KINGS COUNTY

LAKE MONITORING PROGRAM

2017 SEASON

Municipality of the County of Kings

Results presented to TAC in November 2018.

PREPARED AND PRESENTED TO THE TAC BY

Jérôme Marty, PhD

Freshwater ecologist.

EXCECUTIVE SUMMARY

This field season marked the 21th year of the Kings County Lake Monitoring Program. The long-term monitoring program of the Kings County lakes has a unique value as it allows assessing changes associated with global (climate) and regional changes (watershed scale) that would not be detected using only a few years of data. The dataset collected used in this study is also among the longest ever reported for a citizen-based program in Canada.

This report summarizes the findings on 2017 data and provides a comparison with long-term trends to assess if the lakes are in a stable state or in a state of transition toward a new ecological condition. The main goal of the analyses is to provide an overview of the current health of the lakes by comparing water quality index values using a standardize tool developed by the CCME.

The analysis of 2017 water quality data on the Kings County lakes showed that nutrient (total phosphorus and total nitrogen) levels in all the lakes remain most of the time below guideline values. In the recent years, an increase in productivity was observed: in 2015 and 2016, the concentration in chl.a increased to values never observed before. In 2017, this trend was not maintained and the concentration in Chl. a declined in most of the lakes. In the past years, no relationship between nutrient levels 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 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 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. 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 2017, 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.

Table of Contents

1 Introduction 10
2 Methodology 18
2.1 Parameters Measured..22
2.1.1 Total Phosphorus, chl.a, Secchi Depth, Total Nitrogen 22
2.1.2 Dissolved Organic Carbon 23
2.1.3 pH and Alkalinity 24
2.1.4 Turbidity and Colour 24
2.1.5 Conductivity 25
2.1.6 Water Temperature 25
2.2 Establishing Water Quality Objectives 26
2.2.1 Phosphorus...27
2.2.2 Chl.a...28
2.2.3 Secchi Depth, pH and Colour 29
2.2.4 Total Nitrogen...29
2.2.5 Dissolved Organic Carbon 29
2.2.6 Turbidity...30
2.3 Water Quality Index..30
2.4 Quality Assurance / Quality Control...31
3 Results..32
3.1 Lake George 33
3.2 Loon Lake...37
3.3 Aylesford Lake..41
3.4 Gaspereau Lake..45
3.5 Murphy Lake...48
3.6 Little River Lake..54
3.7 Black River Lake 58
3.8 Lumsden Pond 62
3.9 Hardwood Lake 66
3.10 Sunken Lake..70
3.11 Tupper Lake...75

3.12 Lake Torment 79
3.13 Armstrong Lake 83
4 Conclusions and Recommendations 87
5 References 93

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
- Andrew Sinclair – Nova Scotia Environment
- Wesley White – Saint Mary's University
- Anne Muecke – Griffiths Muecke Associates, Citizen Member
- Joe Kerekes – Scientist Emeritus, Environment Canada
- Reg Newell – Nova Scotia Department of Natural Resources
- Drew Peck – Citizen Member

This program would not be successful without its volunteers. The volunteers who sampled the lakes between 1999 and 2017 are as follows:

Mike Armstrong
Jim Gray
Andy Bryski
Terry Bryski
Susan Bryski
Delmar Jordan
Kurt Arsenault
Dave Sheehan
Kelly Sheehan
Pamela Zwicker
Paul Devries
Gloria Armstrong

Arnold Forsythe
Barry Davidson
Michael Lowe
Marion Schlaich
Mike Ryan
Mark Raymond
Gary Weisner
Wendy Weisner
Ray Cote
Gary Henderson
Bob Pearce
Carl Kent
Vivian Kent

Ben Raymond
Zack Raymond
Drew Peck
Warren Peck
Patti-Dexter Peck
Bob Church
Terry Church
Mark Richardson
Rayden Richardson
Ken Smiley
Mary Claire Smiley
Own Smiley
Denise Young

1 Introduction

The Kings County Lake Monitoring Program is an initiative begun by the Municipality of the County of Kings in 1997. It was started based on 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. The data 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 2017 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 2017 is presented in Table 1-1 and Figure 1-1.

The program lakes are all within the boundaries of Kings County and are located in the Gaspereau River watershed, with the exceptions of Lake Tupper, which falls within the Cornwallis Watershed and Hardwood, Torment, and Armstrong lakes, which fall within the LaHave River watershed.

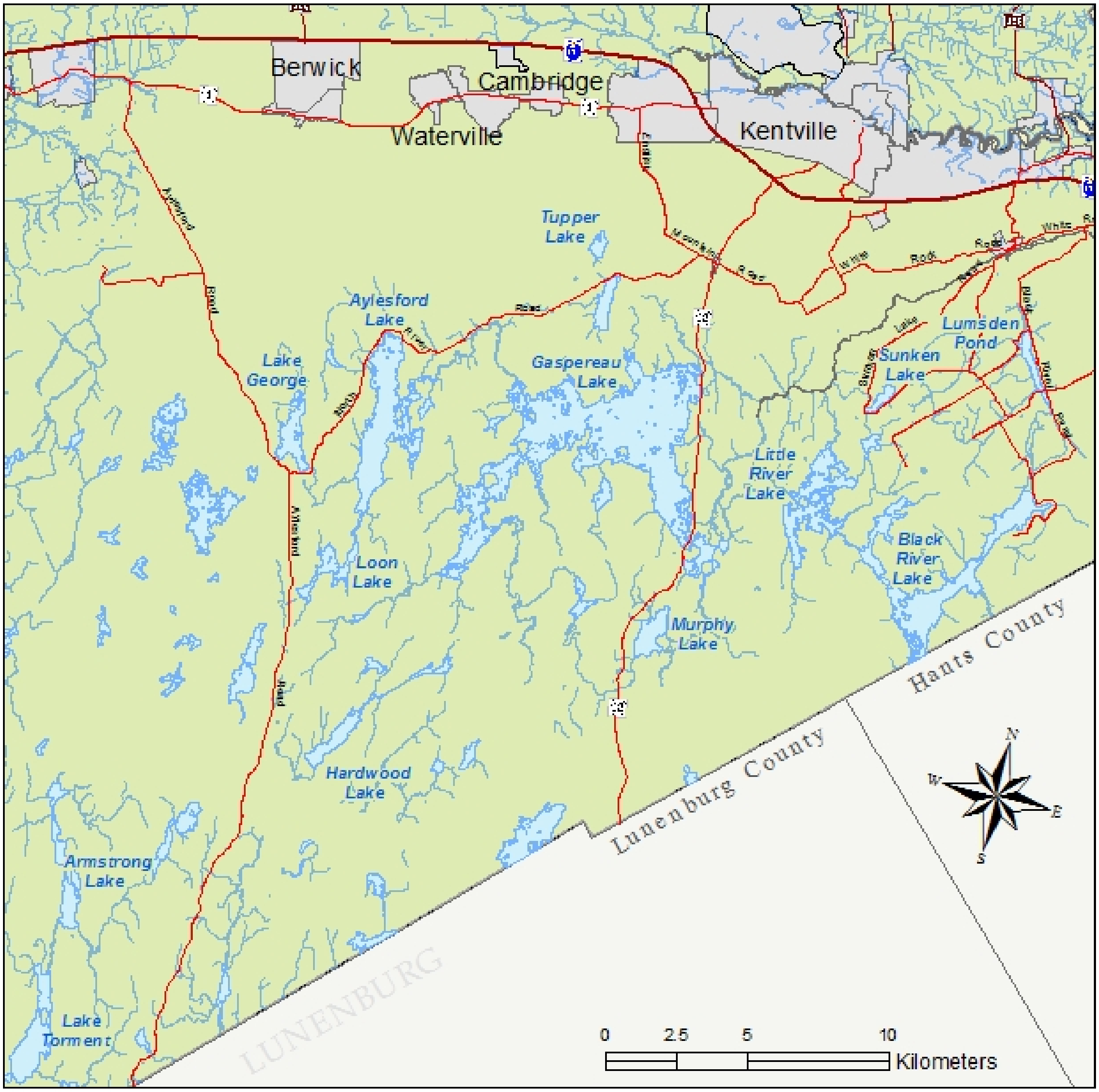


FIGURE 1-1 LAKES OF THE KINGS COUNTY LAKE MONITORING PROGRAM (SOURCE: MUNICIPALITY OF THE COUNTY OF KINGS)

All of the lakes are located 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).

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.

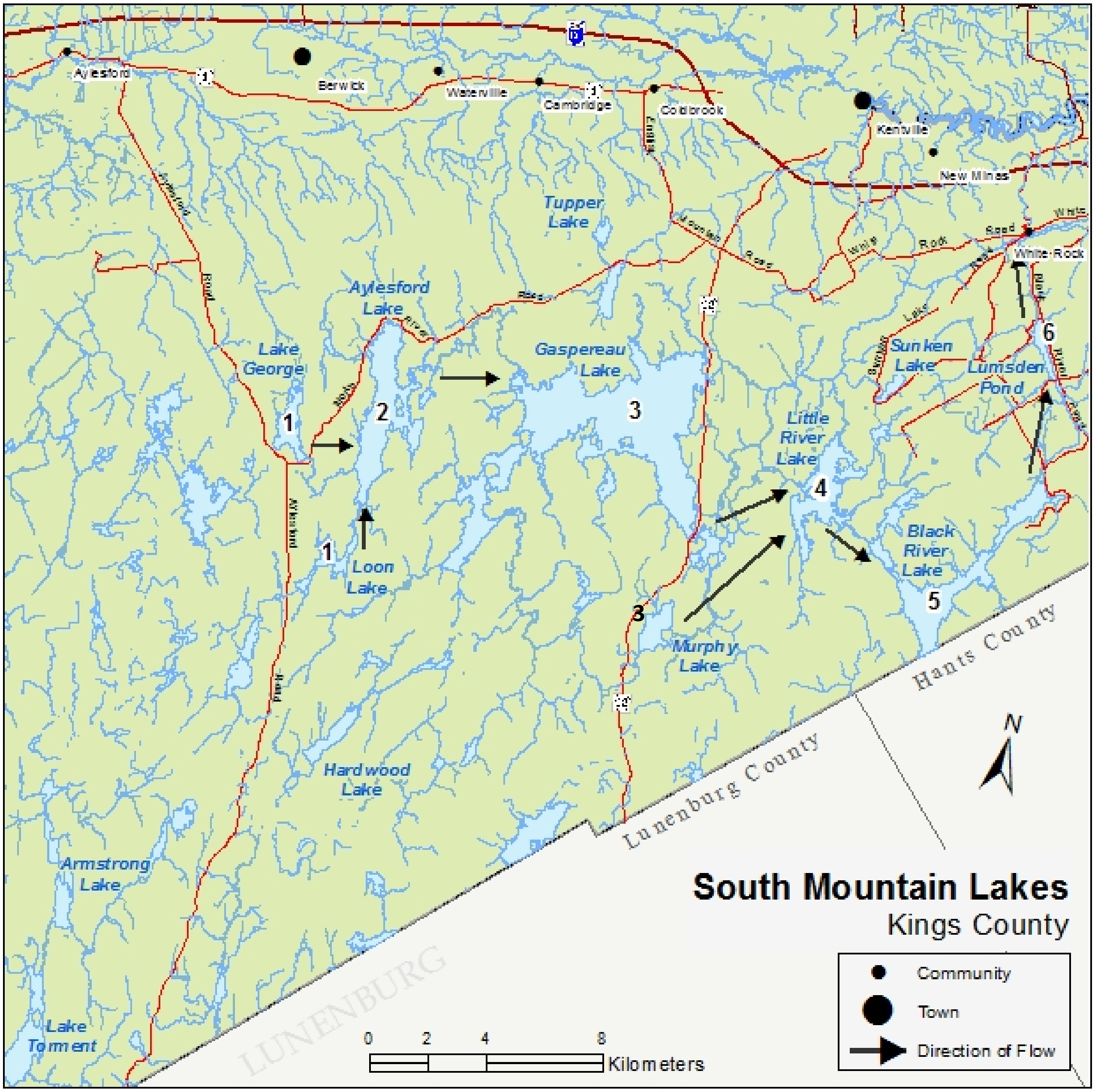


FIGURE 1-2 DRAINAGE MAP OF THE AYLESFORD LAKES

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 2017 following yearly review comments from the Technical Advisory Committee (TAC).

Thirteen lakes were sampled during the 2017 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 2017 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 due to high content in bicarbonates will have a high conductivity compared to soft waters. 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 2017 averages for each parameter were compared against the historical average from 1997 to 2016 (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 from 1993, and 1997 to 2017 for each lake were calculated. 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 2017) (µg/L)	Total Phosphorus Objective (µg/L)
George	10	13.9
Loon	12	18.1
Aylesford	10	15.6
Gaspereau	12	17.8
Murphy	12	17.4
Little River	14	**20 (21.6)**
Black River	11	16.4
Lumsden	12.5	18.9
Hardwood	13	19.1
Sunken	9.4	18.9
Tupper	11.4	16.8
Torment	17	**20 (25.4)**
Armstrong	18	**20 (27)**

** **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 (2.5 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, we excluded variables related to humic content of the water 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 2017 data as well as an interpretation and recommendation for lakes showing a poor rating in water quality.

The Water Quality index (WQI) for 2017 developed by the CCME was calculated using the following variables: chl.a concentrations, 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.

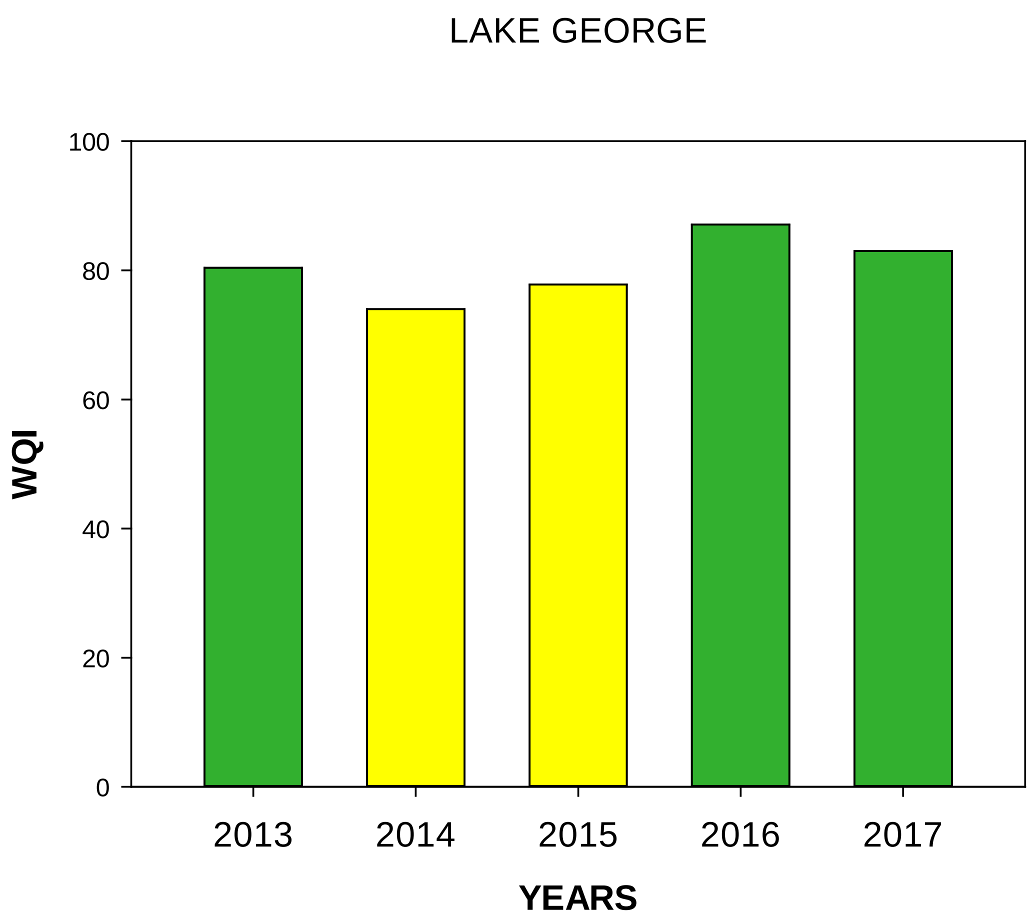
The following section provides includes an interpretation of the data collected for each lake sampled as part of this study including and illustrated with a summary table of all water quality parameters, histograms of the trends in WQI between 2013 to 2017, histograms of the concentration in chl.a, TP and estimates of colour.

