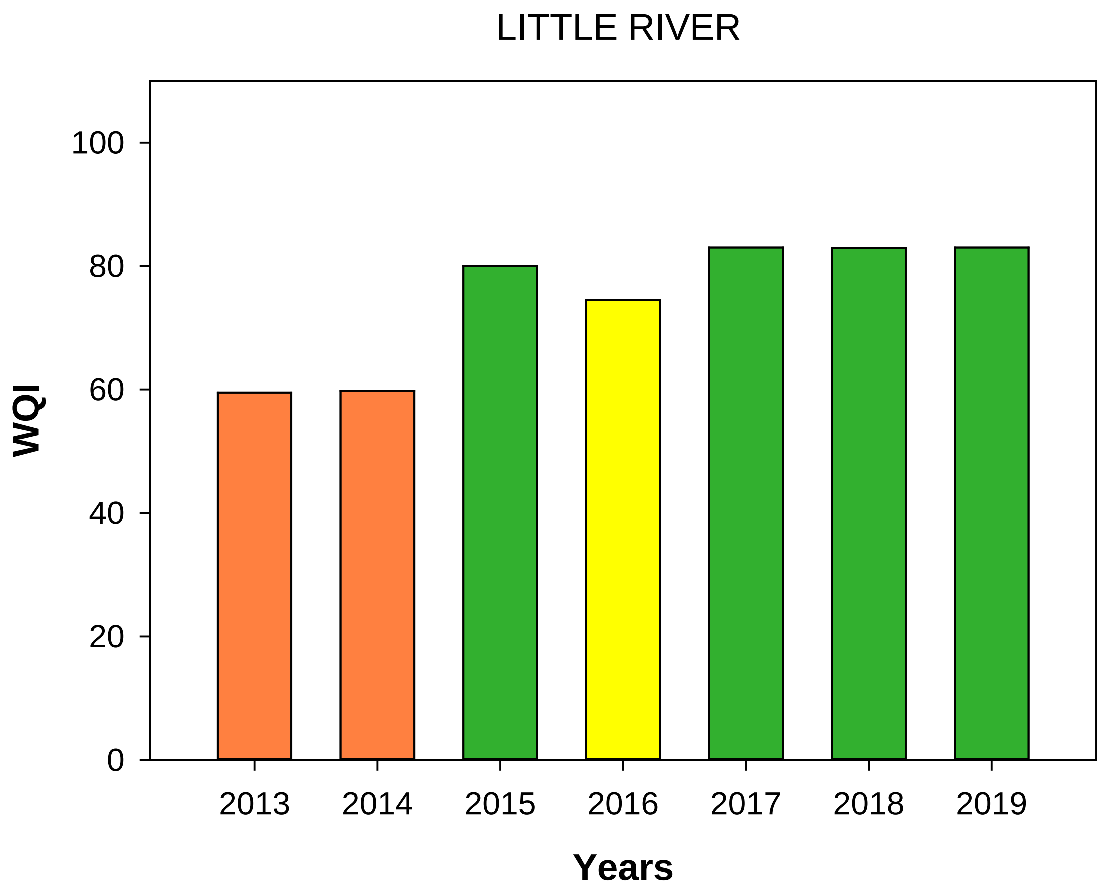
## 3.7 Little River Lake

Little River Lake is a medium size lake (surface: 520 ha) and has a maximum depth of 6.6m. Little River Lake is located between 2 much larger lakes: Lake Gaspereau upstream and Black River Lake downstream. It has almost no residential development.




**Water Quality Index (WQI):**

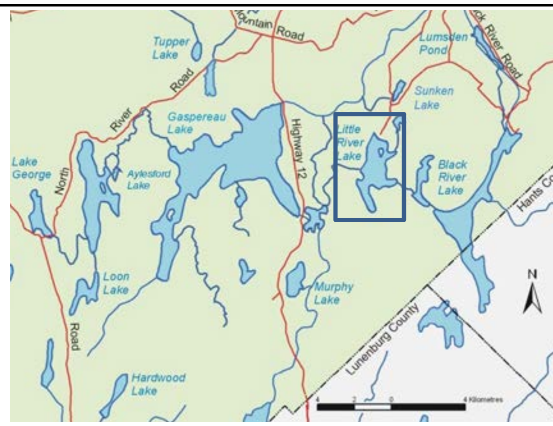
In 2019, the Water Quality Index for Little River Lake was 83, indicative of a good water quality. This value is comparable to that recorded over the last years. Similar to Murphy Lake, exceedances were observed only for chl.a that reached a value of 2.7 µg/L (guideline: 2.5 µg/L), once in the summer. None of the seasonal mean values for all parameters exceeded the guidelines for this lake.




**Summary report card:**

The 2019 results for Little River Lake are comparable to those in Murphy Lake. There were only 2 values above exceedances (2/28) and all mean values were below guidelines in 2019.

# LITTLE RIVER LAKE




**83**

Drainage Order = 4

Elevation = 189 m

Lake Area = 520 ha

Max Depth = 6.6 m

**1997-2019 Trends:**

**WQI change (1Y and 5Y):**
-8 and +11%

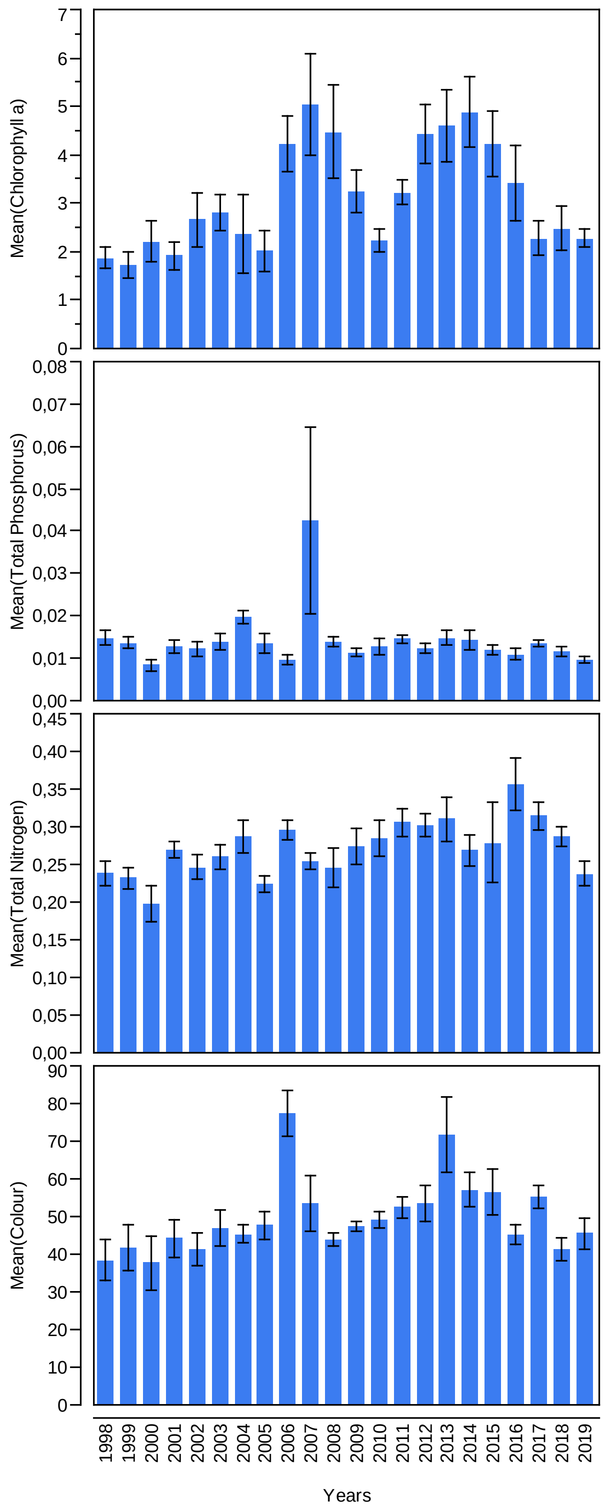
| | Parameter | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **TP (µg/L)** | **Chl A (mg/m³)** | **DOC (mg/L)** | **pH** | **Secchi Depth (m)** | **Colour (TCU)** | **TN (µg/L)** | **Turbidity (NTU)** |
| **Guideline** | 20 | 2,5 | 5.2-7.8 | 6.2-6.5 | 1.8-2.4 | 43-55 | 350 | 1,3 |
| **2019 average** | 9.75 | 2.3 | 6,70 | 6.4 | 2,00 | 45.5 | 237 | 0.96 |
| **2019 (min - max)** | (8-12) | (1.8-**2.7**) | (6.3-7.3) | (5-**7.6**) | (1.7 - 2.3) | (36-**56**) | (190-260) | (0.7-**1.4**) |
| **1997-2018 average** | 14.1 | **3.1** | 6.5 | 6.4 | 2,12 | 49.2 | 270 | 1.0 |

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

## Long-term trends:

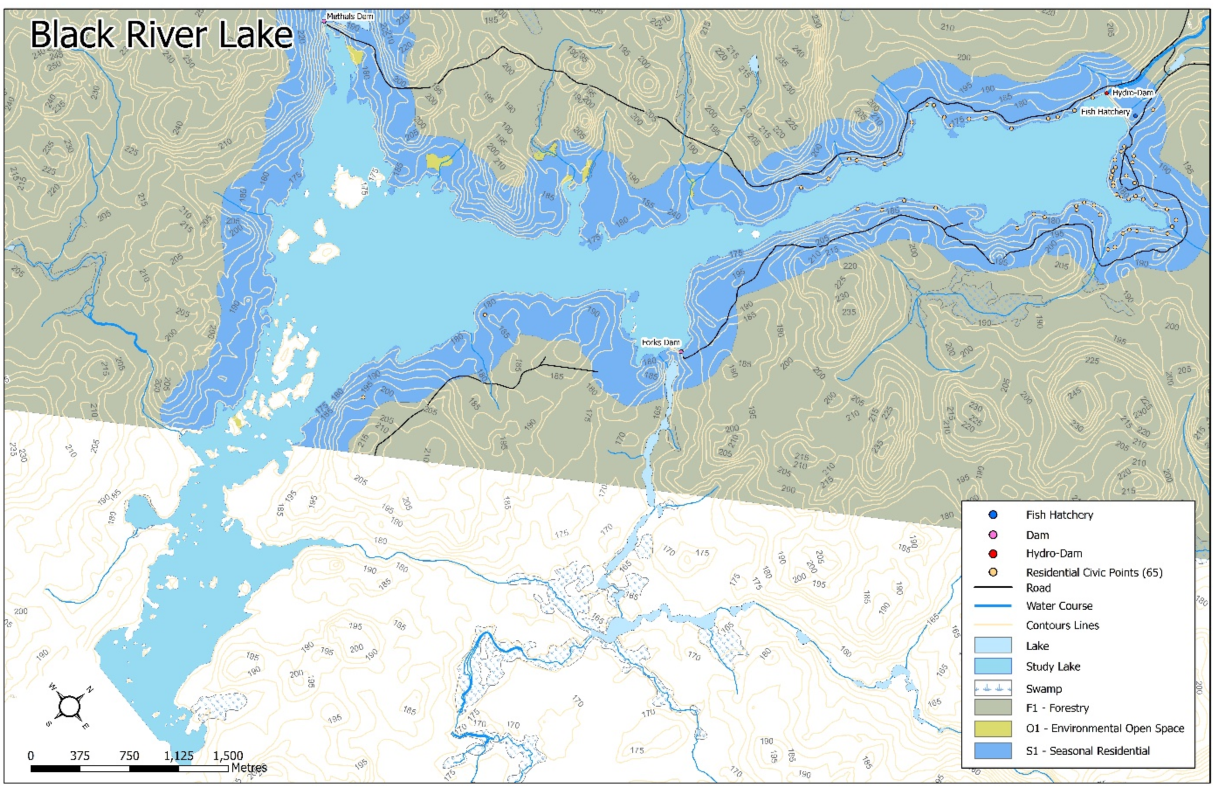
The long-term trend in chl.a is showing a decline between 2014 to 2019, although similar values were reported for the last 3 years. No change in TP concentration was recorded in 2019 compared to the last decade. The concentration in TN has decreased over the last 3 years. Both TP and TN values remain very low in the lake, consistently below guideline values.

