2023 Benthic Count – Citizen Science in Action

2023 Kahshe and Bass Lake Steward Report

Ron Pearson, M.Sc. - Kahshe and Bass Lake Steward

ABSTRACT

The findings of all environmental water quality and biological monitoring for both Kahshe and Bass Lakes in 2023 have been summarized and compared to acceptable water quality indicators for algal friendly nutrients phosphorus and nitrogen as well as over 30 other parameters. Historical trends in water quality over four decades have identified no major contamination issues that would explain why Kahshe Lake was impacted by harmful algal blooms (HABs) in both 2020 and 2021 resulting in it being designated as 'Vulnerable' by the Muskoka Official Plan. Elevated levels of phosphorus in Bass Lake have been attributed to natural causes following a District Causation Study; however, an HAB was documented in late 2023 and the Health Unit alert remains active. This report discusses why HABs are happening and identifies four key actions waterfront owners can take to reduce the likelihood of future HABs as our climate changes. Based on a KLRA-funded near-shore sampling program in 2021, we need look no further than to our own shorelines to understand why the historical monitoring at mid-lake, deep water sampling locations is not generating a biologically relevant picture of water quality close to the shore. This report also identifies some insights and linkages between our changing climate and its role in the development of late season HABs.

2023 Kahshe and Bass Lake Steward Report

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Executive Summary

2023 Kahshe and Bass Lake Steward Report

A review and analysis of all historical environmental monitoring on Kahshe and Bass Lakes can be found in annual Lake Steward Reports from 2012 through 2023. These documents have been posted on the KLRA web-site: https://kahshelake.ca/Water-Quality. This report captures the findings from sampling and analysis of both Kahshe and Bass Lakes in 2023 and has been structured to address the following parameters of potential concern for both Kahshe and Bass Lakes:

- Algal Nutrients and Other Factors Promoting Algal Growth
- Calcium Depletion
- Lake Acidification
- Metals and Other Chemicals of Concern
- Dissolved Oxygen Depletion
- Benthic Organism Health

The 2023 report also includes an overview of the climatological factors that have the potential to influence lake conditions. This demonstrated that air temperatures in 2023 were generally similar to the three previous years and to the 30 year normal for most months, with the exception of much warmer winter conditions in December and January. In the case of precipitation, total monthly amounts in April, June and July were noticeably greater than in previous years and compared to the 30 year normal, with much dryer conditions being recorded in November and December.

In 2023, the ice-out date for Kahshe Lake was April 14. The data from 1987-2023 for Kahshe Lake appear to generally follow the ice-out dates for the larger Muskoka Lakes and there appears to be a trend towards earlier ice-out dates on both Muskoka Lakes and Kahshe since the early 1970s.

Based on the DMM and MECP investigations, the following conclusions have been reached regarding the six water quality parameters identified above.

Algal Nutrients and Other Factors Promoting Algal Growth

Water quality monitoring of Kahshe and Bass Lakes by the DMM and the MECP has not identified any major water chemistry issues or trends in terms of algal friendly nutrients – phosphorus and nitrogen. Although both lakes have been classed as 'Vulnerable' under the updated Muskoka Official Plan (MOP), Bass Lake is expected to be removed due the findings of a DMM-funded Causation Study that identified natural causes as the reason for the elevated (>20 µg/L) levels of phosphorus, which is now one of three 'Water Quality Indicators' under the updated MOP. Kahshe Lake remains on the 'Vulnerable' list due to the documented presence of harmful blue-green algal blooms (HAB) in both 2020 and 2021, although none have been recorded since then. While Bass Lake is slated to be removed from the 'Vulnerable' listing, it may be re-listed, as there was an HAB in 2023 and it remains on the Simcoe-Muskoka Health Unit's active list.

Trends in water temperature, which can accelerate algal growth also were examined and there was no evidence of a warming trend in either lake based on water temperature measurements dating back to the early 1980s. Water clarity also has remained fairly steady over this four decade period, although clarity in Bass Lake is noticeably lower than in Kahshe.

And finally, it should be noted that the trend towards increasing numbers of HABs in Muskoka lakes continued in 2023, with 13 water bodies with documented HABs. This is cause for concern as the levels of algal-friendly phosphorus in Muskoka lakes have not increased over this time period. As such, changes in other factors that are known to accelerate algal growth and bloom development are happening. And, as we discovered in our Near-Shore Sampling Project in 2021, it is also possible that the historical sampling in mid-lake, deep water locations by the DMM and MECP is giving an excellent historical record of nutrient levels but not reflecting the elevated levels that have been documented in near-shore areas where algal blooms typically form.

Calcium Depletion

Decreasing lake water calcium concentration is an emerging concern for lakes on the Precambrian Shield in Ontario due to its impact on the reproduction and survival of zooplankton and other aquatic species that are important components of the aquatic food chain. The 2023 data confirm that there is no detectable trend towards decreasing levels of calcium in either Kahshe or Bass Lakes. However, as levels of calcium are fairly close to the aquatic growth limiting threshold of 1.5 mg/L and, as this threshold value would not be protective of all aquatic organisms, continued vigilance is necessary.

This is underscored by late season population explosions of *Holopedium* in Kahshe Lake since 2021. These pea sized, jelly-like orbs are not known to be toxic, but are an uncomfortable nuisance as they can be felt against your skin while swimming.

Lake Acidification

The waters of Kahshe and Bass Lake have acidity (pH) levels that are within a normal range and there is no evidence of an increasing or decreasing trend in acidity over the two decade monitoring period.

While the pH findings represent good news, it should also be recognized that the waters of Kahshe and Bass Lakes have low levels of alkalinity, and as such, are more susceptible to acidification as the ability of the water to buffer the acid input is low.

Metals and Other Chemicals of Concern

The analysis of over 30 additional anions, cations and other chemicals by the DMM in 2023 has, with one possible exception, identified no trends or aquatic toxicity issues. While there were some minor exceedances of chronic (long term) health protection benchmarks established by the MECP and other agencies in the early years, most of these exceedances were likely due to sampling or laboratory artifacts, as more recent sampling has shown concentrations that are in the expected range for non-impacted surface water bodies in Ontario.

In the case of aluminum, the aquatic benchmark has been exceeded in Bass Lake, with the highest concentration in 2023; however, the benchmark consists of a range in values and must be evaluated based on the pH and DOC concentrations in lake water. Based on these findings, the levels of aluminum need to be followed carefully in future monitoring to ensure that the waters of Kahshe and Bass Lakes are safe from an aquatic perspective.

The other finding from this data set is that there are numerous parameters that, like total phosphorus, are higher in Bass Lake compared to Kahshe Lake. There are also a couple of parameters (silicon and N-

NO_3) where levels in Kahshe are higher than in Bass. The reason for these differences in the two lakes is unknown and was not evaluated in the DMM-funded Causation Study on Bass Lake.

Dissolved Oxygen Depletion

Dissolved oxygen (DO) in lake water is important, as it is essential for the survival of all aquatic organisms. A lack of oxygen in the lower layers of the lake (referred to as being anoxic) also can cause mobilization (release) of phosphorus from sediments.

Dissolved oxygen is influenced by seasonal temperature changes that factor into lake stratification, the process whereby lake water is turned over (mixed) in the late fall and again following the winter ice melt and then begins to stratify through the spring, summer and early fall as water temperature increases at the surface and DO levels decrease with increasing depth.

As expected, the spring measurement of DO at increasing water depths in both Kahshe and Bass Lakes for 2023 revealed that with only one exception (Bass Lake >4m), DO was adequate for aquatic organism survival down to lake bottoms. However, by early August 2023, as in all previous decades, DO levels in Kahshe Lake fell below the aquatic health-based Provincial Water Quality Objective (PWQO) at around 4-5m depth and remain that way down to lake bottom (20m). In Bass Lake, by mid-August, the 2023 DO levels steeply declined beyond a depth of 2m and fell below the aquatic PWQO at depths greater than around 2.5m.

From a biological perspective, unlike Kahshe Lake, there appears to be a trend towards DO levels in Bass Lake falling below the PWQO at more shallow depths (just below 2m) than back in the 1980s and 1990s when DO crossed below the PWQO at depths almost at lake bottom (just below 3m).

Benthic Organism Health

The presence of benthic organisms indicates the health of both the riparian and littoral zones, as these areas can be impacted by snowmelt, runoff, sedimentation and other shoreline development activities. Collected benthos are grouped into seven different categories based on their typical response to environmental contamination and are then compared to the Muskoka average from locations known to be remote from any shoreline development sources.

The 2023 assessment at two sites on Kahshe Lake confirmed that the benthic community is comparable to the Muskoka average for most family groupings, with the exception of % Chironimids and % EOT, where lower and higher benthic counts, respectively, are desirable outcomes. And, based on the benthic monitoring over the period from 2006 through 2023, there appears to be no increasing or decreasing trend in the various families of benthic organisms in Kahshe Lake.

Although the KLRA has not provided volunteer benthic counting support to the DMM for Bass Lake, we have been provided with the analysis results for 2023 and they revealed that the average (all years) index values for two sites on Bass Lake for %Chironimids are slightly lower than the Muskoka Average, and this is a good sign, as the species in this grouping are pollution tolerant. In the case of %EOT, the lower values relative to the Muskoka Average are not a desirable outcome, as these benthos are sensitive to pollutants. However, it was noted that in the case of %EOT, the 2023 findings do indicate a healthier outcome for this grouping that was masked in the averaging approach using data from all years. An evaluation of trends in benthic family groupings at both sites over time revealed no evidence of any trend in the health of these organisms over the period from 2016 to 2023.

Based on the 2023 water quality and benthic monitoring of Kahshe and Bass Lakes by the DMM and the MECP, no major water quality issues or trends were identified. However, given the documented occurrence of HABs in Kahshe Lake in both 2020 and 2021 as well as the late season population explosion of a zooplankton organism (*Holopedium*) known to be associated with decreasing levels of available calcium in Muskoka region lakes, it is clear that the tracking of water quality via the mid-lake, deep water sites of the DMM and MECP should not be completely relied upon as a fully representative assessment of water quality in the near-shore environment where algal blooms have been documented.

In the case of Bass Lake, the DMM identified it as a 'Vulnerable' lake and carried out a Causation Study in 2021-22. This study concluded that the elevated levels of total phosphorus in Bass Lake have resulted from natural causes. However, for the first time, Bass Lake had a documented HAB in 2023 and remains on alert status by the Simcoe-Muskoka Health Unit.

So, where do we go from here?

Kahshe Lake also has been identified by the DMM as a 'Vulnerable' lake and a DMM-funded Causation Study will be undertaken when funds are available. However, based on our concern following the development of late season HABs in 2021 and 2022, the KLRA funded a Near-Shore Water Sampling Project in 2021 to explore the chemistry of near-shore waters over the spring and summer season in an effort to better understand why Kahshe Lake has been impacted by HABs in spite of reasonably low and unchanged phosphorous levels reported by the DMM and MECP over the past 40 years.

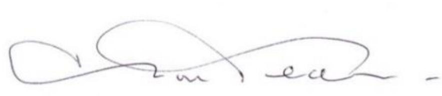
The findings from this Near-Shore Water Sampling Project (NSWSP) have been published in a final report available on the KLRA Water Quality web portal. The NSWSP identified some very useful insights and linkages between our changing climate, its impact on water quality and the development of late season HABs in Kahshe Lake. Briefly, the NSWSP demonstrated that:

- Mid-lake, deep water sampling in the spring of the year is a reasonable way to track long-term, historical changes in water quality but is not providing a biologically relevant assessment of water quality in the near-shore environment where HABs have been documented.
- The mid-lake, deep water sampling also has failed to capture higher total phosphorus levels in the east end of the lake which is subject to inflow from Bass Lake, as there are no DMM sampling sites in that area.
- Levels of algal-friendly nutrients (phosphorus and nitrogen) in the near-shore areas tend to increase and fluctuate as the season progresses, further limiting the relevance of the spring sampling of mid-lake sites in terms of assessing the potential for HAB development.
- The near-shore water chemistry findings for some algal-friendly nutrients appear to be associated with human & animal waste sources which are known to be linked with algal growth and HABs.
- Although more study is warranted, the near-shore findings point to accelerated leaching and/or runoff of soil-borne nutrients due to a changing climate which is resulting in more intense rainfall events.

Although we have virtually no control over the change that is affecting our climate, there are actions we can and must take to minimize the accelerated leaching of algal friendly nutrients to our shoreline water and thereby reduce the potential for future algal blooms. These actions have been thoroughly explored by the Conservation Committee and are summarized below:

1. **Divert roof drainage and runoff from paths and other hard surfaces away from your septic system and the shoreline. If necessary, direct rain water into rock-filled drainage pits.**
2. **Keep most of your shoreline as natural as possible with a zone of trees, shrubs or tall grass between the shore and any lawn area to discourage grazing by Canada geese and to reduce soil & goose poop runoff into the lake.**
3. **Have a licensed professional pump out and inspect your septic system for failures and deficiencies every 3-5 years and more often for aging systems installed pre-2000. The Town will be inspecting in 2023, but we don't need to wait until then and be subject to system shutdown until failing systems are repaired.**
4. **Don't use phosphorus or nitrogen fertilizers or cleaning agents anywhere near the shore.**

Well, that's it for me. It has been a pleasure to serve as your Lake Steward since 2011 and I now hand it over to Sara Varty who has accepted the role going forward. All the best Sara!



Ron Pearson, M.Sc.

Kahshe and Bass Lake Steward - Conservation Committee

1.0 Kahshe Lake Stewardship Mandate

As a standing member of the Kahshe Lake Conservation Committee, the roles and responsibilities of the Lake Steward include:

- Educating the residents and other users of Kahshe and Bass Lakes on how to **preserve** and **improve** the quality of both lakes and their shorelines.

- Monitoring the water quality of both lakes and keeping the association members up to date on the results of all analytical and biological monitoring programs.

In accordance with this mandate, a comprehensive review and analysis of all historical environmental monitoring on Kahshe and Bass Lakes has now been completed and presented in annual Lake Steward Reports from 2012 through 2023. These documents as well as Executive Summaries are posted on the **Lake Health** tab of the KLRA web-site https://kahshelake.ca/Water-Quality. Prior to 2012, a few Lake Steward reports were located; however, this was prior to development of the KLRA web site, and as such, these reports are not currently on-line.

Before moving on to discuss the chemical and biological monitoring since 2012, it is important to discuss another water quality parameter that is **not** being routinely monitored in either lake or at the public beaches by any organization - coliform bacterial contamination. If you are drinking water from the lake – **which is strongly not recommended** - and want to ensure that your filtering system is functioning properly, you can submit a sample of water to the Simcoe Muskoka Health Unit for coliform analysis. The contact info is:

- 2-5 Pineridge Gate, Gravenhurst, ON, P1P 1Z3. PHONE: 705-684-9090, FAX: 705-684-9887.

Anyone who suspects that a neighbouring septic system is in need of pumping or improved management can also take a sample from the lake and submit it to the Simcoe Muskoka Health Unit. If this is something you would rather not do, then you should inform the Building Department at the Town of Gravenhurst of your concern and follow-up with them to determine if action is/was/will be undertaken.

Given the importance of and responsibility for maintaining fully functional septic systems and keeping septic-sourced fecal coliform levels as low as possible, the following information has been extracted from a *Good Neighbour Resource Hand book* article which was updated in 2014 by the KLRA's Conservation Committee.

Your septic system is a sewage treatment facility that requires careful attention to design, construction, operation and maintenance. **As a property owner, this is your responsibility.** In Ontario, the specifications for construction and maintenance of sewage systems with a flow of less than 10,000 litres per day are regulated under the *Ontario Building Code*, and municipalities are responsible for the inspection and approval of all septic installations. For Kahshe and Bass Lakes, the Building Department of the Town of Gravenhurst is the agency with this responsibility. In addition to permitting the installation of septic systems, the Town operates a septic re-inspection program as follows:

- the re-inspection on Kahshe Lake is carried out every 5 years;
- it consists of a trained student visiting most (but not always all) properties and carrying out a visual inspection of the tank and bed;

- if there are visual signs of failure of the leaching bed, they leave a notice and the Building Department follows up with a letter requiring a pump-out and system inspection with a receipt from a licensed pumper to confirm that it has been carried out;
- if the visual signs point to a **serious** failure, the Building Department issues a stop order until evidence is provided that the problem has been corrected.

Unfortunately, there is no systematic process for re-inspections based on when the septic system was installed or on previous re-inspection findings. Up until 2023, the last Town inspections for road access properties was conducted in 2013 and in 2009 for water access properties. The COVID-19 pandemic further delayed planned re-inspection in 2021 and the program was aborted in 2022 due to staffing issues. Inspections did resume in 2023; however, it is not known whether all road and water-access properties were inspected. Given this performance history, cottage owners are encouraged to report any suspected problems to the Building Department so they can follow up with an inspection of the system.

The KLRA has been asked on a number of occasions to include coliform monitoring as part of the chemical and biological sampling programs carried out by DMM and for MECP by the Lake Steward. Although coliform analysis was included as part of the Near-Shore Water Sampling Project which was funded and undertaken by the KLRA in 2021, this was a once only sampling and will not be carried out on a routine basis for several reasons:

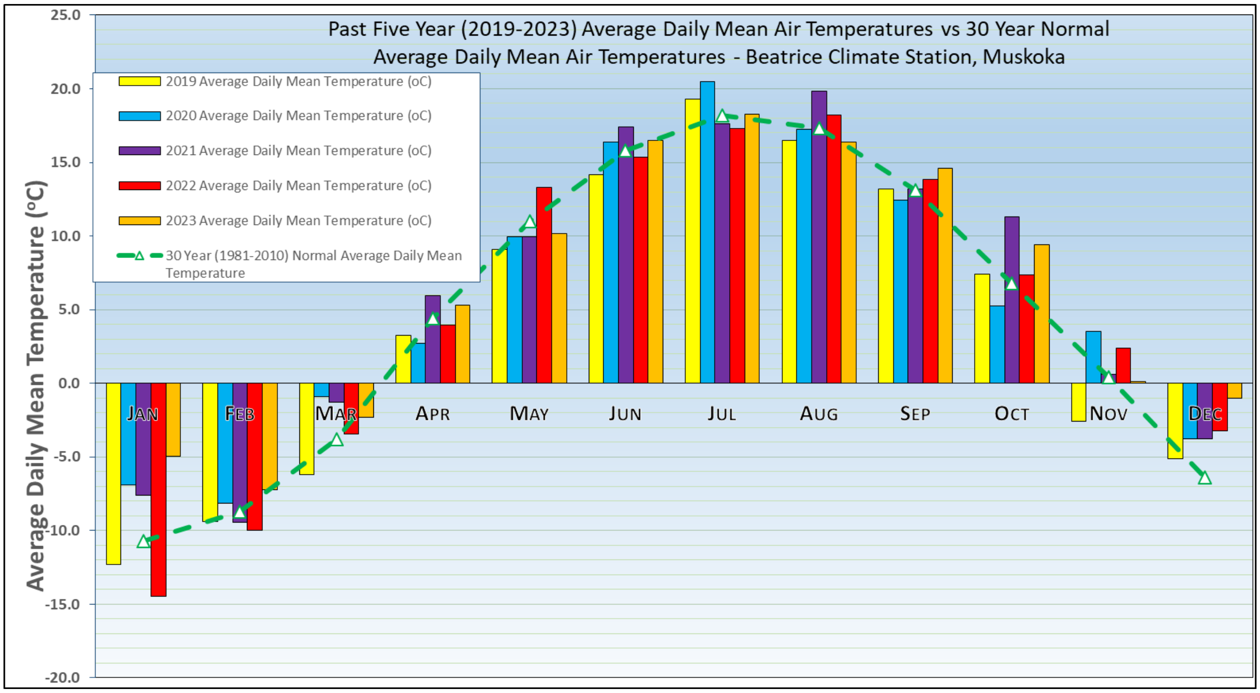
- as KLRA citizen volunteers, we are not qualified as a medical or public health authority to interpret or advise on the findings from this type of sampling program.
- Coliform concentrations are highly variable, which would make any predictive type of notification regarding use of the water for consumption or swimming virtually impossible.
- Given the length of time it would take to collect, submit and receive the results from this type of monitoring program, any benefit would be limited, as exposure and possible health effects would already have taken place by the time the results were received.

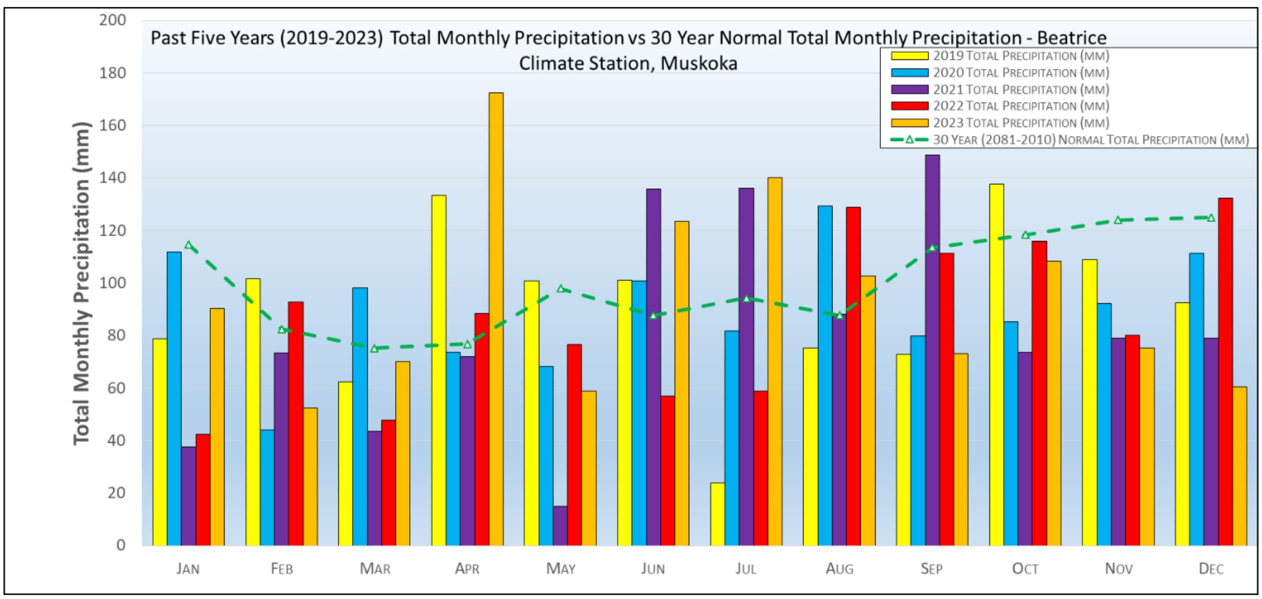
2.0 Overview of Climatic Factors and Water/Ice Conditions

In order to better understand the chemical and physical data that have been collected and their relationship (if any) to weather conditions, this year's report again includes an overview of average monthly air temperature and monthly total precipitation that have the potential to influence the lake monitoring findings. These findings have been compared to the data from 2019 through 2022 as well as to the 30 year normal results.

Air Temperature and Precipitation

Air temperature and rainfall records from the Beatrice Climate Station were evaluated. The charts below show the average daily mean monthly air temperature and total monthly precipitation (rain + snow) for 2023 and for the four previous years for comparison. These results are also compared to the 30 year (1981-2010) normal monthly temperature and precipitation.





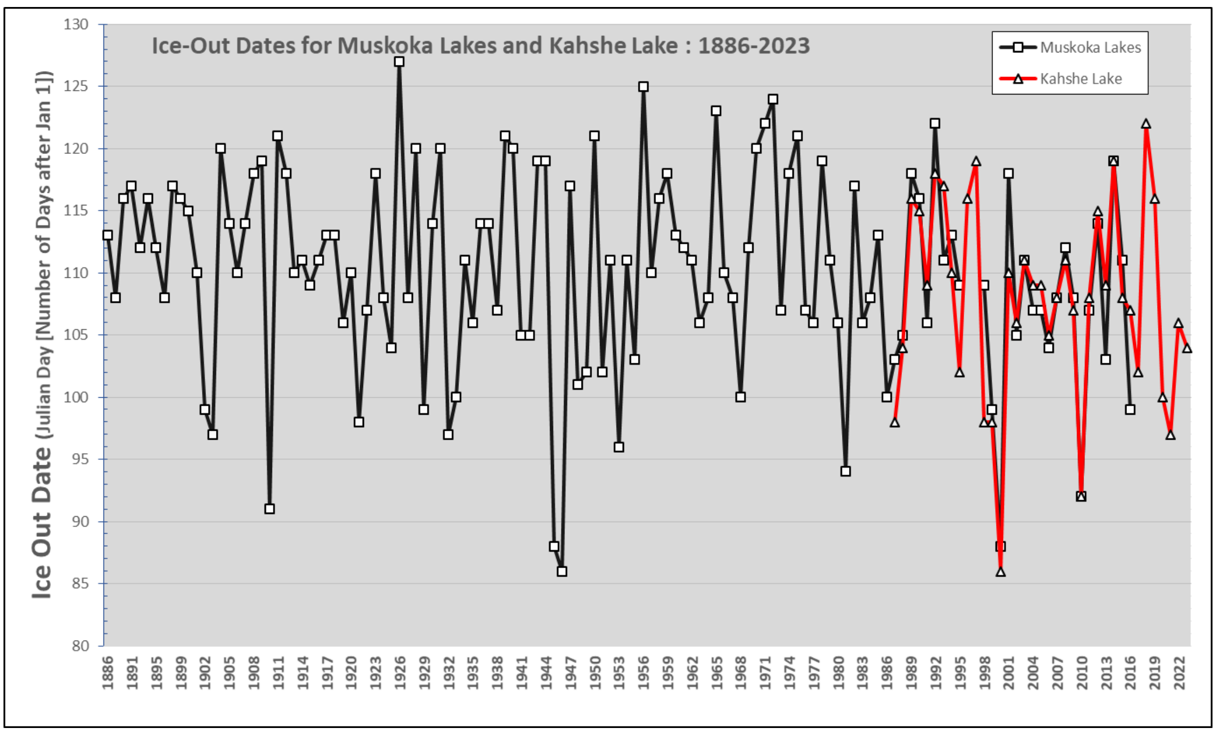
This comparison demonstrates that air temperatures in 2023 were generally similar to the four previous years and to the 30 year normal for most months. The only notable departure from this finding was a much warmer winter period in December and January. In the case of precipitation, total monthly amounts were noticeably greater than in previous years and compared to the 30 year normal in April, June and July, with much dryer conditions being recorded in November and December. In 2023, the lower levels of precipitation from September through December may have played a role in the absence of a late-season blue-green algal bloom as in 2020 and 2021. However, Bass Lake did experience a blue-green algal bloom in late August and this may be associated with the higher precipitation (combined with much higher total phosphorus levels vs. Kahshe Lake) in June and July. Obviously, these algal-bloom relationships with temperature and precipitation are subjective and would require a much more robust data set to demonstrate at typical scientific levels of probability.