3.1 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. 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 83, corresponding to a good water quality rating. This value is similar to that observed in 2016 (2016: 87; 2017:75). Among the lakes samples in this study, Lake George shows consistent results between years, with a high WQI value.



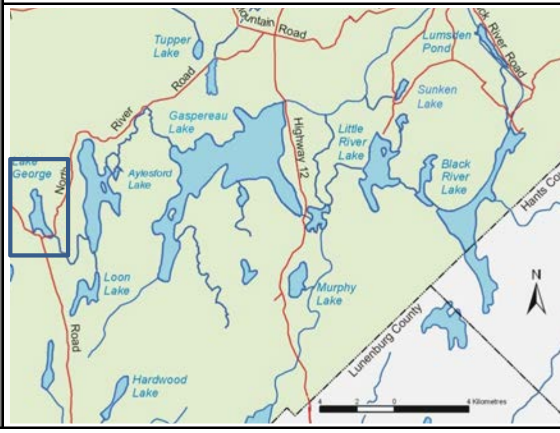
Summary report card:

In 2017, there was only one exceedance observed among all sampled variables in Lake George: Chl. a concentration peaked at 3.1 µg/L. No other variable entered in the WQI exceeded guideline values.

There was a positive trend in Chl. a (+0.1 µg/L/Yr) and in total nitrogen (+22 µg/L/Yr). This increase in TN is the highest among all lakes in 2017 in this study. The mean value for TP is very low in Lake George (TP: 6.7 µg/L) which is a concentration representative of oligotrophic lakes.

LAKE GEORGE

83



Drainage Order = 1

Elevation = 231 m

Lake Area = 153 ha

Max Depth = 9.5 m

1997-2017 Trends:

Chl.a = 0.1 µg/L/yr
TP= n.s.
TN =22 µg/L/yr
WQI % Change = -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	13,9	2,5	3.5-5.3	6.2-6.7	2.9-4.1	17-31	350	1,3
2017 average	6,7	2,2	4,2	6,6	**3**	20,9	185	0,8
2017 (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)
1997-2016 average	9,61	2,42	4,39	6,51	3,56	24,52	164	0,71

*** Trends for WQI are relative to 2016 only.**

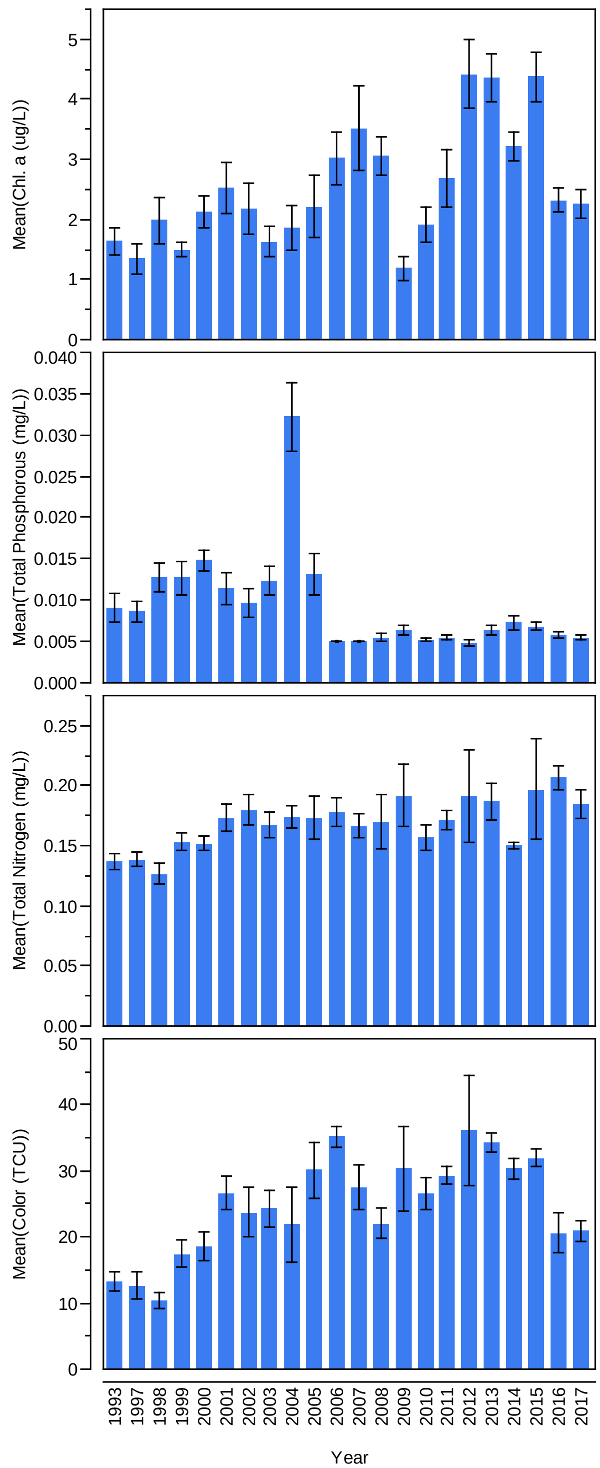
Numbers in red indicate exceedances of the criteria. n.s. indicates non significant result.

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

Long-term trends:

In both 2016 and 2017, the concentration in Chl. a decreased by almost 50% compared to 2012-2015. The variation in Chl. a does not follow the trends for TP that remained close or below 5 µg/L for the last 12 years.

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

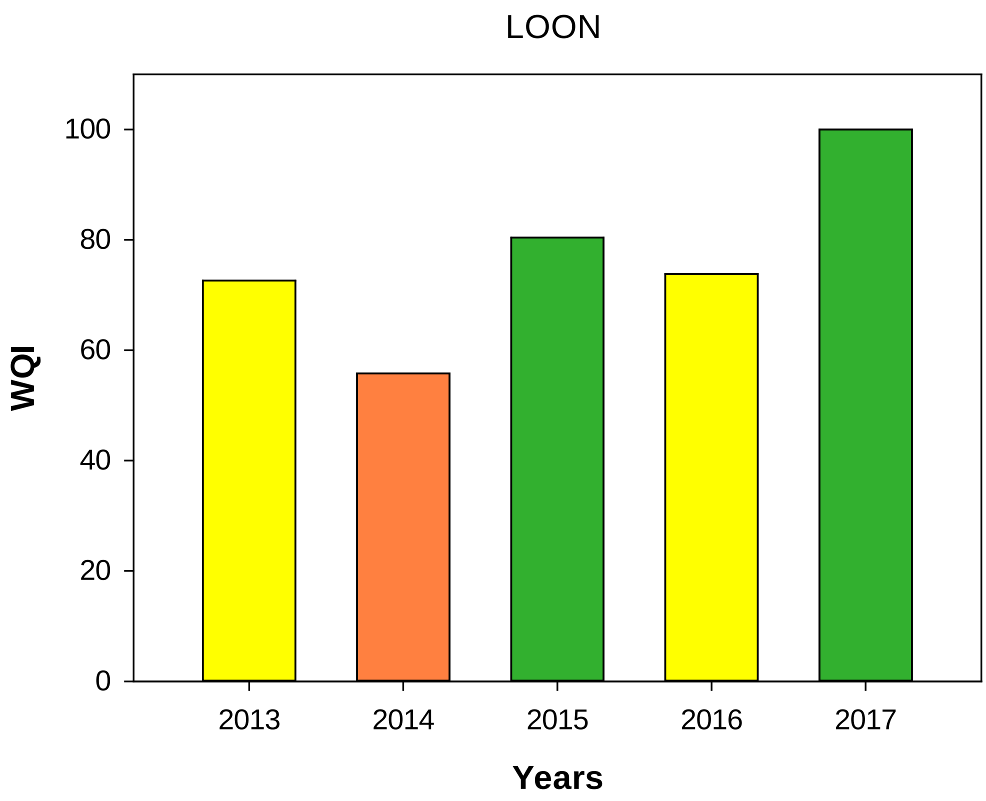


3.2 Loon Lake

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 and some residential activities in the southern section of the lake.

Water Quality Index (WQI):

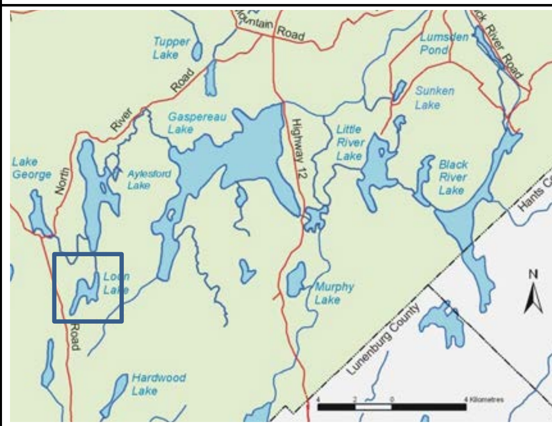
The Water Quality Index value for Lake Loon in 2017 reached 100, an excellent water quality rating. This value is the result of no data exceeding guideline values. In 2017, there was a significant increase in WQI compared to 2016 (from 74 to 100).



Summary report card:

No exceedance was reported for any of the parameters used to calculate the WQI in 2017. Statistically, a marginal trend in chl.a is reported (0.1µg/L/Yr), as well as a small increase in TN (2.4 µg/L/Yr). No trend was observed for TP.

LOON LAKE



100

Drainage Order = 1

Elevation = ~206 m

Lake Area = ~90 ha

Max Depth = 8.1 m

1997-2017 Trends:

Chl.a = 0.1 µg/L/yr

TP= n.s.

TN = 2.4 µg/L/yr

WQI % Change = 36% *

	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	4.4-6.5	6-6.4	2.1-2.8	25-44	350	1,3
2017 average	10	1,7	5,3	6,3	2,7	35,3	196	0,9
2017 (min - max)	(10 - 10)	(1.2-2.4)	(5-5.7)	(6.2-6.4)	(2.5-**2.9**)	(26.2-40.4)	(190-200)	(0.6-1.2)
1997-2016 average	12,20	**3,40**	5,50	6,20	2,50	35,50	191	1,03

*** Trends for WQI are relative to 2016 only.**

Numbers in red indicate exceedances of the criteria. n.s. indicates non significant result.

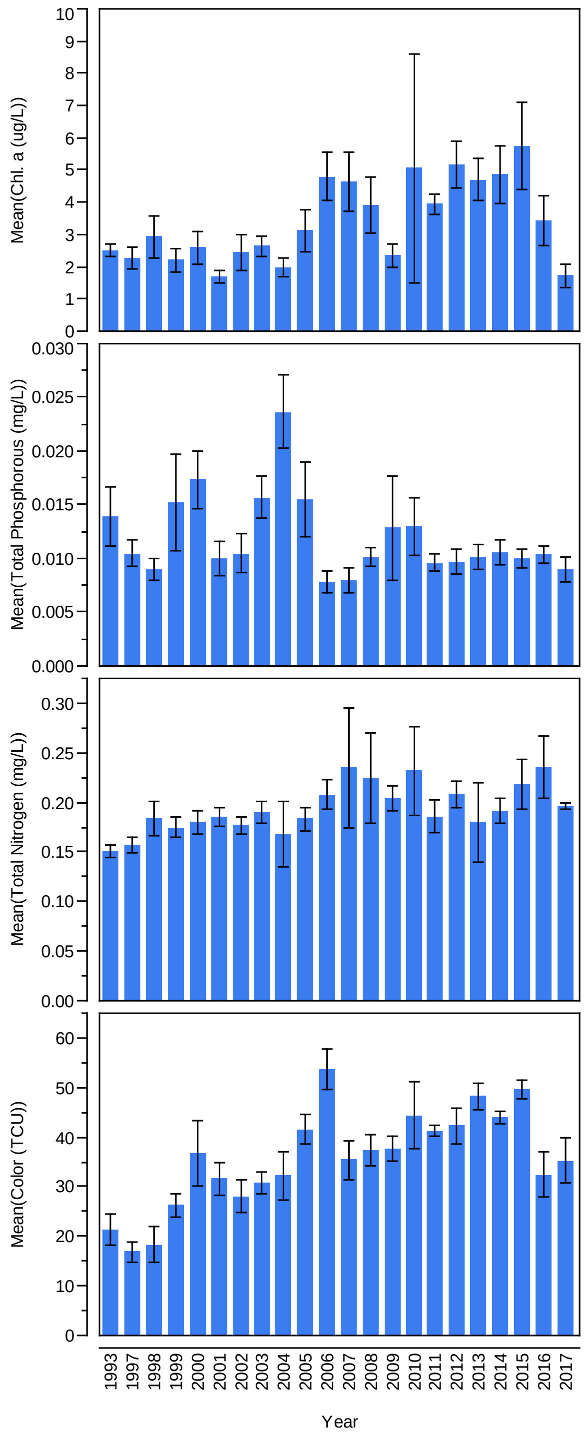
0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Long-term trends:

The long-term trends for Lake Loon are showing a decline in Chl.a in the last 3 years, despite nutrient levels remaining at constant level. The concentrations in TP are close to 10 µg/L for the last 7 years.

The values in colour declined in both 2016 and 2017 after a constant increase between 1993 to 2015.

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

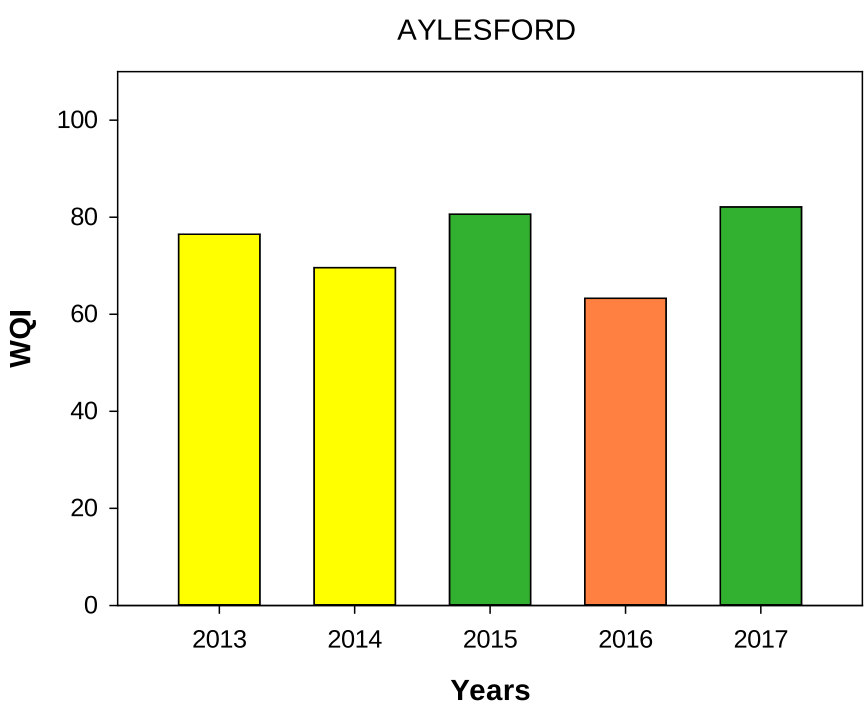


3.3 Aylesford Lake

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 and has some residential development mostly situated at north and south ends.