**Little River Lake: Histograms of the long-term values in chl.a, TP, total nitrogen concentrations and colour**



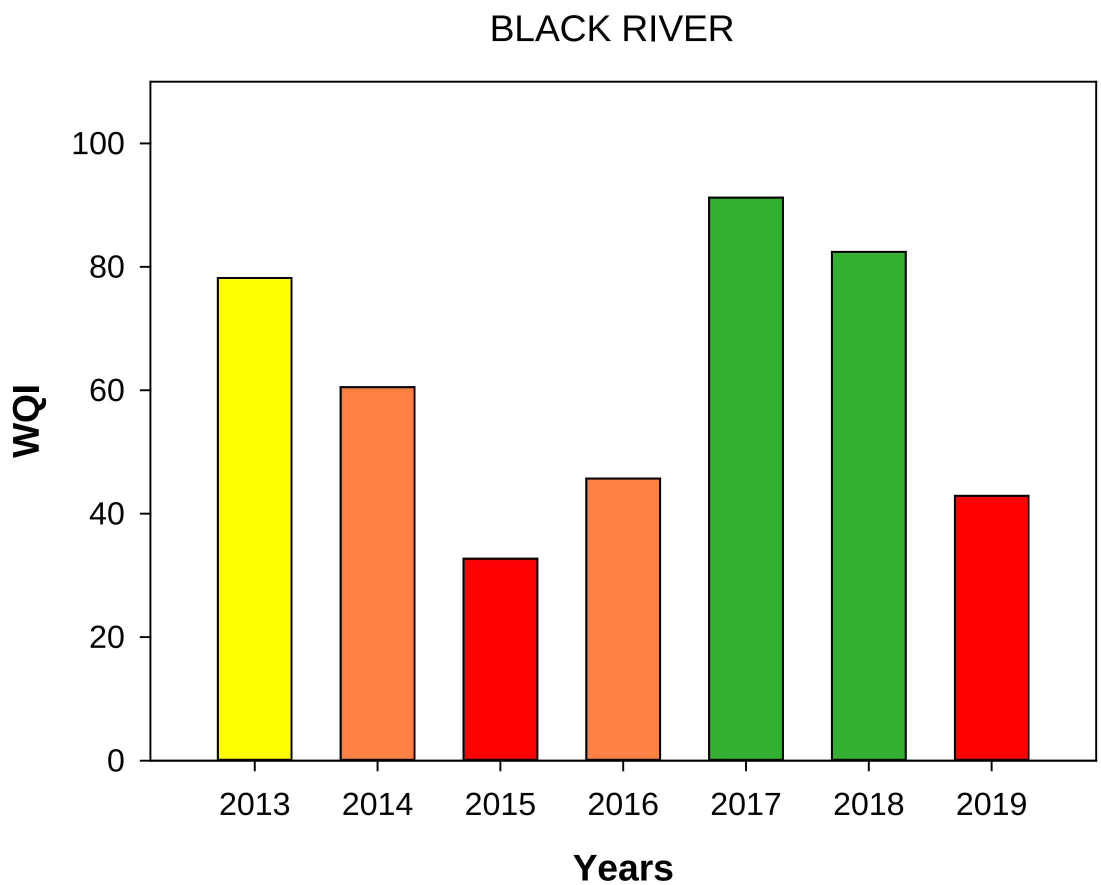
## 3.8 Black River Lake

Black River Lake is the second largest lake in this study (surface: 668 ha) and is also the deepest (max depth: 15 m). The lake has a long narrow shape and receives most of its water from Little River Lake. Compared to the other lakes in this study, Black River Lake is more coloured, because of higher content in dissolved organic carbon. The tea colour of the water may explain the name of the lake. Black River Lake water levels are managed by 2 dams and residential properties are found in a small number in the north east side of the lake.



**Water Quality Index (WQI):**

The Water Quality Index value for Black River Lake in 2019 was 42.9 which is indicative of a poor water quality. This is a significant decline in water quality compared to the last 2 years (about 48% decline compared to 2018). In 2019, the WQI value dropped back to a value similar to 2014 to 2016.

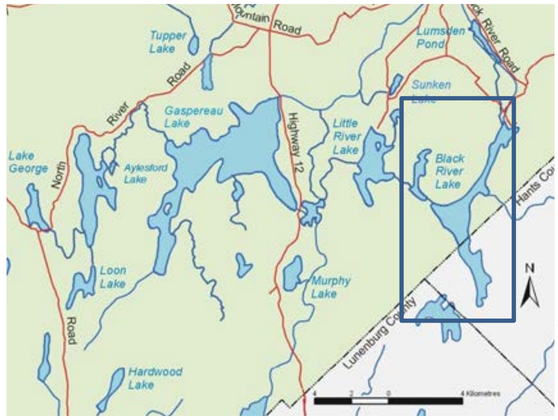



**Summary report card:**

Overall, the number of exceedances in Black River Lake was not low (6/35) and almost all related to chl.a (4/5 values exceeding guideline). The mean value for chl.a was above guideline (2.7 µg/L) and one value was more than twice that of the guideline (max: 5.4 µg/L).

# BLACK RIVER LAKE

**42.9**




Drainage Order = 5

Elevation = 170 m

Lake Area = 668 ha

Max Depth = 15 m

**1997-2019 Trends:**

**WQI change (1Y and 5Y):**
-48 and -34%

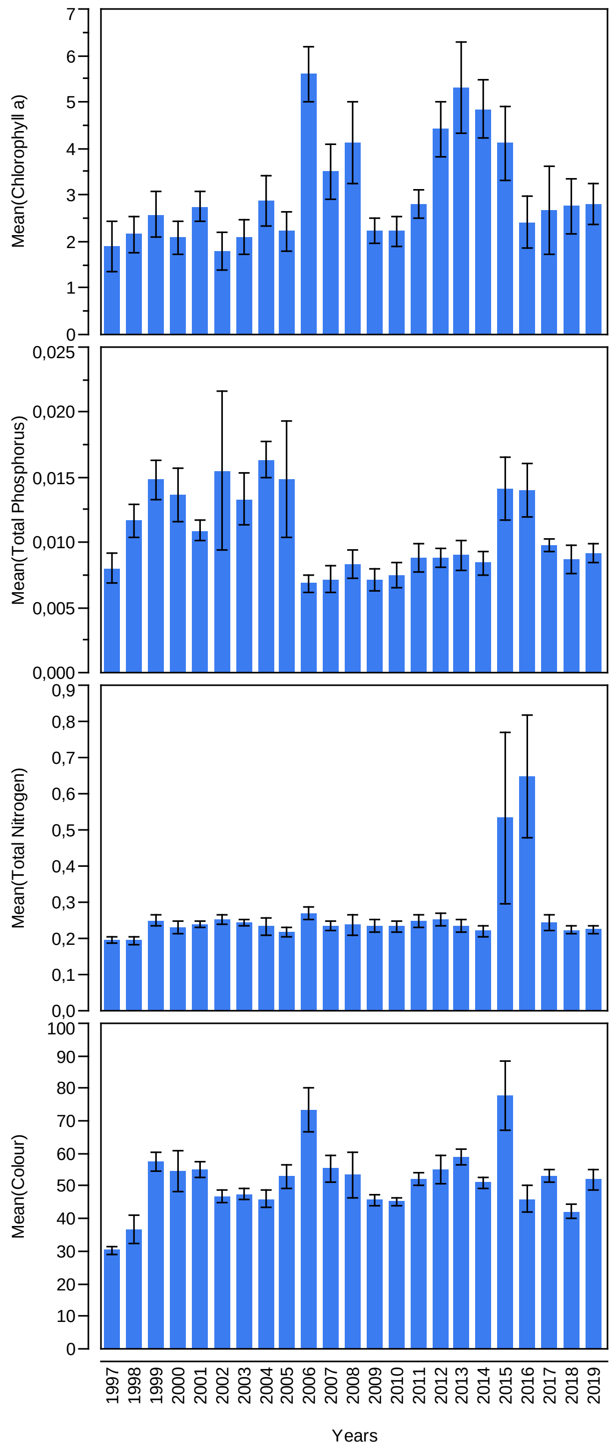
| | **Parameter** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **TP (µg/L)** | **Chl A (mg/m$^3$)** | **DOC (mg/L)** | **pH** | **Secchi Depth (m)** | **Colour (TCU)** | **TN (µg/L)** | **Turbidity (NTU)** |
| **Guideline** | 16.1 | 2,5 | 5.3-8.0 | 6.1-6.5 | 1.6-2.3 | 44.3-56.2 | 350 | 1,3 |
| **2019 average** | 13,30 | **2,70** | 6,20 | 6,40 | 1,70 | 53,10 | 242 | **1,00** |
| **2019 (min - max)** | (10-10) | (1.1-**5.4**) | (5.7-6.7) | (6.2-6.5) | (1.3-1.8) | (48.1-57) | (200-300) | (0.9-1.1) |
| **1997-2018 average** | 10.8 | **3.09** | 6.6 | 6.3 | 2,00 | 52.2 | 267 | 1.0 |

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

## Long-term trends:

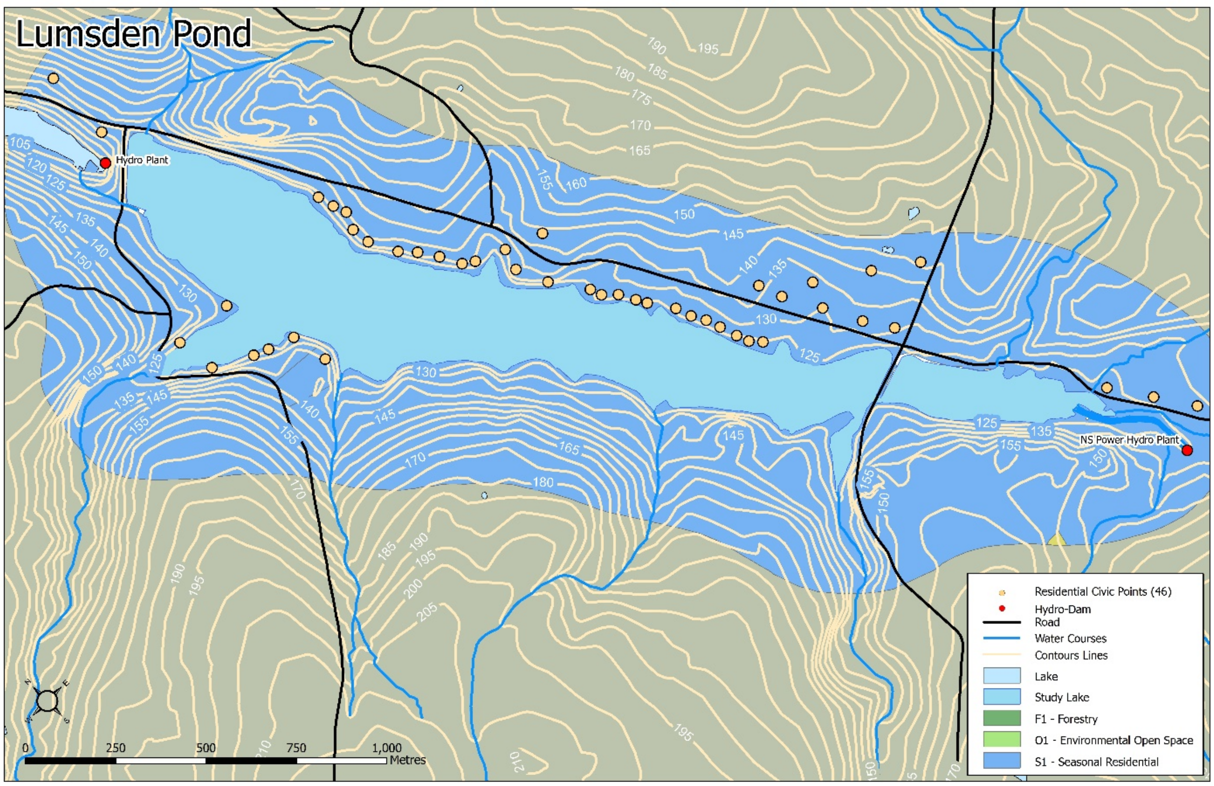
The mean chl.a concentration in Black River Lake has been increasing over the last 4 years. The mean concentration in both TP and TN declined significantly in 2017, 2018 and 2019 compared to 2015 and 2016.