Ice-Out Times

Although there are no DMM or MECP records for ice-out times on Kahshe or Bass Lakes, a publicly available record for ice-out times of Muskoka Lakes (Rosseau and Joseph) dating back 125 years was located. These data from 1886 through 2016 have been charted below using Julian Day, which is the number of days after January 1 each year. A trendline based on the assumption of a linear relationship was generated and did slope toward an earlier ice out times over this 125 year period; however, as this finding was not statistically significant (an R-squared value of only 0.0197) it was removed from the Muskoka Lakes chart.

To give some perspective on how ice-out conditions on Kahshe Lake compare with corresponding dates from Muskoka Lakes, data generated by R. Cronin from the Deep Bay area of Kahshe Lake have been located for the period from 1987 through 2019. This database has been updated with ice-out dates for Kahshe Lake based on personal records (R. Pearson) from 2020 through 2023, and these dates have been plotted in Figure 1. In 2023, the ice-out date was April 14. The data for Kahshe Lake (red line) appear to generally follow the ice-out dates for the larger Muskoka Lakes (black line) and there appears to be a trend towards earlier ice-out on both Muskoka Lakes and Kahshe Lake since the early 1970s. Attachment 1 provides the ice-out dates for Muskoka and Kahshe Lakes which were used to generate this chart.

Figure 1:



3.0 Overview of Environmental Monitoring

Kahshe and Bass Lakes are monitored for water quality and biological health under two main initiatives as outlined below:

Lake Partner Program (LPP) – MECP – Kahshe Lake Only

This program is operated by the Ontario Ministry of the Environment, Conservation and Parks (MECP) through the Dorset Environmental Science Centre. Under this program, water sampling and measurement of water clarity on Kahshe Lake is conducted on behalf of the MECP by your Lake Steward <u>every year</u>. The program consists of the following activities:

- **Water quality testing**

  Water is sampled in May each year from three locations on Kahshe Lake and sent to the MECP Dorset laboratory where it is analyzed for total phosphorous, calcium and chloride.

- **Water clarity measurements**

  Clarity of the water is measured every two weeks during the ice-free period at the same three locations using a Secchi disc, and these findings are forwarded to the MECP after 8-10 measurements have been completed.

Lake System Health Program (DMM) – Kahshe and Bass Lakes

This program is one of several components of a larger Muskoka Water Strategy which is operated by the District Municipality of Muskoka (DMM), with support from the Muskoka Watershed Council (MWC), the MECP and several other participating agencies.

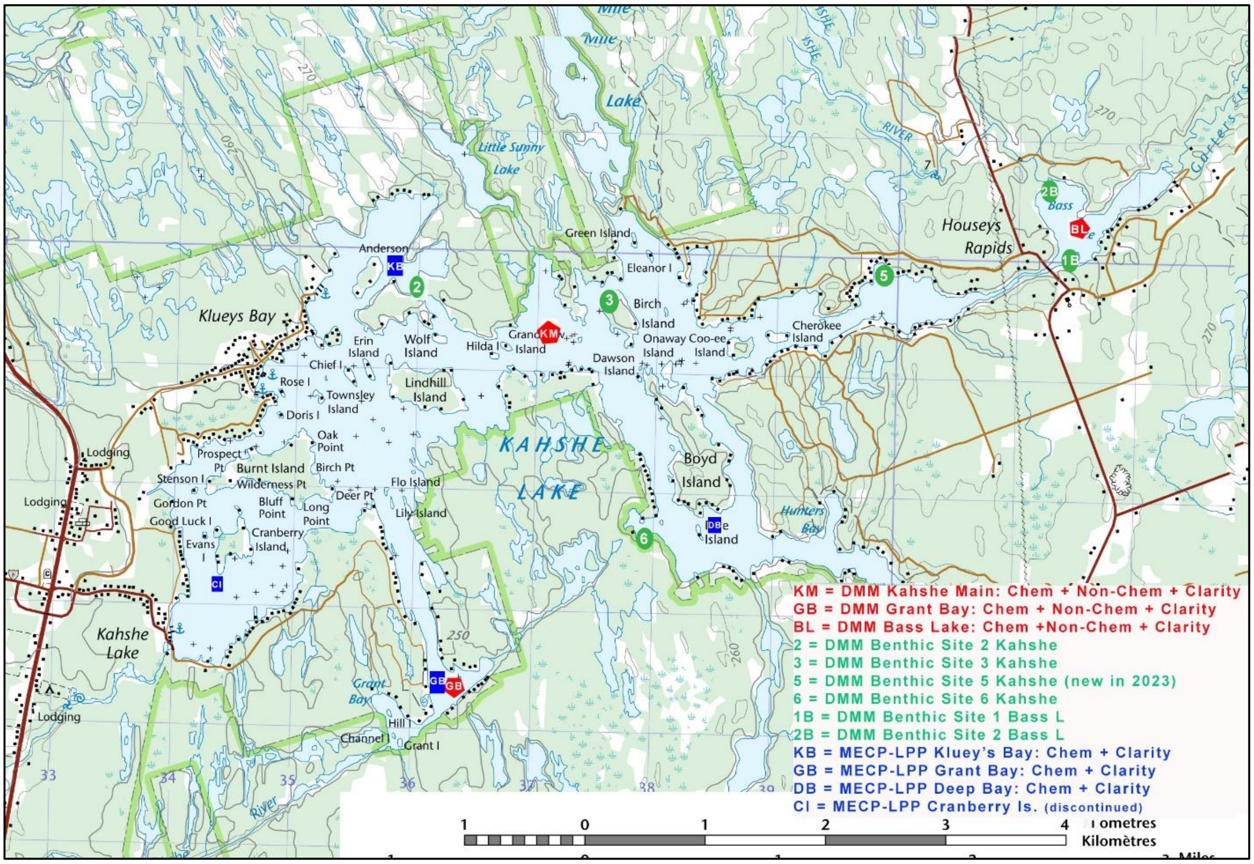
The program was designed to establish a long-term record of key water quality parameters so that trends in water quality and lake system health could be identified and appropriate management decisions taken to protect, maintain and where possible, to enhance the health of Muskoka's watershed for present and future generations. For Kahshe and Bass Lakes, the DMM program consists of the following activities which have been conducted every second year for Kahshe Lake and every third year for Bass Lake:

- Water sample collection for total phosphorus and a suite of other physical and chemical parameters in the spring (May/June at two sites in Kahshe Lake and one site in Bass Lake);
- Secchi disc water clarity measurements collected in the spring (May/June) and late summer (August – at two sites in Kahshe Lake and one site in Bass Lake);
- Temperature and dissolved oxygen at increasing water depths taken in the spring (May/June) and late summer (August at two sites in Kahshe Lake and one site in Bass Lake);
- Benthic invertebrate sampling at one or two of four established sites in Kahshe Lake in August each year from 2004 through 2007, 2011 through 2015 and 2019-2022 and at two sites in Bass Lake from 2016 through 2023.

Although water quality and benthic sampling of Kahshe and Bass Lakes in 2023 would not normally have been carried out, it was conducted to further assess water quality, as both lakes have been determined to be "Vulnerable" due to either elevated levels of total phosphorus (Bass Lake) or to the documented presence of a blue-green algal bloom (Kahshe Lake) in both 2020 and 2021.

The locations of water sampling and benthic monitoring on both lakes have been shown on Figure 2 below.

Figure 2: Map Showing All MECP and DMM Sampling Locations on Kahshe and Bass Lakes



4.0 Results of Monitoring on Kahshe and Bass Lakes

In this report, the results have been presented in several sections to focus on the main parameters of concern. Because both the DMM and the MECP include sampling of some of the same parameters, this report also compares the findings from each agency. The main components of this report will address the following main areas of interest/concern in terms of water quality:

- Algal Nutrients and Other Factors Promoting Algal Growth
- Calcium Depletion
- Lake Acidification
- Metals and Other Chemicals of Concern
- Dissolved Oxygen Depletion
- Benthic Organism Health

4.1 Algal Nutrients and Other Factors Promoting Algal Growth

Harmful algal blooms (HABs) are a global water quality issue and are the result of ongoing nutrient (nitrogen and phosphorus) loading from watersheds (Downing et al., 2001; Elmgren, 2001; Conley et al., 2009; Smith and Schindler, 2009; Brookes and Carey, 2011; and Paerl et al., 2011). Climate change, which can result in warmer temperatures, changes in the frequency and intensity of precipitation and stronger stratification (Jöhnk et al., 2008; Wagner and Adrian, 2011; Carey et al., 2012; and Posch et al., 2012) also play a causal role. Adding to the complexity of algal bloom development is the fact that algae also play a role in both nitrogen and phosphorus cycling within the water column (U.S. EPA, 2008); in the fixation of nitrogen from the atmosphere and in the release of phosphorus from sediments under low oxygen conditions. Micronutrients such as iron, molybdenum and copper also are involved in the cycling and release of algal friendly nutrients and can play a causal or contributing role in the development of an algal bloom.

The most harmful, blue-green algae, are actually cyanobacteria. They are primitive microscopic organisms that have inhabited the earth for over two billion years. They are bacteria, but have features in common with algae. Although often blue-green in colour, they can range from olive-green to red. Blue-green algae occur naturally in a wide variety of environments including ponds, rivers, lakes and streams. For more information on these organisms and their impacts on lakes in Ontario and other areas, refer to fact sheets published by the Ontario Environment Ministry (2014) and Municipal Affairs and Environment, Newfoundland and Labrador (2019).

Why are we concerned about the development of blue-green algal blooms? Because blue-green algal blooms can produce toxins that pose a health risk to both humans and animals (Hudnell, 2008). The blooms also negatively affect the appearance and aesthetic qualities of the lake and this is likely to impact recreational enjoyment and reduce property values.

The severity of symptoms and the level of risk to health depend on how receptors are exposed to blue-green algal toxins. Human health effects from contact with these toxins may include:

- itchy, irritated eyes and skin from direct contact through activities such as bathing or swimming; and,
- flu-like symptoms, such as headache, fever, diarrhea, abdominal pain, nausea and vomiting if large amounts of impacted water are ingested.

To give a better idea of the potential impact of an HAB, a copy of the Simcoe-Muskoka Health Unit's 2020 advisory to the property owners on Kahshe Lake following a late-season bloom in the vicinity of Oak Road has been shown below:

- The health unit advises residents and businesses not to drink the water from this lake and to take the following precautions:
- do not use the lake water for drinking or for food preparation including breastmilk substitute (infant formula), even if it is treated or boiled;
- do not cook with the lake water because food may absorb toxins from the water;
- do not allow pets or livestock to drink or swim in the water where an algae bloom is visible; and,
- do not eat the liver, kidneys and other organs of fish caught in the lake and be cautious about eating fish caught in water where blue-green algae blooms occur.

Based on the foregoing discussion, the most obvious question is how can the potential for HABs be minimized? There are essentially two main drivers in the formation of HABs - nutrient enrichment and warming waters. The first is within our control while the second is associated with a changing climate. In the case of nutrient enrichment, the main causal factors in algal growth are essential nutrients phosphorus and nitrogen. For lakes like ours, which have no identifiable inputs from industrial, municipal or agricultural operations, nitrogen and phosphorus enters primarily in these ways:

- from septic system effluents via leaching or runoff
- from lawn and garden fertilization via leaching or runoff
- from land-clearing/shoreline disturbance and soil/water runoff to the lake
- from atmospheric inputs (mainly nitrogen via rainfall and dust)
- from aquatic and semi-aquatic wildlife excretions, and
- from re-suspension of minerals from rock/sediments as part of phosphorus and nitrogen cycling.

Those sources that to some degree are within our control are highlighted in yellow above.

The main focus of water quality monitoring in Muskoka and Ontario by both the DMM and the MECP has been to track the quality of the water in terms of its total phosphorus levels. This in turn has served as a driver of shoreline management and property development strategies. However, emerging research shows that nitrogen is more involved in harmful algal growth than originally thought (Great Lakes Commission, 2017).

While nutrient enrichment is important, it is not the only factor involved in the promotion of harmful algal growth. Blue-green algae thrive in areas where the water is shallow, slow moving and warm, but they may also be present in deeper, cooler water. Accordingly, this section has been structured to examine the three main causal factors (excluding light which is essential for photosynthesis) in the development of harmful algal growth: **phosphorus, nitrogen and water temperature**.

The analysis in this section also includes water clarity, as although it's more a symptom of nutrient enrichment and degraded water quality than a fundamental driver of algal growth, it can provide an early warning for lake water conditions that are susceptible to algal growth.

PHOSPHORUS

In the 1960s and 70s, many North American rivers and lakes were experiencing rapid declines in water quality. Industrial and municipal effluents were stimulating the growth of algae and other aquatic plants (termed 'eutrophication') leading to unsightly mats of green sludge, oxygen depletion, massive die-offs of fish and other aquatic life, and problems with the taste and odour of municipal drinking water.

The public, industry, and all levels of government agreed that something had to be done. However, there was disagreement over the most effective course of regulatory action because at the time, scientists and policymakers were still debating which nutrients were most responsible for eutrophication.

In the late 1960s and early 70s, David Schindler, a Canadian limnologist managed a number of whole-lake experiments designed to determine which nutrient (out of nitrogen and phosphorus) was primarily responsible for eutrophication. His studies clearly demonstrated that phosphorus was the main contributor.

As a result of that work and other studies, the main focus of the recreational lake monitoring programs in Ontario has been on measuring total phosphorus concentrations and linking the findings to management strategies. In Muskoka, the DMM now evaluates the quality of recreational lakes under the Muskoka Official Plan (MOP, 2023). The shaded text below has been extracted from the MOP to provide some background on the role of phosphorus and its sources in Muskoka.

Phosphorus enters Muskoka's waterbodies naturally each year from animal waste, soil erosion, decomposing plant material, and the atmosphere. Phosphorus also enters waterbodies through anthropogenic sources such as changes in land use near waterbodies such as shoreline clearing, **development**, and also from stormwater runoff and **individual on-site sewage services** effluent. With increasing human activities, and when shoreline plants are removed or diminished and can no longer manage to properly filter out sediments in surface runoff, phosphorus levels rise.

Because phosphorus is a nutrient, high phosphorus levels in waterbodies encourage excessive growth of aquatic plants and algae. Over the past several years, strengthened planning policies across Muskoka have contributed to stabilized phosphorus levels. Since 2000, there have been no statistically **significant** increases in phosphorus concentrations in any waterbody in Muskoka.

Apart from shoreline **development**, Muskoka's water is impacted by a variety of environmental stressors. The potential effects of multiple environmental stressors must now be considered, including, but not limited to a changing climate with resultant changes in precipitation, temperature, runoff and evaporation that affect physical, chemical and biological conditions of waterbodies, invading species populating an increasing number of waterbodies, declining concentrations of calcium, and internal phosphorus loading from sediments. Appropriate shoreline **development** will contribute to the resiliency of each waterbody against a variety of environmental stressors. Resiliency of a waterbody is defined as its ability to be resistant or adaptable to change.

While the consideration of multiple environmental stressors is important, Hutchinson Environmental Sciences Limited's Report, Revised Water Quality Model and Lake System Health Program (April 2016), advises that the District of Muskoka's monitoring program should continue to be used to track phosphorus in waterbodies and the focus should be on key water quality indicators which offer insight into measurable and observable changes in **recreation**al water quality on a waterbody-specific basis.

A description of the water quality indicators which replace the former "Background and Threshold Levels" are fully described in the MOP and the shaded text below describes how these indicators are applied.

WATER QUALITY INDICATORS

a) The identified water quality indicators are as follows:

i) A long-term statistically **significant** (p<0.1) increasing trend in total phosphorus concentration demonstrated by at least five (5) spring overturn phosphorus measurements obtained through the District of Muskoka water quality sampling program since 2001;

ii) A long-term total phosphorus concentration of greater than 20 μg/L demonstrated by the average of five (5) most recent spring overturn phosphorus measurements obtained through the District of Muskoka water quality sampling program within the last ten (10) years ; and/or

iii) A blue-green algal (cyanobacteria) bloom confirmed and documented by the Province and/or Health Unit.

b) While the identified water quality indicators continue to focus on phosphorus as a recognized and measurable gauge of **recreation**al water quality, a long-term shift in focus to include a wider variety of indicators addressing multiple environmental stressors is anticipated as science evolves and stronger links are made between potential indicators, lake health and best management practices.

c) The District of Muskoka shall support and monitor scientific research, including promoting, conducting, co-ordinating and/or participating in scientific water quality research or pilot projects with partners such as Muskoka Watershed Council, the Province, Area Municipalities, Lake Associations, and universities/colleges.

d) Additional water quality indicators may be included in Section C2.6.3.2 a) by amendment to this Plan to address multiple environmental stressors and/or to incorporate advances in science, provided that they are evidence-based and to the satisfaction of the District of Muskoka and/or Provincial Ministry with jurisdiction.

e) The District of Muskoka will monitor waterbodies for the presence of the phosphorus related water quality indicators on a rotating basis. When the presence of an indicator is confirmed, monitoring of the waterbody will be annual. Notwithstanding Section C2.6.3.2 a), the District of Muskoka will also monitor waterbodies for linear short-term increases in total phosphorus as identified through the most recent three total phosphorus samples. Should a waterbody demonstrate such a trend and/or the presence of any water quality indicator, water quality sampling frequency will be increased.

Schedule E2

WATERBODIES WHERE A WATER QUALITY INDICATOR HAS BEEN CONFIRMED IN ACCORDANCE WITH THE POLICIES OF SECTION C2.6 OF THE MUSKOKA OFFICIAL PLAN

WATERBODY	INDICATORS		
	P Concentrations >20 ug/L*	Increasing P Trend**	Blue Green Algal Bloom***
BARRON'S LAKE (GB)	x		
BASS LAKE (GR)	x		
BASS LAKE (ML)			x
BLACK LAKE (ML)			x
BRANDY LAKE (ML)			x
BRUCE LAKE (ML)			x
CLARK POND (ML)			x
ECHO LAKE (LB)			x
KAHSHE LAKE (GR)			x
LAKE MUSKOKA – BOYD BAY (BR/ML)			x
LAKE MUSKOKA – WEISMILLER BAY (ML)			x
LAKE OF BAYS – TEN MILE BAY (LB)			x
LEONARD LAKE (ML)			x
LITTLE LAKE (GB)			x
RIL LAKE (LB)			x
SILVER LAKE (ML)			x
STEWART LAKE (GB/ML)			x
THREE MILE LAKE (ML)			x

NOTES:

* WATERBODIES WHERE LONG-TERM PHOSPHORUS CONCENTRATIONS EXCEED 20 MICROGRAMS/LITRE

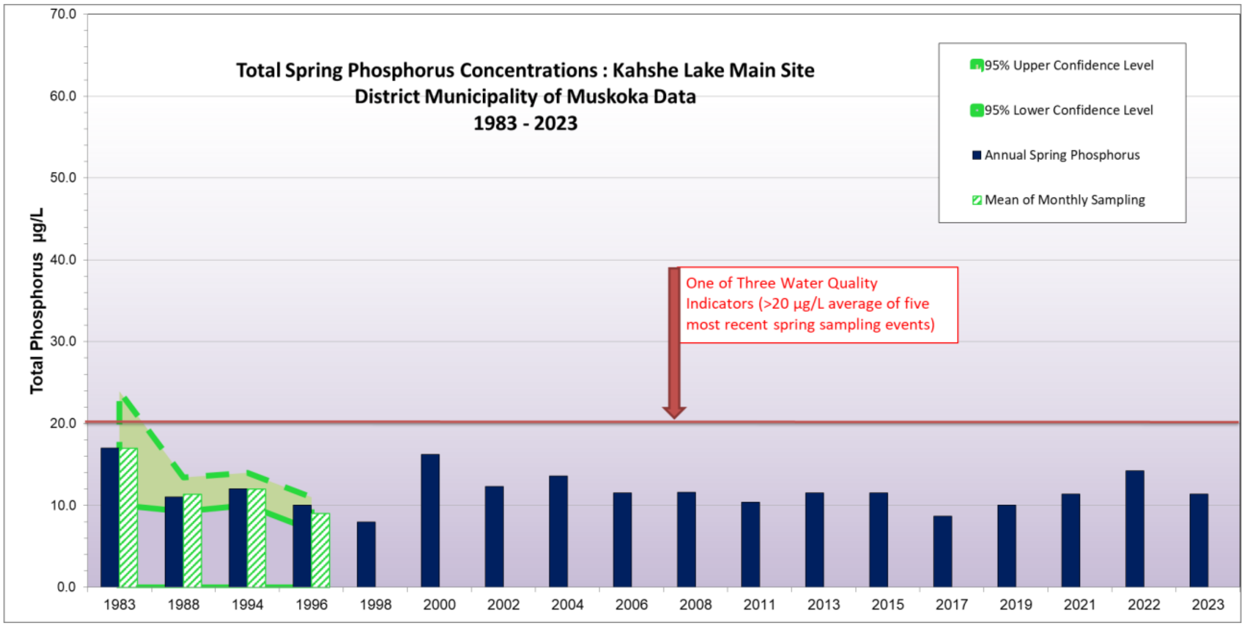
** WATERBODIES WITH A LONG-TERM STATISTICALLY SIGNIFICANT INCREASING TREND IN PHOSPHORUS CONCENTRATION

*** WATERBODIES WITH A CONFIRMED AND DOCUMENTED OCCURRENCE OF A BLUE-GREEN (CYANOBACTERIAL) ALGAL BLOOM

Based on the above referenced water quality indicators, lakes in Muskoka have been identified as 'Vulnerable' in Schedule E2, which has been reproduced aside. As noted, Kahshe Lake remains a 'Vulnerable' lake due to its confirmed blue-green algal blooms in 2020 and 2021. Bass Lake remains on Schedule E2, but will be removed on the next update, as a DMM funded Causation Study concluded that the elevated phosphorus was due to natural causes and was not related to shoreline development activity. However, given a confirmed blue-green algal bloom in Bass Lake in 2023, it may end up being removed based on the causation study, and then re-listed because of the HAB. Staff at DMM could not provide any further information on this matter as it has not been encountered in any other lake which passed one indicator but subsequently failed another.

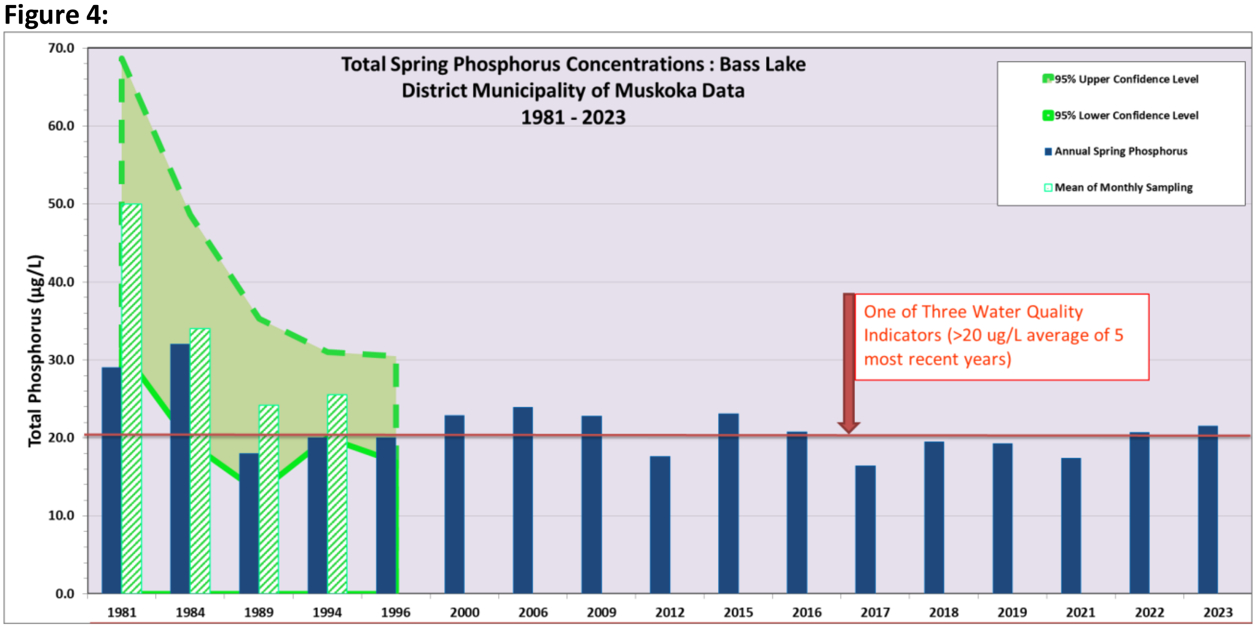
The DMM's total spring phosphorus results for 2023 in Kahshe Lake as well as those of the past 40 years are shown in Figure 3 below:

Figure 3:



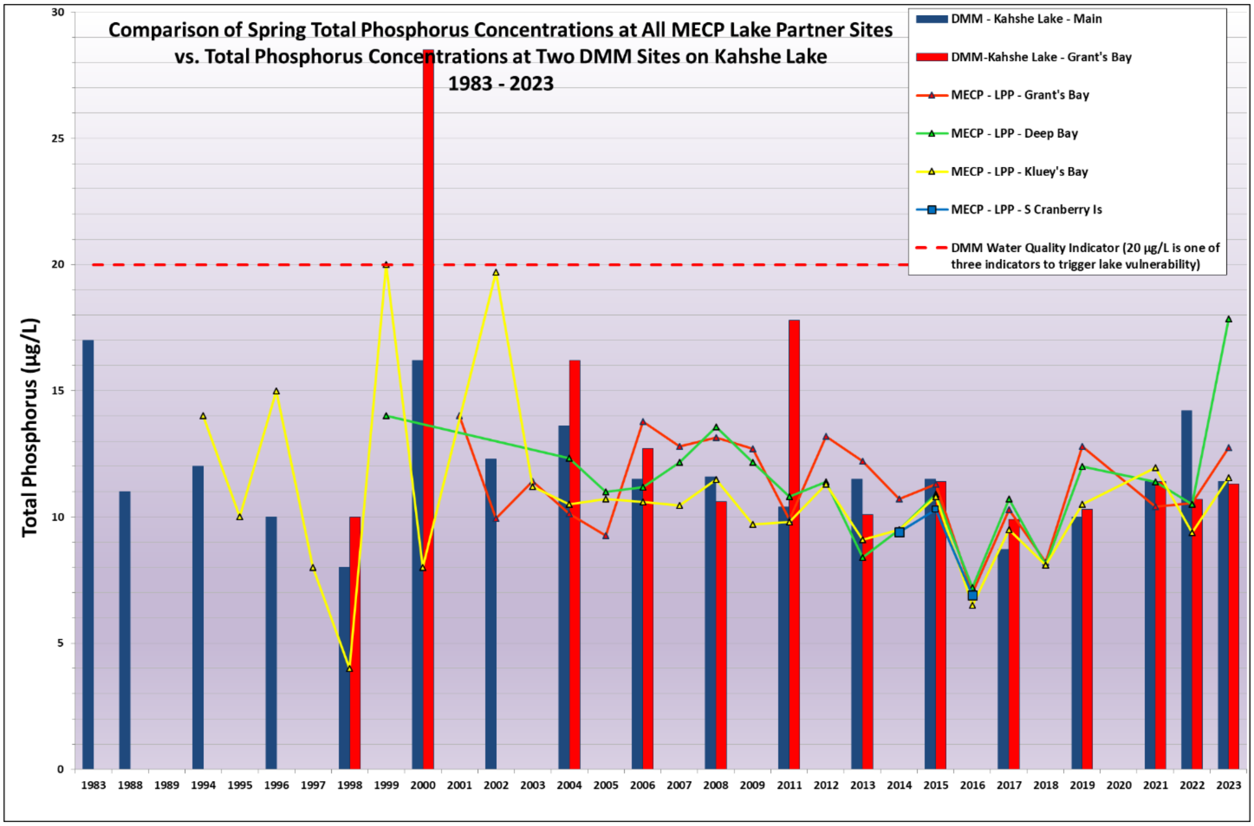
The DMM's 2023 total spring phosphorus results for Bass Lake are shown below in Figure 4:

Figure 4:



Kahshe Lake also was sampled and analyzed for total spring phosphorus under the Lake Partner Program (LPP). Figure 5 below shows the total phosphorus levels at the three LPP sampling sites in Kahshe Lake for 2023. The historical findings dating back to 1994 for the LPP program and to 1983 for the DMM results also are presented for comparison purposes.