Water Quality Index (WQI):

The Water Quality Index for Lakes Aylesford was 82.1 in 2017, which is a classified as good. This is a 30% increase compared to 2016 and a similar value to that measured in 2015 (from 63 to 82). The only variable that showed exceedances above guideline value was Chl. a concentration.



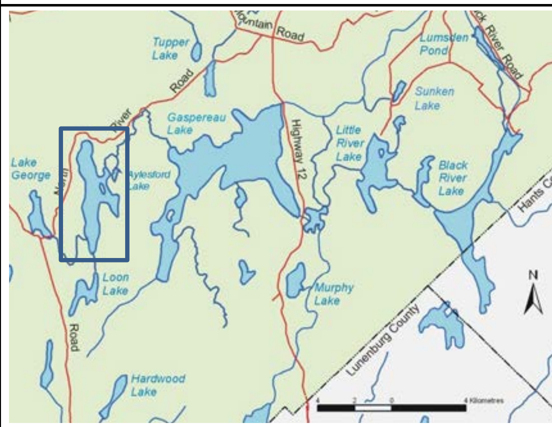
Summary report card:

Exceedances were observed in chl.a concentration, causing the mean value for 2017 to be slightly above guidelines (2017: 2.6 µg/L; guideline: 2.5 µg/L). This result was caused by high concentrations reaching 4.7 µg/L. All other variables were below guideline levels.

A weak increase in chl.a was observed over time (+0.1 µg/L/Yr) and there was no trend observed for TP and TN over time.

AYLESFORD LAKE

82,1



Drainage Order = 2

Elevation = 216 m

Lake Area = 532 ha

Max Depth = 12 m

1997-2017 Trends:

Chl.a = 0.1 µg/L/yr
TP= n.s.
TN = n.s.
WQI % Change = 30% *

	Parameter							
	TP (µg/L)	**Chl A (mg/m^3)**	**DOC (mg/L)**	**pH**	**Secchi Depth (m)**	**Colour (TCU)**	**TN (µg/L)**	**Turbidity (NTU)**
Guideline	15,6	2,5	4.4-6.6	6-6.3	2.2-3.2	24-45	350	1,3
2017 average	8,30	**2,60**	5,30	6,10	2,50	33,30	193	0,60
2017 (min - max)	(3-10)	(1.4-**4.7**)	(5.2-5.4)	(6 - 6.3)	(**1.7-3.9**)	(26.7-40)	(170-220)	(0.45-0.7)
1997-2016 average	10,50	**3,00**	5,50	6,20	2,70	33,90	178	0,66

*** Trends for WQI are relative to 2016 only.**

Numbers in red indicate exceedances of the criteria. n.s. indicates non significant result.

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

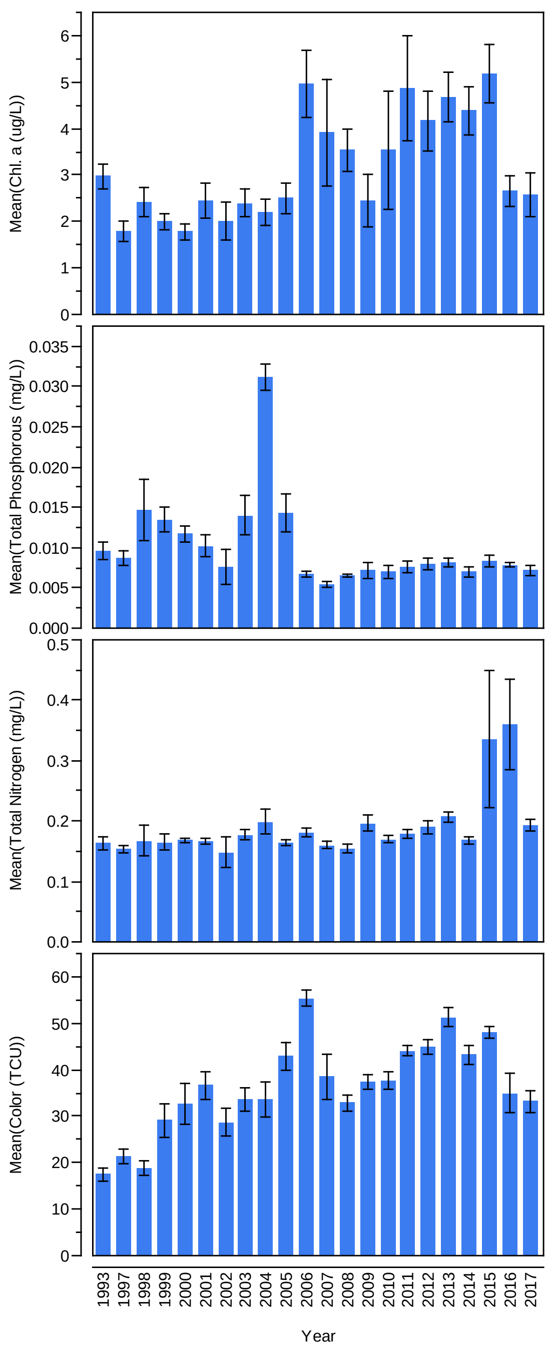
Long-term trends:

In 2017, the concentration in chl.a in lake Aylesford was similar to 2016 when a sharp decline was observed (almost 50%). The recent variation in chl.a was not related to changes in TP concentrations which have remain similar for the last 12 years, and below 10 µg/L.

The concentrations in TN peaked in 2015 and 2016, to levels above guidelines but have returned in 2017 to more frequent levels (less than 200 µg/L).

Consistent with several other lakes in the area, the mean value for colour has declined in the last 2 years, with similar values observed for both 2016 and 2017.

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

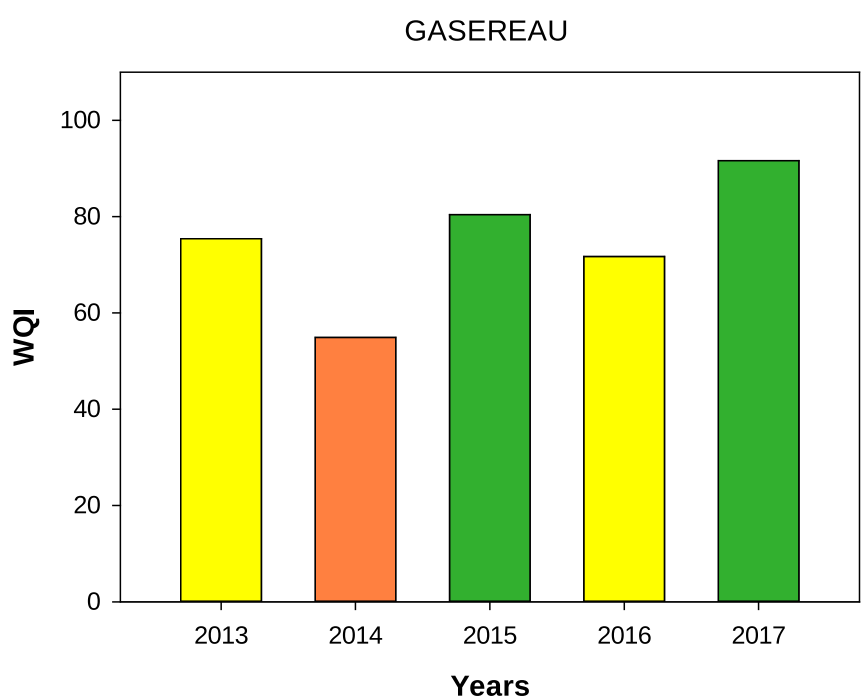


3.4 Gaspereau Lake

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):

The Water Quality Index for Gaspereau Lake was 91.6 in 2017- a good rating. This value is 28% higher compared to that measured in 2016 (2016: 72; 2017:91). Only chl.a concentration showed an exceedance compared to guideline value (max value: 2.8 µg/L; Guideline: 2.5 µg/L).

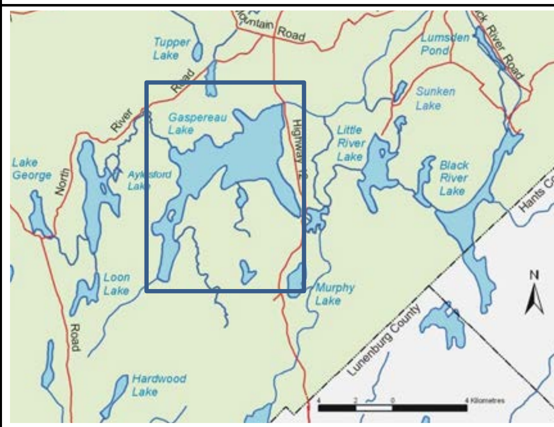


Summary report card:

All variables excepted one were below guidelines values in 2017 for Lake Gaspereau. As mentioned above, Chl. a concentration reached a high value of 2.8 (although the mean value for 2017 (1.6 µg/L) was well below guideline).

Consistent with previous years, there was no trends (increase or decrease) over time in chl.a, TP and TN concentrations.

GASPEREAU LAKE



91,6

Drainage Order = 3

Elevation = 175 m

Lake Area = 2200 ha

Max Depth = 10.9 m

1997-2017 Trends:

Chl.a = n.s.
TP= n.s.
TN = n.s.
WQI % Change =28% *

	Parameter							
	TP (µg/L)	Chl A (mg/m^3)	DOC (mg/L)	pH	Secchi Depth (m)	Colour (TCU)	TN (µg/L)	Turbidity (NTU)
Guideline	17,8	2,5	4.6-6.9	6.1-6.4	1.7-2.2	35-48	350	1,3
2017 average	10,00	1,60	4,90	6,30	**2,60**	30,80	208	0,83
2017 (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)
1997-2016 average	12,00	**3,60**	5,80	6,30	1,96	41,50	228	0,98

*** Trends for WQI are relative to 2016 only.**
Numbers in red indicate exceedances of the criteria. n.s. indicates non significant result.

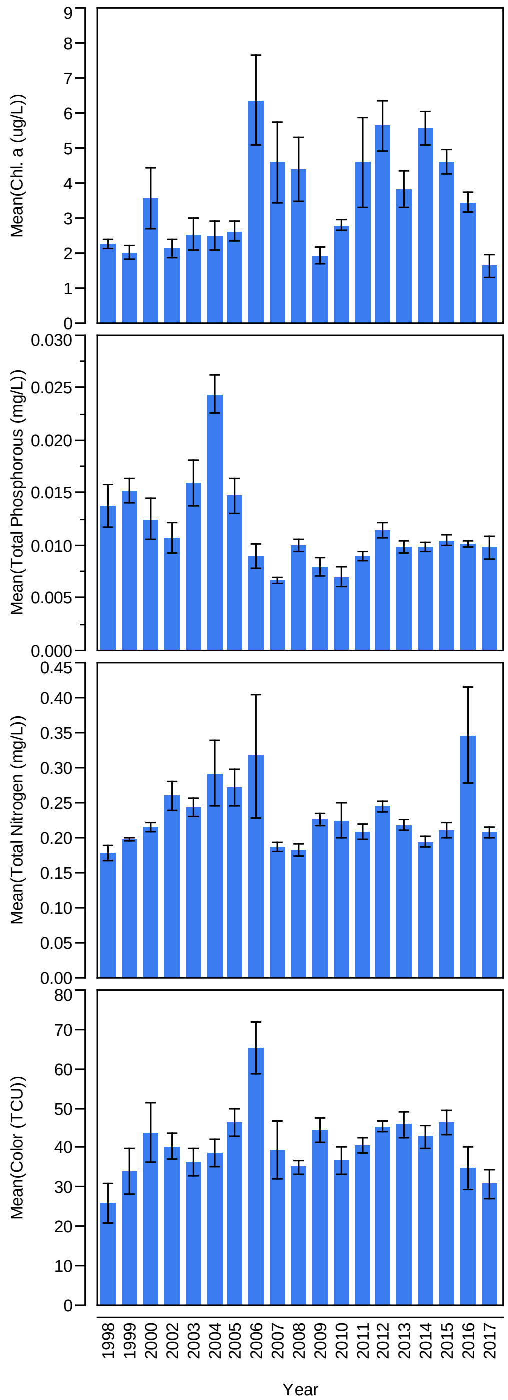
0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Long-term trends:

The increase in WQI value in 2017 compared to 2016 was explained by a decline in 2 variables: Chl.a and TN concentrations. TP levels remained very homogenous over the last 12 years and are not able to explain the variation in chl.a concentration.

Similar to other lakes in the region, the colour of Lake Gaspereau also declined in 2017, and this decline has been observed for the last 3 years.

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

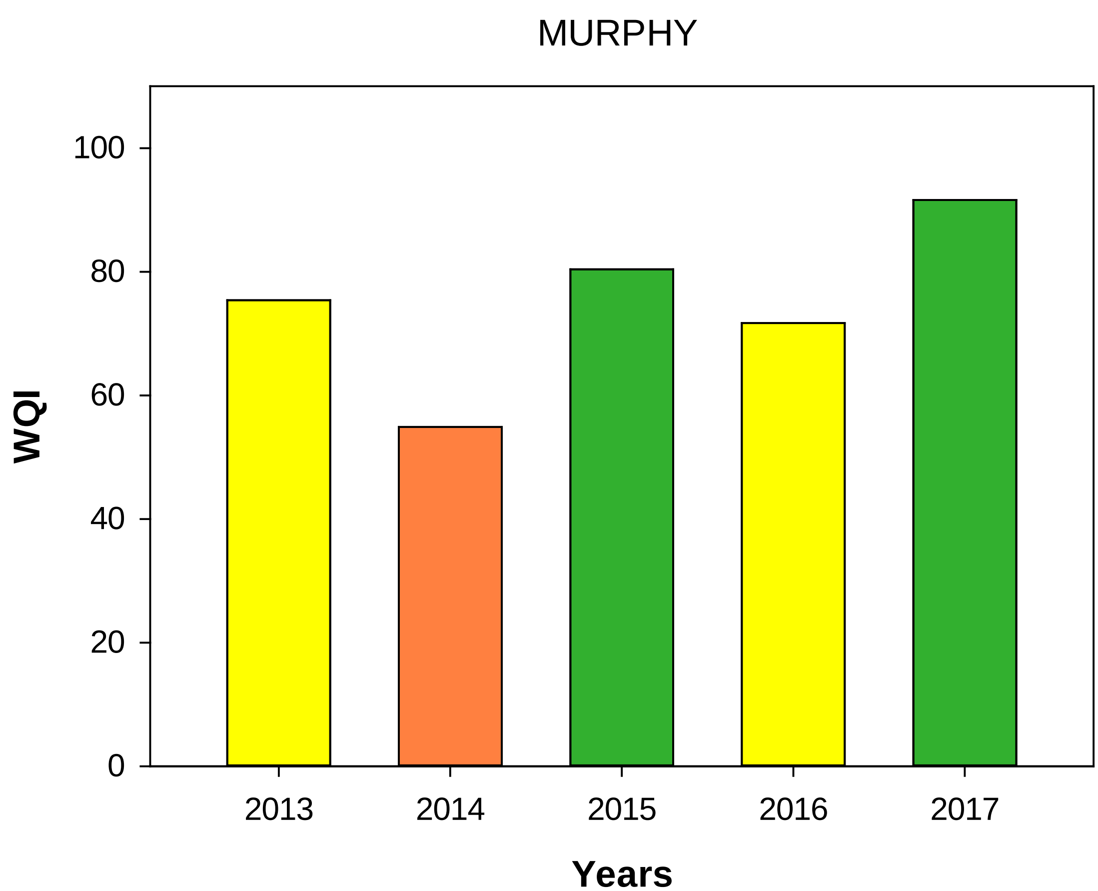


3.5 Murphy Lake

Murphy Lake is a fairly small (121 ha), and shallow (max depth: 6.8 m) lake. Its watershed is surrounded by a forested area and residential development can be observed in the northern and southern sections of the lake.