**Black River Lake: Histograms of the long-term values in chl.a, TP, total nitrogen concentrations and colour**



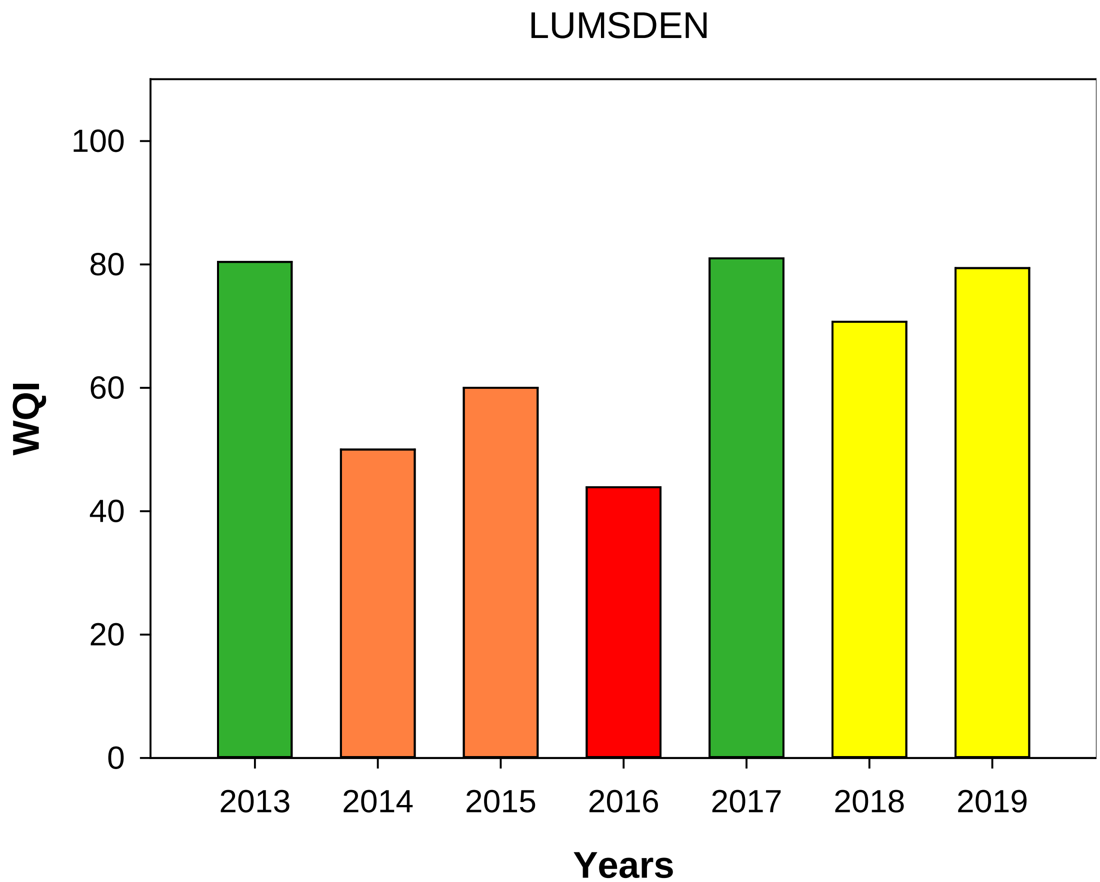
## 3.9 Lumsden Pond

Lumsden pond is an enlargement of a river system. This body of water is small (88 ha) and has a reported maximum depth of 19 m (which is unexpected given the surface and the fact that this is a pond). The pond is receiving water from Black River Lake and is the last system in the chain of lakes in this study. The pond has some residential development (east side of the lake) and also some agriculture development in its watershed. It is a regulated system, with water levels being managed by 2 hydro electrical dams.




**Water Quality Index (WQI):**

The Water Quality Index for Lumsden Pond was 79.4 in 2019, which corresponds to a fair water quality rating. This rating is similar to that observed in 2018. Both chl.a and turbidity values showed exceedances relative guideline values. The mean value for chl.a was above guideline value (mean: 3.6 µg/L; guideline: 2.5 µg/L), with all values measured during the sampling season exceeding the guideline.

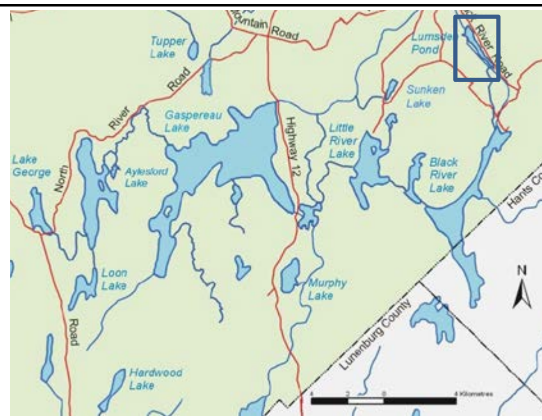



**Summary report card:**

In 2019, the water quality of Lumsden Pond was fair. In past years, several exceedances in nutrient concentrations supported the high chl.a values however such correlation was not observed in 2019. It is possible that changes in water levels may contribute to a higher productivity of the lake. Over time, Lumsden Pond has shown signs of mesotrophic conditions. As noted in 2018, bloom-like algae have been reported by volunteers in the nearshore areas of the lake.

# LUMSDEN POND

**79.4**




Drainage Order = 6

Elevation = 126 m

Lake Area = 88 ha

Max Depth = 19 m

**1997-2019 Trends:**

**WQI change (1Y and 5Y):** +12 and +23%

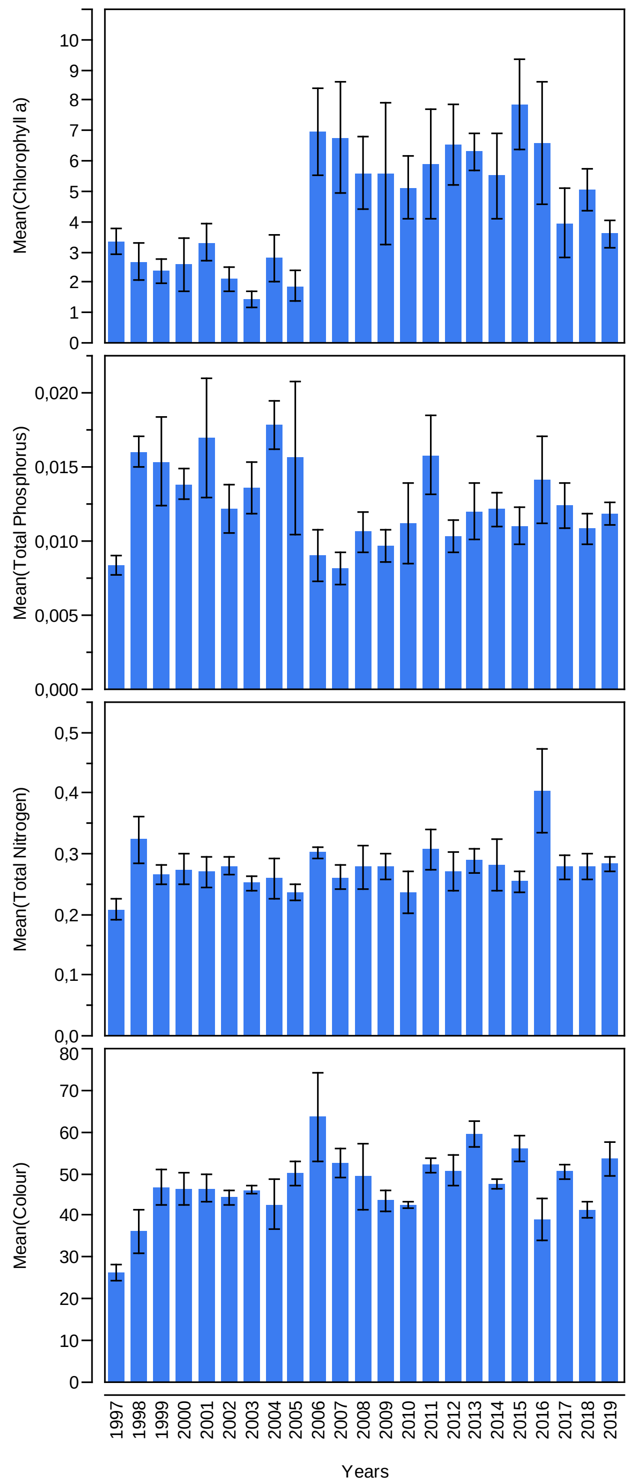
| | Parameter | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **TP (µg/L)** | **Chl A ($mg/m^3$)** | **DOC (mg/L)** | **pH** | **Secchi Depth (m)** | **Colour (TCU)** | **TN (µg/L)** | **Turbidity (NTU)** |
| **Guideline** | 18.7 | 2,5 | 5.0-7.6 | 6.2-6.6 | 1.6-2.0 | 41-52 | 350 | 1,3 |
| **2019 average** | 11.8 | **3.6** | 7.3 | 6.5 | 1,80 | 53.5 | 283 | **1.5** |
| **2019 (min - max)** | (9-14) | (**2.7-5.2**) | (6.4 - **8.1**) | (6.3 - 6.6) | (**1.5-2.2**) | (41.3-**64.7**) | (240-320) | (0.9-**2.8**) |
| **1997-2018 average** | 12.5 | **4.5** | 6.3 | 6.4 | 1,85 | 46.5 | 276 | 1.1 |

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

## Long-term trends:

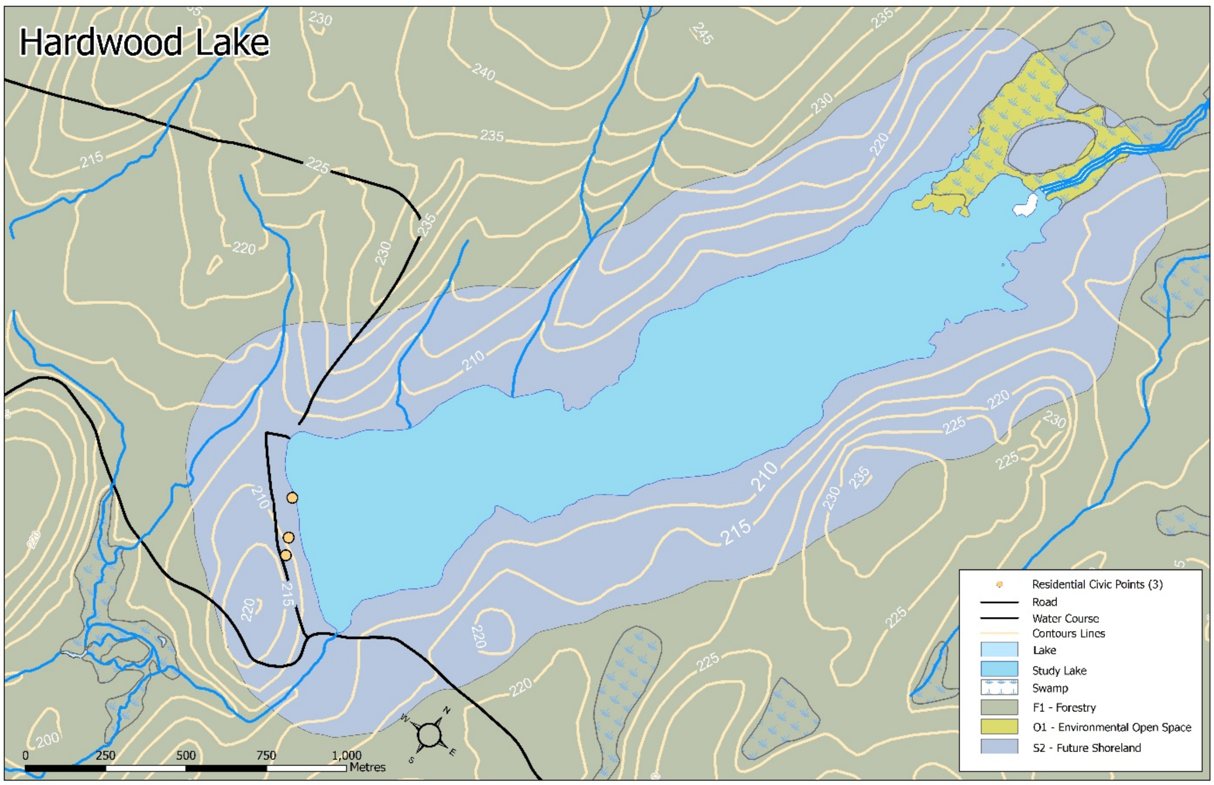
The histograms for Lake Lumsden are showing a decline in chl.a for the last 4 years. There was no significant change in TP and colour values in 2019 compared to the last 10 years.