Figure 5:



These total phosphorus findings are summarized below:

- In both lakes, there has been no long term trend in total phosphorus concentrations over the past 40 years.
- Historically, the total phosphorus levels in Bass Lake are about twice as high as those in Kahshe Lake.
- A comparison of the total phosphorus concentrations determined via the DMM and MECP sampling programs have yielded very similar findings, with most of the differences in phosphorus likely due to different spring sampling dates which would be influenced by snow melt, precipitation and the degree of lake stratification (turnover).
- While the DMM and MECP mid-lake, deep water sampling sites on Kahshe Lake generate an excellent historical record of total phosphorus concentrations for long-term trend analysis, the findings of the 2021 KLRA-funded Near Shore Water Sampling Project demonstrated two important weaknesses in this historical record:
    - it fails to capture higher total phosphorus concentrations at the East end of Kahshe Lake which receives input flow of higher phosphorus water from Bass Lake; and
    - the mid-lake levels are not representative of the higher and more variable near-shore total phosphorus levels which are influenced directly via shoreline sources in areas where HABs are likely to manifest.

NITROGEN

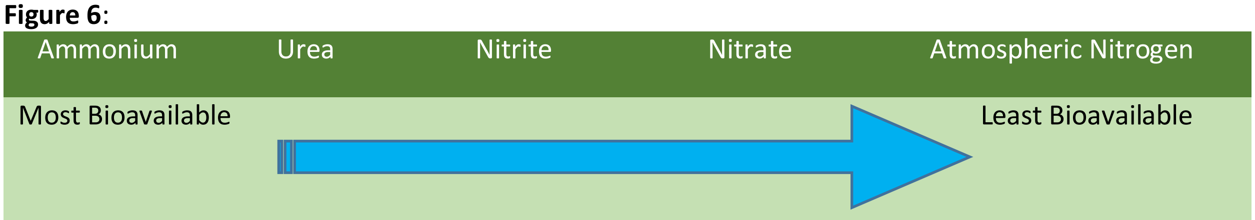
In a recently published document (Great Lakes Commission, 2017) on the role of nitrogen in the formation of harmful algal blooms, the current knowledge was summarized and is further discussed below. While this work was focussed on algal blooms in Lake Erie, the findings appear applicable to smaller freshwater bodies such as Kahshe and Bass Lakes.

Based on their work, nitrogen dynamics in aquatic systems was found to play a role in understanding both algal biomass trends (i.e. the size/extent of bloom development) and potential toxicity. For example, nitrogen additions can increase both biomass and toxin production in algal blooms, but at different rates depending on the form of nitrogen. (Harke et al., 2016).

In water, nitrogen occurs in several different dissolved forms. These forms influence communities of algae and cyanobacteria in different ways based largely on their abilities to convert the different nitrogen forms into biomass and compete with other organisms. Regardless of the form, cyanobacteria must convert nitrogen to ammonium (NH_4^+) within the cell before they can use it for biomass or toxin production. Ammonium is also the easiest nitrogen form for primary producers to acquire and transport into the cell. Nitrate and nitrite (NO_3^- /NO_2^-) must be actively transported into the cell and then converted to ammonium, which, in turn, requires energy and micronutrients, such as iron.

The differences in nitrogen bioavailability for algal growth are graphically summarized in Figure 6 below:

Figure 6:



(adapted from Harke et al. 2016 as presented in Great Lakes Commission, 2017)

As noted earlier, the primary sources of nitrogen to inland lakes like Kahshe and Bass would be from septic system discharge and soil erosion and leachate migration from fertilized lawns/gardens. Residue from bird and aquatic animal feces, plant decay (leaves, aquatic weeds) and to a lesser extent from atmospheric deposition also contribute, especially in areas where food sources like lawn grass are available.

The nitrogen monitoring results for two forms of nitrogen that are analyzed by DMM have been charted below in **Figures 7 and 8**. Although no aquatic benchmarks were located for total nitrogen, the calculated (up to 2019) and measured (post 2019) concentrations in both Kahshe and Bass Lakes are shown in **Figure 9**.

Figure 7:

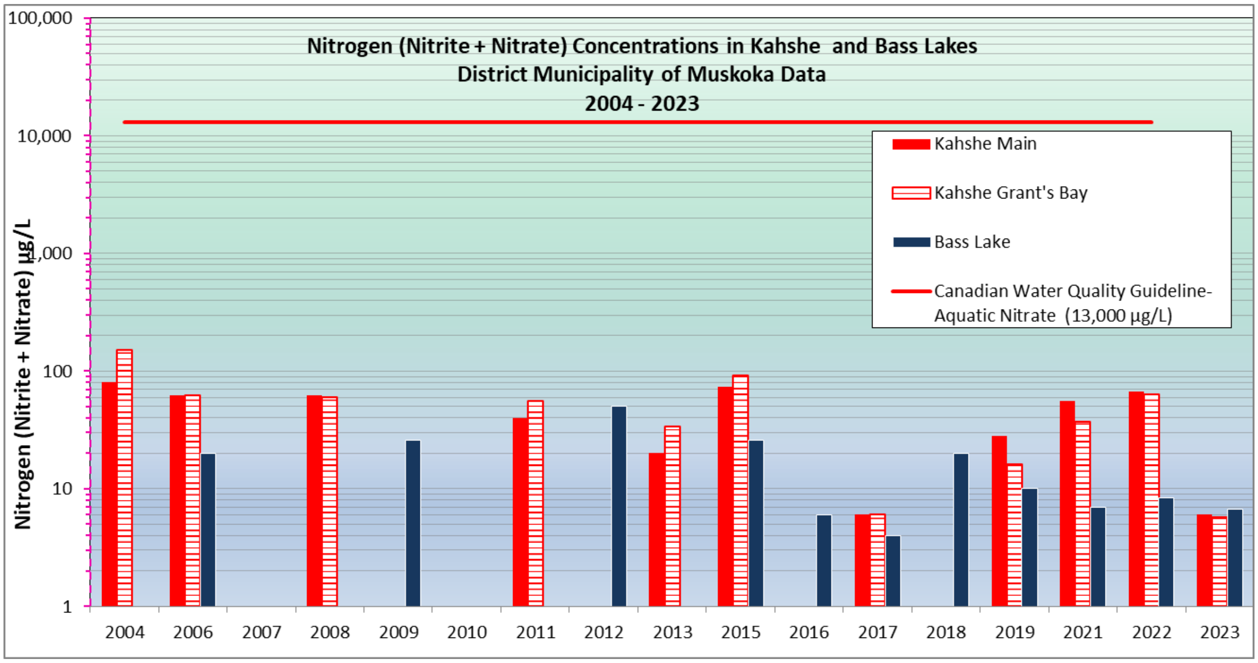


Figure 8:

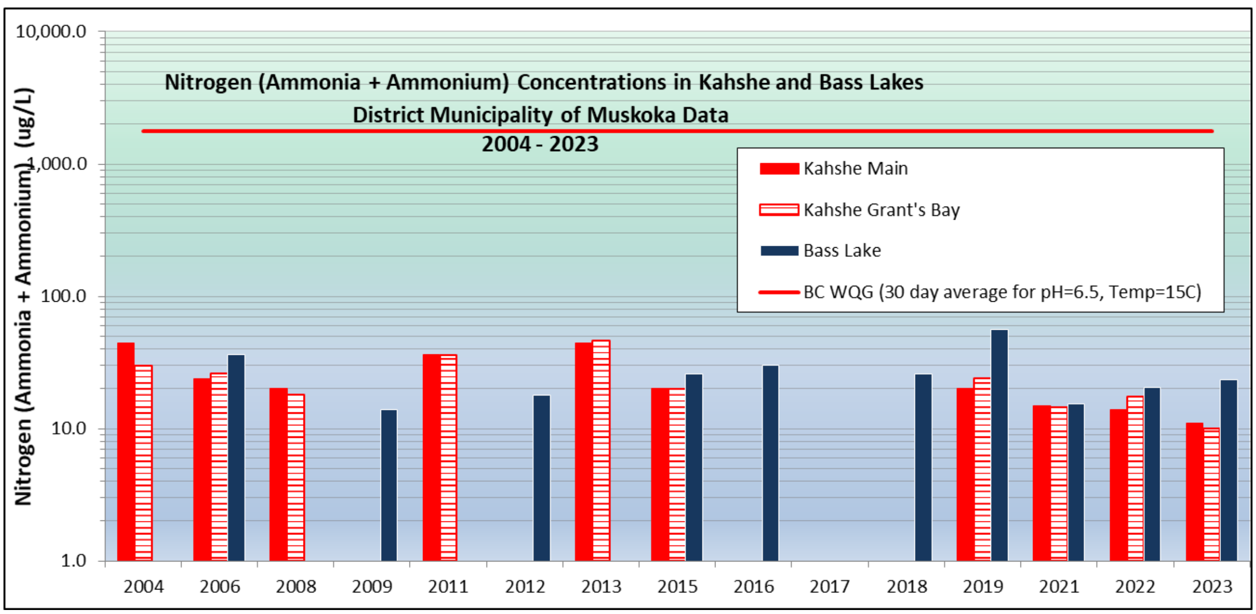
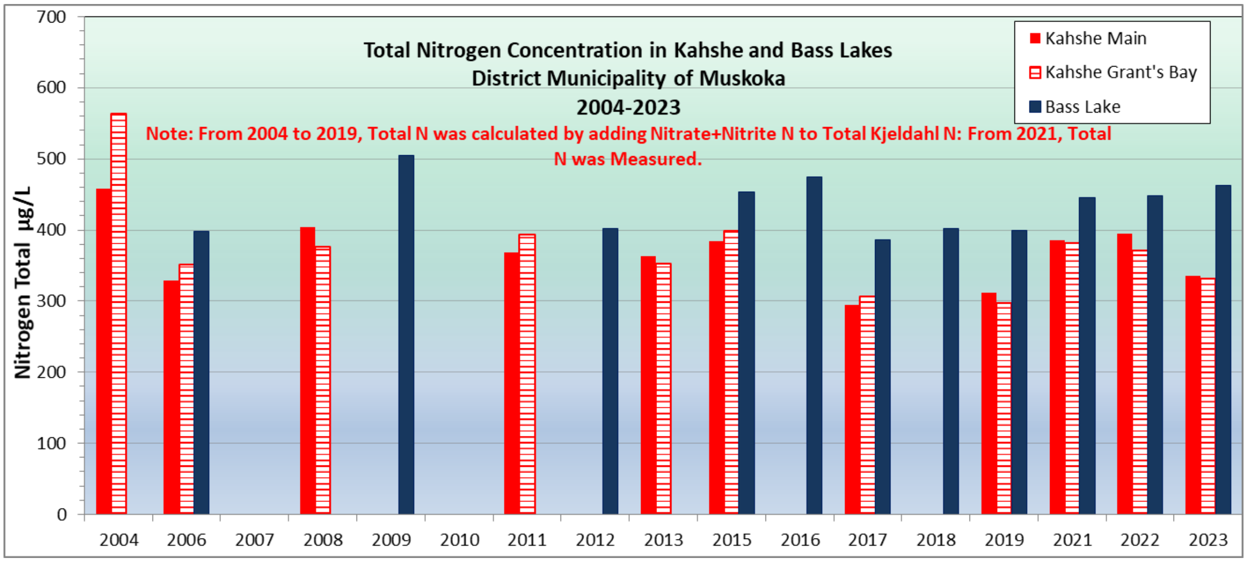


Figure 9:



The results of the analysis for nitrogen in both lakes are summarized below.

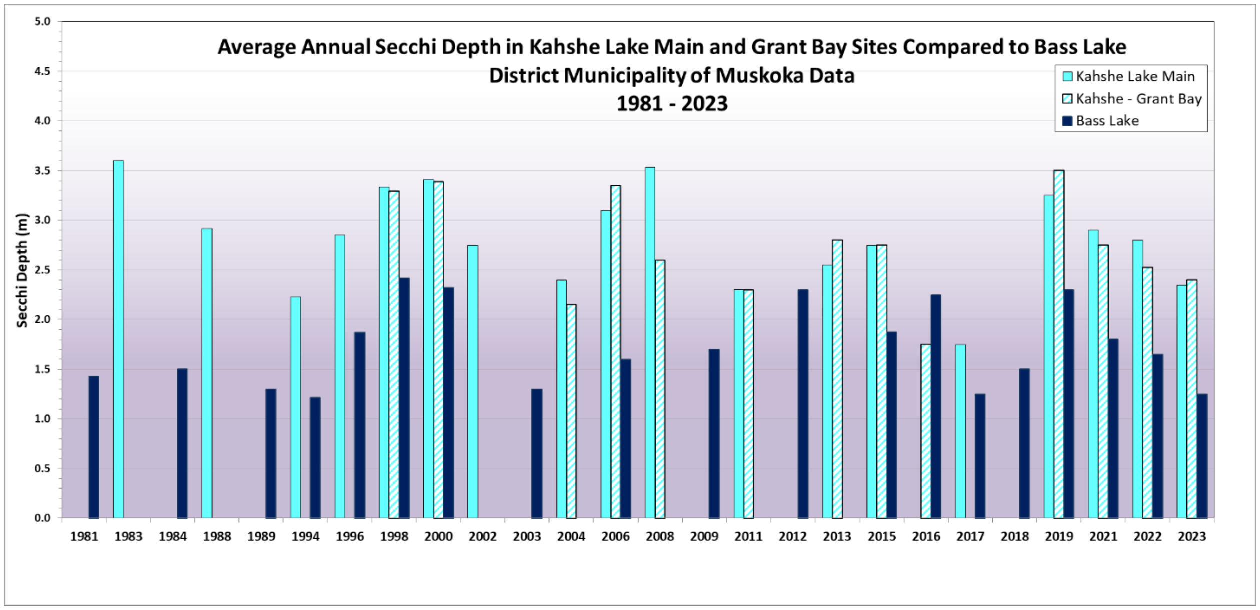
- No evidence of a concentration trend in either of the two analyzed forms of nitrogen or total nitrogen has been detected in Bass or Kahshe Lakes over the years dating back to 2004.
- In contrast to total phosphorus, the concentrations of nitrate + nitrite in Bass Lake are generally lower than the corresponding analysis results for Kahshe Lake; and as noted in Figure 9, this is not the case for total nitrogen, where levels in Bass Lake are always higher than in Kahshe Lake.
- In all cases, the reported nitrogen concentrations are well below any aquatic benchmarks that have been set to protect sensitive aquatic species.
- No algal growth benchmarks for either form of nitrogen have been located, as the linkage between phosphorus, nitrogen and water temperature is too complex to set individual nutrient benchmarks.
- While not shown above, the findings from the KLRA-funded Near-Shore Water Sampling Project conducted in 2021 demonstrated that nitrogen concentrations in the near-shore environment are often considerably higher than these spring-sampled mid-lake levels, often increase or decrease as the season progresses and appear to have played a causal or contributing role in the development of the HABs bloom that were documented in 2021.

WATER CLARITY

While the linkage between total phosphorus concentrations and water clarity are typically weak in tea coloured waters where clarity also is impacted by dissolved organic carbon (DOC), both sampling programs have monitored clarity via the Secchi disc method.

The DMM's 2023 water clarity levels for both lakes have been compared with the historical results dating back to 1980s in Figure 10 below.

Figure 10:

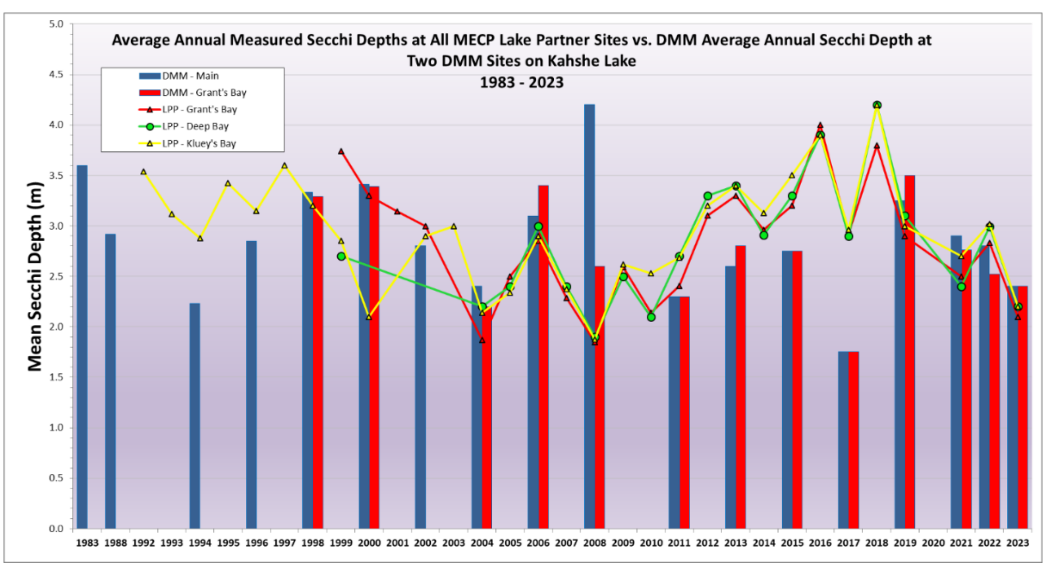


The findings from this comparison are summarized below:

- Water clarity in Bass Lake in 2023 continued a downward trend from 2019 but was generally in line with low water clarity in some earlier years.
- Water clarity in Kahshe Lake in 2023 followed a similar downward trend from 2019 but was generally similar to historical measurements dating back to 1983.
- Water clarity is noticeably better in Kahshe Lake than in Bass Lake, most likely due to the more tea coloured nature of Bass Lake - as confirmed by slightly higher Dissolved Organic Carbon [DOC] levels in Bass Lake.

To further explore the water clarity in Kahshe Lake as determined by the DMM, the MECP's Lake Partner data for water clarity at the three sampling sites in Kahshe Lake also were charted for comparison. The findings are shown below in Figure 11.

Figure 11:



Evidence of greater MECP-measured water clarity compared to DMM clarity measurements that was recorded from 2011 through 2017 was not repeated in the years from 2019 through 2023. This may be related to the methodology for recording water clarity, as the DMM measurements are the average of two sampling events (spring and late summer) while the MECP's LPP measurements recorded by the Lake Steward represent an average of 8-10 measurements at each site over the period from May through October. Another possible reason for the divergence is that DMM measurements are scheduled in advance and as such, they are taken irrespective of weather conditions. Those taken by your Lake Steward are not strictly pre-scheduled and as such, they are typically taken during sunny days when water clarity is enhanced – i.e. the Secchi disc is more visible down to lower depths under sunny conditions.

WATER TEMPERATURE

Another parameter involved in algal bloom development is water temperature, as warm water increases the rate of photosynthesis and promotes algal growth. Water temperature is important for several other reasons including:

- It affects the solubility of oxygen in water.
- It affects the metabolic rates, life cycles and the sensitivity of all aquatic organisms to parasites and disease.
- It factors into the classification of a lake as a cold or warm water body (both Kahshe and Bass are considered warm water lakes – i.e. not a Lake Trout Lake).

The DMM water temperature readings at increasing depths in both Kahshe (main site) and Bass Lake data dating back to 1988 have been plotted in the four charts below (Figures 12-15). In an attempt to explore any trends in water temperature, the 2023 results have been compared with historical means grouped over four time periods:

- Pre 2000 (1980s and 1990s)
- The decade of 2000-2009
- The decade of 2010-2019
- The decade of 2020-2029 (2021, 2022, 2023…)

Figure 12:

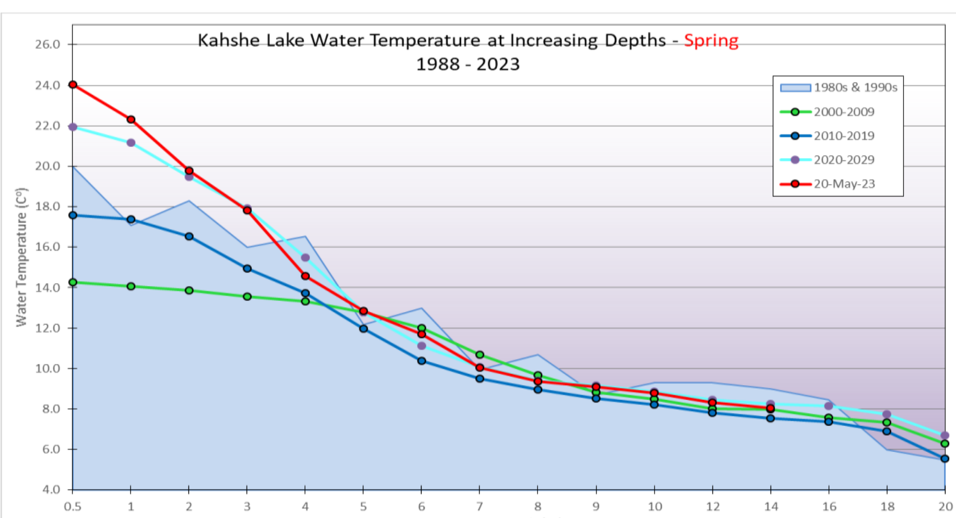
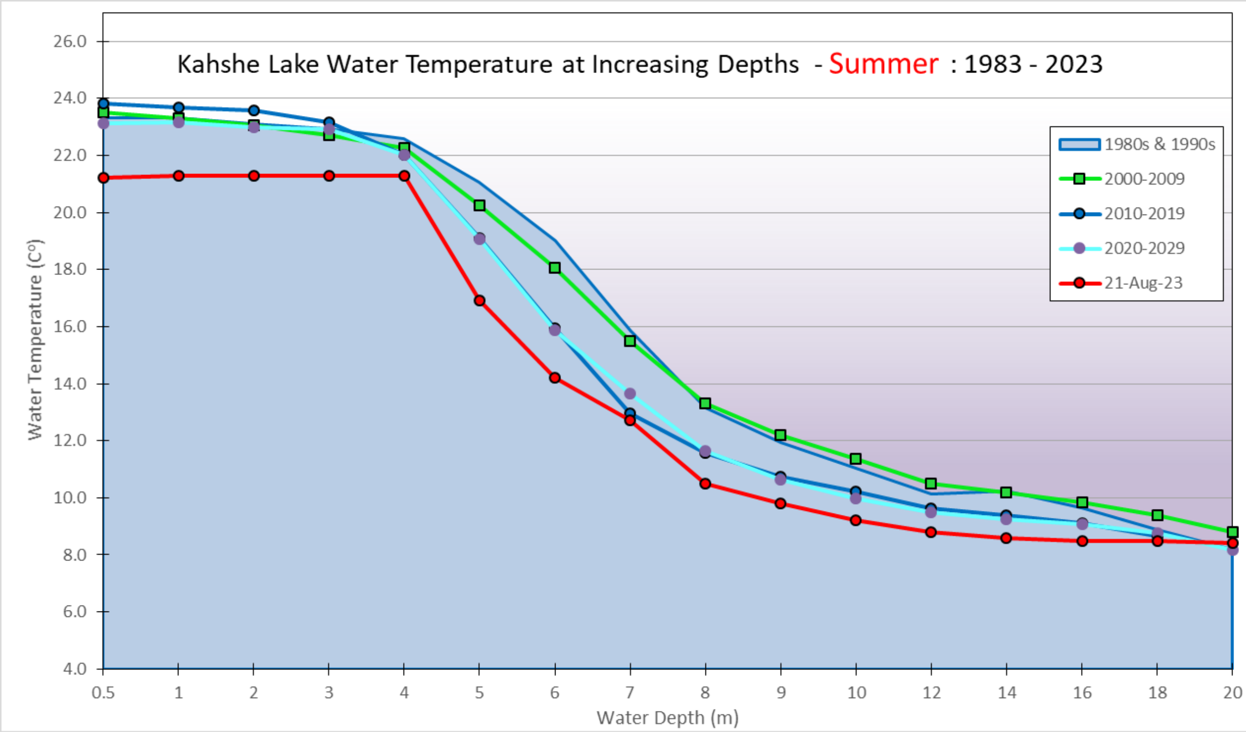


Figure 13:



It is apparent from Figures 12 and 13 that:

- In the spring of 2023, Kahshe Lake was noticeably warmer down to a depth of about 4m but generally similar to all previous averaging periods below that depth.
- By August 2023, the spring warming noticed in the upper 4m was no longer present and the temperature at all depths generally followed the historical trend of decreasing temperature with increasing depth.
- These findings revealed no evidence of increasing lake water temperatures and possibly lower lake temperatures at depths almost to the lake bottom from 2010 onward.