Water Quality Index (WQI):

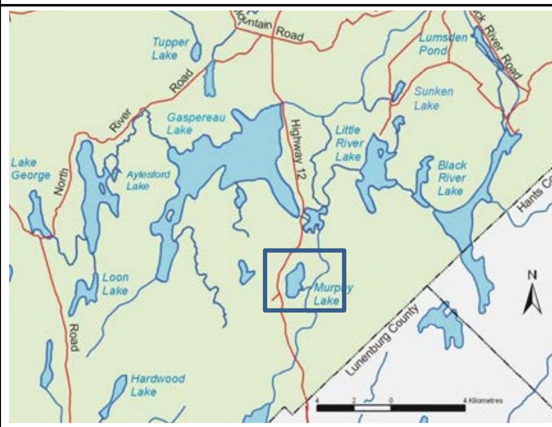
The Water Quality Index of Murphy Lake was 82.5 in 2017, which is rated as a good water quality. This rating has increased compared to 2016 (2016:62; 2017: 82). The value observed of 2017 is the highest for the last five years. It is explained by a low frequency of values above guidelines: only Chl. a concentration and turbidity showed exceedances.



Summary report card:

In 2017, Lake Murphy showed no exceedance in mean values for any of the measured parameters. The lake has low phosphorous concentrations. A small increase in chl.a and TN concentrations was observed over time (+0.1 µg/L/Yr and +3.2 µg/L/Yr respectively). The mean concentration in chl.a for 2017 is close to that of the guideline but ranges from low values (close to detection limits, 1µg/L) to higher values indicative of higher production (5.1 µg/L). These high values in chl.a are consistent with high turbidity values, also above guidelines at this sampling date.

MURPHY LAKE



82,5

Drainage Order = 3

Elevation = 207 m

Lake Area = 121 ha

Max Depth = 6.8 m

1997-2017 Trends:

Chl.a = 0.1 µg/L/yr

TP= n.s.

TN = 3.2 µg/L/yr

WQI % Change= 33 %*

	Parameter							
	TP (µg/L)	**Chl A (mg/m^3)**	**DOC (mg/L)**	**pH**	**Secchi Depth (m)**	**Colour (TCU)**	**TN (µg/L)**	**Turbidity (NTU)**
Guideline	17,4	2,5	5.0-7.5	6.5-6.8	1.7-2.3	25-42	350	1,3
2017 average	10,00	2,40	6,10	6,80	1,70	34,10	263	1,20
2017 (min - max)	(10 - 10)	(1.0-5.1)	(5.5-6.5)	(6.7-6.9)	(1.2-2.1)	(23-49.6)	(250-290)	(0.9-1.6)
1997-2016 average	11,70	2,30	6,20	6,70	2,00	34,10	237	1,40

*** Trends for WQI are relative to 2016 only.**

Numbers in red indicate exceedances of the criteria. n.s. indicates non significant result.

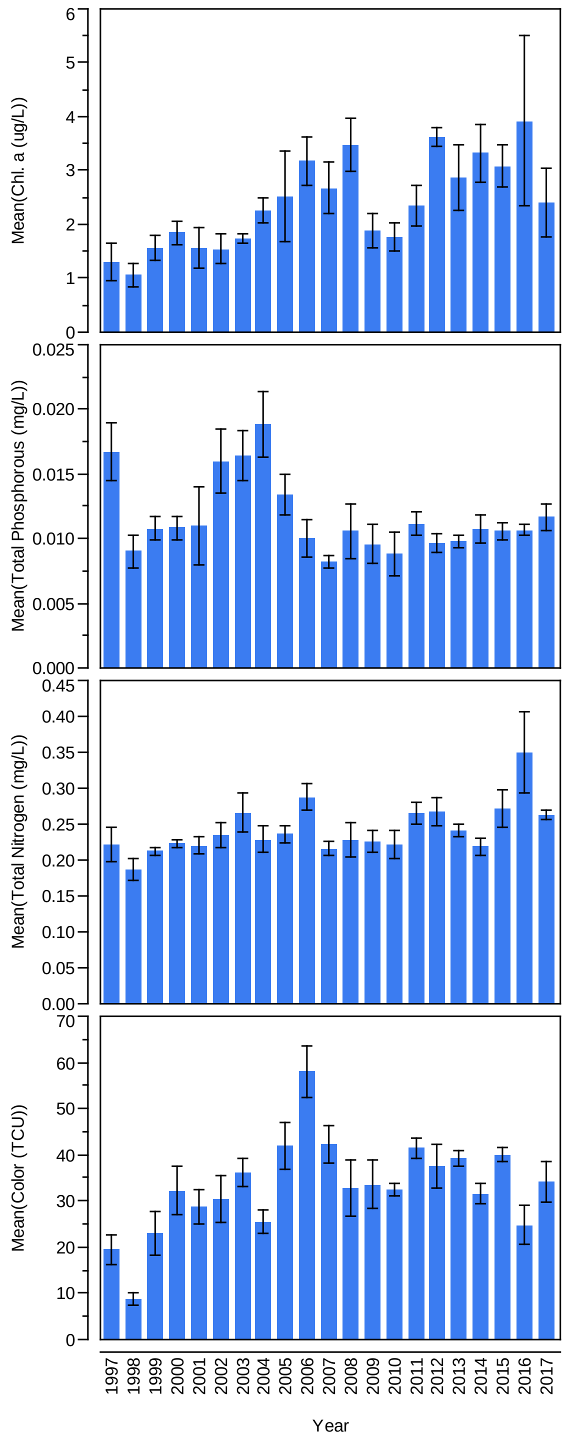
0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Long-term trends:

The long-term trends in Chl. a concentration shows that the increase observed until 2016 is not present in 2017: The mean concentration has almost dropped by 50% between 2016 and 2017. This decline is not related to a decline in TP, as it remained constant for the last 12 years. A decline in total nitrogen was observed in 2017 compared to 2016, but the trend shows that the 2016 values was much higher compared to the overall mean value.

In 2017, colour reached a value similar to that observed between 2008-2015. It is likely that clearer water in 2016 contributed to the increase in algal biomass that year.

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

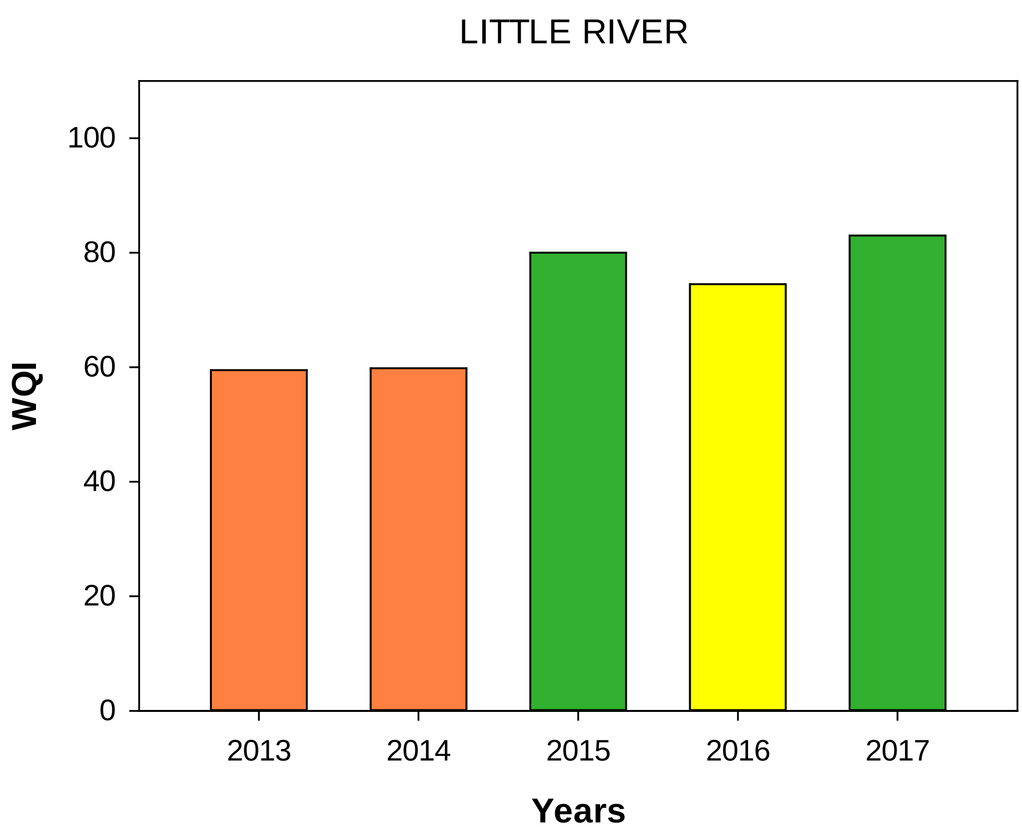


3.6 Little River Lake

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.

Water Quality Index (WQI):

The Water Quality Index for Little River Lake was 83, indicative of a good water quality. This value is slightly higher than that observed in 2016 (2016:74; 2017:83). Little River Lake water quality is similar to that observed in 2015. Similar to Murphy Lake, exceedances were observed only for 2 variables, at 2 occasions: Chl.a reached a value of 3.6 µg/L and TN reached 370 µg/L. None of the seasonal mean values exceeded the guidelines for the lake.

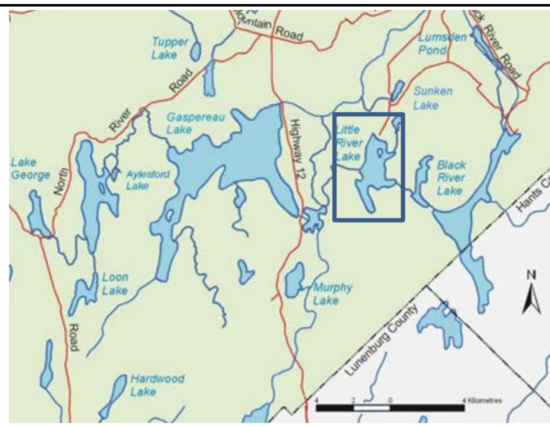


Summary report card:

The 2017 results for Little River Lake are comparable to those in Murphy Lake, with similar trends observed for Chl. a and TN.

LITTLE RIVER LAKE

83



Drainage Order = 4

Elevation = 189 m

Lake Area = 520 ha

Max Depth = 6.6 m

1997-2017 Trends:

Chl.a = 0.1 µg/L/yr
TP= n.s.
TN = 4.6 µg/L/yr
WQI % Change =11 % *

	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	5.2-7.8	6.1-6.5	1.8-2.4	43-55	350	1,3
2017 average	11,60	2,30	6,70	6,50	2,00	55,20	315	0,97
2017 (min - max)	(10 - 20)	(1.4-**3.6**)	(6.3-7.3)	(6.4 - **6.7**)	(1.7 - 2.3)	(44.3-**62.4**)	(260-**370**)	(0.7-1.3)
1997-2016 average	14,40	**3,20**	6,50	6,40	2,12	49,60	261	1,01

*** Trends for WQI are relative to 2016 only.**

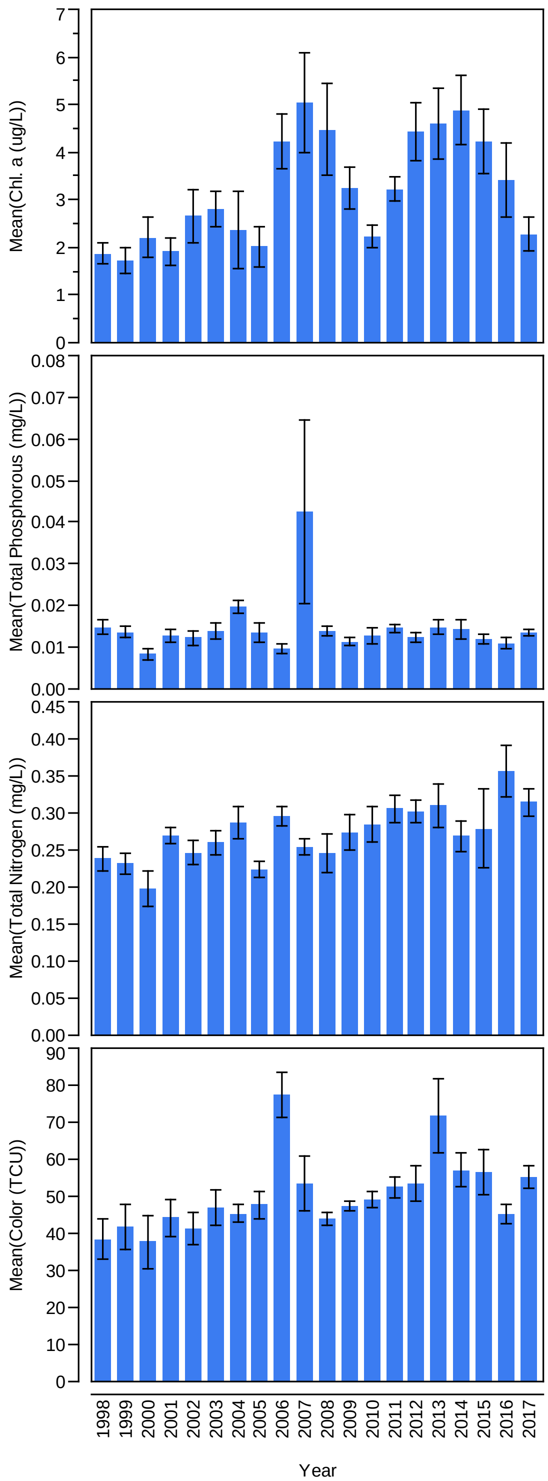
Numbers in red indicate exceedances of the criteria. n.s. indicates non significant result.

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 are showing a decline over the last 4 years (although the trend is positive since 1998). The concentration in chl.a is about half of that observed in 2014. This decline is not related to a reduction in nutrients: the concentrations in TP and TN remained similar for the last 10 years.