**Lumdsen Lake: Histograms of the long-term values in chl.a, TP, total nitrogen concentrations and colour**



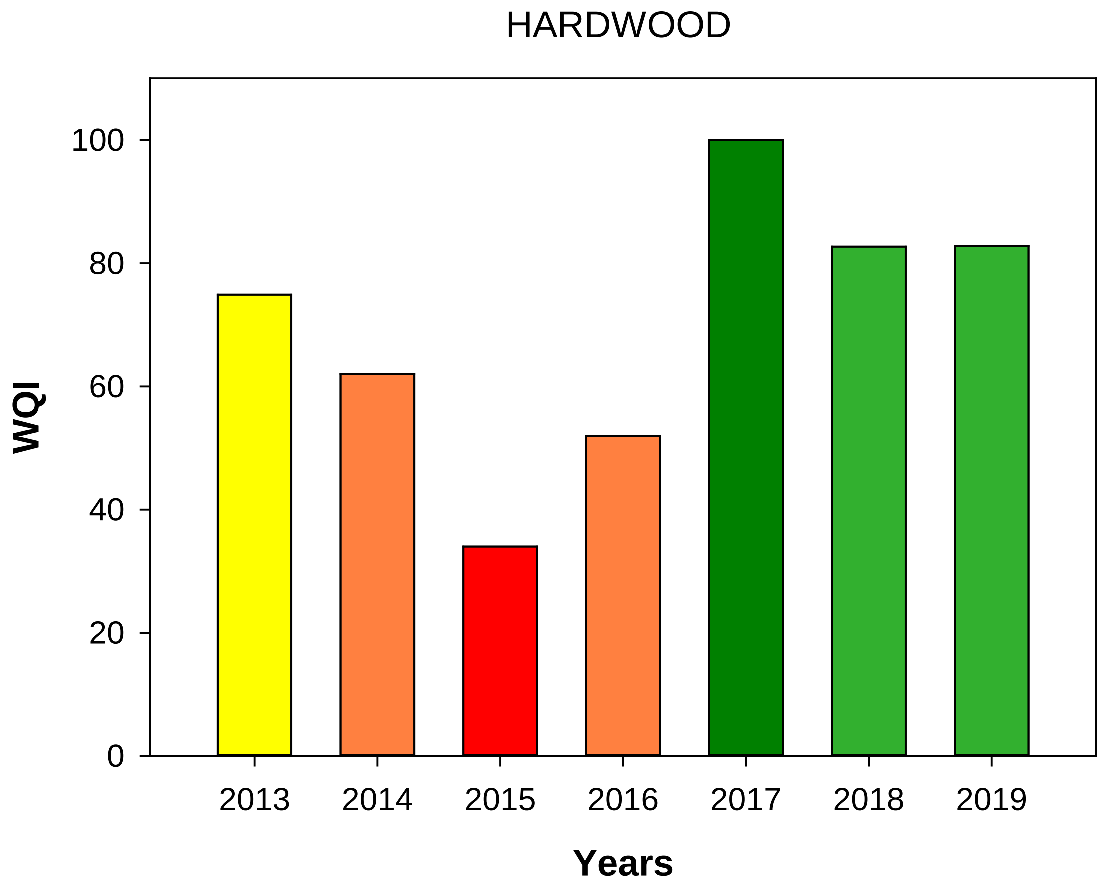
## 3.10 Hardwood Lake

Among the Kings County lakes, Hardwood Lake is not connected to any other lakes sampled as part of this study. It is a fairly small (120 ha), and shallow (max depth: 7m) lake. It has only 3 residences.




**Water Quality Index (WQI)**

In Hardwood Lake, The Water Quality index (WQI) for 2019 reached the value of 82.8 (good rating). None of the mean values exceeded guideline values, but one exceedance was observed for chl.a (3.9 µg/L). The results for Hardwood lake are similar to those observed in 2018.

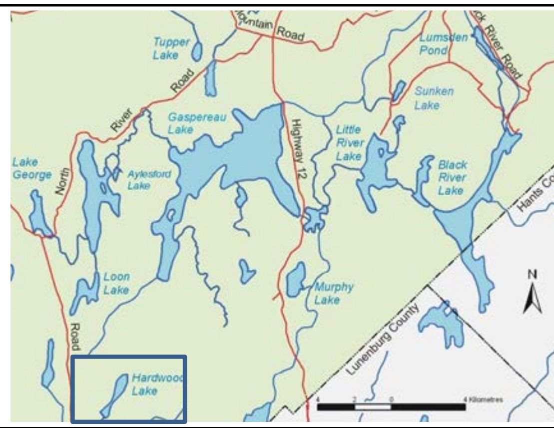



**Summary report card:**

The good water quality rating observed in 2019 was supported by few exceedances. Only 2 exceedances were observed during the sampling season, once for chl.a and once for turbidity. Harwood lake is a colored lake as indicated by the high DOC concentration, colour value and low secchi depth but these high values do not contribute to a low water quality.

## HARDWOOD LAKE

**82.8**




Drainage Order = n/a

Elevation = 208 m

Lake Area = 120 ha

Max Depth = 7.0 m

**1997-2019 Trends:**

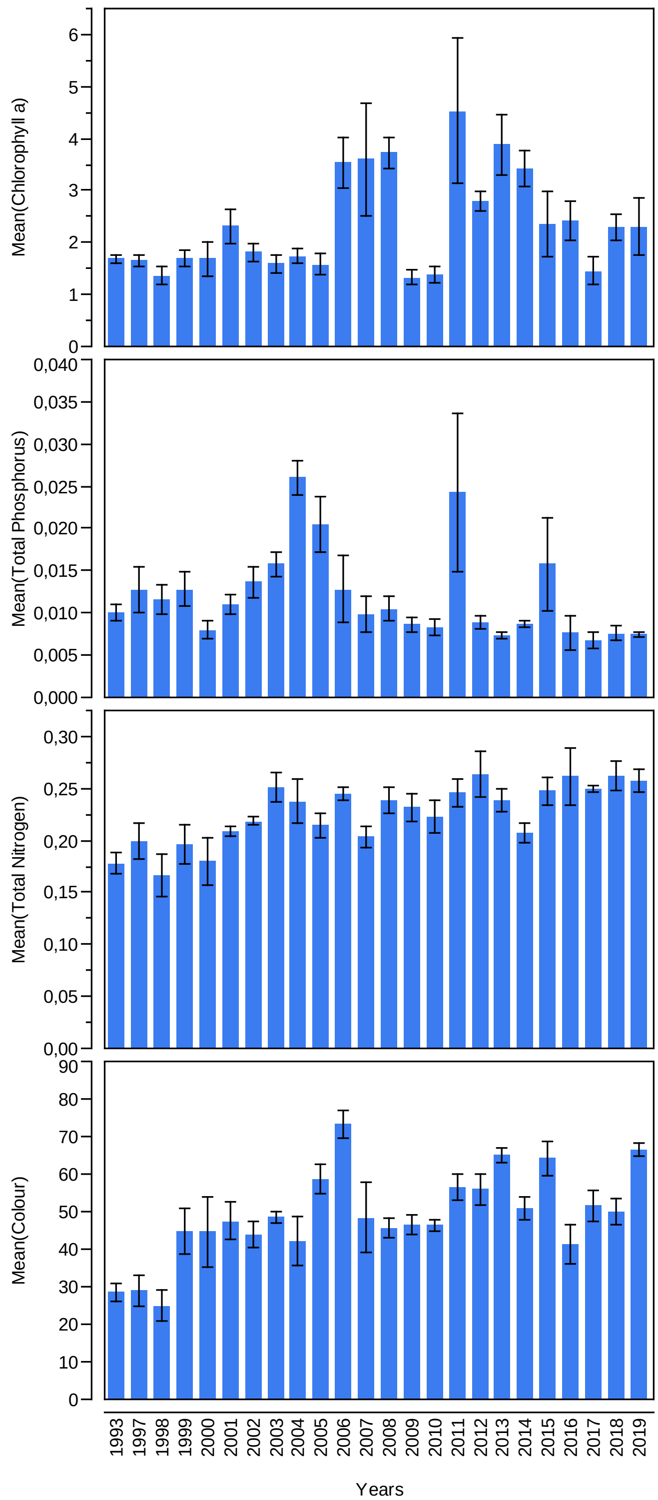
**WQI change (1Y and 5Y):** 0 and +22%

| | Parameter | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **TP (µg/L)** | **Chl A ($mg/m^3$)** | **DOC (mg/L)** | **pH** | **Secchi Depth (m)** | **Colour (TCU)** | **TN (µg/L)** | **Turbidity (NTU)** |
| **Guideline** | 18.4 | 2.5 | 5.7-8.6 | 6.1-6.5 | 1.6-2.4 | 37-60 | 350 | 1,3 |
| **2019 average** | 7.5 | 2.3 | **8.9** | 6.4 | 2,00 | **66.4** | 257 | 1.1 |
| **2019 (min - max)** | (7-8) | (1.4-**3.9**) | (8.4-**9.6**) | (6.2 - **6.8**) | **(1.5-2.7)** | (**61.6-69**) | (240-280) | (0.6 - **2.1**) |
| **1997-2018 average** | 12.4 | 2.3 | 7.1 | 6.3 | 2,07 | 47.1 | 221 | 1.2 |

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

## Long-term trends:

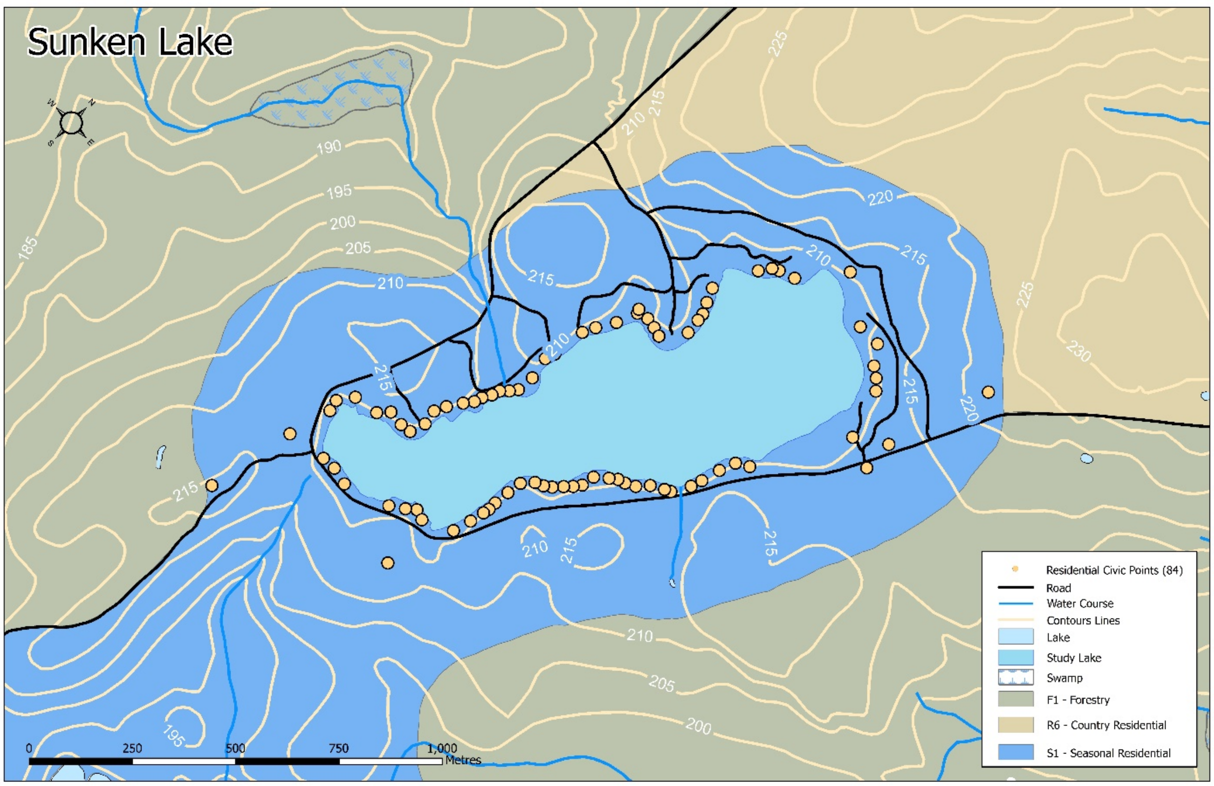
The histograms for Hardwood Lake are not showing significant trends over time. Both TN and colour may seem to increase since 1993 but this trend is marginally significative.