The water temperature findings for Bass Lake in both spring and summer are presented in Figures 14 and 15 below:

Figure 14:

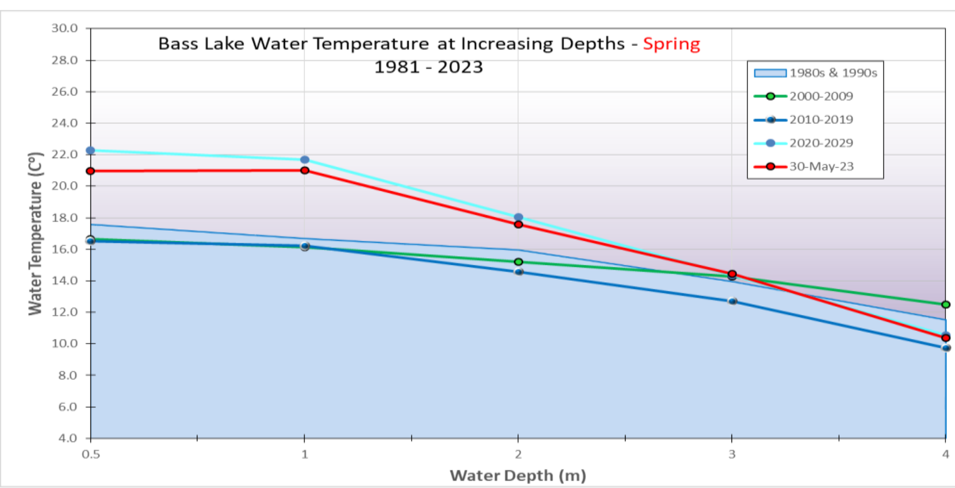
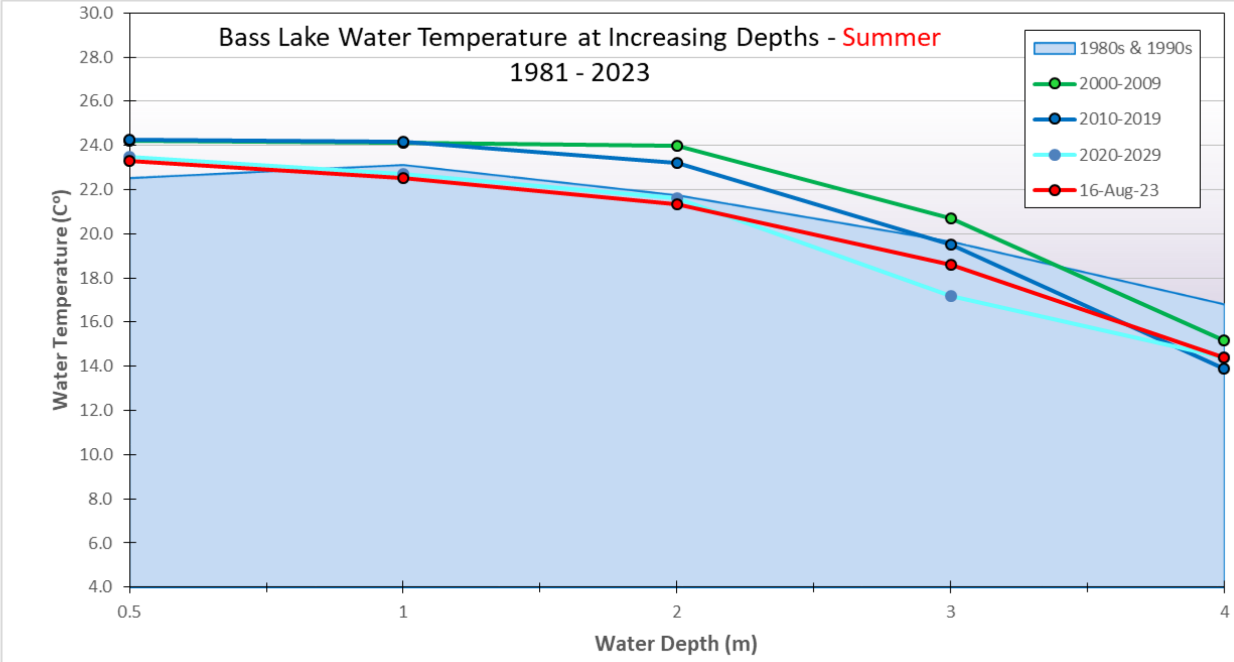


Figure 15:



It is apparent from Figures 14 and 15 above for Bass Lake that:

- In the spring of 2023, Bass Lake was noticeably warmer in the top 3m compared to water temperatures in this surface layer in all previous years.
- This finding was similar to the warmer surface water temperatures reported for Kahshe Lake.
- However, by August 2023, the surface water warming was no longer evident and temperatures below this depth were in line with those of all previous decades.

In summary, it appears that in both lakes, the spring temperatures, which are taken during the period of active lake stratification (turnover) are more variable and likely reflect seasonal differences in air temperature and timing relative to the ice-out date. However, by August, the measurements in both lakes show no evidence of lake water warming over the past four decades with more recent findings in Kahshe Lake pointing to a possible cooling of lake water below the surface layers.

Algal Growth

Algae are simple, typically small aquatic organisms and range in structure from unicellular (a microscopic single cell) to multicellular. As they produce and grow, they form colonies that appear on the surface or attached to various substrates. Algae are always present in lakes and rivers and are at the base (primary) of most lake food webs, and as such, are critical components of a healthy aquatic environment. Without algae, zooplankton (small animals that feed on algae) would not survive, and this would impact the survival of fish and other animals farther up the food chain.

When conditions are favourable, both benthic and planktonic cyanobacteria as well as other types of algae can increase to levels that result in poor water quality and an algal bloom or scum may form.

Conditions that promote bloom development include:

- elevated levels of nutrients in either sediments or water (mainly phosphorus and to a lesser extent nitrogen);

- calm weather conditions and shallow water with low water flow;
- strong sunlight; and,
- elevated air and surface water temperatures.

Nutrient enrichment and phosphorus in particular has been associated with increases in algal biomass in freshwater systems worldwide. Recent studies indicate that climate change is a potent catalyst for the further expansion of algal blooms because of the warming of surface waters, longer periods of open water (fewer ice covered days) and more intense rainfall which can flush or leach soil-borne nutrients into near-shore waters. Rising air and water temperatures favour most bloom-forming planktonic blue-green cyanobacteria because they have higher temperature requirements and because they are able to regulate their buoyancy under conditions of reduced vertical water column mixing (lake turnover) which occurs under rising surface water temperatures as the season progresses.

Although algal blooms are the primary focus of concern, the sediment dwelling algae and those that grow on rocks along the shoreline are also of concern. They are aesthetically unpleasant and also make shoreline navigation difficult, due to their slimy and slippery nature. As the season progresses, and they complete their life cycle, they can be dislodged from bottom and shore growing locations and can drift into slow moving water of bays along the shore where they start to decompose. Many on Kahshe Lake have noticed the unpleasant odours that begin to arise in the late summer and fall as this process takes place. These floating mats also can be mistaken for late-season blooms, as they are dislodged and float into shoreline locations. However, on closer examination, they typically appear less vibrant than the colours of algae in an active bloom.

In a 2011 publication (Winter et al., 2011), the Environment Ministry's investigations of algal blooms in Ontario were summarized and their findings confirmed the following trends:

- The total number of algal blooms reported in Ontario increased significantly from 1994 to 2009, and there also were significant increases in the number of blooms dominated by cyanobacteria and chlorophytes.
- Most lakes (50) had a single bloom report, 11 lakes had blooms reported in two years, four lakes had reports in three years, and one lake had reports in eight of the years between 1994 and 2009.
- In 2009, 16 of the 24 blooms reported tested positive for the presence of microcystin, one of several toxic substances which can be released by blue-green algae.
- A significant increase in day of year the last bloom was reported in a given year was observed, indicating that blooms are being detected and reported later in the year compared to 15 years ago. In contrast, no change was seen in day of year the first bloom was reported.

While this Environment Ministry report only covered algal bloom development through 2009, the detection of increasing numbers of HABs has continued, as confirmed by the Simcoe- Muskoka Health Unit in Table 1 below.

Table 1: Blue-Green Algae Impacted Lakes in the Simcoe-Muskoka Area- 2018 through 2023

Year	Blue-Green Algal Bloom Impacted Lakes	Number of Bloom Alerts
2018	Three Mile, St. John, Leonard, Rosseau, Lamont Creek	6
2019	Three Mile, Brandy, Bass*, Echo, St. John, St. George and MacLean	8
2020	Three Mile, Brandy, St. John, Black, Leonard, Simcoe, Bruce, Muskoka, Silver, Stewart, Little, Ten Mile, Otter and **Kahshe**	18

Year	Blue-Green Algal Bloom Impacted Lakes	Number of Bloom Alerts
2021	Georgian Bay, Three Mile, Little, Stewart, **Kahshe**, Mary, Menaminee, Fawn, Paint, St. John, Leonard and Bass*	12
2022	Fairlain, St. John, Three Mile, St. George, Georgian Bay (Penetang Harbour), Bass*, Mary, Leonard, Simcoe (Smith's Bay) and Muldrew	10
2023	Little, Orr, MacLean, Three Mile, Stewart, Midland Bay, Hogg Bay, Bass, Trout, Longs, **Bass**, Mary and Tea	13

*another Bass Lake in Township of Muskoka Lakes

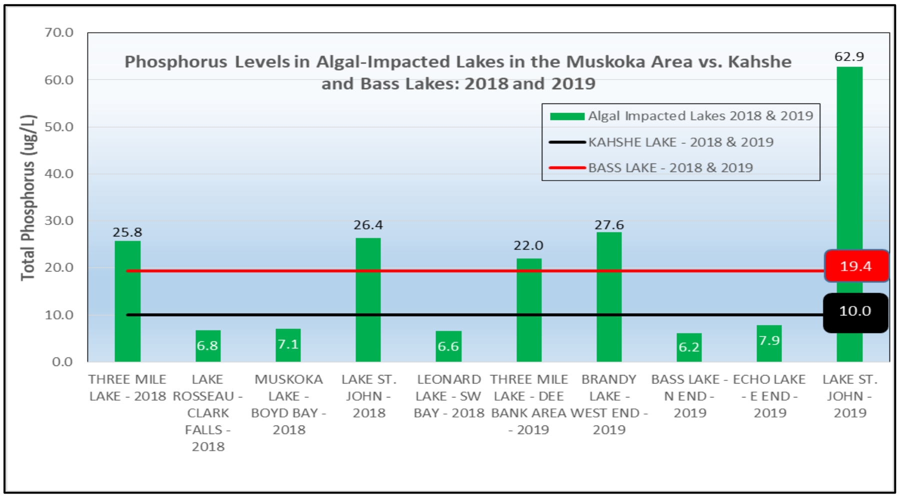
The presence of an HAB has now been included as one of three 'Water Quality Indicators' under the 2023 Muskoka Official Plan and all lakes with documented HABs are listed in Schedule E2 of the MOP and are considered 'Vulnerable' which will trigger a DMM-funded 'Causation Study'. HABs were confirmed in Kahshe Lake in both 2020 and 2021 although none have been documented since 2021. However, in 2023, an HAB was confirmed in Bass Lake and it remains on the Simcoe-Muskoka Health Unit's listing as active.

No date has been set for the 'Causation Study' that will be undertaken on Kahshe Lake; however, the DMM has finalized the 'Causation Study' on Bass Lake, and it was concluded that the elevated phosphorus levels in Bass Lake are naturally occurring and not related to shoreline development. As such, Bass Lake is likely to be removed from Schedule E2 of the MOP (unless it is re-listed due to the confirmed HAB in 2023).

In 2020, the Kahshe Lake HAB was located along the northern shoreline in the Oak Road vicinity and was investigated by staff from the MECP. In 2021, the first report of an HAB was in the east end of the lake (actually in the Kahshe River), but this was followed by reports of similar blooms in several areas of the lake: as such, the health alert was issued to cover the entire lake. Further details on these specific blooms and any others going forward have been described in greater detail in the KLRA Web's Water Quality portal and can be accessed via this link: https://kahshelake.ca/resources/Documents/Lake%20Steward/2022/Current%20Algal%20Bloom%20Status%20for%20Kahshe%20and%20Bass%20Lake-R3%20Feb2022-TCAccepted.pdf

To further explore the relevance of these harmful algal blooms in lakes in the Muskoka and surrounding areas, the MECP's 2018 and 2019 LPP total phosphorus data for each of the above algal-impacted lakes were examined and compared to the phosphorus levels in Kahshe and Bass Lakes over the same time period. In cases where there was no LPP data, the total phosphorus levels from the DMM investigations were used. Of the 13 impacted lakes, total phosphorus levels for 10 were found. While it must be noted that the phosphorus levels for the above water bodies in 2018 and 2019 may not accurately reflect the water concentrations at the specific location or time each bloom was detected, they do provide a general picture of the concentrations that were documented in the impacted lakes. In the case of larger lakes, with multiple sampling locations, the water quality sampling sites located closest to the general area where the algal bloom was detected were utilized.

The total phosphorus levels in the 10 lakes with data are shown in Figure 16 (below). As is apparent from Figure 16, three of the impacted lakes (Three Mile, St. John and Brandy) had very high total phosphorus levels, so the presence of an algal bloom in these lakes could not be considered a surprising outcome. However, five of the impacted lakes (Rosseau, Muskoka, Leonard, Bass and Echo) had total phosphorus levels well below those of both Kahshe and Bass Lakes.



These findings give cause for concern, as this trend towards increasing numbers of late-season HABs throughout Muskoka does not appear to be directly associated with increasing levels of total phosphorus or nitrogen compounds determined via these early spring water quality sampling programs from the deep water of mid-lake sampling sites.

This apparent anomaly prompted the development of the KLRA-funded Near Shore Water Sampling Project (NSWSP) in 2021 and the findings from those water sampling activities identified a possible causal linkage between algal bloom development and water quality in two near-shore sampling sites which were sampled immediately prior to bloom development. The analysis demonstrated a notable increase (compared to the same sites sampled earlier in the year) in the concentration of ammonia+ammonium nitrogen levels at these sites. While this does not provide definitive causality due to the limited number of sampling sites, it suggested that the leaching of soil-borne and mobile nitrogen compounds from septic systems or lawns located near the shore which attract large numbers of Canada geese may be involved. This is also consistent with higher intensity rainfall events characteristic of a changing climate which may be accelerating the leaching process. The findings from the NSWSP have been reported and posted on the KLRA's Water Quality web portal which is accessible via this link: https://kahshelake.ca/resources/Documents/Lake%20Steward/2022/FULLNSWSP-RevNov-2022-FinalwCoA.pdf

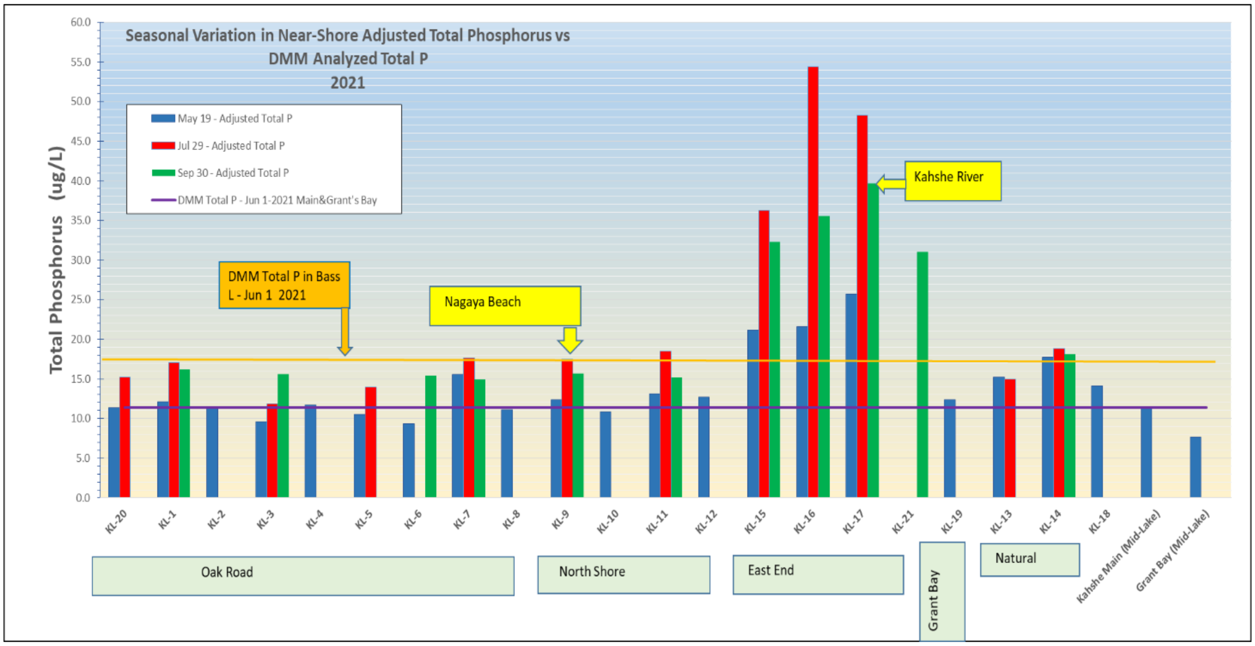
The NSWSP findings are briefly summarized below:

- Mid-lake, deep water sampling in the spring of the year is a reasonable way to track long-term, historical changes in water quality but is not providing a biologically relevant assessment of water quality in the near-shore environment where HABs have been documented.
- The mid-lake, deep water sampling also has failed to capture much higher total phosphorus levels in the east end of Kahshe Lake, as there are no DMM sampling sites in that area.
- Levels of algal-friendly nutrients (phosphorus and nitrogen) in the near-shore environment are almost always higher than in the mid-lake deep waters and tend to fluctuate as the season progresses, further limiting the relevance of the spring sampling of mid-lake sites in terms of assessing the potential for HAB development.

- The near-shore water chemistry for some algal-friendly and biologically available nutrients appear to be associated with effluents from human & animal waste sources and are known to be linked with HABs.
- Although more study would be required to scientifically confirm this finding, the near-shore results combined with air and precipitation records suggest that accelerated leaching and/or runoff of soil-borne nutrients are related to a changing climate, with more intense rainfall events.

To demonstrate some of the above NSWSP findings, Figure 4A from the near-shore project has been reproduced here as Figure 17, and shows how total phosphorus levels in the near-shore environment compare to those from the historical DMM and MECP mid-lake, deep water monitoring locations.

Figure 17:



Although we have virtually no control over the change that is affecting our climate, there are very definitely actions we can and must take to minimize the accelerated leaching of algal friendly nutrients to our shoreline water and thereby reduce the potential for future HABs. These actions have been thoroughly explored by the Conservation Committee and are summarized below:

1. **Divert roof drainage and runoff from paths and other hard surfaces away from your septic system and the shoreline. If necessary, direct rain and surface water runoff into rock-filled drainage pits.**
2. **Keep most of your shoreline as natural as possible with a zone of trees, shrubs or tall grass between the shore and any lawn area to discourage grazing by Canada geese and to reduce soil erosion and goose poop runoff into the lake.**
3. **Have a licensed professional pump out and inspect your septic system for failures and deficiencies every 3-5 years and more often for aging systems installed pre-2000. The Town recommenced their inspections in 2023, but we don't need to wait for an official inspection before calling in a septic professional to check our complete systems for signs of failure.**
4. **Don't use phosphorus or nitrogen fertilizers or cleaning agents anywhere near the shore.**

4.2 Calcium Depletion

Another chemical of potential concern to the health of our lake is calcium. In this case, the concern is not related to shoreline development, but arises from a Muskoka trend towards decreasing levels of calcium which have been documented in a recent Canada Water Network Research Program in the Muskoka watershed.

Why is calcium so important? Calcium is a nutrient that is required by all living organisms, including very small organisms called zooplankton that live in the waters of Muskoka lakes and are a key component of the lower levels of the food chain for other aquatic and terrestrial organisms higher up the food chain. The reproduction of these organisms as well as others like mollusks, clams, amphipods and crayfish have been shown to be adversely affected by low levels of calcium in lake waters.

Based on data from over 700 lakes in Ontario, about 35% currently have calcium levels below 1.5 mg/L, which is considered a limiting threshold for the survival of zooplankton species like *Daphnia* that comprise a major component of the aquatic food chain. Other species require more than 1.5 mg/L while some can tolerate levels as low as 0.5 mg/L. One of the implications of reduced calcium is a lowering of biodiversity. Dr. N. Yan explained how this can happen using calcium as an example in response to a Toronto Star article in 2014. He elaborated on a study designed to highlight a fairly fundamental shift from crusty to jelly-clad species as dominants in the zooplankton population, as we move from a higher calcium, phosphorus world in our lakes to a lower calcium, lower phosphorus world.

This has resulted in *Holopedium* taking dominance over *Daphnia*, as it needs 20 times less calcium, and two times less phosphorus than *Daphnia*. It also survives attacks from invertebrate predators better and was already widespread in our lakes. As such, *Holopedium* have become more dominant over the last 20-30 years at the expense of more calcium-needy competitors.

There are a few possible ecological concerns of the change. Yan explained:

1) We are losing biodiversity here, as several species of *Daphnia* are losing out to only one *Holopedium* species;
2) The nutritional value of the large animal plankton is reduced, as *Holopedium* has a much lower mineral content than *Daphnia*. The implications of this should be explored, but are not yet known; and,
3) There may well be less food passed up the food chain to fish in our small lakes where invertebrate predators are actually key steps between plankton and fish, because *Holopedium* is pretty well protected from most invertebrate predators by its jelly coat. When it is eaten, it has lower mineral content.

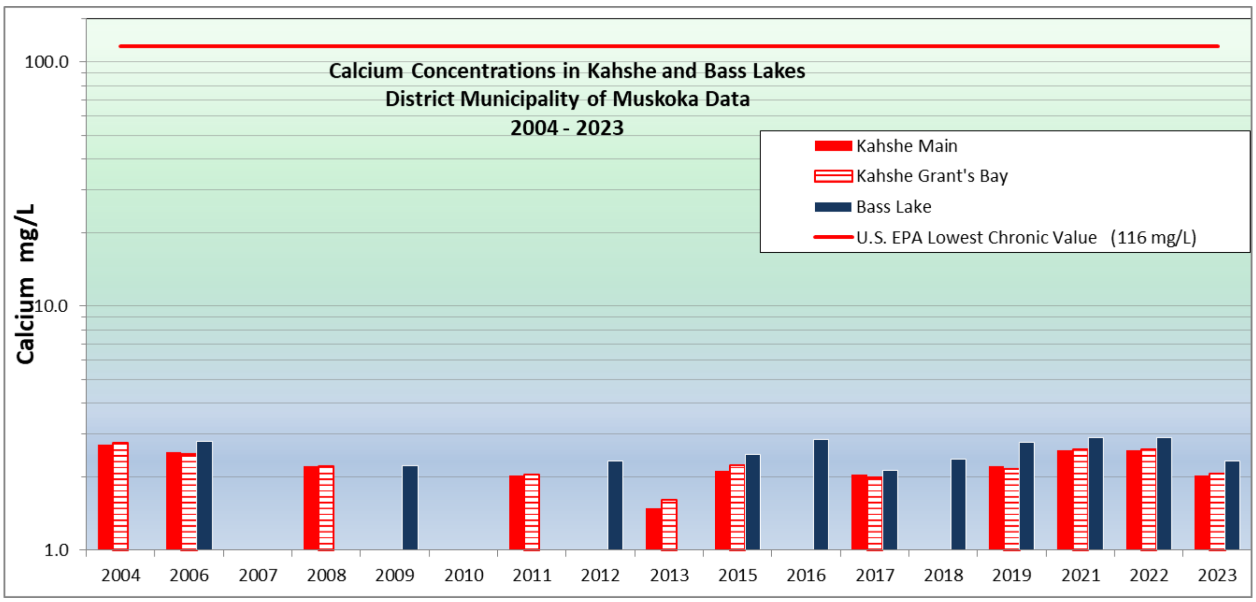
In our Muskoka lakes, the absolute abundance of *Holopedium* has increased by an average of about two fold over the last 20 years, and the relative abundance has increased more, said Yan, while the abundance of five species of *Daphnia* has declined. There are two other, smaller species of *Daphnia* that need less calcium than their congeners, and they are still doing well, but this won't last if calcium continues to fall, he said.

Still, jellification doesn't mean the end to fish in our lakes. The thing to understand, said Yan, is that "the sky is not falling, but it's not quite the same sky as it once was." No doubt ongoing research and monitoring is critical to the health of our lakes. The upside to the attention raised by The Toronto Star's article this week, said Yan is that it highlights how "research in Muskoka is alerting the world to intriguing and fundamental changes that accompany human interventions in the natural world."

Studies have shown that the gradual reduction in calcium levels in watershed soils and the water of lakes and rivers is associated with acidic rainfall, forest harvesting and climate change. In the early days, very acidic rain leached the calcium from soils faster than it could be regenerated via natural weathering of underlying rocks and this resulted in increased levels in the water of some lakes. However, as acid deposition rates were reduced, less calcium is now being leached from watershed soils into lakes, resulting in lower calcium concentrations that are threatening the health of aquatic species. Forest harvesting also has played a role, as the removal of timber and subsequent re-growth of forests following timber harvesting has further diminished the supply of calcium in soils that is available for leaching to lakes. Finally, climate change is also playing a role, as it has in some areas, resulted in decreased water flow within the watershed, resulting in less calcium being exported from watersheds to lakes.

Fortunately, the DMM water sampling program has included calcium since 2004, while the MECP have been analyzing Kahshe Lake water for calcium since 2008. Figure 18 below shows the DMM Calcium levels for the period from 2004 through 2022.

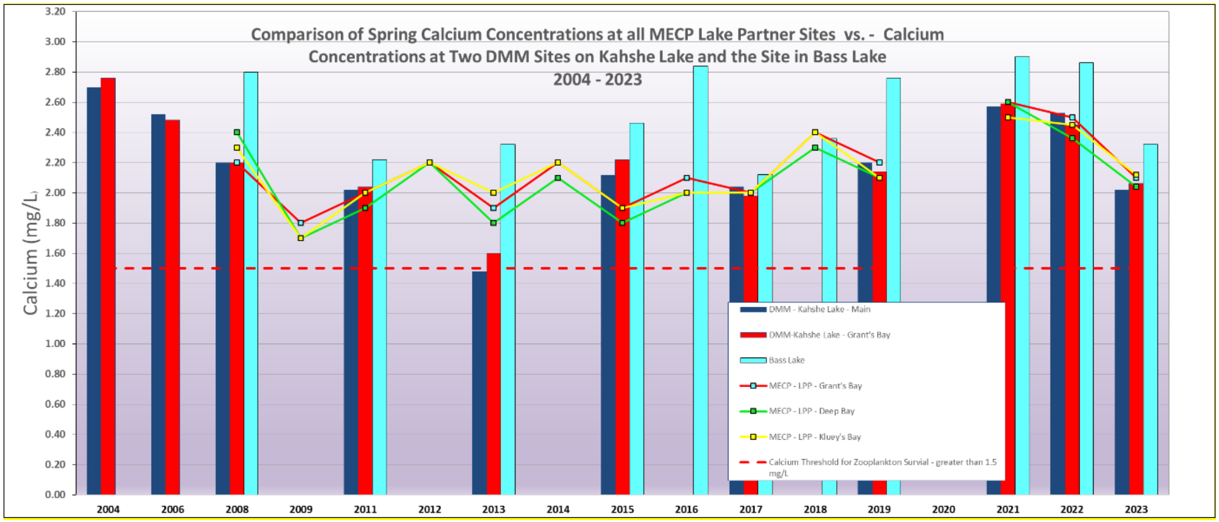
Figure 18:



These analytical findings demonstrate that there has been no major decline in calcium concentrations in either Kahshe or Bass Lakes over this 19 year monitoring interval. While the concern with calcium is lower levels, this chart also demonstrates that there is no concern in either lake from a toxicity perspective.