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

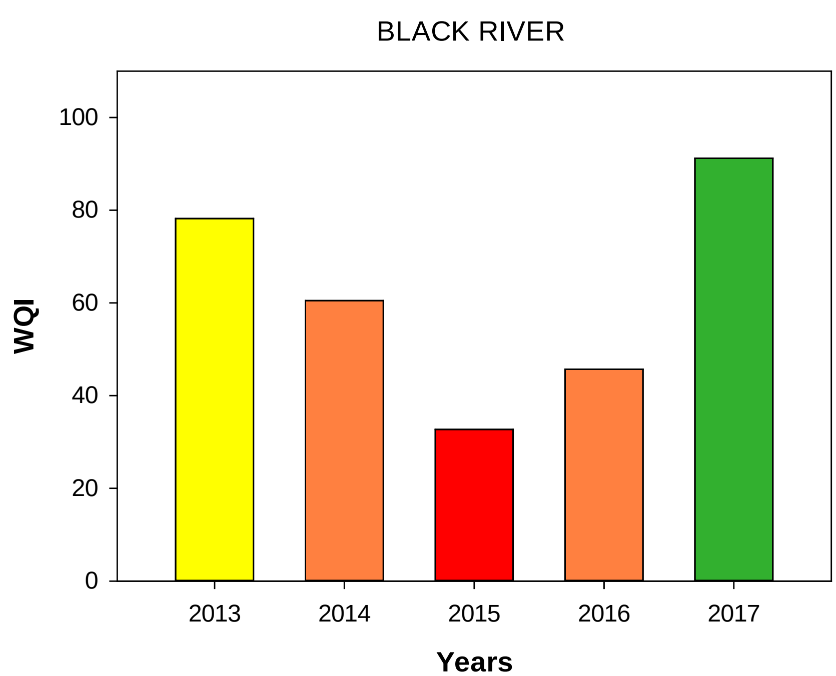


3.7 Black River Lake

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.

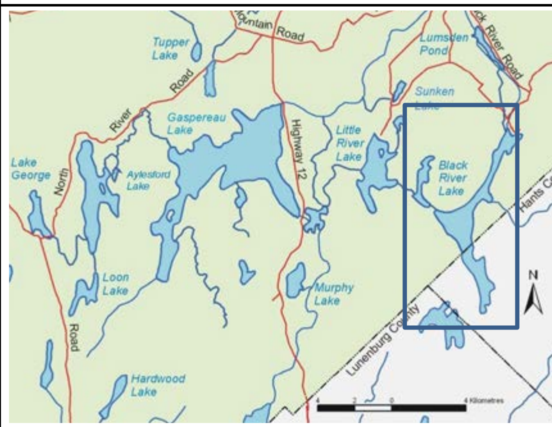
Water Quality Index (WQI):

The Water Quality Index value for Black River Lake in 2017 was 91 which is indicative of a good water quality. This value has doubled from 45 in 2016 to 91 in 2017.Overall, an improvement of the water quality has been observed in this lake for the last 3 years. One variable exceeded guideline values in 2017: Chl. a value reached 5.4 µg/L and with a mean value of 2.7 µg/L (guideline: 2.5 µg/L)



Summary report card:

There were not long-term trends in both TP and TN for Black River Lake. Only a small increase in chl.a was observed (+0.1 µg/L/Yr).



BLACK RIVER LAKE

91,2

Drainage Order = 5

Elevation = 170 m

Lake Area = 668 ha

Max Depth = 15 m

1997-2017 Trends:

Chl.a = 0.1 µg/L/yr
TP=n.s.
TN = n.s.
WQI % Change = 100 % *

	Parameter							
	TP (µg/L)	Chl A (mg/m^3)	DOC (mg/L)	pH	Secchi Depth (m)	Colour (TCU)	TN (µg/L)	Turbidity (NTU)
Guideline	16,4	2,5	5.3-8.0	6.1-6.5	1.6-2.3	44-57	350	1,3
2017 average	13,30	**2,70**	6,20	6,40	1,70	53,10	242	**1,00**
2017 (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)
1997-2016 average	10,80	**3,10**	6,60	6,27	2,00	52,90	251	1,00

*** Trends for WQI are relative to 2016 only.**

Numbers in red indicate exceedances of the criteria. n.s. indicates non significant result.

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

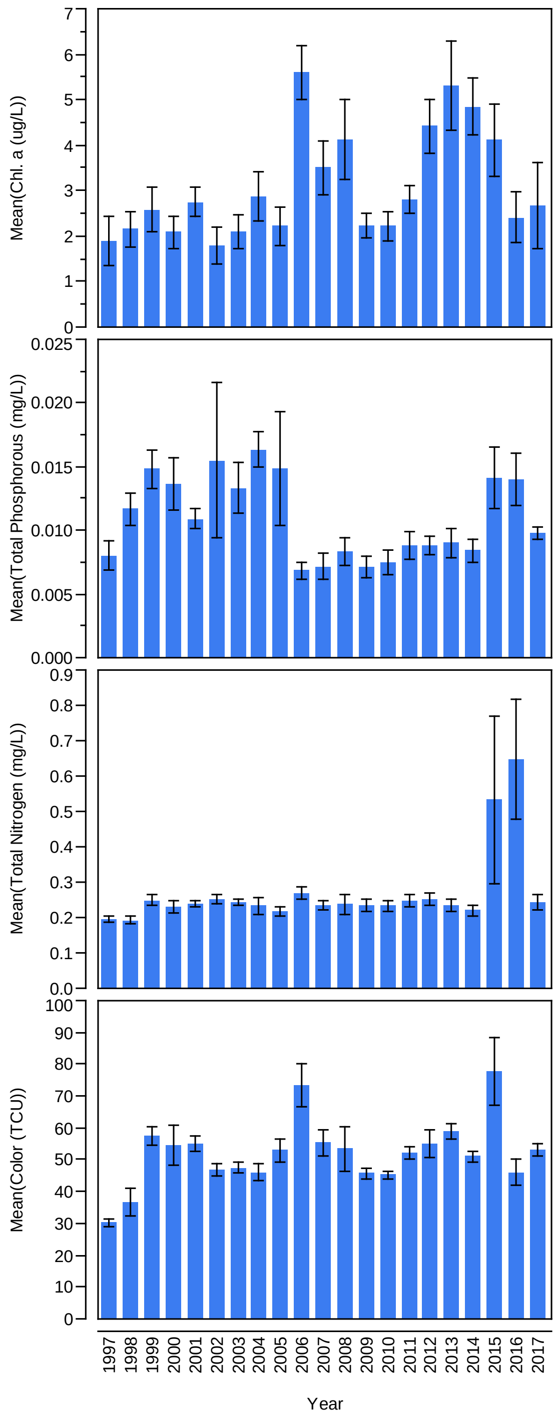
Long-term trends:

The mean concentration in chl.a declined in both 2016 and 2017 compared to 2013-2015.

The mean concentration in both TP and TN declined significantly in 2017 compared to 2015 and 2016. Interestingly, this decline was not correlated with chl.a variation.

The value for colour peaked in 2015 and has not returned to a value close to overall mean in 2017.

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

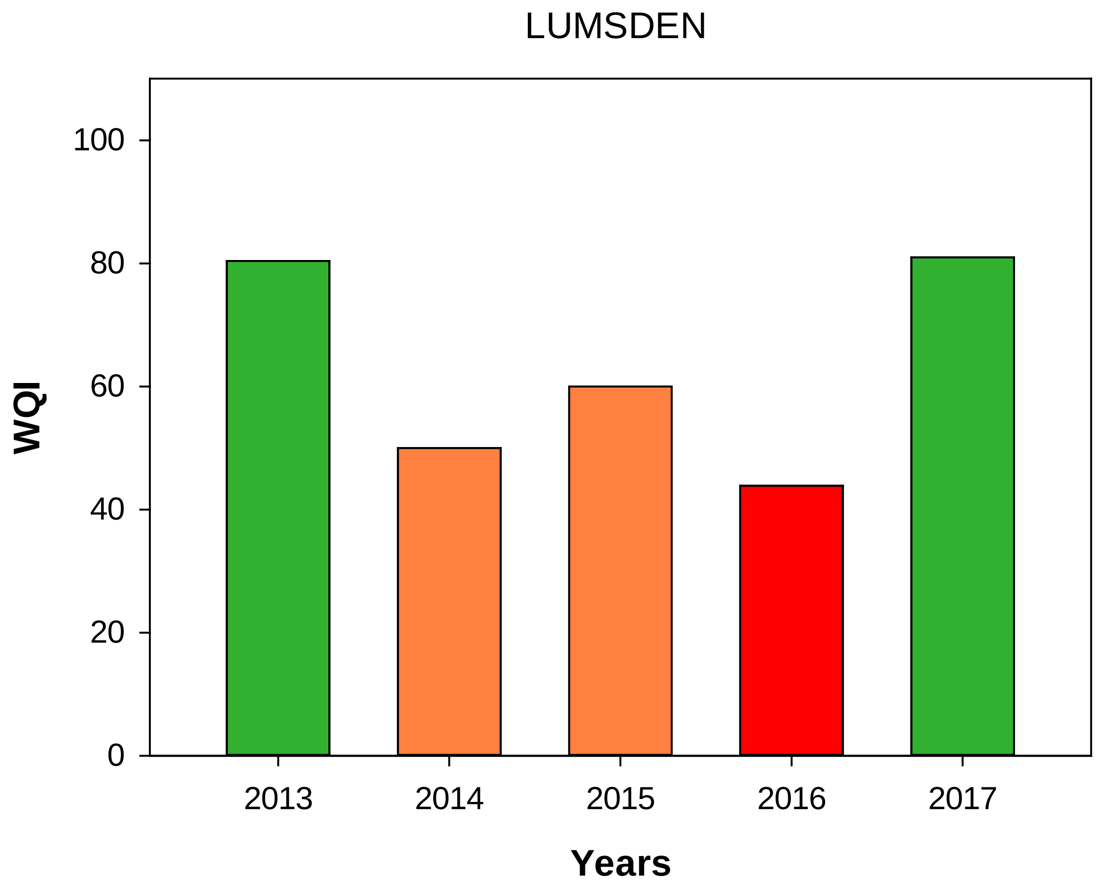


3.8 Lumsden Pond

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 and also some agriculture development in its watershed.

Water Quality Index (WQI):

The Water Quality Index for Lumsden Pond was 81 in 2017, which correspond to a good water quality rating. This rating has significantly increased compared to 2016 (2016:44; 2017:81). The rating for the lake in 2017 is similar to that measured in 2013. There were 3 variables showing some exceedances compared to guideline values: TP, chl. a and Turbidity. The mean value in chl.a remained above guideline values (mean: 3.9 µg/L; Guideline: 2.5 µg/L), although this value is heavily influence by the maximum value (max: 8.5 µg/L).

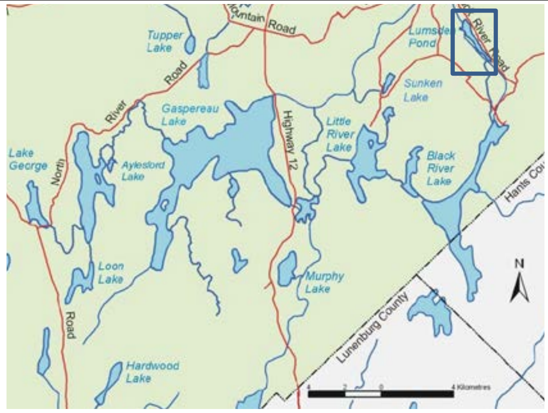


Summary report card:

In 2017, the water quality of Lumsden Pond was good but several values are indicating that this lake sees some excessive nutrient levels (max TP: 20 µg/L and max Chl.a : 8.5 µg/L). These values are typical of a mesotrophic conditions (and these conditions were observed in previous years).

Over the long-term, a significant increase in Chl. a is observed (+0.2 µg/L/Yr). No temporal trends were observed for TP and TN.

LUMSDEN POND



81

Drainage Order = 6

Elevation = 126 m

Lake Area = 88 ha

Max Depth = 19 m

1997-2017 Trends:

Chl.a = 0.2 µg/L/yr
TP= n.s.
TN = n.s.
WQI % Change = 85% *

	Parameter							
	TP (µg/L)	**Chl A (mg/m^3)**	**DOC (mg/L)**	**pH**	**Secchi Depth (m)**	**Colour (TCU)**	**TN (µg/L)**	**Turbidity (NTU)**
Guideline	18,9	2,5	5.0-7.6	6.2-6.6	1.6-2.0	40-52	350	1,3
2017 average	12,00	3,90	6,00	6,50	1,80	50,50	278	0,90
2017 (min - max)	(10-20)	(2.4-8.5)	(5.4 - 6.3)	(6.4 - 6.6)	(1.5-2.2)	(44.4-54.3)	(240-340)	(0.2-1.4)
1997-2016 average	12,50	4,40	6,30	6,42	1,85	47,00	270	1,02

*** Trends for WQI are relative to 2016 only.**
Numbers in red indicate exceedances of the criteria. n.s. indicates non significant result.

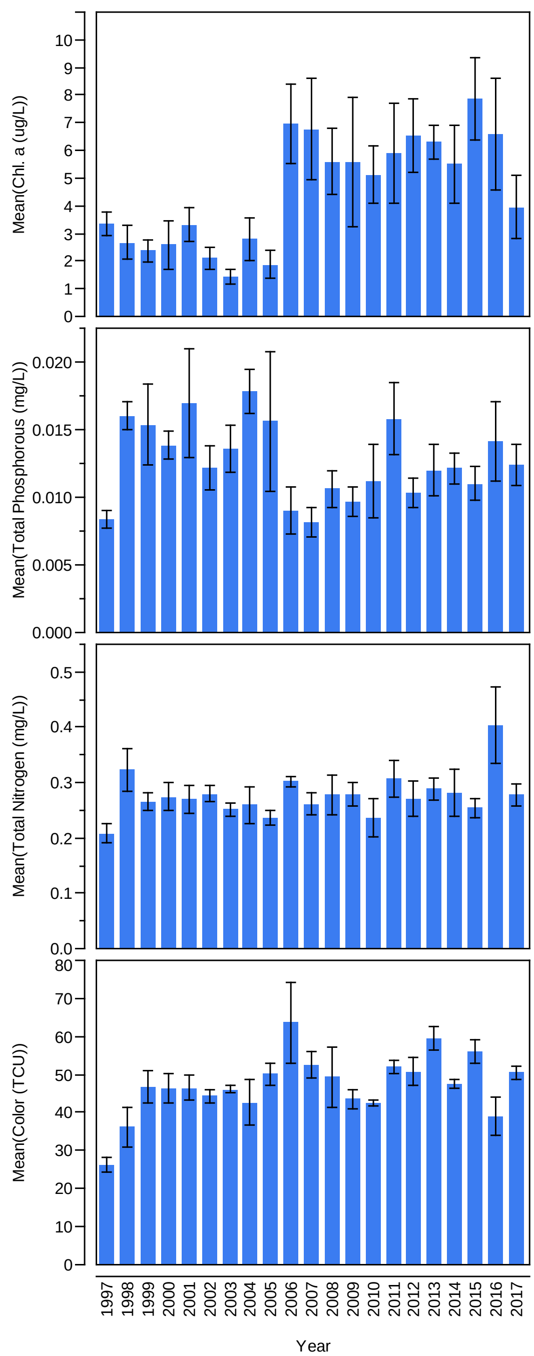
0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Long-term trends:

The histograms for Lake Lumsden are showing a decline in chl.a and TN for 2017 compared to 2016. The concentration in Chl. a significantly declined compared to the last 2 years and this explains the increase in water quality rating.