**Hardwood Lake: Histograms of the long-term values in chl.a, TP, total nitrogen concentrations and colour**

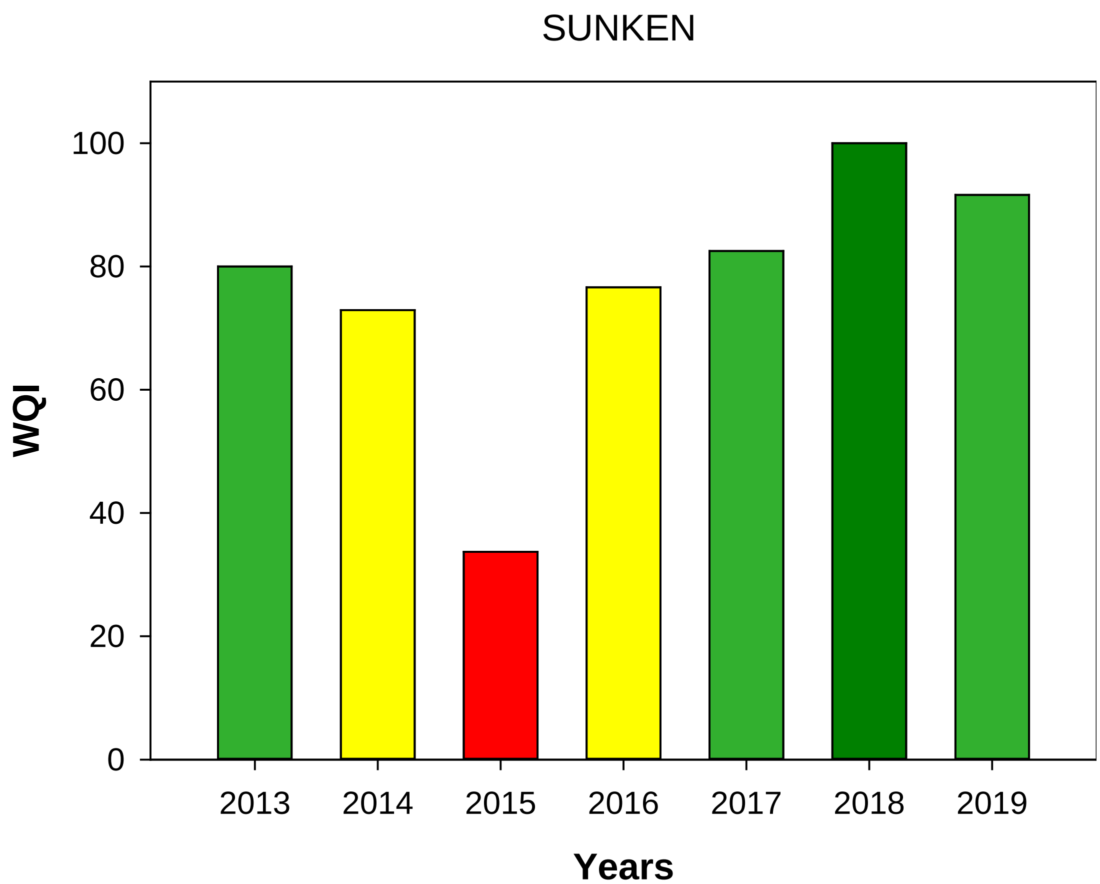
## 3.11 Sunken Lake

Sunken lake is a small (22.2ha), shallow (max depth: 7m) lake. It is connected to other much larger lakes from Kings County watershed. Depending on the direction of the flow, the water quality of this lake could be influenced by Gaspereau and/or Little River Lake. Sunken Lake has a large number of residences located near the water front.




**Water Quality Index (WQI):**

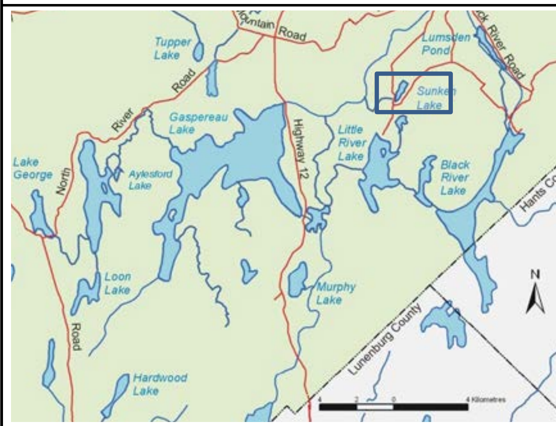
In Sunken Lake, the Water Quality index (WQI) for 2019 was 91.6, a good rating. The water quality in this lake has been similar over the last 3 years and is consistent with a recovery since 2015 when a poor WQI was recorded. This value reflects the low nutrient levels and low chl.a concentrations measured during the sampling season. There was no exceedance observed for all parameters measured in 2019.




**Summary report card:**

The good water quality rating observed in 2019 for Sunken Lake was supported low nutrient concentrations and in turn supporting low chl.a concentrations. The values reported in 2019 are similar to those reported over the last 2 years.

# SUNKEN LAKE




**91.6**

Drainage Order = n/a

Elevation = ~209 m

Lake Area = ~22.2 ha

Max Depth = 6.9 m

**1997-2019 Trends:**

**WQI change (1Y and 5Y):**
-8 and +23%

| | Parameter | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **TP (µg/L)** | **Chl A (mg/m$^3$)** | **DOC (mg/L)** | **pH** | **Secchi Depth (m)** | **Colour (TCU)** | **TN (µg/L)** | **Turbidity (NTU)** |
| **Guideline** | 13.0 | 2,5 | 2.2-3.3 | 7.1-7.3 | 2.8-3.6 | 6.3-13.7 | 350 | 1,3 |
| **2019 average** | 7.0 | 1.6 | 3.3 | 7.2 | 3,60 | 5,60 | 198 | 1.0 |
| **2019 (min - max)** | (6-8) | (1.1-2.2) | (2.7-3.8) | (7.1-7.3) | (2.7-4.6) | (5-7.4) | (180-260) | (0.7-1.7) |
| **1997-2018 average** | 8.7 | 3.0 | 2.8 | 7.2 | 3,25 | 10.6 | 208 | 1.2 |

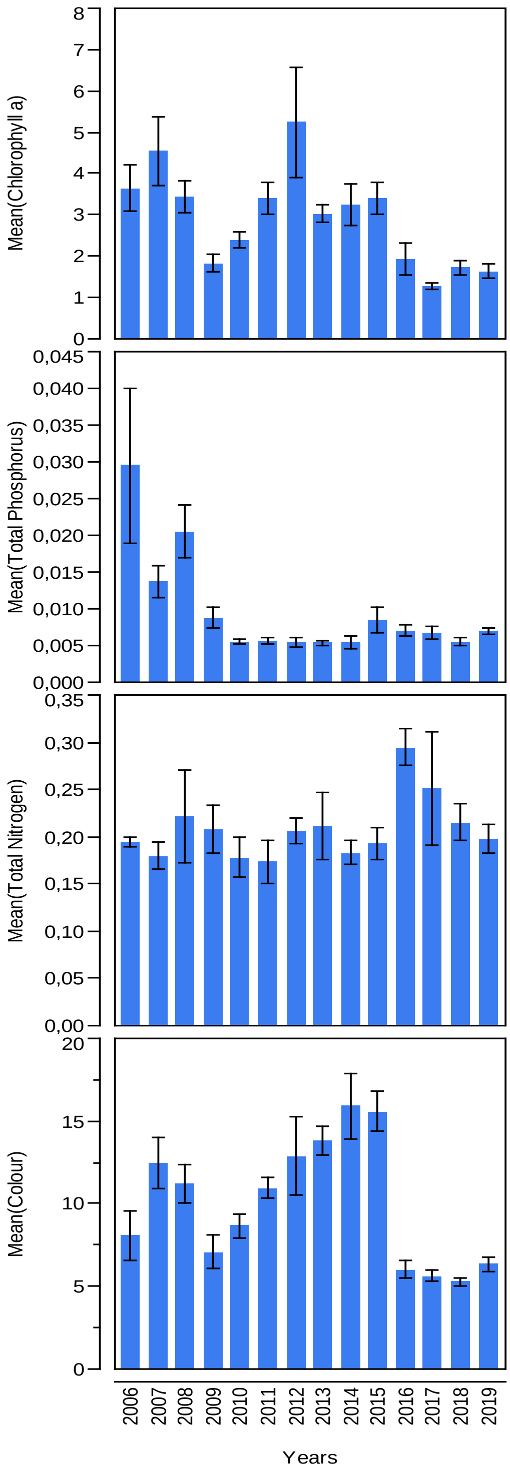
| 0-44 | 45-64 | 65-79 | 80-94 | 95-100 |
|---|---|---|---|---|
| Poor | Marginal | Fair | Good | Excellent |

## Long-term trends:

In 2019, temporal trends for nutrient (TP and TN) as well as for chl.a a are not showing any statistical trends over time. The concentrations in chl.a were lower for the last 3 years compared to the last 6 years (explaining the increase in WQI values). The concentrations in TP remained low (below 10 mg/L) and constant over the last 8 years. These findings are consistent with oligotrophic conditions for Lake Sunken. The mean concentrations in

TN have been declining since 2016. Further analyses would be needed to confirm if this trend is maintained over the longer-term.

Interestingly, water colour has declined to a mean value of 5.6 TCU over the last 4 years. This result is unclear because Secchi depth or DOC concentrations did not follow a similar trend.



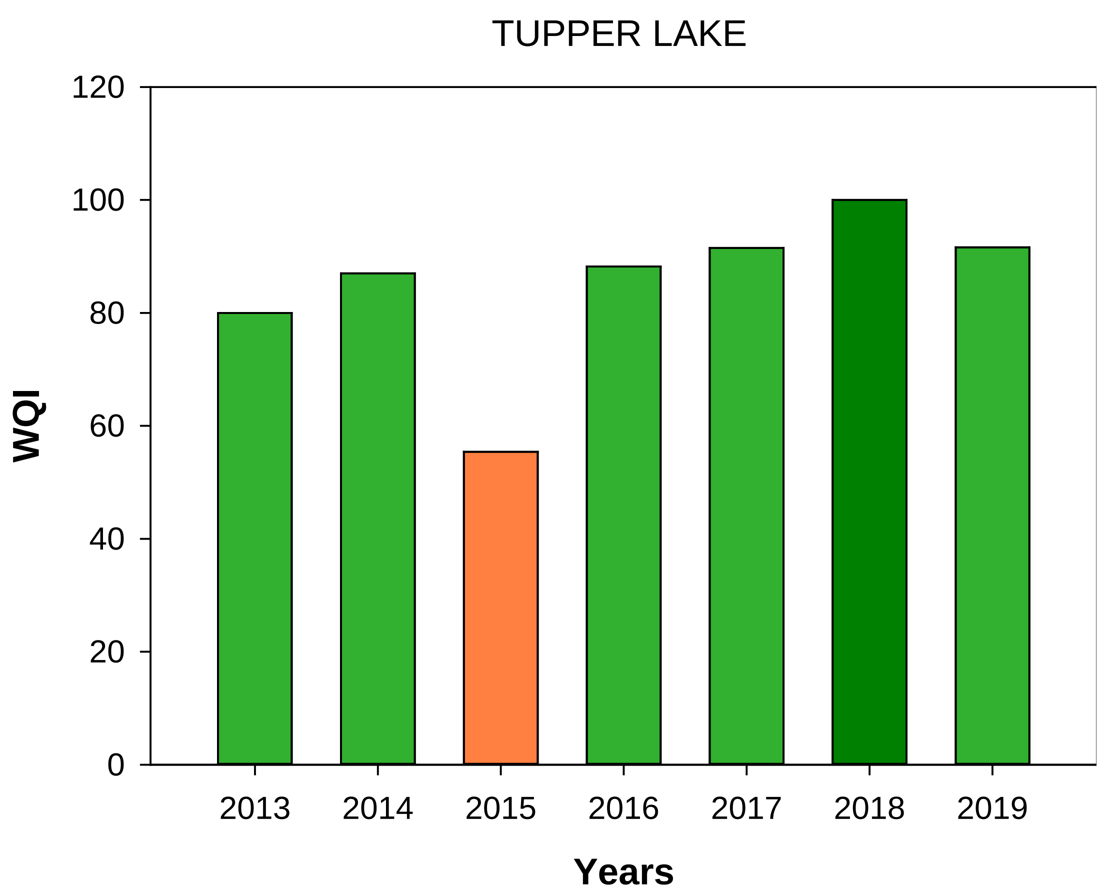

**Sunken Lake: Histograms of the long-term values in chl.a, TP, total nitrogen concentrations and colour**

## 3.12 Tupper Lake

Lake Tupper is a small (36 ha), shallow (max depth: 3m) lake. This lake is not connected to other lakes in this study.