Figure 19 that follows plots the calcium data for Kahshe Lake by the two sampling programs (DMM and LPP) over this same time period. It also shows the lower limit threshold of 1.5 mg/L which has been recognized as a level below which the survival of sensitive species such as *Daphnia* may be impacted.

Figure 19:



Based on this information, it can be concluded that:

- Calcium concentrations in both Kahshe and Bass Lakes are well above the lower limit that has been set to protect some sensitive zooplankton species.
- In every year, the calcium concentrations in Bass Lake are well above the levels in Kahshe Lake, and as such, there is less likelihood of negative zooplankton impacts in Bass Lake.
- Although we don't have an extensive history of calcium monitoring results, the data we do have show no obvious signs of increasing or decreasing concentrations.
- While the calcium results look favourable, there was a population explosion of *Holopedium sp*. In Kahshe Lake late in 2021 through 2023; although these jelly-like orbs were a nuisance in the water for swimmers in late summer, it is not known if this represents a concern ecologically further up the aquatic food chain as per Dr. Yan's findings.

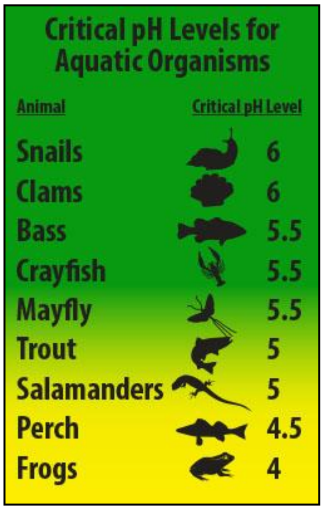
4.3 Lake Acidification

Water acidity is measured on a unitless scale referred to as pH. The pH of water is a measure of the hydrogen ion concentration expressed on a scale of 0 to 14, with a pH of 7 being neutral, values below 7 being acidic and above 7 being alkaline. As the hydrogen ion concentration is measured on a logarithmic scale, the change in pH of 1 unit (i.e. from 7.0 to 6.0) represents a 10-fold increase in acidity. Distilled water is considered to be neither acidic nor alkaline, and has a pH of 7.0. However, even in the absence of any man-made acidic gases, the natural levels of carbon dioxide in the atmosphere will react with water to generate carbonic acid, and this will cause rain to have a natural pH of about 5.6.

Although source-oriented acid gasses and particulates have contributed significantly to the acidification of lakes in Ontario, particularly around major sulphur sources in the Sudbury basin, there has been noticeable recovery over the last two decades as emission controls were implemented. The ingress of acidic gasses and particulates of nitrogen and sulphur from transboundary air flows into southern Ontario also have been reduced.

The Provincial water quality objective is to keep pH between 6.5 and 8.5, as values above or below those levels can be harmful to some aquatic organisms.

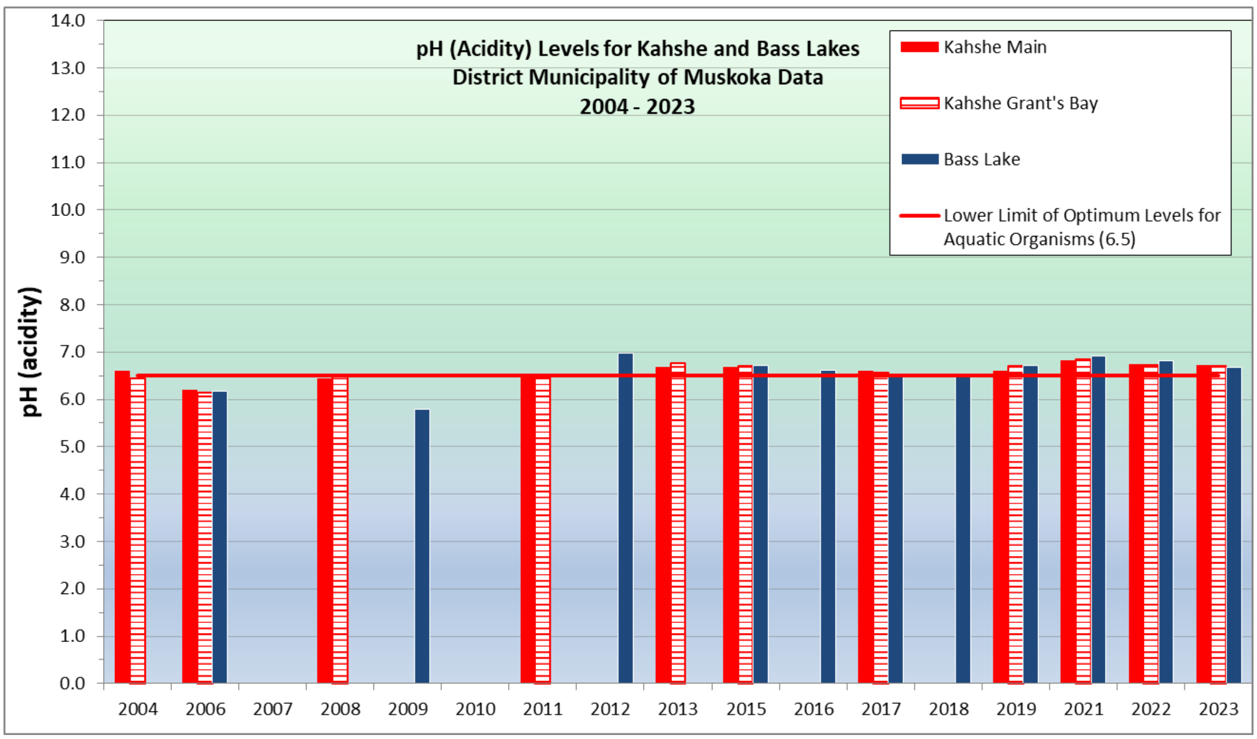
In the green-shaded figure to the left, the pH level at which key organisms may be lost as their



environment becomes more acidic has been shown (EPA. 2017; Effects of Acidification on Ecosystems). Some types of plants and animals are able to tolerate acidic waters and moderate amounts of aluminum. Others, however, are acid-sensitive and will be lost as the pH becomes more acidic. Generally, the young of most species are more sensitive to environmental conditions than adults. At pH 5, most fish eggs cannot hatch. At lower pH levels, some adult fish die. Even if a species of fish or animal can tolerate moderately acidic water, the animals or plants it eats might not. For example, frogs have a critical pH around 4, but the mayflies they eat are more sensitive and may not survive pH below 5.5.

The chart below in Figure 20 shows the pH values for Kahshe and Bass Lakes from 2004 through 2023.

Figure 20:



It is apparent from Figure 20 that the pH of Kahshe and Bass Lakes is:

- At or slightly above the lower end of the optimum pH range of 6.5-8.5, which is good.
- Above the level of 6.0 where impacts to some sensitive aquatic species might be encountered (see EPA species sensitivity picture above), which also is good news.
- Not showing any evidence of either an increase or decrease in acidity over the 19 year period of monitoring.

While the pH findings represents good news, it should also be recognized that the waters of Kahshe and Bass Lakes have low levels of alkalinity, and as such, are more susceptible to acidification, as the ability of the water to buffer (neutralize) incoming acid in precipitation is low.

4.4 Metals and Other Chemicals of Concern

The DMM has analyzed water samples for a much larger suite of chemical parameters than those that are routinely reported in their year-end report and data sheet summaries. This leaves a large number of chemicals that have been analyzed but which have not been specifically evaluated in terms of their potential impacts on aquatic species.

The full suite of chemicals analyzed via the DMM sampling program in 2023 included: chloride, nitrogen (ammonia + ammonium), nitrogen (nitrite+nitrate), total nitrogen, sulphate, aluminum, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, silicon, sodium, strontium, titanium, vanadium, zinc. In addition, the following additional parameters were added to the suite of chemicals in 2012 and repeated annually since then: antimony, arsenic, boron, selenium, silver, thallium and uranium.

As some of these parameters have not been included in the DMM summary table of additional chemical parameters, this report attempts to do this by comparing the results for all years for which data exist to surface water benchmarks that are available from the MECP or other regulatory agencies. A brief description of the benchmarks which have been used and what they're designed to protect follows:

- For the anions and cations and other parameters included in the DMM dataset, the findings have been compared to currently available aquatic protection values (APVs) used by the Ontario MECP (MOE, 2011). These values represent the highest concentration of a contaminant in surface water to which an aquatic community can be exposed indefinitely without resulting in an adverse impact.

- In cases where an MECP APV was not available, a similar format to the one used by the MECP in protecting surface water from ground water discharges associated with contaminated sites (*O. Reg. 153/04* as amended) has been followed. This involved first checking for a U.S. EPA chronic ambient water quality criterion (based on a continuous chronic criterion, (U.S. EPA, 2012; U.S. EPA, 1986));

- If neither of these sources had a value, a Canadian Water Quality Guideline (CCME, 2012), a B.C. Ambient Water Quality Criterion (B.C. 2000; B.C. 2001a and b) or a U.S. EPA Tier-II Secondary Chronic Value (Suter II and Tsao, 1996) was used.

In all cases, the surface water protection provided via these benchmarks is for long term exposure to concentrations that are considered chronic, as opposed to short-term protection against acute effects.

Charts for all anions/cations/parameters with concentrations greater than the laboratory detection limits along with their respective water quality benchmarks have been inserted in Attachment 2 and a summary of the findings has been presented in Table 2 below.

Table 2: Summary of Metals and Other Chemicals of Concern – Kahshe and Bass Lake – 2023

Analyzed Parameter	Evaluation Benchmark[1]	Comments
Chloride	MECP APV	All reported values are well below aquatic benchmark and chloride concentrations in Bass Lake are marginally higher than those in Kahshe. Note that the chart uses a logarithmic scale.

Analyzed Parameter	Evaluation Benchmark[1]	Comments
Nitrogen (Ammonia + Ammonium)	BC Water Quality Guideline	All reported values are well below aquatic benchmark and concentrations in Bass Lake are slightly higher than those in Kahshe. Note that the chart uses a logarithmic scale. The impact of ammonium nitrogen also is important as an algal friendly nutrient, and this has been discussed in Section 4.1 of the report.
Nitrogen (Nitrite + Nitrate)	Canadian Water Quality Guideline	All reported values are well below aquatic benchmark and concentrations in Kahshe are slightly higher than those in Bass. Note that the chart uses a logarithmic scale. The impact of nitrate nitrogen also is important as an algal friendly nutrient, and this is discussed in Section 4.1 of the report.
Total Nitrogen	None Found	Total nitrogen (organic + inorganic) concentrations from 2004 to 2019 were calculated by adding measured total Kjeldahl nitrogen (which consists of organic nitrogen and ammonia+ammonium nitrogen) and measured nitrate+nitrite nitrogen. This was discontinued in 2021, as the laboratory now reports its findings for total nitrogen as a measured value. The impact of nitrogen also is important as an algal friendly nutrient, and this is discussed in Section 4.1 of the report. Also it is interesting to note that total nitrogen is higher in Bass L while nitrate+nitrite nitrogen is noticeably lower in Bass vs. Kahshe.
Sulphate	BC WQC	All reported values well below benchmark and no trend is apparent.
Aluminum	Interim Canadian WQG	All reported values for Kahshe Lake are well below the WQG for aluminum. In contrast, Bass Lake values are higher than those from Kahshe Lake and most are close to or above the upper range in the WQG. Note that the CWQG for aluminum is both pH and DOC dependent. As such, the low end of the range of CWQGs based on the pH and DOC levels has been plotted. Given the higher than normal concentration of Al in Bass Lake in 2023, this parameter will need to be evaluated carefully going forward.
Barium	MECP APV	All reported values well below benchmark. Note that the chart uses a logarithmic scale.
Iron	U.S. EPA CCC	All reported values for both lakes are well below benchmark, although the 2023 results for Bass Lake continue the trend of being about 2-times higher than in Kahshe Lake.
Magnesium	U.S. EPA LCV	All reported values are well below benchmark. For some reason, Mg was not analyzed in 2021, but has been since. Note that the chart uses a logarithmic scale.
Manganese	BC AWQC	All reported values are well below aquatic benchmark and as for iron and aluminum, manganese concentrations in Bass Lake are noticeably higher than those in Kahshe.
Potassium	U.S. EPA LCV	All reported values well below benchmark. Note that the chart uses a logarithmic scale.
Silicon	None Found	In most years, including 2023, silicon (reactive silicate) concentrations in Kahshe Lake are noticeably higher than those in Bass Lake. No aquatic protection benchmark was found for comparison.
Sodium	MECP APV	All reported values are well below aquatic benchmark and concentrations in Bass Lake are slightly higher than those in Kahshe. Note that the chart uses a logarithmic scale.
Strontium	U.S. EPA T-II SCV	All reported values well below benchmark. Note that the chart uses a logarithmic scale.
Zinc	MECP APV	All reported values well below benchmark.

Analyzed Parameter	Evaluation Benchmark[1]	Comments
Dissolved Organic Carbon	DMM Notes	Although there is no aquatic benchmark, the findings for Bass Lake are noticeably higher than those in Kahshe and also are at or slightly higher than 7 mg/L, which is the Ontario aesthetic objective for recreational use. This is the compound that gives the lakes their tea colour.
Electrical Conductivity	None Found	In most years, including 2023, EC levels in Bass Lake are slightly higher than those in Kahshe Lake. No aquatic protection benchmark was found for comparison.
Alkalinity	DMM Notes	Although there is no aquatic protection benchmark, the alkalinity of both Kahshe and Bass Lakes (generally higher in Bass L) is below 10 mg/L, indicating that both lakes have low buffering capacity and therefore, are potentially susceptible to acidification.

Legend:
[1] Evaluation Benchmarks to Protect Aquatic Organisms
MECP APV means Ontario Ministry of Environment, Conservation and Parks – Aquatic Protection Value
EC CWQG means Environment Canada – Canadian Water Quality Guideline
BC AWQC means British Columbia Ambient Water Quality Criterion
U.S. EPA CCCC means United States Environmental Protection Agency Continuous Chronic Criterion

Although the main goal of the above discussion was to examine the potential of these parameters to impact water quality in terms of aquatic health, the comparison also identified a number of cases where concentrations in Kahshe or Bass Lake were higher in one than in the other. While the cause of this finding is not immediately apparent, it is interesting given the finding of noticeably higher concentrations of total phosphorus in Bass Lake compared to Kahshe Lake. To explore this further, Table 3 below identifies the parameters which are either slightly or noticeably elevated in one lake compared to the other. The increase in the laboratory DL for several parameters since 2021 has masked this type of comparison for titanium, but the DL increase did not affect the intra lake comparison for any others.

Table 3: Comparison of Chemical Parameters in Kahshe vs Bass Lakes - 2023

Bass Lake Concentrations Higher than in Kahshe		Kahshe Lake Concentrations Higher than in Bass	
Noticeably	**Slightly**	**Noticeably**	**Slightly**
▪ Total N ▪ Al ▪ Fe ▪ Mn ▪ DOC ▪ Alkalinity	▪ Cl ▪ $N\text{-}NH_4$ ▪ Ca ▪ Na ▪ EC	▪ Si ▪ $N\text{-}NO_3$	▪ None

As noted above, the reason for these water quality differences remains unknown and in the case of Bass Lake, these findings were apparently beyond the scope of the DMM Causation Study as they were not considered in the development of the conclusion that elevated phosphorus in Bass Lake was attributed to natural factors. Of additional note here, there have been several reports from property owners along the river that connects Bass to Kahshe Lake of red-coloured water that was visible flowing westward.

Although there is no definitive proof, it is quite possible that the elevated levels of iron (and manganese) in Bass Lake water may be promoting the growth of iron loving bacteria. Iron bacteria are small living organisms that naturally occur in soil, shallow groundwater and surface waters. They combine iron (or manganese) and oxygen to form deposits of rust-coloured bacterial cells which can form slimy, reddish material that can be carried in river water.

4.5 Dissolved Oxygen Depletion

Dissolved oxygen (DO) in lake water is important for two main reasons: 1) it is essential for the survival of all aquatic organisms, and 2) a lack of oxygen in the lower layers of the lake (referred to as being anoxic) can cause mobilization of phosphorus from sediments. This is referred to as internal phosphorus loading.

In addition to the consumption of oxygen by fish and other aquatic organisms, the decomposition of organic matter in all layers of the lake consumes oxygen. However, because of the thermal stratification of lake water during the ice-free period, only the upper layers of water are replenished with oxygen as a result of photosynthesis by aquatic plants, in-bound water from streams and atmospheric oxygen as a result of mixing caused by wind and waves. As such, the gradual depletion of oxygen in the lower layers (hypolimnion) of the lake progresses following spring turnover and these lower waters do not get re-oxygenated until the late fall turnover again takes place.

Water temperature also plays a role in the dissolved oxygen cycling process, as warm water becomes saturated at lower concentrations than required for cold water – i.e. warm water is able to hold less DO in solution. However, the bottom line is that the colder waters near the bottom of the lake become gradually depleted of oxygen over the ice-free period and can reach levels that will not support aquatic species.

The setting of an aquatic benchmark for DO is typically conducted under both an acute (short term, high concentration) and a chronic (long term, lower concentrations) basis. For chronic exposure, aquatic organism effects include the traditional growth and reproduction impairment, swimming impairment and long term impacts on survival. The low oxygen threshold at which some reaction first becomes apparent is usually referred to as the incipient or critical level. At this level, the organism must extend or adjust its available energies to counteract the influence of hypoxia (oxygen starvation) and/or to move to waters with higher DO levels. Unfortunately, the variability in toxicity symptoms and exposure times challenges the derivation of water quality guidelines for DO, and as a result, the guideline derivation does not follow the standard process.

For warm water lakes like Kahshe and Bass, the Provincial Water Quality Objective (PWQO) and the Canadian Water Quality Guideline (CWQG) are set at 5 and 5.5mg DO/L, respectively. This report will use the lower of the two, as some other agencies have set DO benchmarks in the 3-4 mg/L range.

To examine the DMM findings for DO, the data have been averaged in a manner similar to what was done with water temperatures. This generated a mean for the 1980s&1990s, 2000-2009, 2010-2019 and 2020-2029 (incomplete) for all spring and summer sampling up to 2023, and these findings for Kahshe Lake are plotted below in Figures 21 and 22.

Figure 21:

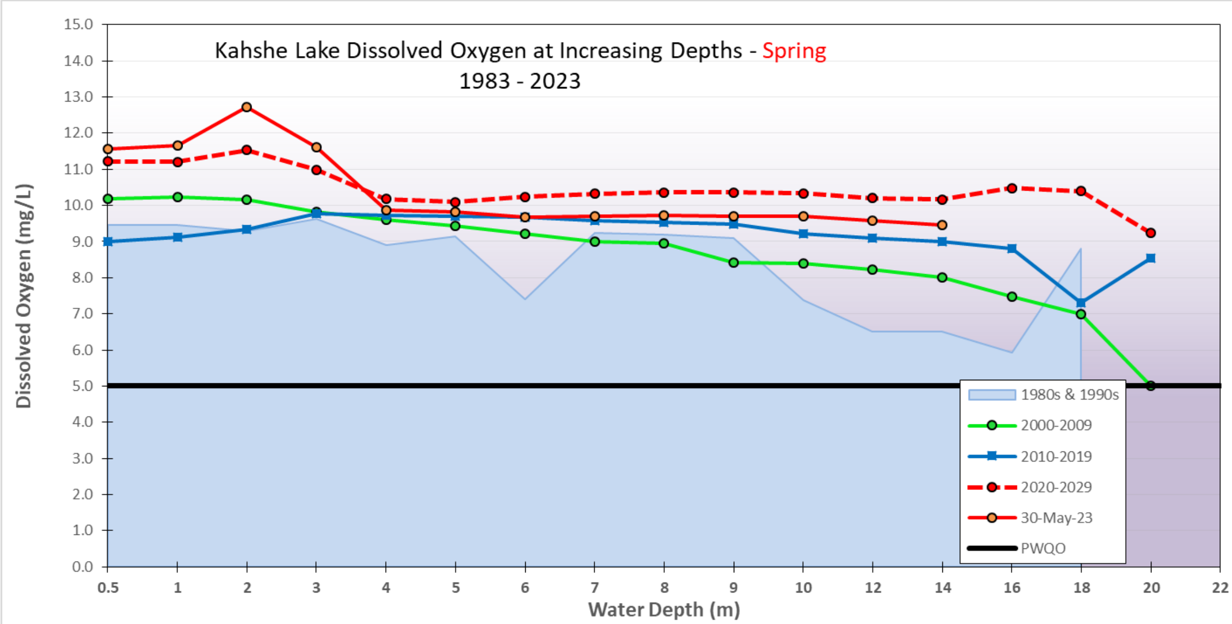
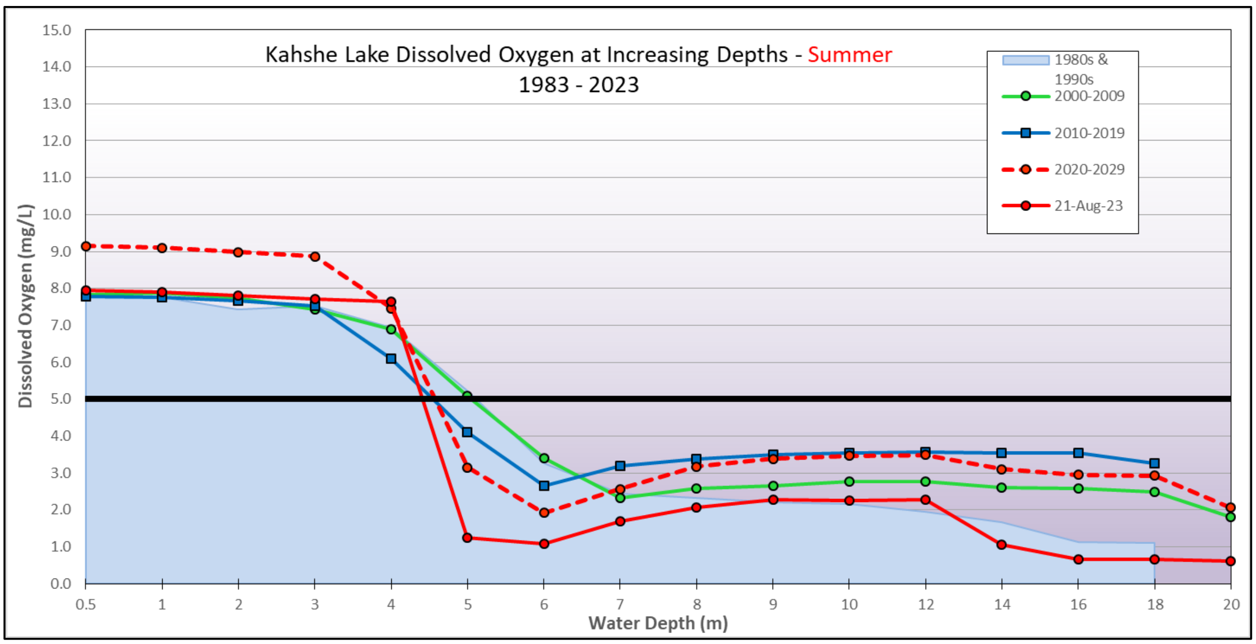


Figure 22:



The above two charts for Kahshe Lake have been summarized below:

- As expected, the DO levels in the spring sampling event reveal only a slight trend of decreasing DO levels with increasing water depth, and in all cases the DO levels are well above the aquatic health-based PWQO. These findings are consistent with lake water turnover that vertically mixes the water across the depth of the lake commencing when the ice cover period ends in March or April.
- However, by early August, the 2023, as in all previous decades, DO levels drop below the aquatic health-based PWQO at around 4-5m depth and remain that way down to 20m depth (lake bottom).
- While the findings of DO levels below the aquatic benchmark are of concern, the trend towards slowly increasing levels at depths below around 6m that has been happening after the 1980s and

1990s is a positive sign, but this will continue to require evaluation, as the 2023 findings demonstrate continued decline in DO at depths below 12m.

The DO levels in Bass Lake for both Spring and Summer sampling times are charted below in Figures 23 and 24.