There was no significant change in TP and colour values in 2017 compared to the last 10 year.

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

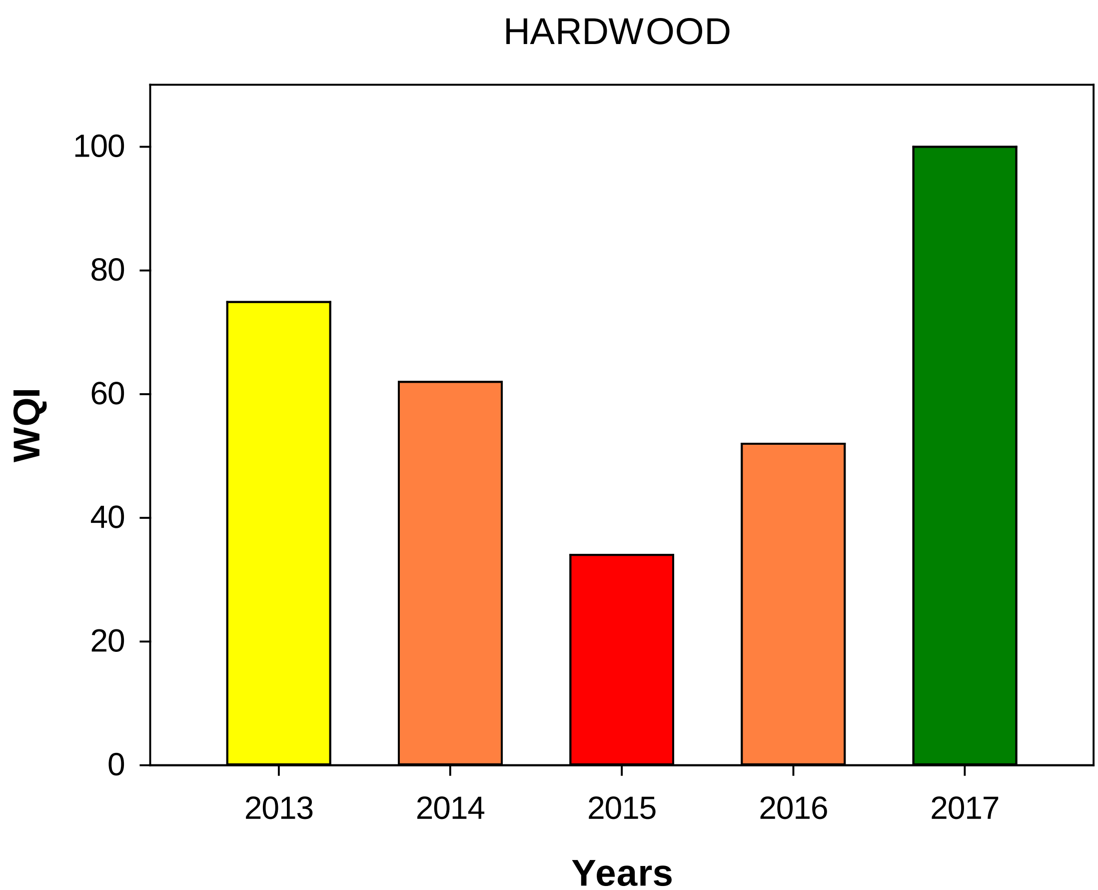


3.9 Hardwood Lake

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.

Water Quality Index (WQI)

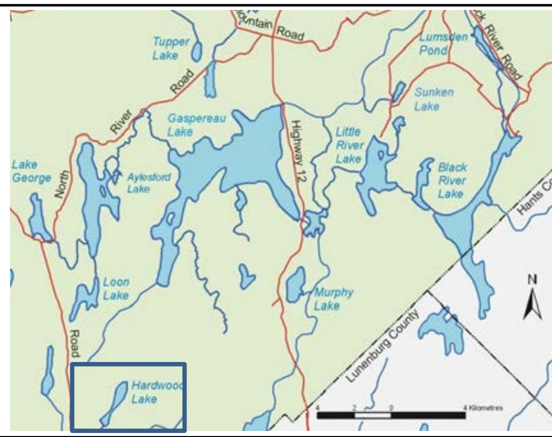
In Hardwood Lake, The Water Quality index (WQI) for 2017 reached the value of 100 (Excellent) because none of the values used in the calculation exceeded guidelines values. The trends in WQI are showing an improvement over the last 3 years, with a value that as doubled from 52 to 100 between 2016 and 2017.



Summary report card:

In 2017, Lake Hardwood showed a few minor exceedances in water colour and Secchi depth. These values are not used to calculate the WQI and are not a sign of water quality deterioration.

HARDWOOD LAKE



100

Drainage Order = n/a

Elevation = 208 m

Lake Area = 120 ha

Max Depth = 7.0 m

1997-2017 Trends:

Chl.a = n.s.

TP=n.s.

TN = 3.1 µg/l/yr

WQI % Change =92% *

	Parameter							
	TP (µg/L)	**Chl A (mg/m^3)**	**DOC (mg/L)**	**pH**	**Secchi Depth (m)**	**Colour (TCU)**	**TN (µg/L)**	**Turbidity (NTU)**
Guideline	19,1	2,5	7.5-8.5	6.1-6.4	1.6-2.4	36-59	350	1,3
2017 average	8,30	1,46	7,20	6,40	2,00	51,70	250	0,90
2017 (min - max)	(0 - 10)	(0.7-2.2)	(6.8-7.6)	(6.3 - 6.5)	**(1.5-2.7)**	(41.6-63.3)	(240-260)	(0.6 - 1.2)
1997-2016 average	12,88	2,30	7,09	6,27	2,07	46,57	216	1,14

*** Trends for WQI are relative to 2016 only.**

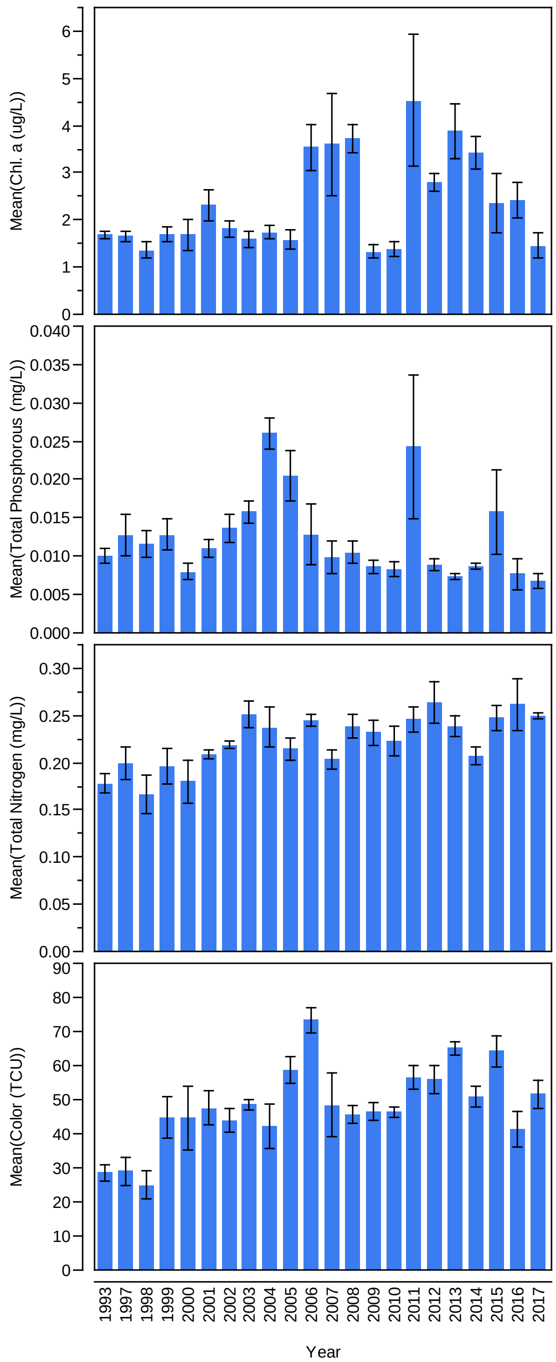
Numbers in red indicate exceedances of the criteria. n.s. indicates non significant result.

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

Long-term trends:

The 2017 data confirms the trends observed in nutrient over the last years: nutrient levels are low in Hardwood Lake, with TP levels remarkably constant over the last decade, indicating low loading or changes in loading from the watershed. The mean concentration in total phosphorus in 2017 is the lowest observed since the start of the project. Consistent with 2016 results, the concentration in total nitrogen is increasing, as shown by a significant temporal trend of 3.1 µg/L/year. In 2017, the concentration in Chl. a has also declined (1.46 µg/L) which may be explained by lower phosphorus loading.

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

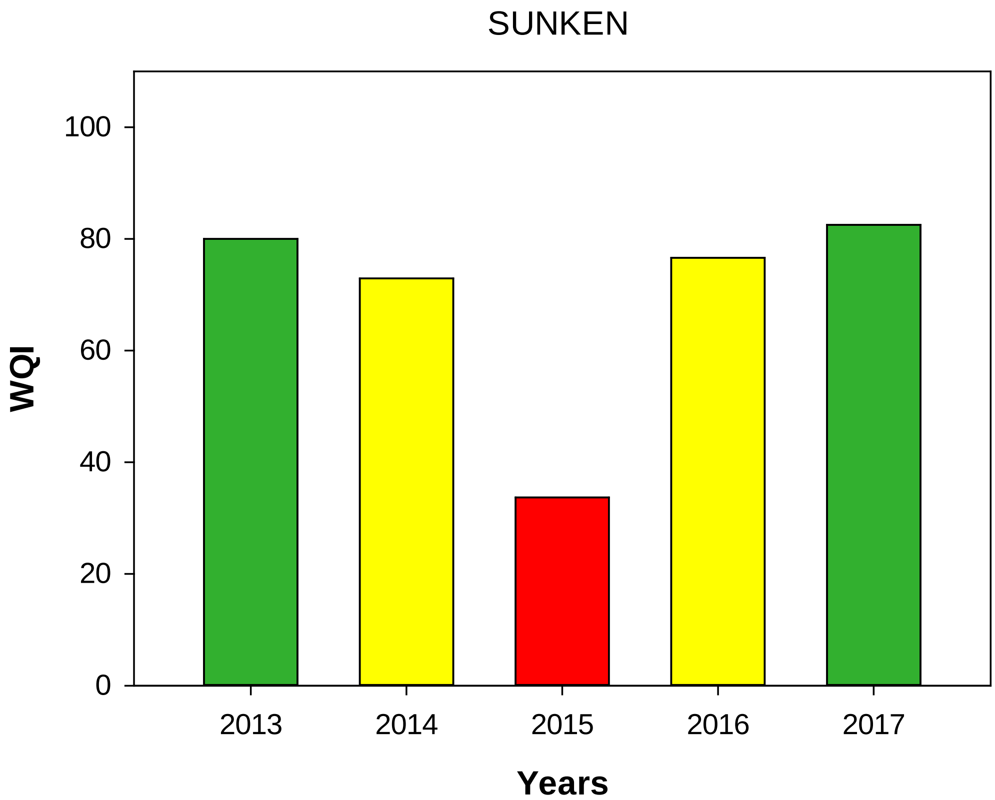


3.10 Sunken Lake

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.

Water Quality Index (WQI):

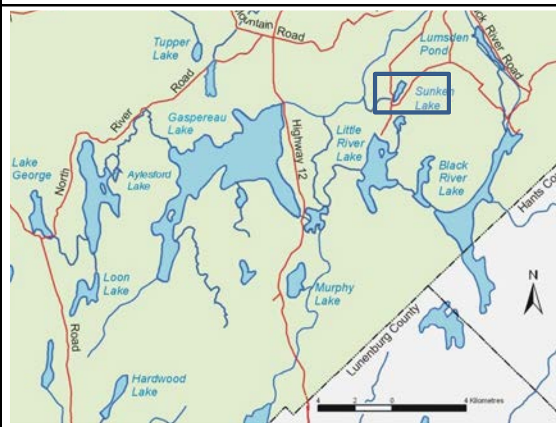
In Sunken Lake, the Water Quality index (WQI) for 2017 reached the value of 82.5 (Excellent). This value reflects the low nutrient levels and low chl.a concentrations measured during the sampling season. There were very minor exceedances in total nitrogen (TN). The trends in WQI are showing an improvement over the last 3 years. Between 2016 and 2017, the WQI has increased from 77 to 82. Over the last 5 years, it appears that 2015 was an unusual year with a very low WQI rating compared to other years.



Summary report card:

In 2017, Sunken Lake showed a few minor exceedances in total nitrogen, turbidity and secchi depth. Turbidity and secchi depth are not used to calculate the WQI and their values are not a sign of water quality deterioration.

SUNKEN LAKE



82,5

Drainage Order = n/a

Elevation = ~209 m

Lake Area = ~22.2 ha

Max Depth = 6.9 m

1997-2017 Trends:

Chl.a = n.s.

TP= n.s.

TN = n.s.

WQI % Change = 8 % *

	Parameter							
	TP (µg/L)	**Chl A (mg/m³)**	**DOC (mg/L)**	**pH**	**Secchi Depth (m)**	**Colour (TCU)**	**TN (µg/L)**	**Turbidity (NTU)**
Guideline	18,9	2,5	2.2-3.3	7.1-7.3	2.8-3.6	4.1-8.5	350	1,3
2017 average	8,30	1,30	2,50	7,00	3,60	5,60	251	1,10
2017 (min - max)	(0 - 10)	(1.1-1.5)	(2.3-2.8)	(6.9-7.0)	(**2.7-4.6**)	(5-7.4)	(170-**550**)	(0.8-**1.8**)
1997-2016 average	9,65	**3,42**	2,77	7,15	3,25	**11,73**	194	1,14

*** Trends for WQI are relative to 2016 only.**

Numbers in red indicate exceedances of the criteria. n.s. indicates non significant result.