**Water Quality Index (WQI):**

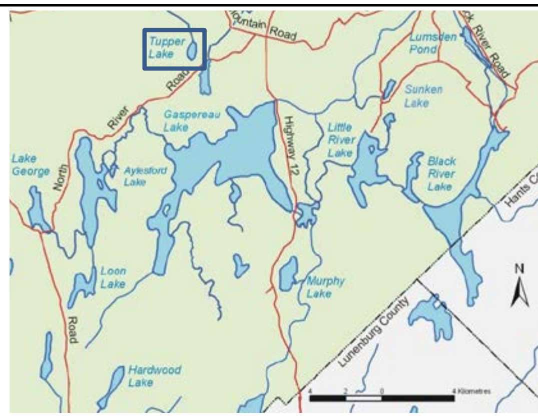
In 2019, the Water Quality Index for Lake Tupper was 91.6, which indicates a good water quality rating. The value has been similar over the last 4 years. Lake Tupper is a lake that had among the best water quality rating compared to all lakes sampled in this study.



**Summary report card:**

The good WQI rating recorded in 2019 in Tupper Lake is supported by only one exceedance for chl.a during the sampling season. This value (2.7µg/L) is close that of the guideline (2.5µg/L).

## TUPPER LAKE




**91.6**

Drainage Order = n/a

Elevation = 201 m

Lake Area = 36 ha

Max Depth = 3.0 m

**1997-2019 Trends:**

**WQI change (1Y and 5Y):**
-8 and +9%

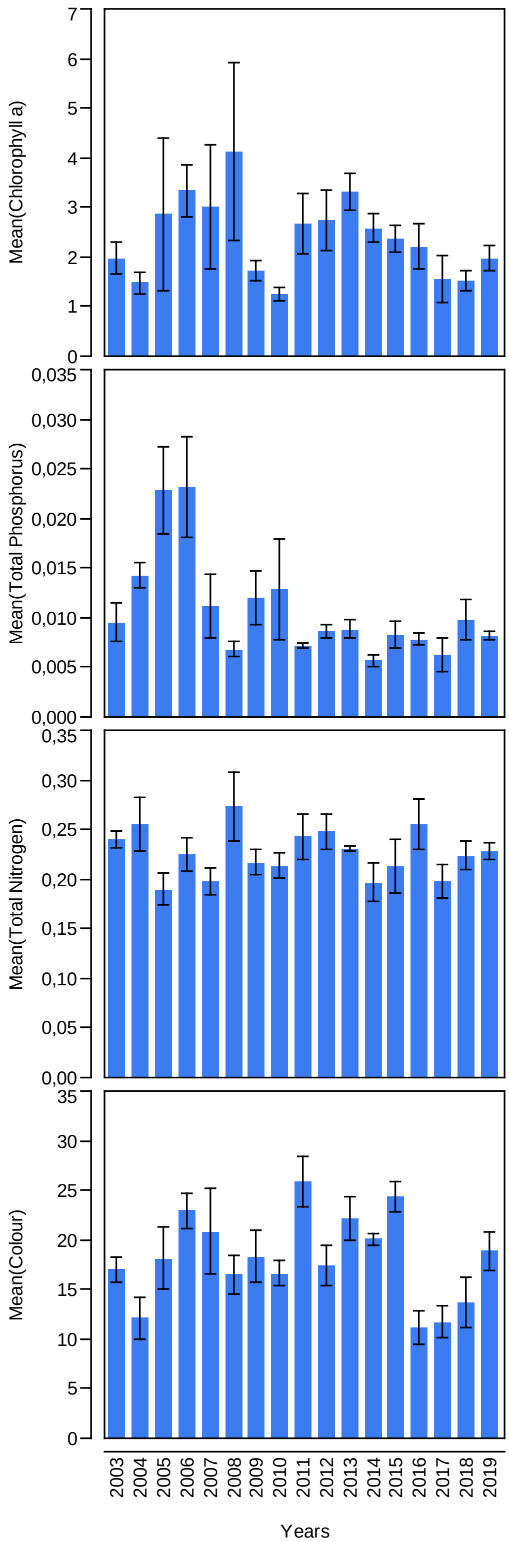
| | Parameter | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **TP (µg/L)** | **Chl A (mg/m$^3$)** | **DOC (mg/L)** | **pH** | **Secchi Depth (m)** | **Colour (TCU)** | **TN (µg/L)** | **Turbidity (NTU)** |
| **Guideline** | 16.1 | 2.5 | 3.6-5.5 | 6.6-7 | 2.6-3 | 14-22 | 350 | 1,3 |
| **2019 average** | 8.2 | 2.0 | 5.4 | 7,00 | - | 18.9 | 228 | 0.92 |
| **2019 (min - max)** | (7-10) | (1.2-**2.7**) | (4.6-**6.5**) | (6.9-**7.1**) | - | (**13.3-24.2**) | (200-250) | (0.8-1.1) |
| **1997-2018 average** | 10.9 | **2.5** | 4.5 | 6.8 | 2,60 | 18.5 | 226 | 0.9 |

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

**Long-term trends:**

In Tupper Lake, Concentrations in nutrients (TP and TN) as well as in chl.a a are not showing any statistical trends over time. The concentrations in TP remained low (below 10 mg/L) and constant over the last 9 years. These findings are consistent with oligotrophic conditions.

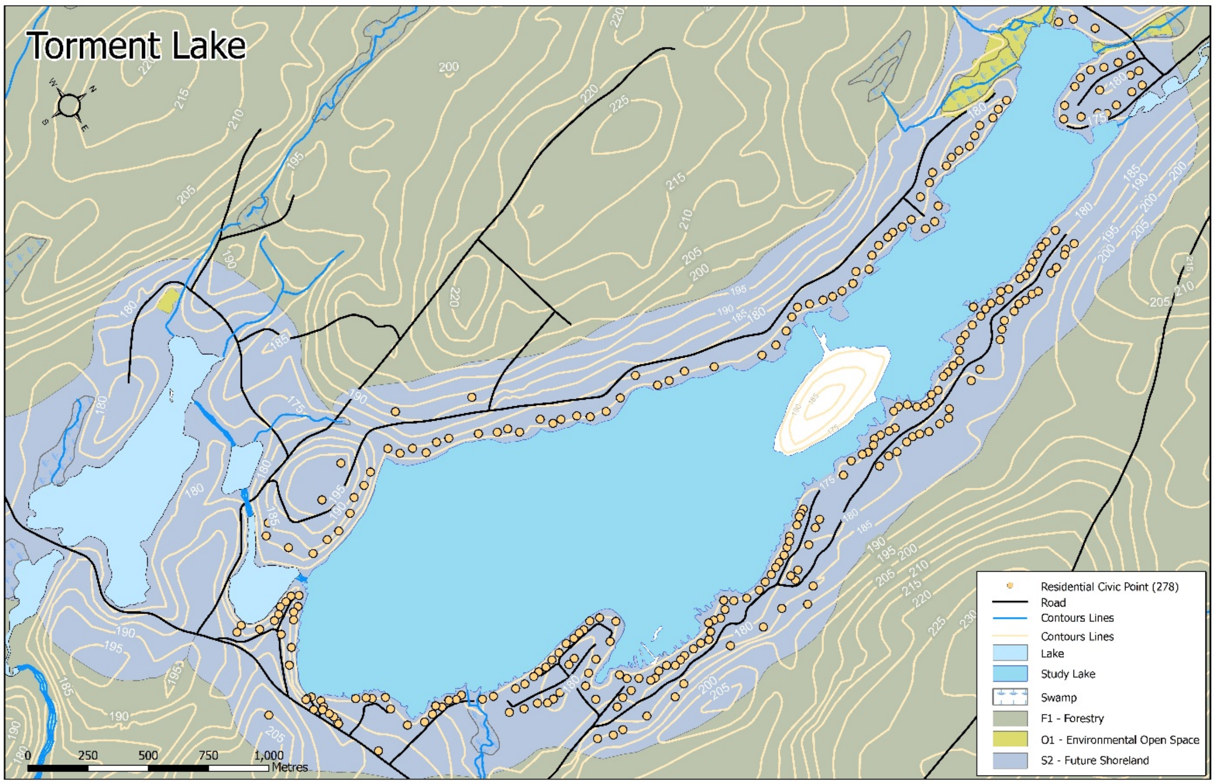
Colour has been increasing in Lake Tupper for the last 4 years after a sharp decline in 2015. The cause of such decline can stem from lower precipitations causing on increase in the concentration of organic matter in the lake.




**Tupper Lake: Histograms of the long-term values in chl.a, TP, total nitrogen concentrations and colour**

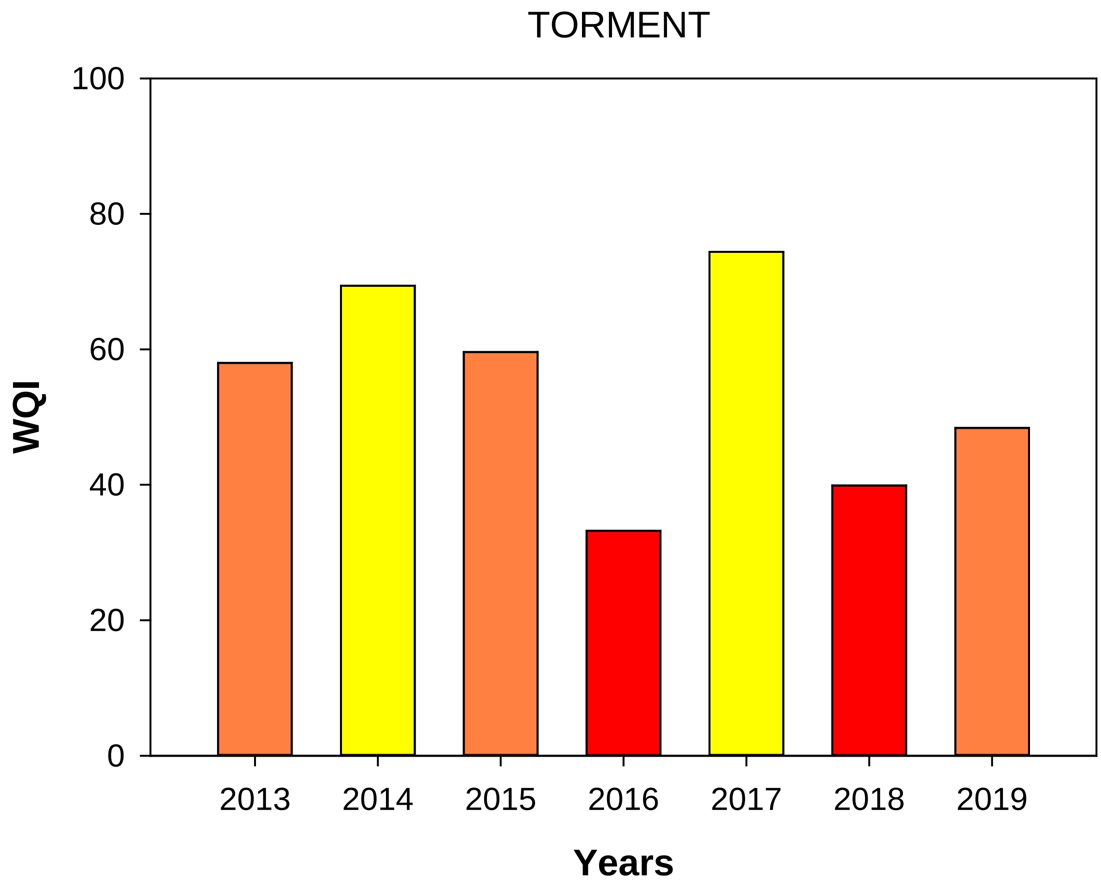
## 3.13 Lake Torment

Lake Torment is a medium size (261 ha), shallow (max depth: 3.4m). Lake Torment is connected to Lake Armstrong. Based on satellite imagery, the lake is surrounded by a forested area. It has a significant residential development in the nearshore area.




**Water Quality Index (WQI):**

In 2010, the Water Quality Index for Lake Torment was 48.4, with a marginal rating. This value is higher than last year (+21% increase) but the long-term rating for this lake remains low, ranging from poor to fair. Lake Torment had 4 marginal rating for 4 out of the past 7 years.