Figure 23:

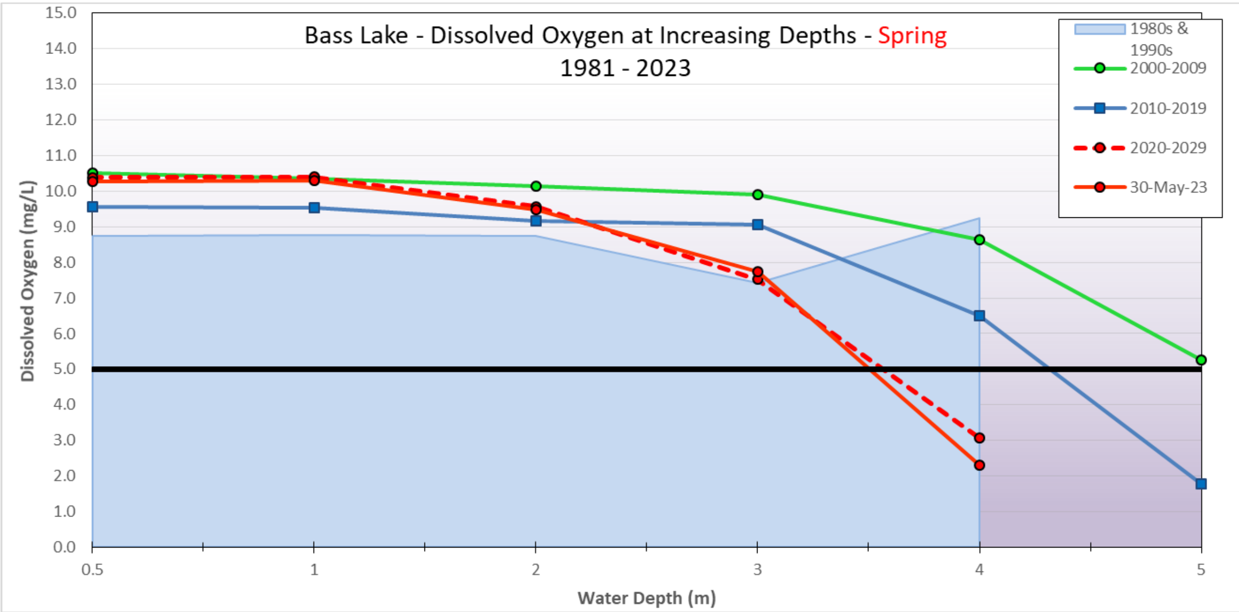
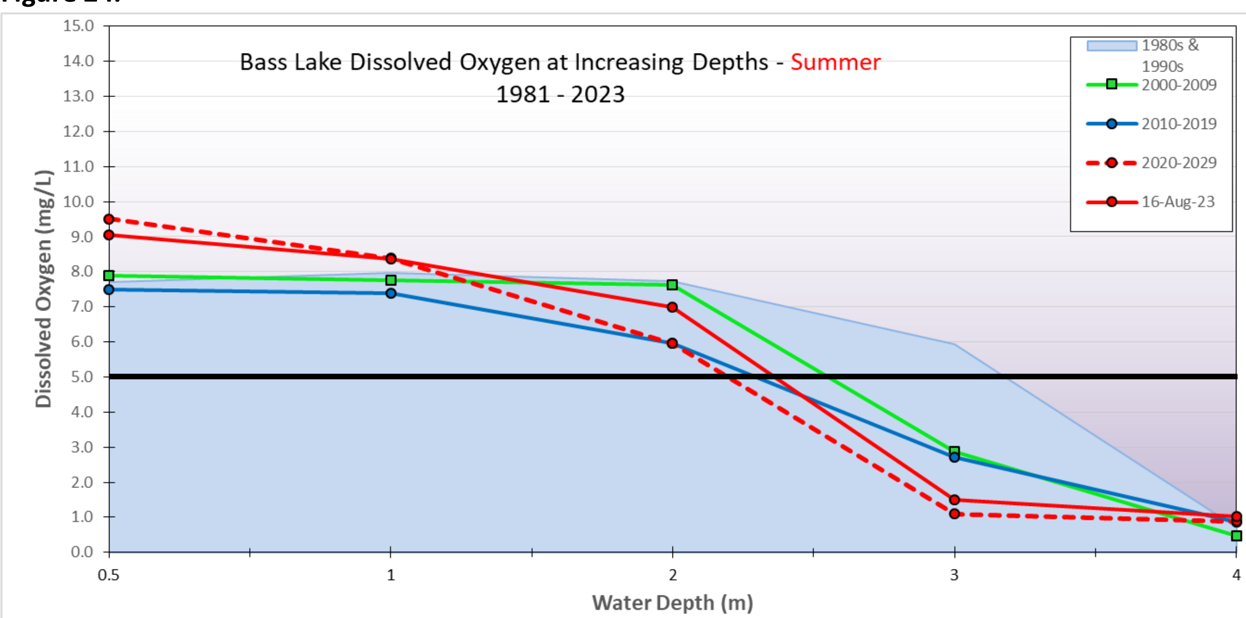


Figure 24:



The above two charts for Bass Lake have been summarized below:

- As for Kahshe Lake, the DO levels in the spring sampling event reveal only a slight trend to decreasing DO levels with increasing water depth, and in all but the lowest depths (>4m), the DO levels are well above the aquatic health-based PWQO. These findings are consistent with lake water turnover that vertically mixes the water across the depth of the lake, although to a lesser extent in Bass Lake due to its more shallow depth.

- However, as was the case since around the year 2000, by mid-August, the 2023 DO levels start a fairly steep decline beyond a depth of 2m and fall below the aquatic PWQO at depths greater than around 2.5m.
- More importantly from a biological perspective, unlike Kahshe Lake, there appears to be a trend towards DO levels falling below the PWQO at more shallow depths (just below 2m) than back in the 1980s and 1990s when DO crossed below the PWQO at depths almost at lake bottom (just below 3m).

4.6 Benthic Organism Health

Monitoring of bottom-dwelling aquatic invertebrate communities which live within the sediment or 'bottom mud' has been carried out at three locations on Kahshe Lake by the DMM since 2003. However, benthic monitoring on Kahshe Lake was suspended in 2016 in order to focus more on Bass Lake due to its classification as a 'Transitional' lake requiring additional assessment due to its elevated total phosphorus levels.

As both lakes were declared 'Vulnerable' in 2020 due to either total phosphorus above 20 μg/L (Bass Lake) or the documented presence of a harmful algal bloom (Kahshe Lake), benthic monitoring was again undertaken in 2021, 2022 and 2023. In the 2023 sampling, a new Site 5 was established in the east end of the lake to ensure that this part of the lake which is now known to contain higher total phosphorus levels is reflected in the sampling site locations. Existing Site 3 also was sampled in 2023 to provide a comparison for the benthic health in 2023.

The locations of all benthic monitoring sites for both Kahshe and Bass Lakes are shown in Figure 1 above.

The findings from the 2023 benthic sampling and counting survey which was undertaken at Sites 3 and 5 on August 23, 2023 are presented below. This activity could not have been undertaken without the support of the following Kahshe Lake volunteers who carried out the count under the supervision of Ms Maggie Dechert, the Biotechnician from the DMM:

- Greig Holder
- Laurie Turner and Toby Fletcher
- Dave Barker
- Wes Treleven
- Gail Pearson
- Russ Pearson
- Kyle Nasim

Following the counting and identification, the DMM biotechnician worked up the benthos identification summary and the organisms were broken into families of benthos as has been the case since monitoring began. The tabular summary for both sites is presented below.

THE DISTRICT MUNICIPALITY OF MUSKOKA

Aquatic Invertebrate Data Sheet

Kahshe Lake

Town of Gravenhurst

Common Name	Site 3 R 2006	2007	2012	2013	2021	2023	Scientific Name	
Hydras							Coelenterata	5
Flatworms	1	1	1	1		2	Turbellaria	4
Roundworms	13			4	5		Nematoda	5
Aquatic Earthworms	10	3	45	5	1	2	Oligochaeta	8
Leeches		1	2	1			Hirudinaea	8
Sow Bugs			42	75	13	14	Isopoda	8
Clams & Mussels	1		1				Bivalvia	8
Scuds	133	219	268	177	38	52	Amphipoda	6
Crayfish						1	Decapoda	6
Mites	20	33	7	26	13	13	Hydracarina	6
Mayflies	31	55	52	105	11	4	Ephemeroptera	5
Dragonflies	29	15	21	24	3	4	Anisoptera	5
Damselflies	17	20	27	15	7	13	Zygoptera	7
Stoneflies							Plecoptera	1
True Bugs	2		1	1			Hemiptera	5
Fishflies & Alderflies	2		1	2		1	Megaloptera	4
Caddisflies	15	4	14	31	23	5	Trichoptera	4
Aquatic Moths			1				Lepidoptera	6
Beetles	17	7	29	12		2	Coleoptera	4
Snails & Limpets	10	4	3			1	Gastropoda	7
Midges	7	25	55	15	1	1	Chironomidae	7
Horse & Deer Flies							Tabanidae	8
Mosquitos							Culicidae	8
No-see-ums	2	2	11	1			Ceratopogonidae	6
Craneflies							Tipulidae	3
Blackflies							Simuliidae	6
Misc. True Flies			3				Misc. Diptera	5
Total Count	310	389	584	495	115	115		
Number of Taxa	16	13	19	16	10	14		
							Muskoka Average *	
Richness	16	13	19	16	10	14	**13**	
% EOT	30	24	20	35	38	23	**17**	
% Chironomids	2	6	9	3	1	1	**8**	
% Predators	29	20	17	17	20	30	**24**	
% Shredders	5	1	3	6	20	4	**2**	
% Collectors/Gatherers	58	78	80	76	56	64	**68**	
Hilsenhoff Index	5.71	5.89	6.17	5.93	5.75	6.17	**6.27**	

R = Reference Site

* The Muskoka Average is based on 228 samples collected at 94 reference sites between 2013 and 2023. Data prior to 2021 is based on three subsamples (min. 300 count) per site while data from 2021 on is based on one sample (min. 100 count) per site.

THE DISTRICT MUNICIPALITY OF MUSKOKA

Aquatic Invertebrate Data Sheet

Kahshe Lake

Town of Gravenhurst

Common Name	Site 5 R 2023	Scientific Name	
Hydras		Coelenterata	5
Flatworms	1	Turbellaria	4
Roundworms		Nematoda	5
Aquatic Earthworms	7	Oligochaeta	8
Leeches		Hirudinaea	8
Sow Bugs	36	Isopoda	8
Clams & Mussels	1	Bivalvia	8
Scuds	31	Amphipoda	6
Crayfish		Decapoda	6
Mites	19	Hydracarina	6
Mayflies	10	Ephemeroptera	5
Dragonflies	6	Anisoptera	5
Damselflies	8	Zygoptera	7
Stoneflies		Plecoptera	1
True Bugs		Hemiptera	5
Fishflies & Alderflies		Megaloptera	4
Caddisflies	8	Trichoptera	4
Aquatic Moths		Lepidoptera	6
Beetles		Coleoptera	4
Snails & Limpets	8	Gastropoda	7
Midges	4	Chironomidae	7
Horse & Deer Flies		Tabanidae	8
Mosquitos		Culicidae	8
No-see-ums	1	Ceratopogonidae	6
Craneflies		Tipulidae	3
Blackflies		Simuliidae	6
Misc. True Flies		Misc. Diptera	5
Total Count	140		
Number of Taxa	13		
		Muskoka Average *	
Richness	13	**13**	
% EOT	23	**17**	
% Chironomids	3	**8**	
% Predators	25	**24**	
% Shredders	6	**2**	
% Collectors/Gatherers	63	**68**	
Hilsenhoff Index	6.53	**6.27**	

R = Reference Site

* The Muskoka Average is based on 228 samples collected at 94 reference sites between 2013 and 2023. Data prior to 2021 is based on three subsamples (min. 300 count) per site while data from 2021 on is based on one sample (min. 100 count) per site.

The DMM Biotechnician provided the following interpretation of the benthic monitoring results for Kahshe Lake in 2023.

Dechert, Maggie <Maggie.Dechert@muskoka.on.ca> Aug 24, 2023, 11:21 AM

o me

Hi Ron,

Please see the results from yesterday's count attached to this email.

Starting with Site 3, we have a lot of historical data to compare to. You can see natural fluctuations in the numbers over the years, and we actuy had the same exact score on the Hilsenhoff Index in 2012 (6.17). The %Chironomids has continued to be low over the past couple of years, and that is good, because chironomids are pollution-tolerant, so if we see heir numbers rising in comparison to the others it could mean that pollution-tolerant species are making up more of the sample. The results are comparable to the Muskoka Average vith the exception of the %Chironomids, so that means Site 3 is testing on the healthier end of the spectrum.

Site 5 looks about the same, except that the Hilsenhoff Index is higher. This is a sign that pollution-tolerant species are more representative in this sample. I would attribute this to the higher number of Oligochaeta and Isopoda. Those species both rank at an 8 on the Hilsenhoff Index, and 8 is equal to a high pollution tolerance. This would have raised the average of he Hilsenhoff Index. So, the results would indicate that Site 5 is in a poorer condition than Site 3.

also did testing at Bass Lake this year, so I have attached those results as well if you are interested. We did not have a volunteer to guide us on that lake so it's nice to have someone o send it to!

Thank you for a nice last event with so many friendly and funny people.

Sincerely,

These data along with the findings from previous benthic monitoring at Sites 2, 3 and 6 have been charted in Figure 25 below. As this year's report from the DMM was not as comprehensive as the 2022 report, some general information on the reasoning for the evaluation of benthic organism growth as well as some clarification on what the various families represent has been extracted from the 2022 report and shown in green shaded text below:

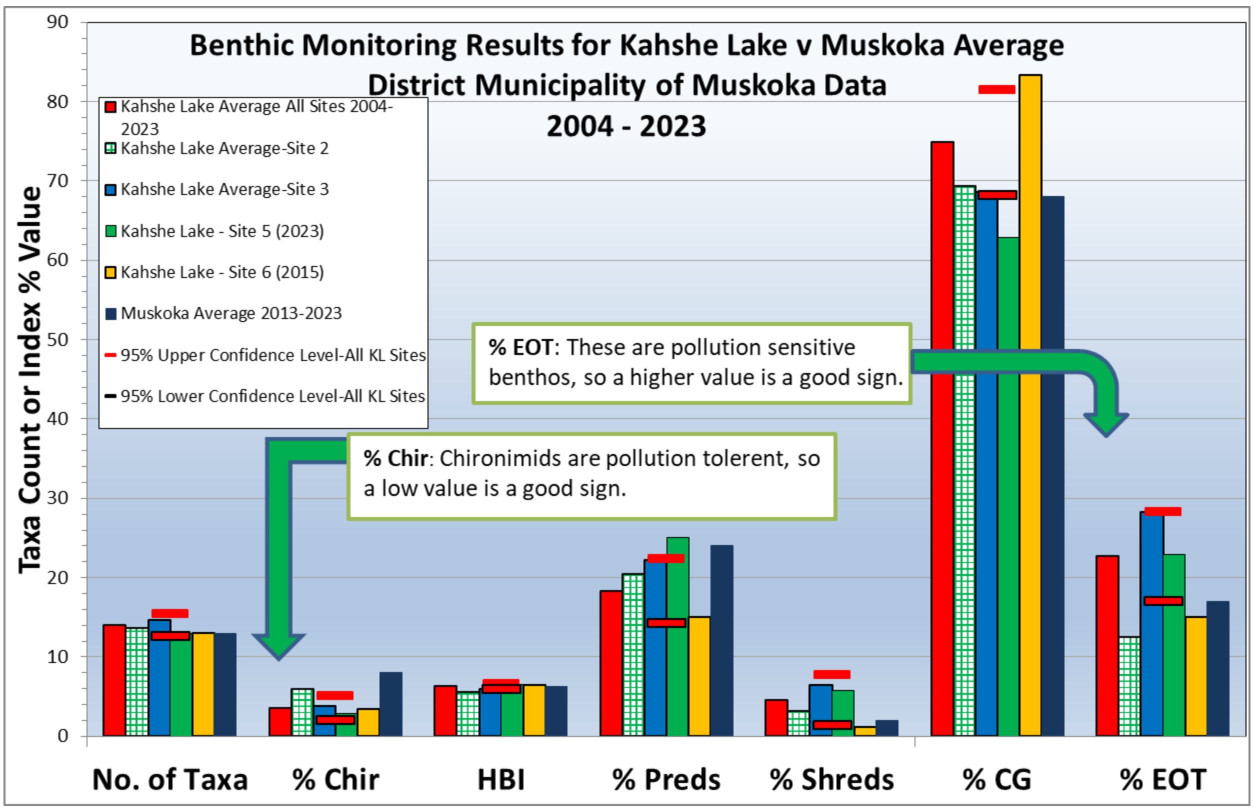
Each year we sample our established sites to determine which benthic macroinvertebrates are found. These benthos indicate the health of the riparian zone (section between shallow water and dry land) and the littoral zone (shallow water nearest to dry land). These two zones are especially important to lake health as they are impacted by snowmelt, runoff, sedimentation, etc.

*Collected benthos are grouped into seven (7) different categories, in which three (3) are mainly focused on: EOT, Chironimids, and Richness. The % EOT includes mayflies, dragonflies, and caddisflies, which are benthic macroinvertebrates that are **intolerant** to pollution. % Chironimids is focused on the invertebrate named a Midge (or blood worm) which are **tolerant** to pollution and can survive in harsh environments. Richness is the biodiversity of species found within the sample, and with biodiversity, the more the better. The other four (4) categories are more used as reference, in that if one year a number drastically jumps or falls, further investigation might be required.*

With these numbers alongside the Muskoka Average, we are able to understand the direction the lake is heading in regards to shoreline and lake health. If the % EOT (intolerant) is low, and % Chironimids (tolerant) is high, this indicates that the environment may not suitable for the intolerant benthic invertebrates. This indicates to us that this section of the lake may be impacted by sources such as development, runoff, or other anthropogenic sources.*

As noted above, Figure 25 displays the full benthic monitoring results for Sites 2, 3, 5 and 6 for the period from 2004 to 2023 as well as the updated Muskoka average from 228 reference sites over the period from 2013 to 2023.

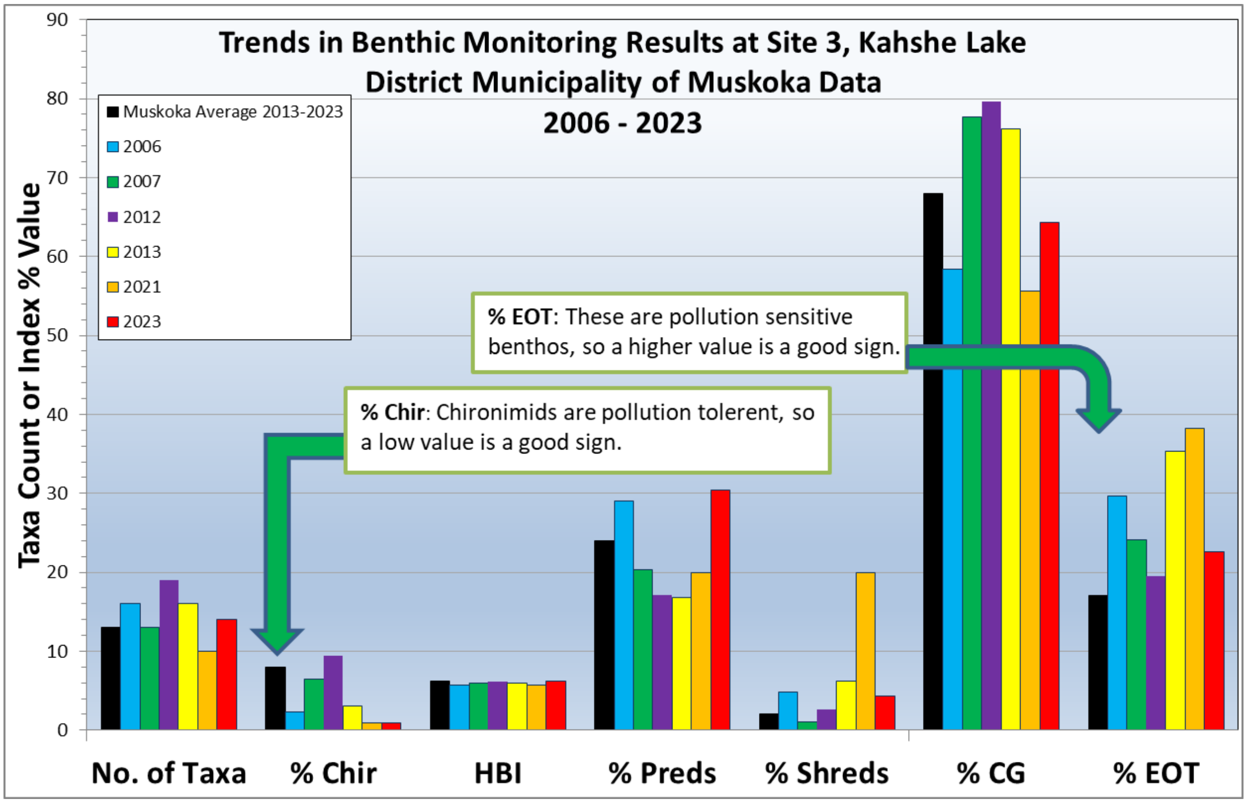
Figure 25:



In addition to the main findings for 2023 identified above, this figure also demonstrates that the benthic community on Kahshe Lake is comparable to the Muskoka average for most family groupings, with the exception of % Chir (Chironimids) and % EOT, where lower and higher benthic counts, respectively, are desirable outcomes. The minor differences for the HBI at Site 5 that are discussed in the 2023 note from the DMM Biotechnician are too small to be captured in this chart.

As the above data summary for Kahshe Lake does not provide any insight to determine if any trends over time are occurring, a closer evaluation was undertaken at Site 3, where data from six years of sampling were available (2006-2023). The results for the various families of benthos are presented in Figure 26 below and can be evaluated in comparison to the Muskoka averages for the period 2013-2023.

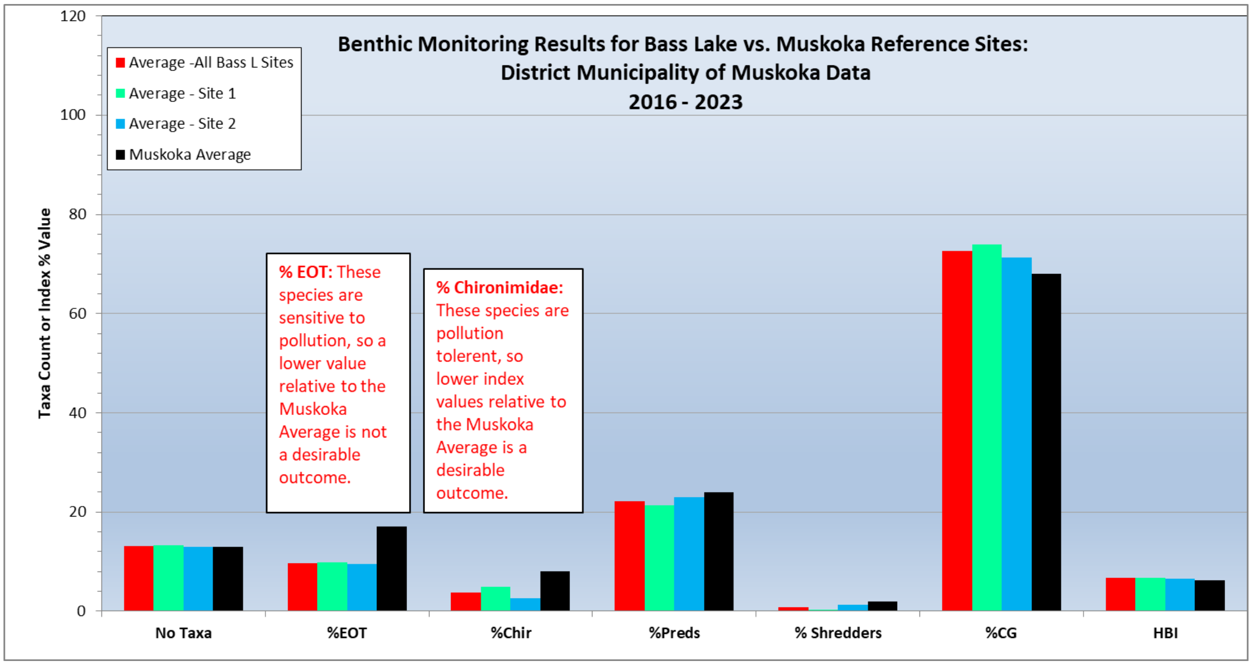
Figure 26:



Based on the benthic monitoring over the period from 2006 through 2023, there appears to be no increasing or decreasing trend in the various families of benthic organisms. The results for Site 3 in Kahshe Lake also appear to lie within the expected range based on the Muskoka average results and generally display the tendency toward lower % Chironimids and higher % EOT (includes mayflies, dragonflies, and caddisflies).

Although the Lake Steward was not involved in the benthic assessment for Bass Lake, the DMM have provided the data for two sites from 2016 through 2023. The average index and taxa data for Sites 1 and 2 are presented in chart form below.

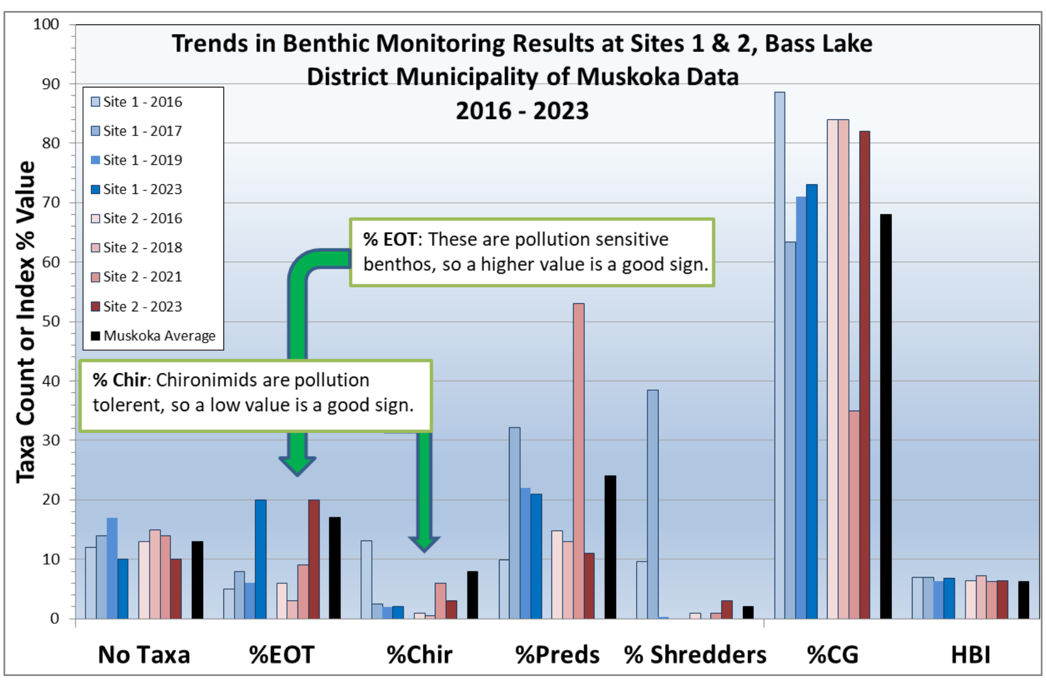
Figure 27:



As shown in Figure 27 above, the average index values for %Chironimids are slightly lower than the Muskoka Average, and this is a good sign, as these benthos are pollution tolerant. However, in the case of %EOT, the lower values relative to the control are not a desirable outcome, as these benthos are sensitive to pollutants. Notwithstanding the above, the differences are minor and there is considerable variability.

As for Kahshe Lake, we have also explored the potential for any trends over time in the index values for both Sites 1 and 2 in Bass Lake. These findings are presented in Figure 28 below:

Figure 28:



The annual variability in the various benthic index values at both sites is significant and may be masking any trends that are taking place. However, as for the average findings (two sites-all years) in the first chart for Bass Lake, the % Chironimids indices are with one exception lower than those for the Muskoka Average, and show no signs of a trend over this time period. In the case of %EOT, where higher values relative to the Muskoka Average are desirable, only the data from 2023 exceeded the Muskoka Average. This suggests that more favourable sediment conditions have developed in 2023, but this finding needs further evaluation to confirm.

A few pictures of the benthic sampling at Site 5 and counting in 2023 follow:

5.0 Summary of the Six Lake Health Parameters

To simplify the reporting of environmental analysis data, this report has been structured to address the following key areas of potential concern for both Kahshe and Bass Lakes:

- Algal Nutrients and Other Factors Promoting Algal Growth
- Calcium Depletion
- Lake Acidification
- Other Chemicals of Concern
- Dissolved Oxygen Depletion
- Benthic Organism Health

Facilitate a better understanding of the main findings from each of the six water quality parameters that were investigated, the following text captures the findings from each of those six areas of potential concern.