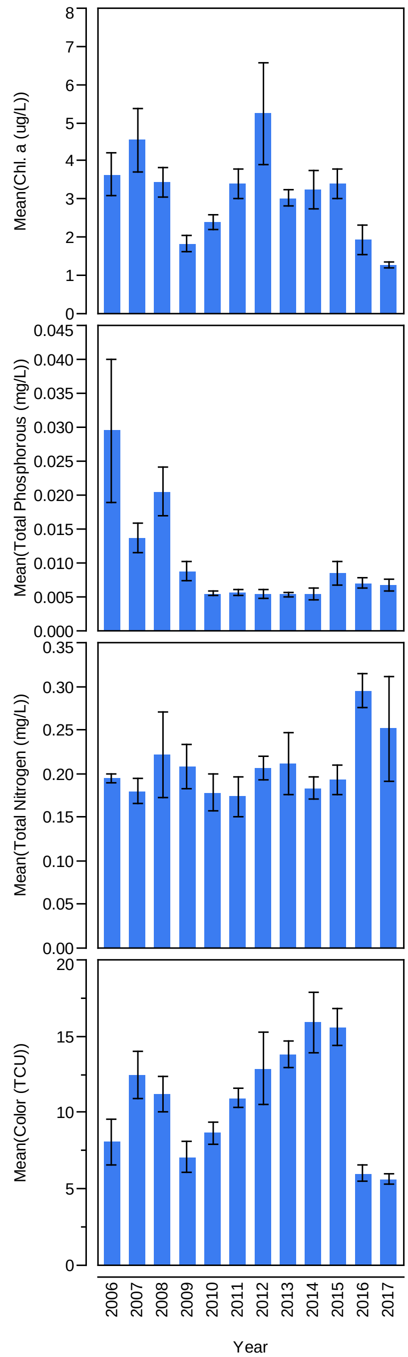
0-44	45-64	65-79	80-94	95-100
Poor	**Marginal**	**Fair**	**Good**	**Excellent**

Long-term trends:

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 in 2017 compared to the last 6 years (explaining the increase in WQI values) and declining over the last 3 years. The mean concentration in chl.a measured in 2017 was the lowest in over a decade. 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 increased (from close to 200 to 300 µg/L) in 2016 and 2017 and 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 2 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

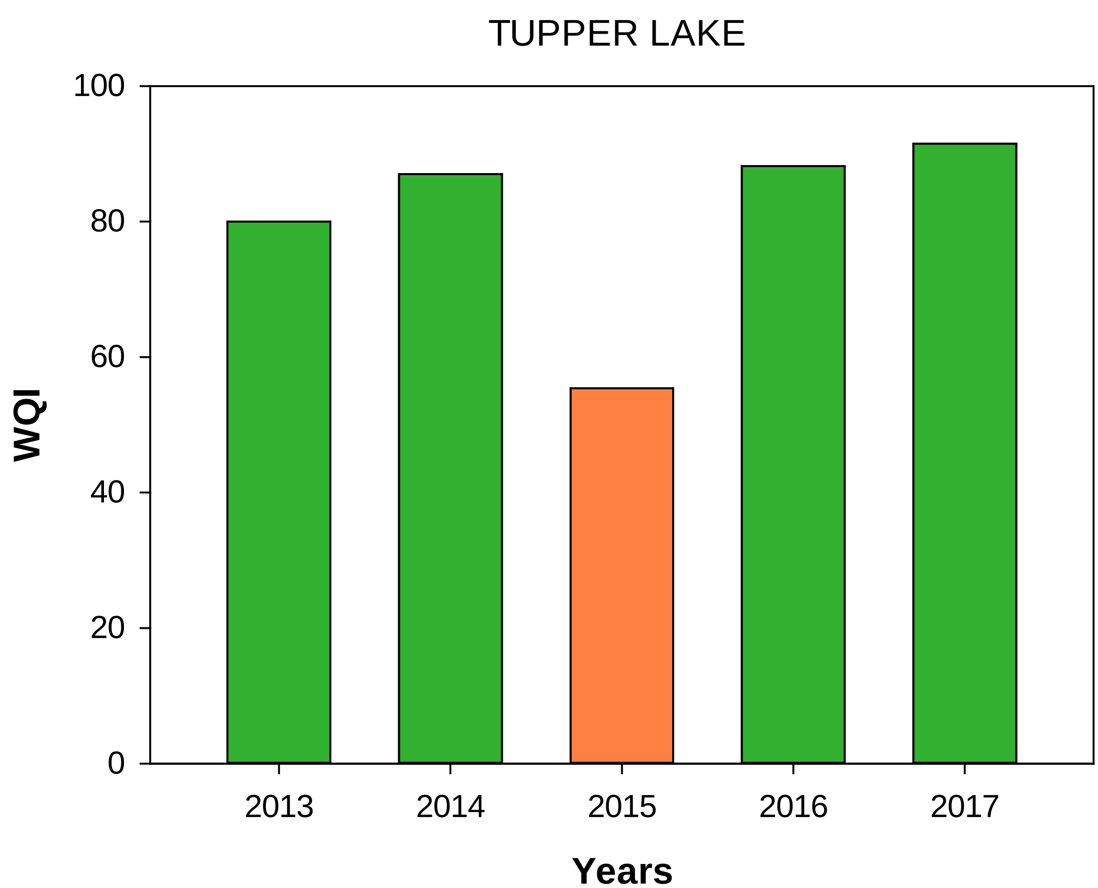


3.11 Tupper Lake

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):

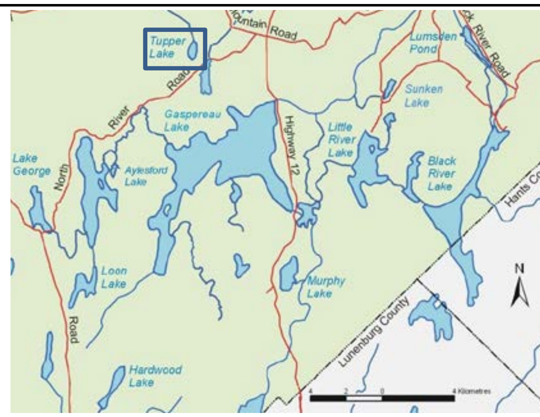
In 2017, the Water Quality Index for Lake Tupper was 91.5, which indicates an excellent water quality rating. The value increased slightly between 2016 and 2017 (2016:88; 2017: 91). This WQI rating has been consistent for this lake, with 4 'excellent' rating over the last 5 years.



Summary report card:

The water quality parameters measured in Tupper Lake were most of the time under guideline values, with the exception of one observation for Chl. a (3 mg/m3; guideline: 2.5 mg/L). The nutrient concentrations (TP and TN) in the lake are very low and support little production. The mean concentration in Chl. a was 1.55 mg/m3, a value that is typical of oligotrophic lakes. The lake has also low colour and DOC and turbidity levels compared to the other lakes in the region.

TUPPER LAKE



91,5

Drainage Order = n/a

Elevation = 201 m

Lake Area = 36 ha

Max Depth = 3.0 m

1997-2017 Trends:

Chl.a = n.s.
TP= -0.7 µg/L/yr
TN = n.s.
WQI % Change =4% *

	Parameter							
	TP (µg/L)	**Chl A (mg/m^3)**	**DOC (mg/L)**	**pH**	**Secchi Depth (m)**	**Colour (TCU)**	**TN (µg/L)**	**Turbidity (NTU)**
Guideline	16,8	2,5	3.7-5.5	6.6-7	2.6-3	14-22	350	1,3
2017 average	5,00	1,55	4,10	7,00	-	**11,75**	197	0,65
2017 (min - max)	(0 - 10)	(0.9-**3.0**)	(**3.4**-5.3)	(6.9-7.0)	-	(**8.3**-14.7)	(160-230)	(0.5-0.9)
1997-2016 average	11,75	**2,64**	4,58	6,78	2,60	19,28	227	0,94

*** Trends for WQI are relative to 2016 only.**
Numbers in red indicate exceedances of the criteria. n.s. indicates non significant result.

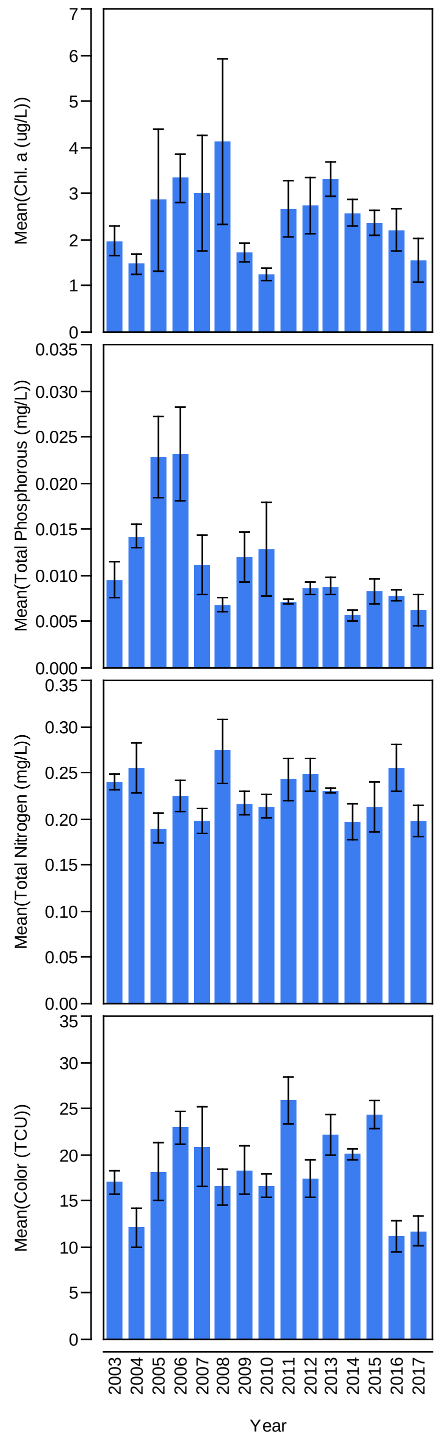
0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Long-term trends:

The 2017 data for Lake Tupper did not lead to significant long-term trends in Chl. a and in total nitrogen. The concentration in chl.a has declined over the last 5 years to reach a mean value close to 2 µg/L in 2017. There is a modest decline in TP (-0.7 µg/L/Yr) over the last 14 years but the concentration has been fairly constant over the last 7 years, with values at less than 10 mg/L. The mean concentration in total nitrogen has remained fairly constant over the years.

Interestingly, the colour of the lake has significantly declined in both 2016 and 2017, with a reduction of almost 50 % compared to 2003-2015.

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

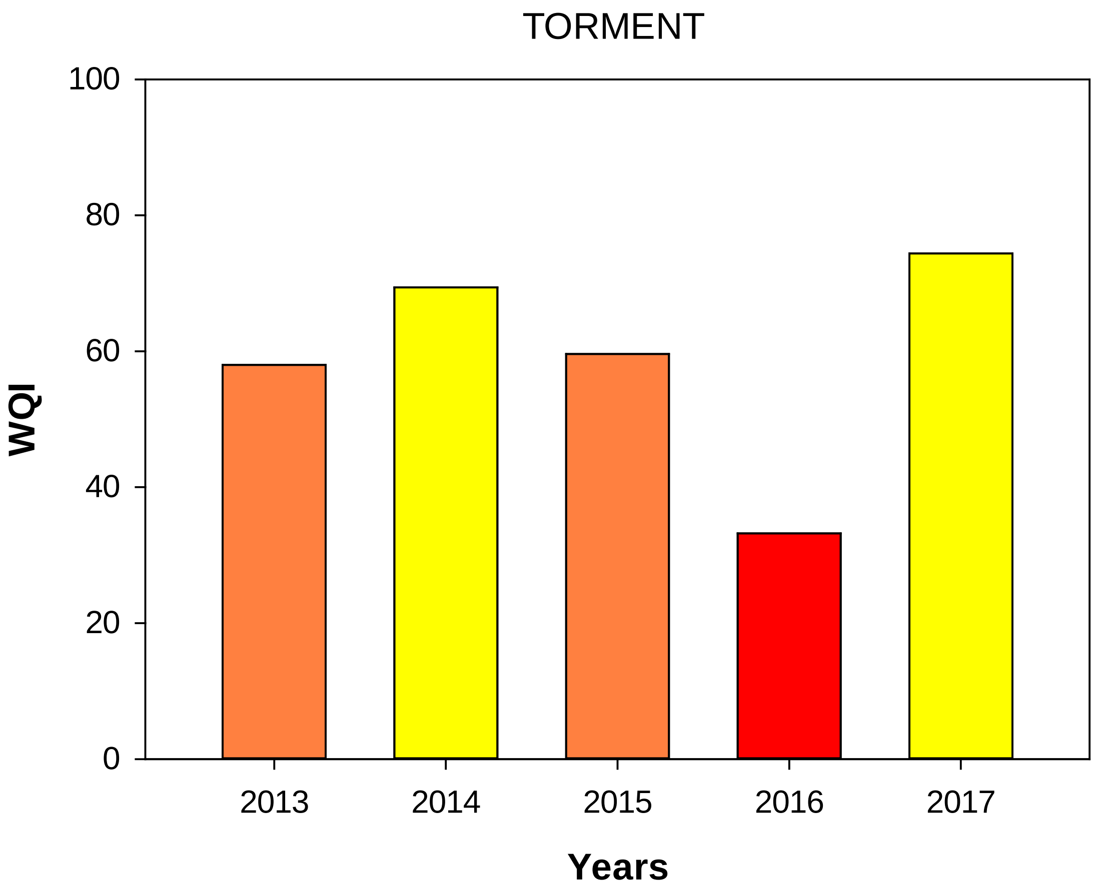


3.12 Lake Torment

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, with some residential development on the shores.

Water Quality Index (WQI):

In 2017, the Water Quality Index for Lake Torment was 74.4, with a Fair rating. This value increased significantly between 2016 and 2017 (from 33 to 75). This increase is the largest among all lakes in sampled in 2017. The value measured in 2017 is also the highest value observed for this lake over the last 5 years.



Summary report card:

The 2017 WQI value for Lake Torment reflects exceedances in 3 variables: Chl. a, total nitrogen and turbidity. Total nitrogen is the only variable for which the mean value (372 µg/L) exceeds the guideline value (350 µg/L). The mean value in chl.a for 2017 has significantly declined compared to the long-term mean value (2017: 2.3 µg/L versus 1997-2016: 5.0 µg/L). No significant increase or decrease over time was detected for chl.a, TP and TN.

Lake Torment

74,4

Drainage Order = n/a

Elevation = 174 m

Lake Area = 261 ha

Max Depth = 3.4 m

1997-2017 Trends:

Chl.a =n.s.
TP= n.s.
TN = n.s.

WQI % Change = 124% *

	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	8.0-12	6.3-6.5	1.1-1.6	53-98	350	1,3
2017 average	14,00	2,30	10,80	6,30	1,30	96,00	**372**	0,96
2017 (min - max)	(10 - 20)	(1.8-**2.8**)	(9.0-**13.8**)	(**6.2** - 6.4)	(1.2-1.4)	(85.8-**118**)	(280-**520**)	(0.52-**1.42**)
1997-2016 average	16,89	**5,02**	9,57	**6,51**	1,53	79,57	304,44	1,03

*** Trends for WQI are relative to 2016 only.**

Numbers in red indicate exceedances of the criteria. n.s. indicates non significant result.

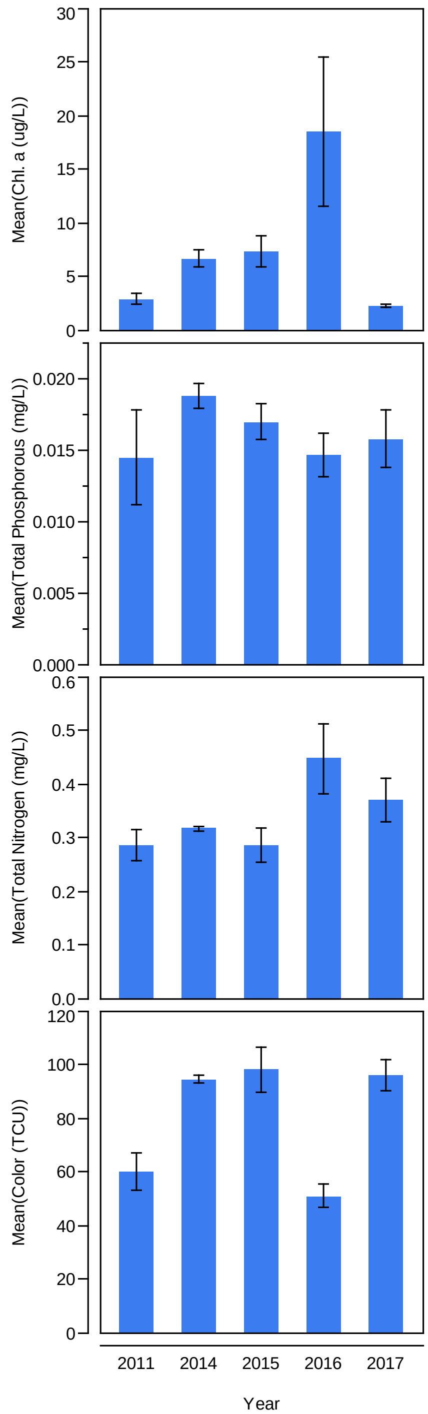
0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Long-term trends:

The reason of the improvement in WQI values in 2017 are clearly related to the decline in chl. a. The mean values have dropped by an order of magnitude between 2016 and 2017. The mean concentration in TP was similar to that observed in previous years. The mean concentration in total nitrogen has declined compared to 2016 (but still remains above guideline value). The colour value came back to that observed in 2014 and 2015.