**Summary report card:**

Lake Torment's rating in 2019 is the results of 7 exceedances (7 out of 28), for TP (3 times), TN (once) and chl.a (once). Although the mean values for the parameters entered to produce the WQI are below guidelines, they are close to reaching them. The high nutrient values (for both TP and TN) correspond to the high value in chl.a. This lake is fairly productive and this state is likely supported by the high number of residences in the watershed and along the lake shores.


## Lake Torment

**48.4**

Drainage Order = n/a

Elevation = 174 m

Lake Area = 261 ha

Max Depth = 3.4 m

**1997-2019 Trends:**

**WQI change (1Y and 5Y):**

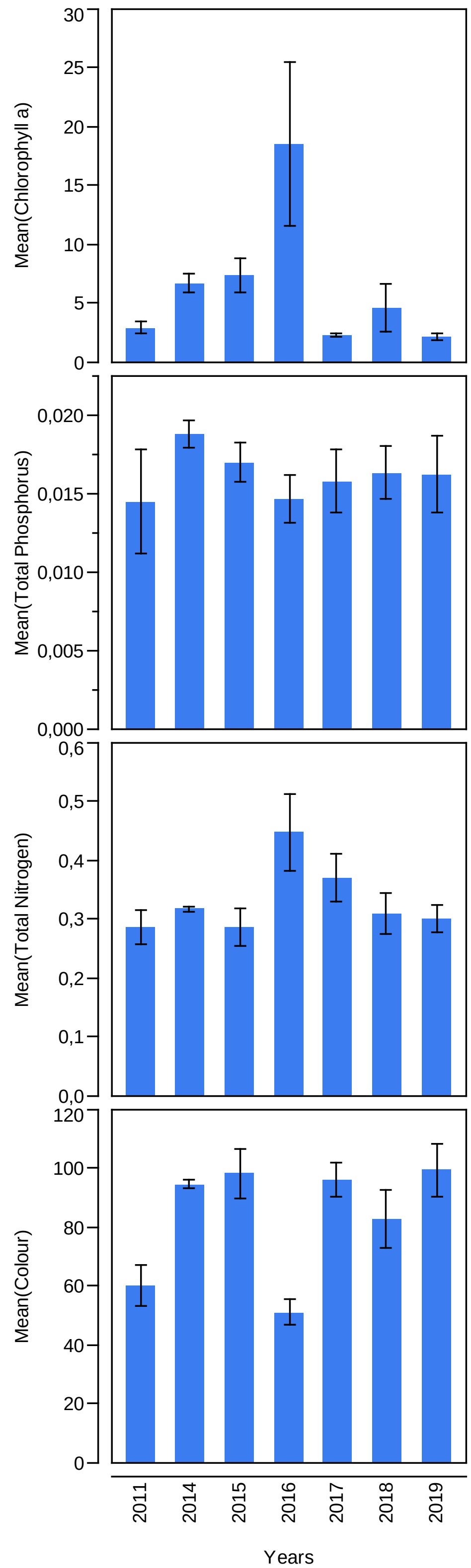
21 and -13%

| | Parameter | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **TP (µg/L)** | **Chl A (mg/m$^3$)** | **DOC (mg/L)** | **pH** | **Secchi Depth (m)** | **Colour (TCU)** | **TN (µg/L)** | **Turbidity (NTU)** |
| **Guideline** | 20 | 2,5 | 7.8-11.8 | 6.3-6.5 | 1.1-1.6 | 67-98 | 350 | 1,3 |
| **2019 average** | 16.2 | 2.2 | 10.5 | 6.1 | 1,30 | **99.6** | **302** | 0,86 |
| **2019 (min - max)** | (11 - **23**) | (1.6-**3.0**) | (8.4-**11.9**) | (5.9-6.4) | (1.2-1.4) | (77.5-**116**) | (250-**360**) | (0.6-1) |
| **1997-2018 average** | 16.2 | **7.2** | 9.7 | 6.4 | 1,53 | 81 | 339 | **1.7** |

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

## Long-term trends:

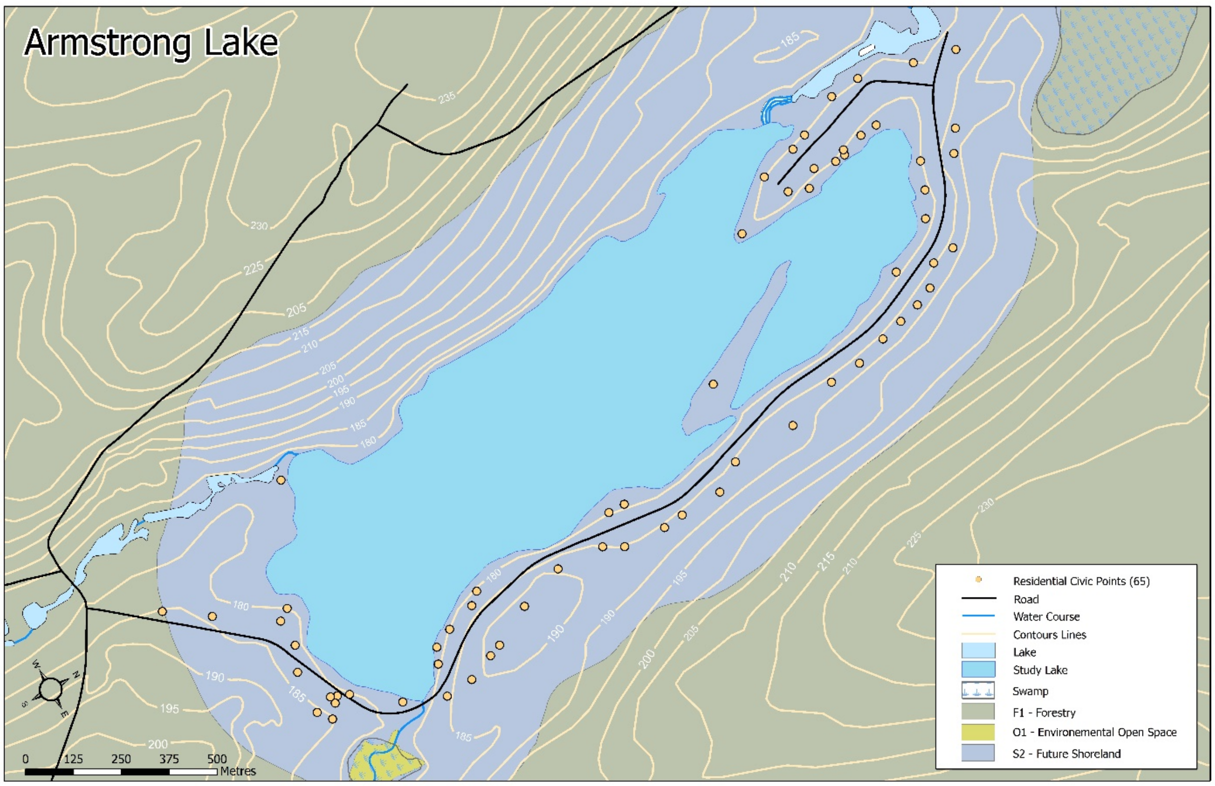
There are only 7 years of measurements available for Lake Torment. For this time period, no significant trends were observed. The concentrations in nutrients has been stable and the concentrations in chl.a are similar over the last 3 years after a sharp increase recorded in 2016.




**Lake Torment: Histograms of the long-term values in chl.a, TP, total nitrogen concentrations and colour**

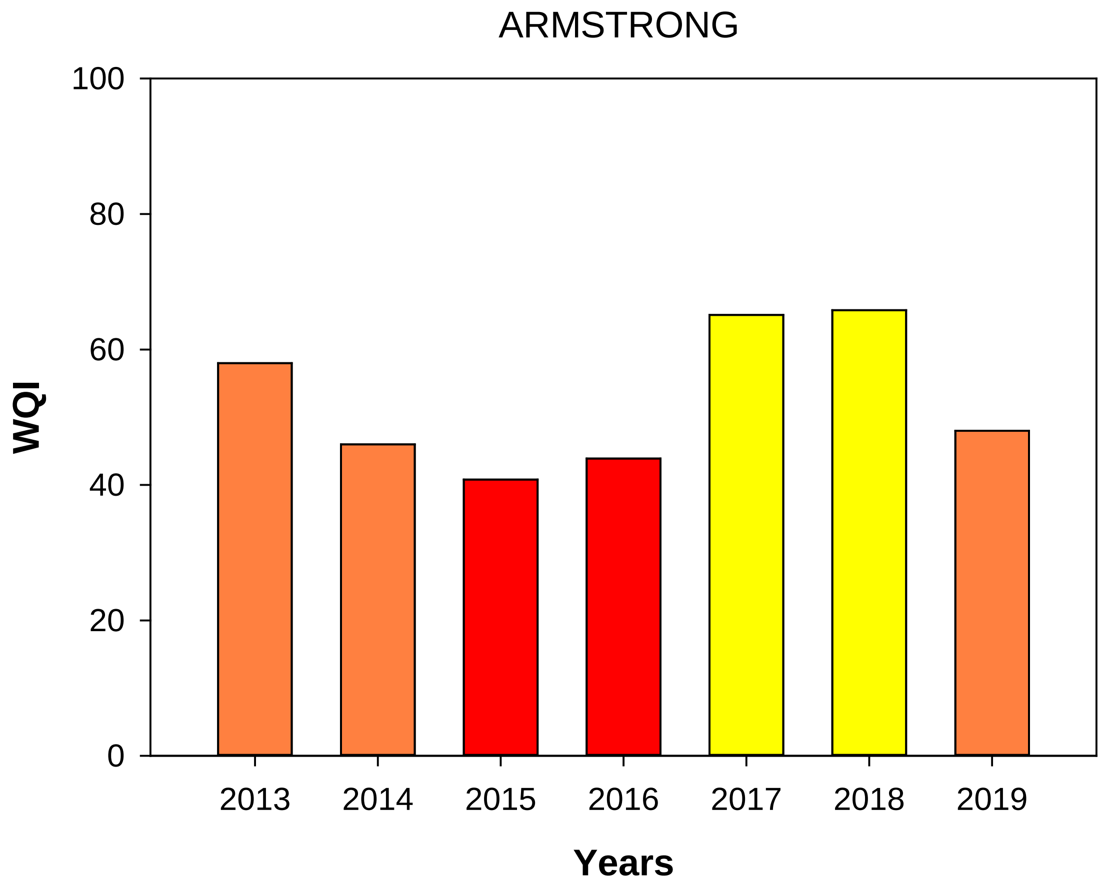
## 3.14 Lake Armstrong

Lake Armstrong is a small (89 ha), deep (max depth: 21m) lake. It is connected to Lake Torment. Based on satellite imagery, the lake has low to moderate residential development on the east side. It is located in close proximity to large forested areas that have been clear-cut.




**Water Quality Index (WQI):**

In 2019, the Water Quality Index for Armstrong Lake was 48, corresponding to a rating of marginal water quality. This value is a decline compared to the last 2 years (with a marginal rating).




**Summary report card:**

The WQI value observed for Lake Armstrong is explained by exceedances in both TP (once) and TN (twice). Overall, exceedances were observed for 10 values measured over the sampling season. No exceedances were observed for chl.a in 2019.