Climatic Factors and Ice Condition - Summary

Air temperatures in 2023 were generally similar to the four previous years and to the 30 year normal for most months with no trend towards warming during the ice-free period. The only notable departure from this finding was a much warmer winter period in December and January. In the case of precipitation, total monthly amounts were noticeably greater than in previous years and compared to the 30 year normal in April, June and July, with much dryer conditions being recorded in November and December.

In 2023, the ice-out date was April 14. The data for both Kahshe Lake generally follow the ice-out dates for the larger Muskoka Lakes and there appears to be a trend towards earlier ice-out on both Muskoka Lakes and Kahshe Lake since the early 1970s.

Algal Nutrients and Other Factors Promoting Algal Growth - Summary

Phosphorus has long been identified as the main concern in terms of water quality and shoreline management due to its major role in algal growth and bloom development. This has been recognized by the DMM in the Muskoka Official Plan and new 'Water Quality Indicators' have been established based on phosphorus and HAB development. While the focus remains on phosphorus, more recently, nitrogen also has been identified as a key factor in algal bloom development and it too enters the lake from sources similar to those for phosphorus.

A summary of the findings for the three major algal bloom development variables (phosphorus, nitrogen and water temperature) and for water clarity that have been evaluated is presented below:

PHOSPHORUS

- In both lakes, there has been no long term trend in total phosphorus concentrations over the past 40 years.
- Historically, the total phosphorus levels in Bass Lake are about twice as high as those in Kahshe Lake.

- A comparison of the total phosphorus concentrations determined via the DMM and MECP sampling programs have yielded very similar findings, with most of the differences in phosphorus likely due to different spring sampling dates which would be influenced by snow melt, precipitation and the degree of lake stratification (turnover).
- While the DMM and MECP mid-lake, deep water sampling sites on Kahshe Lake generate an excellent historical record of total phosphorus concentrations for long-term trend analysis, the findings of the 2021 KLRA-funded Near Shore Water Sampling Project demonstrated two important weaknesses in this historical record:
    - it fails to capture higher total phosphorus concentrations at the East end of Kahshe Lake which receives input flow of higher phosphorus water from Bass Lake; and
    - the mid-lake levels are not representative of the higher and more variable near-shore total phosphorus levels which are influenced directly via shoreline sources in areas where HABs are likely to develop.

NITROGEN

While recognition of the role of nitrogen in nutrient enrichment and algal growth has not been a focus for as long as phosphorus, there is a growing attention on this nutrient now based on a strong weight of published evidence for its role in promoting algal growth. In water, nitrogen occurs in several different dissolved forms and these factor into the growth of algae and cyanobacteria in different ways. Ammonium is the easiest nitrogen form for primary producers to acquire and transport into the cell. Nitrate and nitrite (NO_3^- /NO_2^-) must be actively transported into the cell and then converted to ammonium, which, in turn, requires energy and micronutrients, such as iron. For these reasons, the monitoring has focussed on the two main forms of nitrogen (Ammonia + Ammonium) and (Nitrite + Nitrate). The 2023 findings are summarized below:

- No evidence of a concentration trend in either of the two analyzed forms of nitrogen or total nitrogen has been detected in Bass or Kahshe Lakes over the years dating back to 2004.
- In contrast to total phosphorus, the concentrations of nitrate + nitrite in Bass Lake are generally lower than the corresponding analysis results for Kahshe Lake; and as noted in Figure 8, this is not the case for total nitrogen, where levels in Bass Lake are always higher than in Kahshe Lake.
- In all cases, the reported nitrogen concentrations are well below any aquatic benchmarks that have been set to protect sensitive aquatic species.
- No algal growth benchmarks for either form of nitrogen have been located, as the linkage between phosphorus, nitrogen and water temperature is too complex to set individual nutrient benchmarks.
- While not shown above, the findings from the KLRA-funded Near-Shore Water Sampling Project conducted in 2021 demonstrated that nitrogen concentrations in the near-shore environment are often considerably higher than these spring-sampled mid-lake levels, often increase or decrease as the season progresses and appear to have played a causal or contributing role in the development of the HABs bloom that were documented in 2021.

WATER TEMPERATURE

While nutrient enrichment is important, it is not the only factor involved in the promotion of harmful algal growth. Blue-green algae thrive in areas where the water is shallow, slow moving and warm. Water temperature is also important for other reasons, including:

- It affects the solubility of oxygen in water.
- It affects the metabolic rates, life cycles and the sensitivity of all aquatic organisms to parasites and disease.
- It factors into the classification of a lake as a cold or warm water body (both Kahshe and Bass are considered warm water lakes)

The 2023 findings for Kahshe and Bass Lakes are summarized below:

- In the spring of 2023, Kahshe Lake was noticeably warmer down to a depth of about 4m but generally similar to all previous averaging periods below that depth.
- By August 2023, the spring warming noticed in the upper 4m was no longer present and the temperature at all depths generally followed the historical trend of decreasing temperature with increasing depth.
- These findings revealed no evidence of increasing lake water temperatures and possibly lower lake temperatures at depths almost to the lake bottom from 2010 onward.
- In the spring of 2023, Bass Lake was noticeably warmer in the top 3m compared to water temperatures in this surface layer in all previous years.
- This finding was similar to the warmer surface water temperatures reported for Kahshe Lake.
- However, by August 2023, the surface water warming was no longer evident and temperatures below this depth were in line with those of all previous decades.

In summary, it appears that in both lakes, the spring temperatures, which are taken during the period of active lake stratification (turnover) are more variable and likely reflect seasonal differences in air temperature and timing relative to the ice-out date. However, by August, the measurements in both lakes show no evidence of lake water warming over the past four decades with more recent findings in Kahshe Lake pointing to a possible cooling of lake water below the surface layers.

WATER CLARITY

As noted earlier, water clarity is not a driving variable in algal growth but rather a symptom of nutrient loading and eutrophication. In both Bass and Kahshe Lakes, this is more complicated as the linkage between water clarity and nutrient loading with phosphorus is masked by the tea coloured waters associated with dissolved organic carbon (DOC). However, notwithstanding these limitations, both sampling programs have monitored clarity via the Secchi disc method for as long as we have data on total phosphorus. The 2023 results are summarized below:

- Water clarity in Bass Lake in 2023 continued a downward trend from 2019 but was generally in line with low water clarity in some earlier years.
- Water clarity in Kahshe Lake in 2023 followed a similar downward trend from 2019 but was generally similar to historical measurements dating back to 1983.
- Water clarity is noticeably better in Kahshe Lake than in Bass Lake, most likely due to the more tea coloured nature of Bass Lake - as confirmed by slightly higher Dissolved Organic Carbon [DOC] levels in Bass Lake.
- In looking at the MECP's LPP measurements, the trend of greater clarity compared to DMM clarity measurements that was recorded from 2011 through 2017 was not repeated in the years from 2019 through 2022.
- This may be related to the methodology for recording water clarity, as the DMM measurements are the average of two sampling events while the LPP measurements by the Lake Steward represent an average of 9-10 measurements at each site over the period from May through

October. Another possible reason for the divergence is that DMM measurements are taken irrespective of weather conditions while those for the MECP LPP program are more typically taken during sunny days when water clarity is enhanced by sunlight penetration.

ALGAL GROWTH

Nutrient enrichment and phosphorus in particular has been associated with increases in algal biomass in freshwater systems worldwide. Recent studies indicate that climate change is a potent catalyst for the further expansion of algal blooms because of the warming of surface waters, longer periods of open water (fewer ice covered days) and more intense rainfall which can flush or leach soil-borne nutrients into near-shore waters. Rising air and water temperatures favour most bloom-forming planktonic blue-green cyanobacteria because they have higher temperature requirements and because they are able to regulate their buoyancy under conditions of reduced vertical water column mixing (lake turnover) which occurs under rising surface water temperatures as the season progresses.

The presence of an HAB has now been included as one of three 'Water Quality Indicators' under the 2023 Muskoka Official Plan and all lakes with documented HABs are listed in Schedule E2 of the MOP and are considered 'Vulnerable' which will trigger a DMM-funded 'Causation Study'. HABs were confirmed in Kahshe Lake in both 2020 and 2021 although none have been documented since 2021. However, in 2023, an HAB was confirmed in Bass Lake and it remains on the Simcoe-Muskoka Health Unit's listing as active.

No date has been set for the 'Causation Study' that will be undertaken on Kahshe Lake; however, the DMM has finalized the 'Causation Study' on Bass Lake, and it was concluded that the elevated phosphorus levels in Bass Lake are naturally occurring and not related to shoreline development. As such, Bass Lake is likely to be removed from Schedule E2 of the MOP (unless it is re-listed due to the confirmed HAB in 2023).

The increasing numbers of HABs in Muskoka lakes in spite of stable or gradually decreasing total phosphorus levels prompted the development of the KLRA-funded Near Shore Water Sampling Project (NSWSP) in 2021. The findings from those water sampling activities identified a possible causal linkage between algal bloom development and water quality parameters, suggesting that the leaching of soil-borne and mobile nitrogen compounds from septic systems or lawns located near the shore which attract large numbers of Canada geese were involved. This appeared to be associated with higher intensity rainfall events characteristic of a changing climate.

The NSWSP findings are briefly summarized below:

- Mid-lake, deep water sampling in the spring of the year is a reasonable way to track long-term, historical changes in water quality but is not providing a true assessment of water quality in the near-shore environment where HABs have been documented.
- The mid-lake, deep water sampling also has failed to capture much higher total phosphorus levels in the east end of the lake, as there are no DMM sampling sites in that area.
- Levels of algal-friendly nutrients (phosphorus and nitrogen) are almost always higher than in the mid-lake areas and fluctuate significantly as the season progresses, further limiting the accuracy of the spring sampling of mid-lake sites in terms of assessing the potential for HAB development.
- The near-shore water chemistry for some algal-friendly nutrients were consistent with expected levels of those known to be associated with effluents from human and animal waste sources.

- Although more study is warranted, the near-shore findings point to accelerated leaching and/or runoff of soil-borne nutrients due to a changing climate which is resulting in more intense rainfall events.

Although we have virtually no control over the change that is affecting our climate, there are very definitely actions we can and must take to minimize the accelerated leaching of algal friendly nutrients to our shoreline water and thereby reduce the potential for future HABs. These actions have been thoroughly explored by the Conservation Committee and are summarized below:

1. **Divert roof drainage and runoff from paths and other hard surfaces away from your septic system and the shoreline. If necessary, direct rain and surface water runoff into rock-filled drainage pits.**
2. **Keep most of your shoreline as natural as possible with a zone of trees, shrubs or tall grass between the shore and any lawn area to discourage grazing by Canada geese and to reduce soil erosion and goose poop runoff into the lake.**
3. **Have a licensed professional pump out and inspect your septic system for failures and deficiencies every 3-5 years and more often for aging systems installed pre-2000. The Town recommenced their inspections in 2023, but we don't need to wait for an official inspection before calling in a septic professional to check our complete systems for signs of failure.**
4. **Don't use phosphorus or nitrogen fertilizers or cleaning agents anywhere near the shore.**

Calcium Depletion - Summary

Decreasing lake water calcium concentration is an emerging concern for lakes on the Precambrian Shield in Ontario due to its impact on the reproduction and survival of zooplankton and other aquatic species that are important components of the aquatic food chain. The results of the 2023 sampling of both lakes for calcium are summarized below:

- Calcium concentrations in both Kahshe and Bass Lakes in 2023 are well above the lower limit that has been set to protect some sensitive zooplankton species.
- In every year, the calcium concentrations in Bass Lake are well above the levels in Kahshe Lake, and as such, there is less likelihood of negative zooplankton impacts in Bass Lake.
- Although we don't have an extensive history of calcium monitoring results, the data we do have show no obvious signs of increasing or decreasing concentrations.
- While the calcium results look favourable, there was a population explosion of *Holopedium sp*. In Kahshe Lake late in 2021 through 2023; although these jelly-like orbs were a nuisance in the water for swimmers in late summer, it is not known if this represents a concern ecologically further up the aquatic food chain.

Lake Acidification - Summary

The waters of Kahshe and Bass Lake have acidity (pH) levels that are within a normal range and above the lower limit of the optimum level where aquatic impacts may begin to be shown. There is also no evidence of an increase or decrease in acidity over the 15 year monitoring period.

While the pH findings represent good news, it should also be recognized that the waters of Kahshe and Bass Lakes have low levels of alkalinity, and as such, are more susceptible to acidification, as the ability of the water to buffer the acid input is low.

As such, while there is currently no concern, continued monitoring of the acidity is warranted.

Metals and Other Chemicals of Concern - Summary

The analysis of several additional anions, cations and other chemicals by the DMM has identified no pressing issues from an aquatic health aspect. While there were some minor exceedances of chronic (long term) benchmarks established by the MECP and other agencies to protect aquatic receptors from long term exposure, most of these exceedances were detected in the early years of the sampling program and appear to be related to sampling or laboratory artifacts, as more recent sampling has shown concentrations that are in the expected range for non-impacted surface water bodies in Ontario.

In several cases (cadmium, silver and selenium), the laboratory detection limits are similar to or slightly below the aquatic protection value, and as a result, the non-detected levels of these substances are either just above or below their respective aquatic benchmarks. This situation was exacerbated by the increase in DLs in 2021 through 2023.

In the case of aluminum, the aquatic benchmark has been exceeded in Bass Lake, with the highest concentration in 2023; however, the benchmark consists of a range in values and must be evaluated based on the pH and DOC concentrations in lake water. Based on these findings, aluminum will be followed carefully in future monitoring to ensure that the waters of Kahshe and Bass Lakes are safe from an aquatic perspective.

The other finding from this data set is that there are numerous parameters that, like total phosphorus, are slightly or noticeably higher in Bass Lake compared to Kahshe Lake. There are also a couple of parameters (silicon and $N\text{-}NO_3$) where the opposite (Kahshe higher than Bass) is documented. The reason for these differences in the two lakes is unknown and was not evaluated in the DMM-funded Causation Study on Bass Lake.

Dissolved Oxygen Depletion - Summary

Dissolved oxygen (DO) in lake water is important for two main reasons:

- It is essential for the survival of all aquatic organisms, and
- A lack of oxygen in the lower layers of the lake (referred to as being anoxic) can cause mobilization (release) of phosphorus from sediments.

Dissolved oxygen is influenced by seasonal changes that factor into lake stratification, the process whereby lake water is turned over (mixed) in the late fall and again following the winter ice melt and then begins to stratify through the spring, summer and fall as water temperature increases at the surface and DO levels decrease with increasing depth.

The DO findings for spring and summer at different water depths in both Kahshe and Bass Lakes for 2023 are summarized below.

- As expected, the DO levels in both lakes in the spring sampling event reveal only a slight trend of decreasing DO levels with increasing water depth, and in all but one (Bass Lake , the DO levels are well above the aquatic health-based PWQO. These findings are consistent with lake water turnover that vertically mixes the water across the depth of the lake commencing when the ice cover period ends in March or April.

- However, by early August, the 2023, as in all previous decades, DO levels in Kahshe Lake drop below the aquatic health-based PWQO at around 4-5m depth and remain that way down to 20m depth (lake bottom).
- In Bass Lake, by mid-August, the 2023 DO levels start a fairly steep decline beyond a depth of 2m and fall below the aquatic PWQO at depths greater than around 2.5m.
- From a biological perspective, unlike Kahshe Lake, there appears to be a trend towards DO levels in Bass Lake falling below the PWQO at more shallow depths (just below 2m) than back in the 1980s and 1990s when DO crossed below the PWQO at depths almost at lake bottom (just below 3m).

Benthic Organism Health - Summary

Benthic health assessment is now undertaken annually on both Kahshe and Bass Lakes due to their listing as 'Vulnerable' lakes due to the appearance of HABs in 2020 and 2021 (Kahshe) or the presence of phosphorus at levels above the Water Quality Indicator of 20 µg/L (Bass). This involves sampling by the DMM's Biotechnician at established sites to determine which benthic macroinvertebrates are present in the bottom sediment. These organisms provide information on the health of the riparian zone (section between shallow water and dry land) and the littoral zone (shallow water nearest to dry land). These two zones are especially important to lake health as they are impacted by snowmelt, runoff, sedimentation and other development activities.

Collected benthos are grouped into seven (7) different categories based on their typical response to environmental contamination and are then compared to the Muskoka average for relevance purposes and to detect changes over time in species richness and biodiversity. The 2023 findings are briefly summarized below: The 2023 findings for Kahshe Lake are described below:

- The benthic community on Kahshe Lake is comparable to the Muskoka average for most family groupings, with the exception of % Chir (Chironimids) and % EOT, where lower and higher benthic counts, respectively, are desirable outcomes.
- Based on the benthic monitoring over the period from 2006 through 2023, there appears to be no increasing or decreasing trend in the various families of benthic organisms.

Although the KLRA has not provided volunteer benthic counting support to the DMM for Bass Lake, we have been provided with the analysis results for 2023 and they are summarized below:

- The average (all years) index values for two sites on Bass Lake for %Chironimids are slightly lower than the Muskoka Average, and this is a good sign, as the species in this grouping are pollution tolerant.
- In the case of %EOT, the lower values relative to the Muskoka Average are not a desirable outcome, as these benthos are sensitive to pollutants.
- An evaluation of trends in benthic family groupings at both sites over time revealed no evidence of any trend in the health of these organisms over the period from 2016 to 2023. However, it was noted that in the case of %EOT, the 2023 findings do indicate a healthier outcome for this grouping that was masked in the averaging approach over all years.

6.0 Main Summary and Conclusions

A review and analysis of all historical environmental monitoring on Kahshe and Bass Lakes can be found in annual Lake Steward Reports from 2012 through 2023. These documents have been posted on the KLRA web-site: https://kahshelake.ca/Water-Quality. This report captures the findings from sampling and analysis of both Kahshe and Bass Lakes in 2023 and has been structured to address the following parameters of potential concern for both Kahshe and Bass Lakes:

- Algal Nutrients and Other Factors Promoting Algal Growth
- Calcium Depletion
- Lake Acidification
- Metals and Other Chemicals of Concern
- Dissolved Oxygen Depletion
- Benthic Organism Health

The 2023 report also includes an overview of the climatological factors that have the potential to influence lake conditions. This demonstrated that air temperatures in 2023 were generally similar to the three previous years and to the 30 year normal for most months, with the exception of much warmer winter conditions in December and January. In the case of precipitation, total monthly amounts in April, June and July were noticeably greater than in previous years and compared to the 30 year normal, with much dryer conditions being recorded in November and December.

In 2023, the ice-out date for Kahshe Lake was April 14. The data from 1987-2023 for Kahshe Lake appear to generally follow the ice-out dates for the larger Muskoka Lakes and there appears to be a trend towards earlier ice-out dates on both Muskoka Lakes and Kahshe since the early 1970s.

Based on the DMM and MECP investigations, the following conclusions have been reached regarding the six water quality parameters identified above.

Algal Nutrients and Other Factors Promoting Algal Growth

Water quality monitoring of Kahshe and Bass Lakes by the DMM and the MECP has not identified any major water chemistry issues or trends in terms of algal friendly nutrients – phosphorus and nitrogen. Although both lakes have been classed as 'Vulnerable' under the updated Muskoka Official Plan (MOP), Bass Lake is expected to be removed due the findings of a DMM-funded Causation Study that identified natural causes as the reason for the elevated (>20 µg/L) levels of phosphorus, which is now one of three 'Water Quality Indicators' under the updated MOP. Kahshe Lake remains on the 'Vulnerable' list due to the documented presence of harmful blue-green algal blooms (HAB) in both 2020 and 2021, although none have been recorded since then. While Bass Lake is slated to be removed from the 'Vulnerable' listing, it may be re-listed, as there was an HAB in 2023 and it remains on the Simcoe-Muskoka Health Unit's active list.

Trends in water temperature, which can accelerate algal growth also were examined and there was no evidence of a warming trend in either lake based on water temperature measurements dating back to the early 1980s. Water clarity also has remained fairly steady over this four decade period, although clarity in Bass Lake is noticeably lower than in Kahshe.

And finally, it should be noted that the trend towards increasing numbers of HABs in Muskoka lakes continued in 2023, with 13 water bodies with documented HABs. This is cause for concern as the levels of algal-friendly phosphorus in Muskoka lakes have not increased over this time period. As such, changes in other factors that are known to accelerate algal growth and bloom development are happening. And, as we discovered in our Near-Shore Sampling Project in 2021, it is also possible that the historical sampling in mid-lake, deep water locations by the DMM and MECP is giving an excellent historical record of nutrient levels but not reflecting the elevated levels that have been documented in near-shore areas where algal blooms typically form.

Calcium Depletion

Decreasing lake water calcium concentration is an emerging concern for lakes on the Precambrian Shield in Ontario due to its impact on the reproduction and survival of zooplankton and other aquatic species that are important components of the aquatic food chain. The 2023 data confirm that there is no detectable trend towards decreasing levels of calcium in either Kahshe or Bass Lakes. However, as levels of calcium are fairly close to the aquatic growth limiting threshold of 1.5 mg/L and, as this threshold value would not be protective of all aquatic organisms, continued vigilance is necessary.

This is underscored by late season population explosions of *Holopedium* in Kahshe Lake since 2021. These pea sized, jelly-like orbs are not known to be toxic, but are an uncomfortable nuisance as they can be felt against your skin while swimming.

Lake Acidification

The waters of Kahshe and Bass Lake have acidity (pH) levels that are within a normal range and there is no evidence of an increasing or decreasing trend in acidity over the two decade monitoring period.

While the pH findings represent good news, it should also be recognized that the waters of Kahshe and Bass Lakes have low levels of alkalinity, and as such, are more susceptible to acidification as the ability of the water to buffer the acid input is low.

Metals and Other Chemicals of Concern

The analysis of over 30 additional anions, cations and other chemicals by the DMM in 2023 has, with one possible exception, identified no trends or aquatic toxicity issues. While there were some minor exceedances of chronic (long term) health protection benchmarks established by the MECP and other agencies in the early years, most of these exceedances were likely due to sampling or laboratory artifacts, as more recent sampling has shown concentrations that are in the expected range for non-impacted surface water bodies in Ontario.

In the case of aluminum, the aquatic benchmark has been exceeded in Bass Lake, with the highest concentration in 2023; however, the benchmark consists of a range in values and must be evaluated based on the pH and DOC concentrations in lake water. Based on these findings, the levels of aluminum need to be followed carefully in future monitoring to ensure that the waters of Kahshe and Bass Lakes are safe from an aquatic perspective.

The other finding from this data set is that there are numerous parameters that, like total phosphorus, are higher in Bass Lake compared to Kahshe Lake. There are also a couple of parameters (silicon and $N-NO_3$) where levels in Kahshe are higher than in Bass. The reason for these differences in the two lakes is unknown and was not evaluated in the DMM-funded Causation Study on Bass Lake.

Dissolved Oxygen Depletion

Dissolved oxygen (DO) in lake water is important, as it is essential for the survival of all aquatic organisms. A lack of oxygen in the lower layers of the lake (referred to as being anoxic) also can cause mobilization (release) of phosphorus from sediments.

Dissolved oxygen is influenced by seasonal temperature changes that factor into lake stratification, the process whereby lake water is turned over (mixed) in the late fall and again following the winter ice melt and then begins to stratify through the spring, summer and early fall as water temperature increases at the surface and DO levels decrease with increasing depth.

As expected, the spring measurement of DO at increasing water depths in both Kahshe and Bass Lakes for 2023 revealed that with only one exception (Bass Lake >4m), DO was adequate for aquatic organism survival down to lake bottoms. However, by early August 2023, as in all previous decades, DO levels in Kahshe Lake fell below the aquatic health-based Provincial Water Quality Objective (PWQO) at around 4-5m depth and remain that way down to lake bottom (20m). In Bass Lake, by mid-August, the 2023 DO levels steeply declined beyond a depth of 2m and fell below the aquatic PWQO at depths greater than around 2.5m.

From a biological perspective, unlike Kahshe Lake, there appears to be a trend towards DO levels in Bass Lake falling below the PWQO at more shallow depths (just below 2m) than back in the 1980s and 1990s when DO crossed below the PWQO at depths almost at lake bottom (just below 3m).

Benthic Organism Health

The presence of benthic organisms indicates the health of both the riparian and littoral zones, as these areas can be impacted by snowmelt, runoff, sedimentation and other shoreline development activities. Collected benthos are grouped into seven different categories based on their typical response to environmental contamination and are then compared to the Muskoka average from locations known to be remote from any shoreline development sources.

The 2023 assessment at two sites on Kahshe Lake confirmed that the benthic community is comparable to the Muskoka average for most family groupings, with the exception of % Chironimids and % EOT, where lower and higher benthic counts, respectively, are desirable outcomes. And, based on the benthic monitoring over the period from 2006 through 2023, there appears to be no increasing or decreasing trend in the various families of benthic organisms in Kahshe Lake.

Although the KLRA has not provided volunteer benthic counting support to the DMM for Bass Lake, we have been provided with the analysis results for 2023 and they revealed that the average (all years) index values for two sites on Bass Lake for %Chironimids are slightly lower than the Muskoka Average, and this is a good sign, as the species in this grouping are pollution tolerant. In the case of %EOT, the lower values relative to the Muskoka Average are not a desirable outcome, as these benthos are sensitive to pollutants. However, it was noted that in the case of %EOT, the 2023 findings do indicate a healthier outcome for this grouping that was masked in the averaging approach using data from all years. An evaluation of trends in benthic family groupings at both sites over time revealed no evidence of any trend in the health of these organisms over the period from 2016 to 2023.

Based on the 2023 water quality and benthic monitoring of Kahshe and Bass Lakes by the DMM and the MECP, no major water quality issues or trends were identified. However, given the documented occurrence of HABs in Kahshe Lake in both 2020 and 2021 as well as the late season population explosion of a zooplankton organism (*Holopedium*) known to be associated with decreasing levels of available calcium in Muskoka region lakes, it is clear that the tracking of water quality via the mid-lake, deep water sites of the DMM and MECP should not be completely relied upon as a fully representative assessment of water quality in the near-shore environment where algal blooms have been documented.

In the case of Bass Lake, the DMM identified it as a 'Vulnerable' lake and carried out a Causation Study in 2021-22. This study concluded that the elevated levels of total phosphorus in Bass Lake have resulted from natural causes. However, for the first time, Bass Lake had a documented HAB in 2023 and remains on alert status by the Simcoe-Muskoka Health Unit.

So, where do we go from here?

Kahshe Lake also has been identified by the DMM as a 'Vulnerable' lake and a DMM-funded Causation Study will be undertaken when funds are available. However, based on our concern following the development of late season HABs in 2021 and 2022, the KLRA funded a Near-Shore Water Sampling Project in 2021 to explore the chemistry of near-shore waters over the spring and summer season in an effort to better understand why Kahshe Lake has been impacted by HABs in spite of reasonably low and unchanged phosphorous levels reported by the DMM and MECP over the past 40 years.