Based on this graphics, the high values in chl.a observed in 2016 (leading to a poor WQI) could stem from the higher TN concentration and clearer waters (removing some light limitation).

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

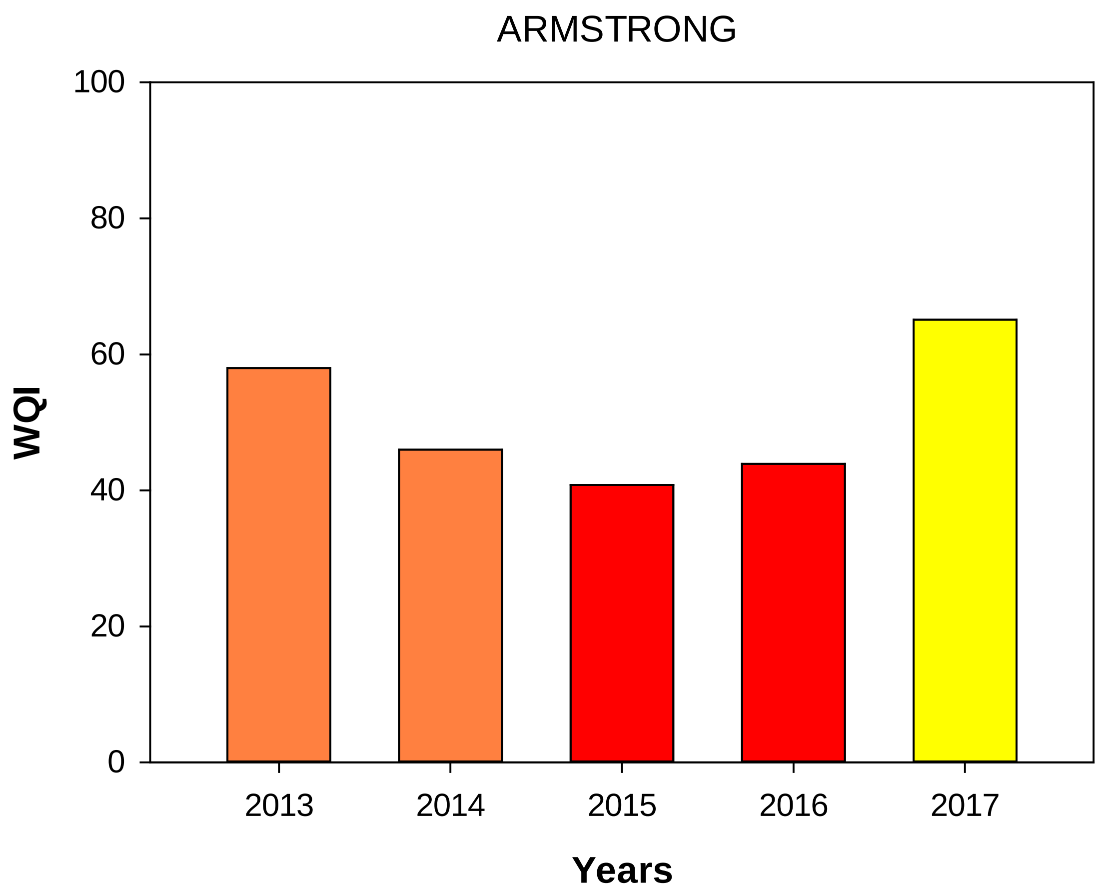


3.13 Armstrong Lake

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 2017, the Water Quality Index for Armstrong Lake was 65.1, corresponding to a rating of Fair water quality. This value has increased from 44 in 2016 to 65.1 in 2017. This value is also the highest value obtained since 2013.



Summary report card:

The WQI value observed for Lake Armstrong is explained by exceedances in 3 variables: Chl.a; total nitrogen and turbidity. Chl.a concentration was on average higher than the guideline for 2017 (mean: 2.7 µg/L, guideline: 2.5 µg/L). There was no significant trends (increase or decrease) in Chl. a; TP and TN since the lake was first sampled.

Armstrong Lake

65,1

Drainage Order = n/a

Elevation = 178 m

Lake Area = 89 ha

Max Depth = 21 m

1997-2017 Trends:

Chl.a = n.s.
TP= n.s.
TN = n.s.
WQI % Change = 48% *

	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	8.6-12.9	6.2-6.4	1.1-1.7	57-104	350	1,3
2017 average	16,67	**2,7**	10,8	6,2	1,1	100,7	355	1
2017 (min - max)	(10 - 20)	(1.1-**5.4**)	(8.8-**13.1**)	(6-6.3)	(**1**-1.3)	(88.1-112)	(280-**430**)	(0.6-**1.6**)
1997-2016 average	19,6	**3,34**	11,22	6,36	**1,63**	94,5	**362**	0,91

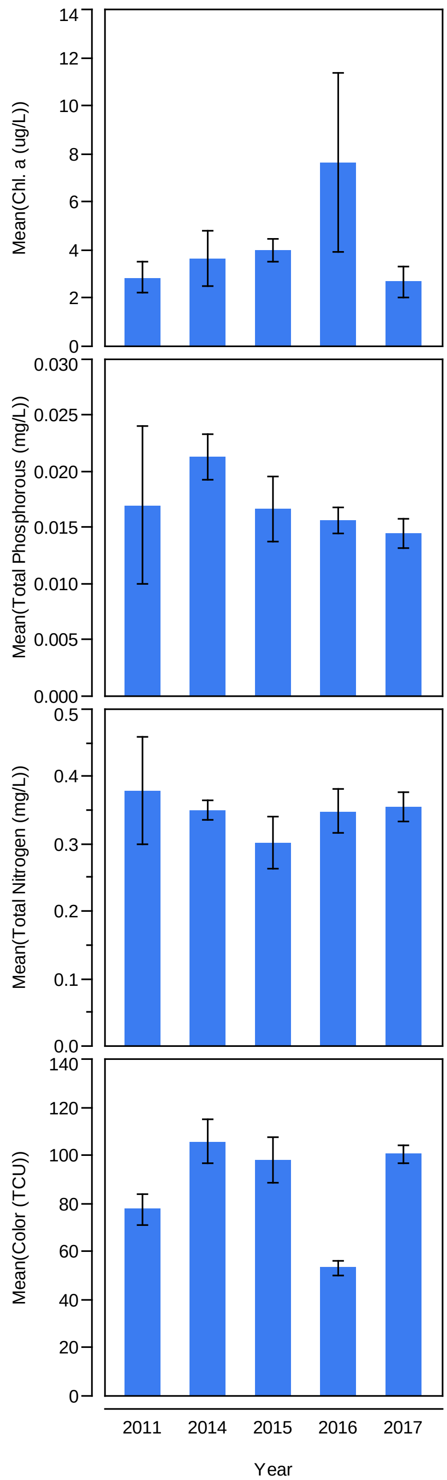
*** Trends for WQI are relative to 2016 only.**
Numbers in red indicate exceedances of the criteria. n.s. indicates non significant result.

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

Long-term trends:

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 4 µg/L in 2017. The concentrations in both TP and TN remained fairly similar since 2011. The value for colour increased in 2017, back to values comparable to 2014 and 2015.

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



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 2017 data:

The analysis of 2017 water quality data on the Kings County lakes observed that nutrient (total phosphorus and total nitrogen) levels in all the lakes remain most of the time below guideline values. In the recent years, an increase in productivity was observed: in 2015 and 2016, the concentration in chl.a increased to values never observed before. In 2017, this trend was not maintained and the concentration in Chl. a declined in most of the lakes. In the past years, no relationship between nutrient levels 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 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 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. 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 2017, 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 this year: although this is good news for 2017, it also indicates that the value varies greatly from year to year. Some lakes were rated with a poor WQI last year, 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). In 2017, the trends in colour was not as clear as in 2016. In some lakes, colour came back at level

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. The analysis will benefit greatly from the following estimates:

   a. Lake surface area and volumes for all lakes;
   b. Watershed area;
   c. Land use (residential, resource forest, wetland cover);
   d. Number of residences on septic systems living in the watershed;
   e. Number of residences along the shores of the lakes;
   f. The presence of beaver dams;
   g. The presence of invasive species (plants, mussels, etc.);
   h. 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.
   i. 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.
   j. 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, 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 (see template shared in 2016 report).

5) Ask the residents about their main concerns and observations: do they observe an increase in plants in the water? The current sampling evaluates the abundance of algae as the only primary producers but does not look at the presence of other aquatic vegetation (macrophytes) which may impact the use and quality of water. The program would benefit from defining what values (aquatic life, recreation,

aesthetics) Municipality of the County of Kings and lake residents wish to protect through the monitoring program to guide continued program development.

6) 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.

7) The accuracy of the year to year comparison is only possible if the data is collected and analysed in a consistent manner. Any changes in laboratory as well as in the team analyzing the data could limit the unique long-term interpretation of the results and should be reported. This is the case for chl.a analysis. In 2017, a review of the protocol for chl.a analysis was conducted: the method used is consistent with good practices (filtration of the sample after collection, freezing of the filters in the laboratory, and extraction of filter at a later date).

8) The frequency of sampling events should 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.

9) 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.

10) 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.

5 References

Brylinsky, M. 2008. Results from the 1997-2008 Kings County Volunteer Water Quality Program. Acadia University, Wolfville, Nova Scotia. Prepared for Kings County Water Quality Monitoring Volunteers and Kings County Department of Community Development Services.

Canadian Council of Ministers of the Environment. 2001. Canadian water quality guidelines for the protection of aquatic life: CCME Water Quality Index

Canadian environmental quality guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg. http://www.ccme.ca/assets/pdf/wqi_techrprtfctsht_e.pdf.

Carignan, R.; D'Arcy, P. and Lamontagne, S. 2000. Comparative impacts of fire and forest harvesting on water quality in Boreal Shield lakes. *Canadian Journal of Fisheries and Aquatic Sciences*, 2000, 57:105-117,https://doi.org/10.1139/f00-125

Carlson, R.E. and J. Simpson. 1996. A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society. 96 pp.

Centre for Water Resources Studies and Stantec. 2009. Kings County Lakeshore Capacity Model Review, Final Report.

Chambers, P.A., Culp, J.M, Brua, R., Benoy, G. April 2011.Defining Nutrient Concentrations to Prevent Eutrophication of Canadian Agricultural Streams. Retrieved June 2, 2011, from http://nitrogen.ceh.ac.uk/nitrogen2011/_poster_presentations/S3_Chambers.pdf.

Clean Annapolis River Project. 2010. Kings County Lake Monitoring Program Report: 2009 Season.

Clean Annapolis River Project. 2011. Kings County Lake Monitoring Program Report: 2010 Season.

Clean Annapolis River Project. 2012. Kings County Lake Monitoring Program Report: 2011 Season.

Clean Annapolis River Project. 2013. Kings County Lake Monitoring Program Report: 2012 Season.

Cole, G. 1983. Textbook of Limnology. 3rd edition. Arizona State University. The C. V. Mosby Company, St. Louis. Government of British Columbia.

1981. Ambient Water Quality Guidelines for Organic Carbon. Last updated August 7, 2001. Water Management Branch, Ministry of Water, Land and Air Protection, British Columbia.

Government of British Columbia. 1981. Water Quality Criteria for Nutrient and Algae. Last updated August 7, 2001. Water Management Branch, Ministry of Water, Land and Air Protection, British Columbia.

Kerekes, J. 1981. Atlantic Region. Chapter I. Pp. I 1-13. In: Janus, L.L and R.A. Vollenveider (Eds.). Summary report. The OECD Cooperative Programme on Eutrophication. Canadian Contribution. (Scientific Series # 131, Pp. 1-13). National Water Res. Inst., Inland Waters Directorate, Canadian Centre for Inland Waters, Burlington, Ont.

Kerekes, J. and B. Freedman. 1989. Characteristics of Three Acidic Lakes in Kejimkujik National Park, Nova Scotia, Canada. Archives of Environmental Contamination and Toxicology, (18), 183-200.

Municipality of the County of Kings. 2009. http://www.county.kings.ns.ca/comdev/lakemon/overview.htm. Access Date: February 9, 2010.

Kevern, N., D. King, and R. Ring. 1996. Lake Classification Systems. The Michigan Riparian, February 1996. http://www.mlswa.org/lkclassif1.htm

Mackie, G. 2004. Applied Aquatic Ecosystem Concepts. 2nd Edition, Kendall/Hunt Publishing Company, Dubuque, Iowa.

MacMillan, J. L., D. Cassie, J. E. LeBlanc and T. J. Crandlemere. 2005. Characterization of water temperature for 312 selected sites for Nova Scotia. Canadian Technical Report of Fisheries and Aquatic Sciences 2582.

Parks Canada. 2008. Water Quality Index Monitoring Protocol, Quebec-Atlantic Bioregion. Draft report. Parks Canada Agency.

Parks Canada. Technical compendium to the 2010 State of Park Report, Kejimkujik National Park and National Historic Site. Parks Canada Agency.

Roy V., Amyot M., Carignan R. 2009. Beaver ponds increase methylmercury concentrations in Canadian Shield streams along vegetation and pond-age gradients. Environmental Science & Technology. 43 (15): 5605-5611. doi : 10.1021/es901193x

Sharpe A. and D. Sullivan. 2006. CARP Quality Assurance/Quality Control Project Plan. – Currently in draft form.

Thienpont, J.R., et al. 2008. An Assessment of Environmental Changes in Three Lakes from King’s County (Nova Scotia, Canada) Using Diatom-Based Paleolimnological Techniques. Water Quality Research Journal of Canada Volume 43, No.2/3, 85-98.

US Geological Survey. 2005. Seasonal Kendall Test for Trend.

Vollenweider, R.A. and J. Kerekes 1982. (OECD 1982). Eutrophication of waters, monitoring, assessment and control. Final Report. OECD Cooperative programme on monitoring of inland waters (Eutrophication control), Environment Directorate, OECD, Paris. 154p.

Water Quality Survey of Fourteen Lakes in the Carleton River Watershed Area, 2016. Report accessed on March 20, 2019, at: https://www.district.yarmouth.ns.ca/index.php/community/community-organizations-programs/224-carleton-river-watershed

WSP Canada Inc. 2014. Kings County Lake Monitoring Report: 2013 Season.

WSP Canada Inc. 2015. Kings Lake Monitoring Final Report: 2014 Season.