## Armstrong Lake

**48**

Drainage Order = n/a

Elevation = 178 m

Lake Area = 89 ha

Max Depth = 21 m

**1997-2019 Trends:**

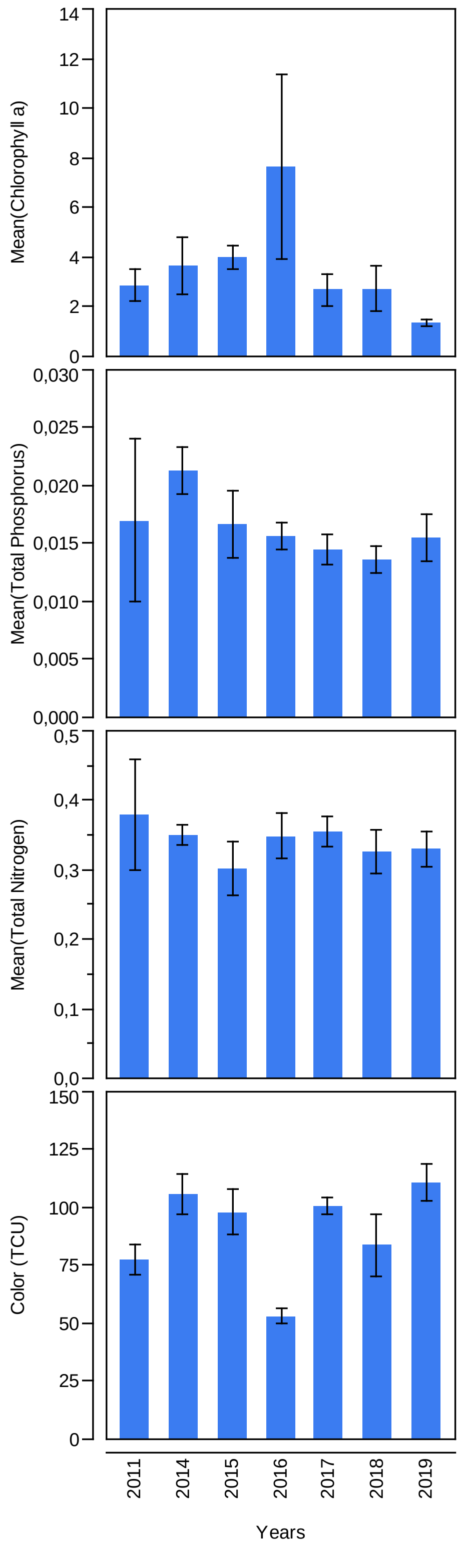
**WQI change (1Y and 5Y):** -27 and -10%

| | Parameter | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | TP (µg/L) | Chl A (mg/m$^3$) | DOC (mg/L) | pH | Secchi Depth (m) | Colour (TCU) | TN (µg/L) | Turbidity (NTU) |
| **Guideline** | 20 | 2,5 | 8.1-12.2 | 6.2-6.6 | 1.1-1.7 | 69-110 | 350 | 1,3 |
| **2019 average** | 15.5 | 1.3 | 11.9 | 6.0 | 1,1 | **111** | 330 | 1 |
| **2019 (min - max)** | (11 - **25**) | (0.7-1.8) | (8.3-**15.6**) | (**5.7**-6.4) | (**1**-1.3) | (75.7-**133**) | (240-**400**) | (0.6-**2.2**) |
| **1997-2018 average** | 15.9 | **4.1** | 9.8 | 6.3 | **1,63** | 85.8 | **338** | 1.1 |

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

### Long-term trends:

In 2019 (and 2018), the long-term trends for Lake Armstrong are similar to those reported for Lake Torment. The concentration in chl.a declined from close to 8 µg/L in 2016 to less than 3 µg/L in 2018 to 1.3 µg/Lin 2019- the lowest value observed in the last 7 years. The concentrations in both TP and TN remained fairly similar since 2011.

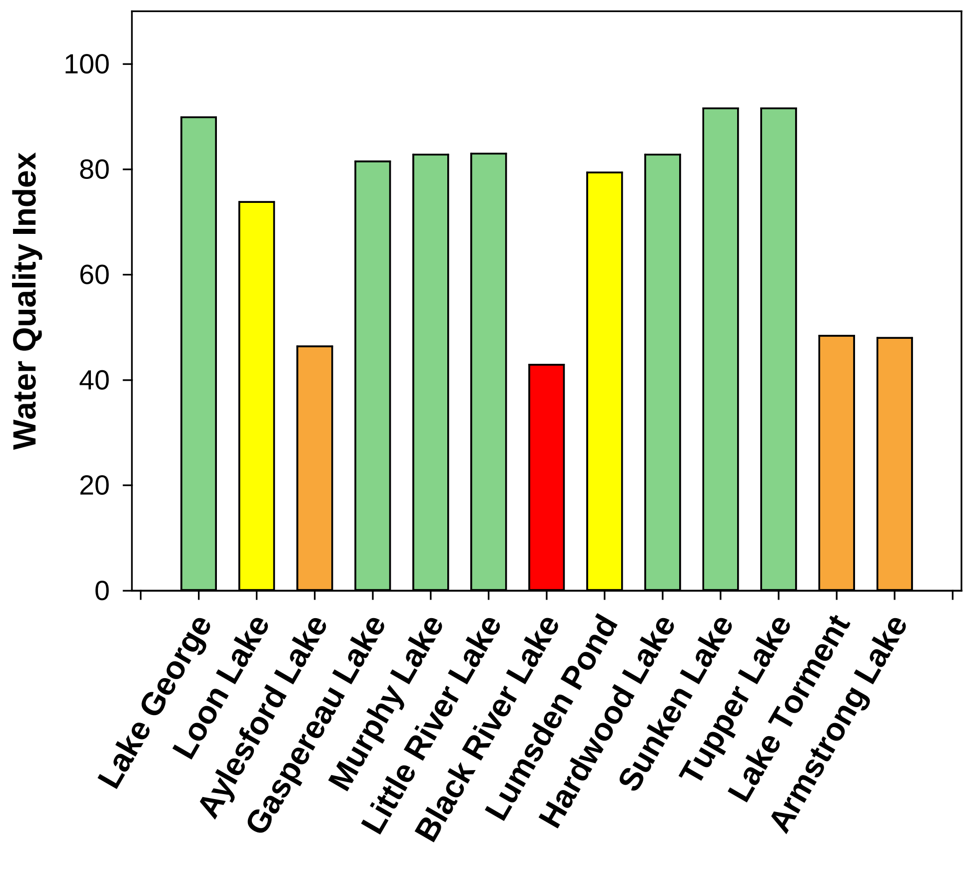


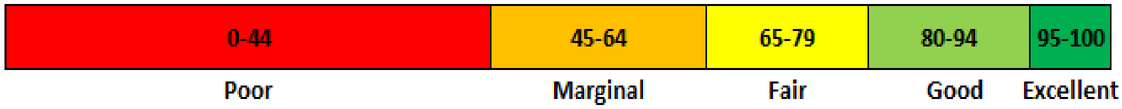

**Lake Armstrong: Histograms of the long-term values in chl.a, TP, total nitrogen concentrations and colour**

**Summary results for the 2019 sampling season**

In 2019, the WQI ranged from Poor (Black River Lake) to Good (Lake Sunken,Tupper, George, Gaspereau, Murphy, Little River and Hardwood Lake). Seven of the 13 sampled lakes had a good water quality rate.

In most lakes, the variation in WQI was related to variation in chl. a concentration. When a poor water quality was observed, it was due to high concentrations in chl.a. that exceeded the guideline values.



# 4 Conclusions and Recommendations

*The following recommendations are suggested for the Kings County Lake Monitoring Program and have been carried forward from previous reports with changes based on the 2019 data:*

In 2019, water quality in the Kings County lakes varied from poor to good. Among the 13 sampled lakes, 7 had a good water quality rating. As such, with only 3 lakes with a poor/marginal rating, the health of the Kings county lake is generally good.

The ratings are strongly related to the concentration in nutrients as TP and TN. In most lakes, nutrients concentrations were below guideline values; and when a lower rating is observed, it was often due to exceedances in chl.a concentrations (and not necessarily in TP and TN). In the recent years (2015, 2016), an increase in productivity was observed in most lakes, reaching values never observed during the course of this time series. This increase was not observed in the last 3 years (2017 to 2019): instead the concentration in chl.a has in many lakes. This decline was not related to changes in nutrients, nor in the amount of precipitations.

The colour values and dissolved organic carbon (DOC) concentrations in the KCVLMP lakes are naturally very high with the exception of Sunken and Tupper lakes where the water is clear. These 2 lakes are showing the best water quality rating (good) in 2019, a level slightly lower compared to 2018 (Excellent rating). It is important to note however that high values in colour and DOC does not impact the water quality rating and that these values are not a sign of poor water quality. These values reflect the input of terrestrial organic matter that enters the lakes via run-off. The low nutrient levels recorded in the lakes indicate that the organic matter loading is nutrient poor, as observed in most boreal shield lakes. As noted by members of TAC, in the Atlantic regions, high DOC and colour in lake water are associated to the presence of *Sphagnum* bogs in the watershed. Because of the strong connection between the land and the water, this report would benefit from a better understanding of the importance of wetlands in the watershed of each lakes, coupled with an assessment of annual and seasonal precipitations.

Although nutrient levels are low in most of the KCVLMP lakes, the influence of the watershed on colour or DOC indicates that local residents should continue and maintain programs aiming at reducing nutrient loading to the lakes. Although most of the WQI rating was good in 2019, it does not mean that the lakes will remain in good health if nutrient loading was to increase in the future or climate change effects to lake biological, physical and chemical processes.

The following recommendations are based on the combined results of this year and previous recent years:

1) Continue with volunteer monitoring programming for all lakes. Ensure consistency of monthly data collection events to allow detection of seasonal trends. Two new lakes were added in 2014 and additional data would be required to understand their characteristics (and year to year variations). Most of the lake WQI increased for the last two years: although this is good news, it also indicates that the value varies greatly from year to year. Some lakes were rated with a poor WQI in previous years are showing improvement this year, which calls for continued monitoring. Although the cause of such variability is not well understood, the analysis would benefit from

considering weather related variables, as well as potential long-term changes in the climate.

2) As per the recommendation from TAC in 2016, the report card includes a temporal trend of colour that was not part of previous report. In 2016, colour declined in most lakes and this finding could explain why more algal biomass was observed in the lakes, as they become clearer (allowing for additional algal production). Since 2017, the trends in colour were not as clear: in some lakes, colour came back to levels comparable to before 2016. It is recommended that variables such as colour, turbidity and Secchi depth continue to be monitored as part of this study to better understand their effects on other variables (such as chl.a).

3) As noted in previous years, with this long-term data set, the opportunity to relate long-term changes to watershed characteristics is evident. This year, maps of each lakes were added to the report and an analysis was performed to assess relationships between local development and sampled variables. Such analysis yielded no significant results. Addition work could be invested to define the limits of the watershed for each lake. This would allow to calculate the amount of precipitation in the drainage area, and then better estimate the influence of precipitations on sampled variables. Other variables are now part of the survey that will help determine the following:

   a. Number of residences on septic systems living in the watershed;

   b. The presence of beaver dams;

   c. The presence of invasive species (plants, mussels, etc.);

d. The assessment of the effect of water flow regulation in some of the lakes affected by a hydroelectric dam. Water levels from the operator would be useful to this study.

e. The use of additional parameters to chl.a as a proxy of algal biomass and speciation to understand what group of algae has an increasing growth.

f. The understanding of water quality variables would benefit from evaluating the impact of seasonal and annual precipitation and run-off amounts. Depending on how much precipitation each watershed receives, an increase in nutrient and contaminants in lake water may be observed during wet periods. Dry periods may cause an increase in biological activity within the lake water column. Characterizing wet and dry years could help refine the findings for each lake.

4) Although not observed in 2017 and 2018, chl.a concentration, and for some of the lakes, to a lesser extend TN concentration are the main variable showing a significant increase in recent years, causing lower values of the WQI. We recommend investigating the type of algae that may support this increase. In particular, it would be useful to know if there is a relative increase in green algae versus cyanobacteria. This question could be answered by using tools and methods that allow for the distinction between various algal groups. For example, a fluoroprobe is able to evaluate the contribution of different algal groups due to differences in algal pigments. Another alternative would be to apply a taxonomic approach to identify the

algal species. A field approach (using a probe) would likely be the most cost-effective measure.

An alternative approach would consist in recording algal observations which is now part of the survey distributed in 2019.

5) We suggest continuing the application of a modified WQI to assess water quality. DOC, colour and Secchi depth should not be included in the calculation, as indicated in this report. As suggested by TAC, the report may benefit from less emphasis on WQI rating and more effort could be invested in evaluating the effect of climate and watershed characteristics on observed water quality.

6) The frequency of sampling events could be increased to capture a minimum of 10 samples per season (biweekly collections) for each monitored lake for improved analysis of sampled parameters if feasible, and pending suitable budgetary support. The rational for such frequency is supported by the high turn-over of the algal community, which is typically completely renewed every 10 to 15 days in boreal lakes. Additionally, averages would be more indicative of the state of the lakes and less skewed by outliers. At a minimum, samples could be taken when volunteers report something unusual in the survey.

7) Despite a weak relationship between nutrients and chl.a reported in this study, , significant increase in lake productivity and chl.a levels would be expected if additional nutrients were added to the watershed. Therefore, nutrient control and reduction strategies are recommended to maintain good water quality and protection of desired water uses. Communities in the watersheds of study lakes are encouraged to continue

to use best practices and reduce/ limit nutrient releases from all sources to protect lake water quality.

8) The Municipality is encouraged to continue to link this lake monitoring program with land use planning activities and to consider supporting watershed management approaches to help maintaining and promote the health of the lakes.

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