The findings from this Near-Shore Water Sampling Project (NSWSP) have been published in a final report available on the KLRA Water Quality web portal. The NSWSP identified some very useful insights and linkages between our changing climate, its impact on water quality and the development of late season HABs in Kahshe Lake. Briefly, the NSWSP demonstrated that:

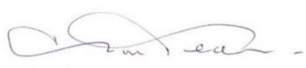
- Mid-lake, deep water sampling in the spring of the year is a reasonable way to track long-term, historical changes in water quality but is not providing a biologically relevant assessment of water quality in the near-shore environment where HABs have been documented.
- The mid-lake, deep water sampling also has failed to capture higher total phosphorus levels in the east end of the lake which is subject to inflow from Bass Lake, as there are no DMM sampling sites in that area.
- Levels of algal-friendly nutrients (phosphorus and nitrogen) in the near-shore areas tend to increase and fluctuate as the season progresses, further limiting the relevance of the spring sampling of mid-lake sites in terms of assessing the potential for HAB development.
- The near-shore water chemistry findings for some algal-friendly nutrients appear to be associated with human & animal waste sources which are known to be linked with algal growth and HABs.
- Although more study is warranted, the near-shore findings point to accelerated leaching and/or runoff of soil-borne nutrients due to a changing climate which is resulting in more intense rainfall events.

Although we have virtually no control over the change that is affecting our climate, there are actions we can and must take to minimize the accelerated leaching of algal friendly nutrients to our shoreline water and thereby reduce the potential for future algal blooms. These actions have been thoroughly explored by the Conservation Committee and are summarized below:

1. **Divert roof drainage and runoff from paths and other hard surfaces away from your septic system and the shoreline. If necessary, direct rain water into rock-filled drainage pits.**

2. **Keep most of your shoreline as natural as possible with a zone of trees, shrubs or tall grass between the shore and any lawn area to discourage grazing by Canada geese and to reduce soil & goose poop runoff into the lake.**
3. **Have a licensed professional pump out and inspect your septic system for failures and deficiencies every 3-5 years and more often for aging systems installed pre-2000. The Town will be inspecting in 2023, but we don't need to wait until then and be subject to system shutdown until failing systems are repaired.**
4. **Don't use phosphorus or nitrogen fertilizers or cleaning agents anywhere near the shore.**

Well, that's it for me. It has been a pleasure to serve as your Lake Steward since 2011 and I now hand it over to Sara Varty who has accepted the role going forward. All the best Sara!



Ron Pearson, M.Sc.

Kahshe and Bass Lake Steward - Conservation Committee

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Attachments

Attachment 1

Ice-Out Records for Muskoka Lakes and Kahshe Lake: 1886-2023

Year	Muskoka Lakes		Kahshe Lake	
	Ice Out Date	Julian Day1	Ice Out Date	Julian Day1
1886	04/23/1886	113		
1889	04/18/1889	108		
1890	04/26/1890	116		
1891	04/27/1891	117		
1892	04/21/1892	112		
1893	04/26/1893	116		
1895	04/22/1895	112		
1896	04/17/1896	108		
1897	04/27/1907	117		
1899	04/26/1899	116		
1900	04/24/1900	115		
1901	04/20/1901	110		
1902	04/09/1902	99		
1903	04/07/1903	97		
1904	04/29/1904	120		
1905	04/24/1905	114		
1906	04/20/1906	110		
1907	04/24/1907	114		
1908	04/27/1908	118		
1909	04/29/1909	119		
1910	04/01/1910	91		
1911	05/01/1911	121		
1912	04/27/1912	118		
1913	04/20/1913	110		
1914	04/21/1914	111		
1915	04/19/1915	109		
1916	04/20/1916	111		
1917	04/23/1917	113		
1918	04/23/1918	113		
1919	04/16/1919	106		
1920	04/19/1920	110		
1921	04/08/1921	98		
1922	04/17/1922	107		
1923	04/28/1923	118		
1924	04/17/1924	108		
1925	04/14/1925	104		
1926	05/07/1926	127		

Year	Muskoka Lakes		Kahshe Lake	
	Ice Out Date	Julian Day1	Ice Out Date	Julian Day1
1927	04/18/1927	108		
1928	04/29/1928	120		
1929	04/09/1929	99		
1930	04/24/1930	114		
1931	04/30/1931	120		
1932	04/06/1932	97		
1933	04/10/1933	100		
1934	04/21/1934	111		
1935	04/16/1935	106		
1936	04/23/1936	114		
1937	04/24/1937	114		
1938	04/17/1938	107		
1939	05/01/19339	121		
1940	04/29/1940	120		
1941	04/15/1931	105		
1942	04/15/1942	105		
1943	04/29/1943	119		
1944	04/28/1944	119		
1945	03/29/1945	88		
1946	03/27/1946	86		
1947	04/27/1947	117		
1948	04/10/1948	101		
1949	04/12/1949	102		
1950	05/01/1950	121		
1951	04/12/1951	102		
1952	04/20/1952	111		
1953	04/06/1953	96		
1954	04/21/1954	111		
1955	04/13/1955	103		
1956	05/04/1956	125		
1957	04/20/1957	110		
1958	04/26/1958	116		
1959	04/28/1959	118		
1960	04/22/1960	113		
1961	04/22/1961	112		
1962	04/21/1962	111		
1963	04/16/1963	106		
1964	04/17/1964	108		
1965	05/03/1965	123		
1966	04/20/1966	110		
1967	04/18/1967	108		

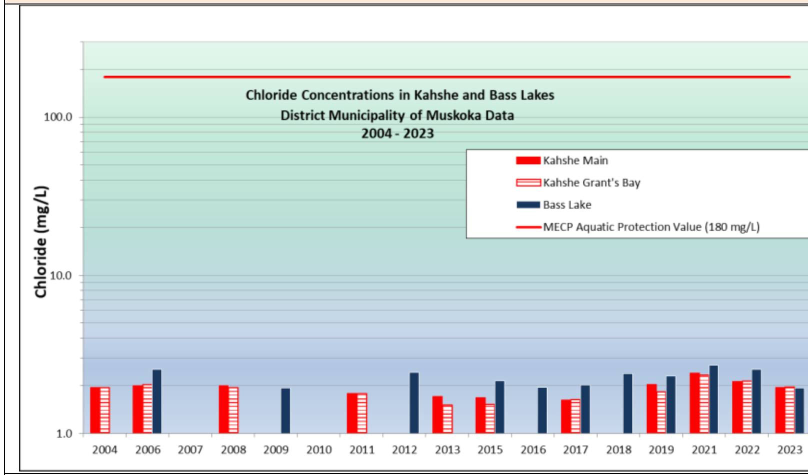
Year	Muskoka Lakes		Kahshe Lake	
	Ice Out Date	Julian Day1	Ice Out Date	Julian Day1
1968	04/09/1968	100		
1969	04/22/1969	112		
1970	04/30/1970	120		
1971	05/02/1971	122		
1972	05/03/1972	124		
1973	04/17/1973	107		
1974	04/28/1974	118		
1975	05/01/1975	121		
1976	04/16/1976	107		
1977	04/16/1977	106		
1978	04/29/1978	119		
1979	04/21/1979	111		
1980	04/15/1980	106		
1981	04/04/1981	94		
1982	04/27/1982	117		
1983	04/16/1983	106		
1984	04/17/1984	108		
1985	04/23/1985	113		
1986	04/10/1986	100		
1987	04/13/1987	103	04/08/1987	98
1988	04/14/1988	105	04/13/1988	104
1989	04/28/1989	118	04/26/1989	116
1990	04/26/1990	116	04/25/1990	115
1991	04/16/1991	106	04/19/1991	109
1992	05/01/1992	122	04/28/1992	118
1993	04/21/1993	111	04/27/1993	117
1994	04/23/1994	113	04/20/1994	110
1995	04/19/1995	109	04/12/1995	102
1996			04/25/1996	116
1997			04/29/1997	119
1998	04/19/1998	109	04/08/1998	98
1999	04/09/1999	99	04/08/1999	98
2000	03/28/2000	88	03/26/2000	86
2001	04/28/2001	118	04/20/2001	110
2002	04/15/2002	105	04/16/2002	106
2003	04/21/2003	111	04/21/2003	111
2004	04/16/2004	107	04/18/2004	109
2005	04/17/2005	107	04/19/2005	109
2006	04/14/2006	104	04/15/2006	105
2007	04/18/2007	108	04/18/2007	108
2008	04/21/2008	112	04/20/2008	111

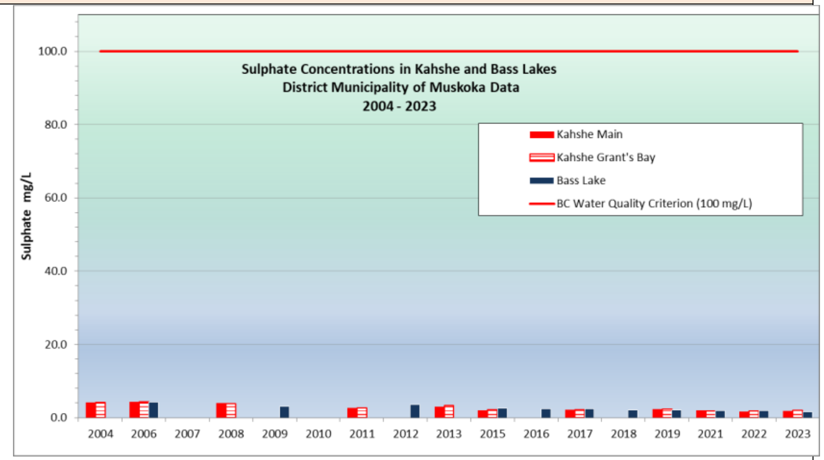
Year	Muskoka Lakes		Kahshe Lake	
	Ice Out Date	Julian Day1	Ice Out Date	Julian Day1
2009	04/18/2009	108	04/17/2009	107
2010	04/02/2010	92	04/02/2010	92
2011	04/17/2011	107	04/18/2011	108
2012	04/23/2012	114	03/24/2012	115
2013	04/13/2013	103	04/19/2013	109
2014	04/29/2014	119	04/29/2014	119
2015	04/21//2015	111	04/18/2015	108
2016	04/08/2016	99	04/16/2016	107
2017			04/12/2017	102
2018			05/02/2018	122
2019			04/26/2019	116
2020			04/09/2020	100
2021			04/07/2021	97
2022			04/16/2022	106
Yellow shaded years designate a leap year, which adds one day to the Julian dates				
Julian Day1 represents the number of days after Jan 1 that ice went out				

Attachment 2

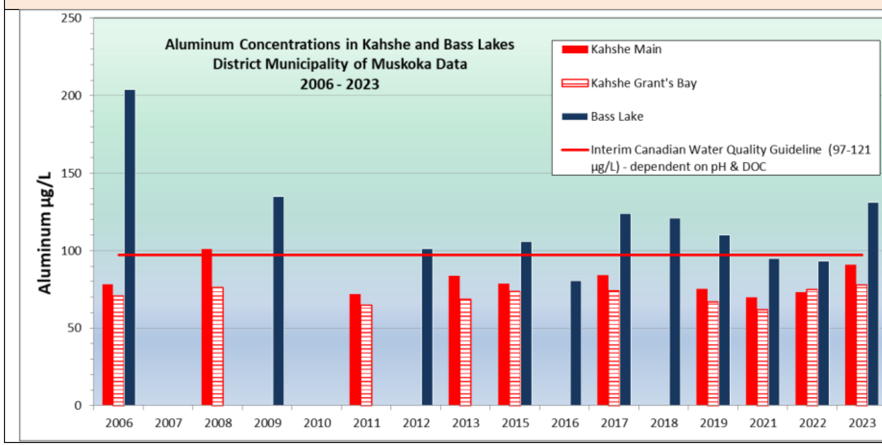
Charts of Water Chemistry Results for Other Chemicals from DMM Sampling of Kahshe and Bass Lakes

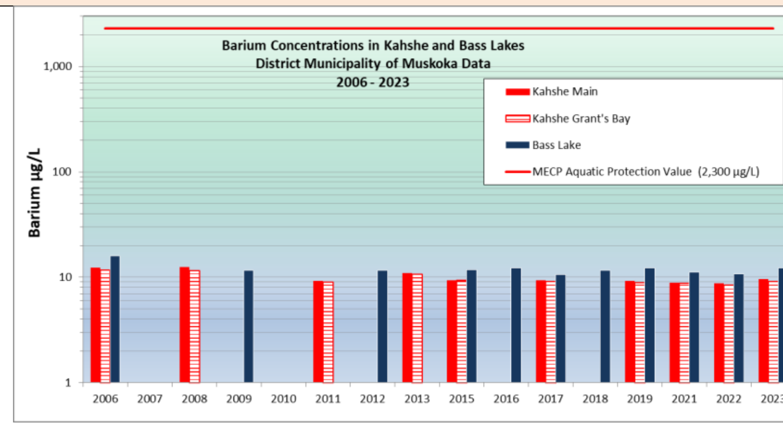
Anions

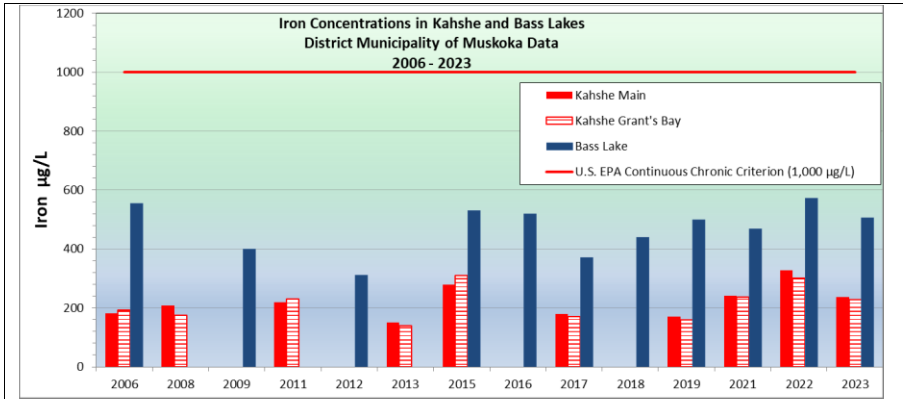


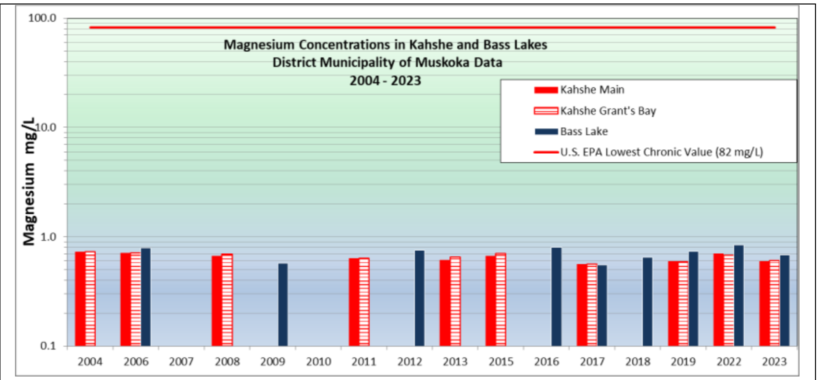


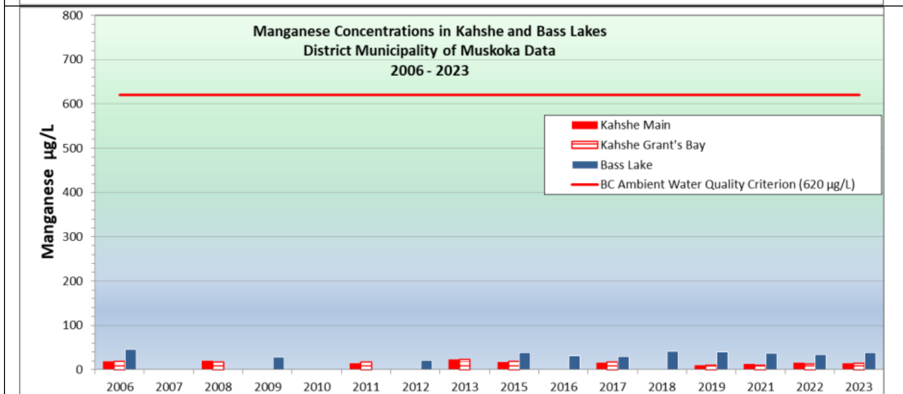
Cations

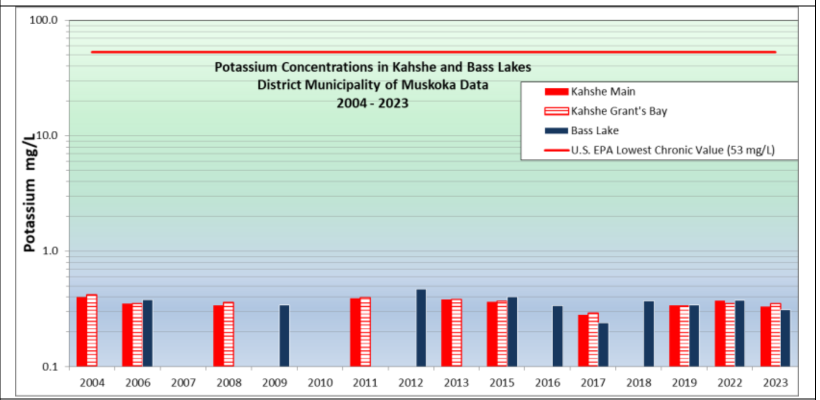


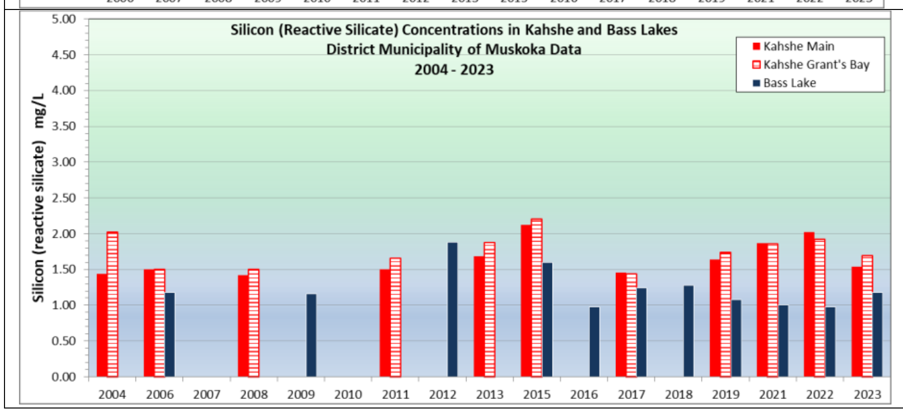


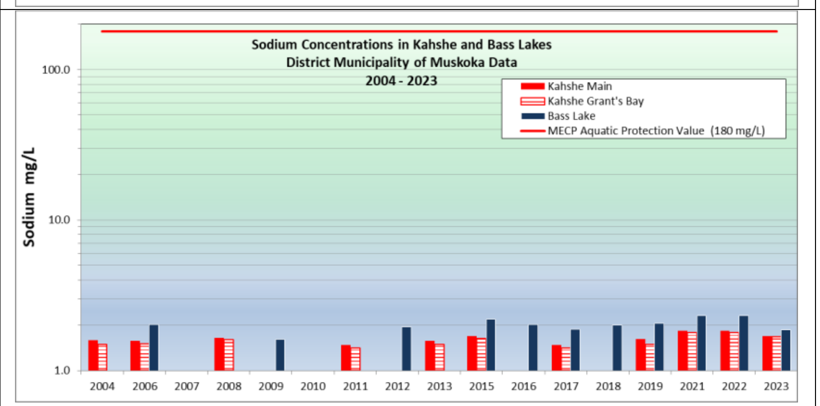

Iron Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2023
Kahshe Main
Kahshe Grant's Bay
Bass Lake
U.S. EPA Continuous Chronic Criterion (1,000 µg/L)
Iron µg/L

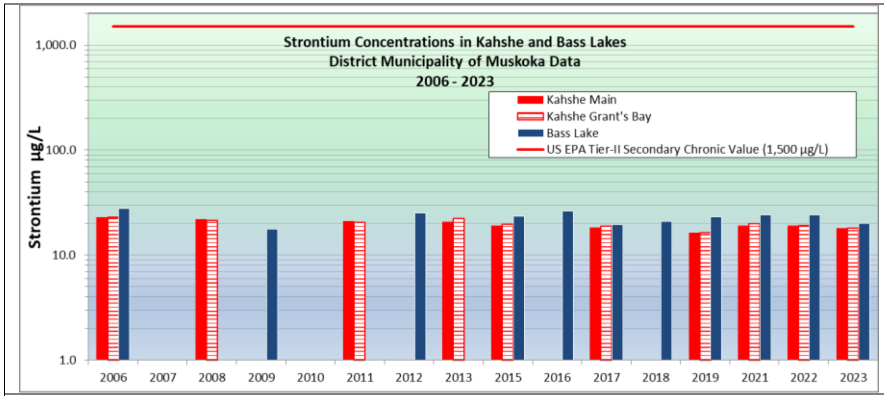

Magnesium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2023
Kahshe Main
Kahshe Grant's Bay
Bass Lake
U.S. EPA Lowest Chronic Value (82 mg/L)
Magnesium mg/L

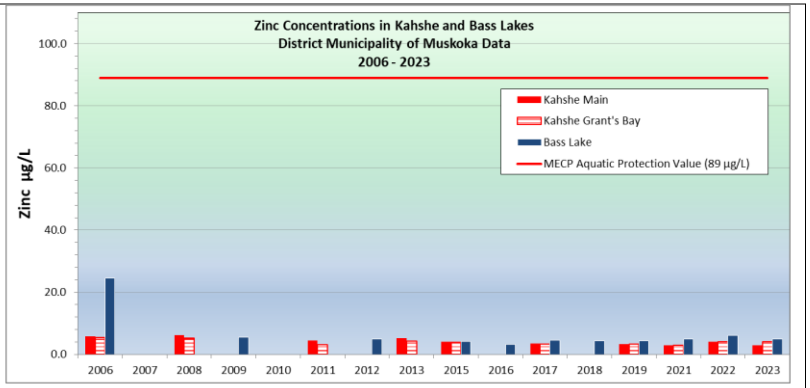

Manganese Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2023
Kahshe Main
Kahshe Grant's Bay
Bass Lake
BC Ambient Water Quality Criterion (620 µg/L)
Manganese µg/L


Potassium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2023
Kahshe Main
Kahshe Grant's Bay
Bass Lake
U.S. EPA Lowest Chronic Value (53 mg/L)
Potassium mg/L

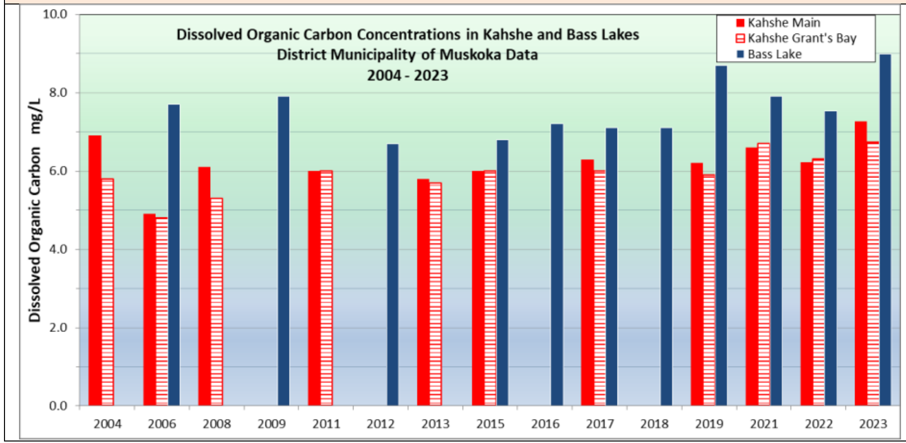

Silicon (Reactive Silicate) Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2023
Kahshe Main
Kahshe Grant's Bay
Bass Lake
Silicon (reactive silicate) mg/L

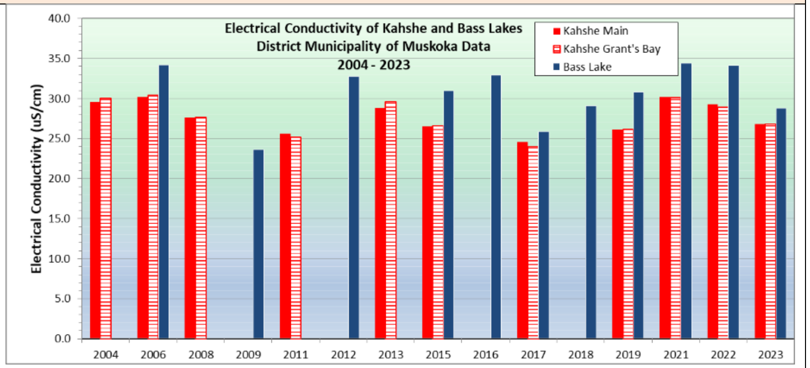

Sodium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2023
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MECP Aquatic Protection Value (180 mg/L)
Sodium mg/L

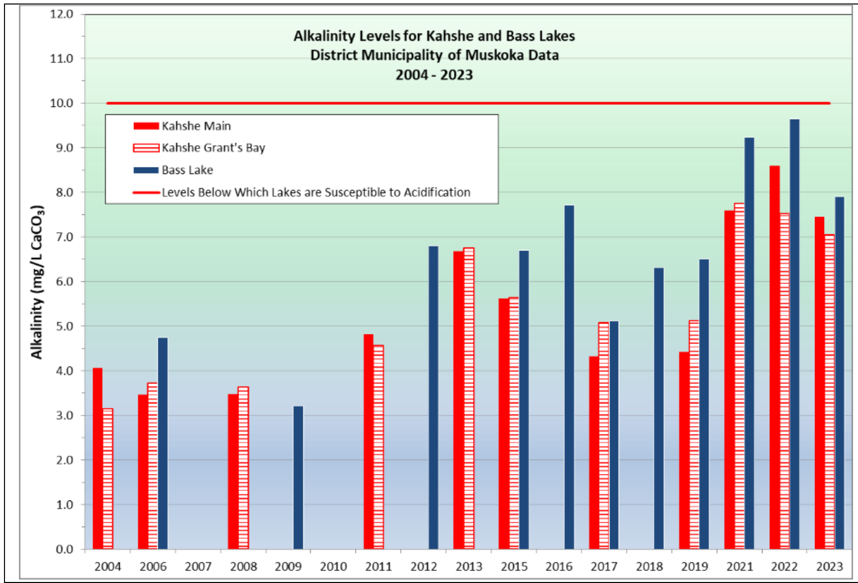




Other Non-Metal Parameters







Alkalinity Levels for Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2023
Kahshe Main
Kahshe Grant's Bay
Bass Lake
Levels Below Which Lakes are Susceptible to Acidification
Alkalinity (mg/L CaCO3)
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2004
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019
2021
2022
2023