HALIFAX

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Item No. 13.1.2
Environment & Sustainability Standing Committee
October 03, 2024

TO: Chair and Members of Environment and Sustainability Standing Committee

FROM: Brad Anguish, Commissioner of Operations

DATE: April 22, 2024

SUBJECT: LakeWatchers Water Quality Monitoring Program Report 2022-2023

ORIGIN

On June 29, 2021, the following motion of Regional Council regarding agenda item 12.1.1 was put and passed:

It is recommended that the Environment and Sustainability Standing Committee recommend that Halifax Regional Council direct the Chief Administrative Officer to:

1. Adopt and implement a detailed water quality monitoring program based on Framework 1 as outlined by AECOM (2020) in their Water Quality Monitoring Policy and Program Development Report, as outlined in the Discussion section of this report.

MOTION PUT AND PASSED

EXECUTIVE SUMMARY

The "State of the Lakes" Report (Attachment A) provides an in-depth analysis of the 2022-23 LakeWatchers program, which was initiated to monitor the water quality of 73 lakes in the Halifax Regional Municipality (HRM). The report outlines the key findings of the LakeWatchers Program related to the current baseline conditions of the lakes, focusing on eutrophication, chloride enrichment, and bacterial contamination.

The LakeWatchers Program actively engages and involves community groups and volunteers in water quality monitoring, setting it apart from a previous municipal water quality monitoring program (2006-2011) which relied solely on consultants. The LakeWatchers program was launched in the spring of 2022. The number of lakes in which community groups and volunteers have participated has grown to include 30 of 73 lakes as of August 2023.

While the 2022-23 LakeWatchers data detected lower phosphorus levels compared to the 2006-2011 HRM Lake Water Quality Monitoring Program (LWQMP), further analysis of other parameters maintains that Halifax-area lakes are experiencing a rise in nutrient levels over time. These results were consistent between both lakes sampled by volunteers and consultants. Duplicate samples will be collected in 2024 to further investigate. Additionally, most lakes displayed consistently elevated deepwater chloride levels, with some in exceedance of federal guidelines for long-term exposure intended to protect freshwater aquatic life. These elevated chloride levels pose a significant threat to the biodiversity of freshwater ecosystems within the HRM and have the potential to disrupt the natural mixing cycle of lakes. Lastly, there were very few (<1%) instances of *E. coli* detected above Health Canada guidelines which suggests that *E. coli* is not a lake wide concern and instead impacts near-shore beaches.

Overall, the initial findings of the LakeWatchers Program indicate that most Halifax-area lakes currently suffer from some level of chloride enrichment and show signs of increasing eutrophication. These findings align with previous studies and emphasize the importance of monitoring to inform proactive measures to protect lake water quality in the municipality.

RECOMMENDATION

It is recommended that the Environment & Sustainability Standing Committee recommend that Halifax Regional Council:

1. Direct the Chief Administrative Officer to initiate a review of the Municipality's current Salt Management Plan guided by the Syntheses of Best Practices Road Salt Management.
2. Direct the Chief Administrative Officer to investigate policy options for setbacks for new stormwater discharge locations into natural waterbodies and consider options for naturalization and/or Low Impact Development (LID) features at existing stormwater discharge locations around priority lakes.
3. Request that the Mayor write a letter to the Province of Nova Scotia's Minster of Environment and Climate Change and the Halifax Regional Water Commission, supporting and encouraging the timely development of provincial stormwater quality standards.

BACKGROUND

Water quality monitoring is an essential component of the successful management of water resources. This responsibility is shared between each level of government, the private sector, and the general community. However, the municipality is the level of government closest to residents and has responsibilities for community planning, parks and recreation, the enjoyment and well-being of residents, as well as overall environmental sustainability. Many municipal programs, services, and responsibilities can impact lake health and water quality and so the municipality is uniquely positioned to monitor lake water quality and proactively address arising issues, as well as ongoing concerns.

Efforts to understand, protect, and manage watershed health at the municipal level date to the Halifax Regional Municipality's Water Resources Management Study[1], which recommended that the Municipality establish a water quality monitoring program. The first iteration of a municipal lake monitoring program, the HRM Lakes Water Quality Monitoring Program (HRM LWQMP) was initiated in 2006 but was suspended in 2011. Since that time the Municipality has seen unprecedented growth and changes across the region and in 2021, Regional Council approved a new lake monitoring program after extensive consultation and a jurisdictional scan of other municipal lake monitoring programs.

In 2021, Council approved 'Framework 1' which adopts a hybrid approach to water quality monitoring where either community organizations or volunteers are invited and recruited to monitor a portion of the lakes and hired consultants to monitor the remaining lakes. The HRM LakeWatchers Program was subsequently launched in the spring of 2022. A total of 73 lakes were identified for bi-annual (spring & summer) water quality monitoring, inclusive of 77 total lake basins. Most lakes are sampled at their deepest basin; however, samples are collected from multiple deep basins for Thomas Lake and Porters Lakes as recommended by

[1] Halifax Regional Council Report. 2003. Water Resource Management Study Project.

AECOM 2020[2]. 70 lakes were selected based on either being highly or moderately vulnerable to development stressors based on previously collected data. A further three lakes were chosen to serve as reference lakes. The LakeWatchers sampling program was designed to establish current baseline conditions for these 73 lakes based on three main water quality concerns for Halifax-area lakes; i) eutrophication, ii) chloride enrichment, and iii) bacterial contamination.

Staff indicated at the time of Council approval that a report would be provided after the first two years of data collection. The attached LakeWatchers – State of the Lakes Report (Attachment A) provides a detailed analysis of the 2022-23 LakeWatchers results discussed below. Fact sheets for each lake are being drafted by Corporate Communications which will be shared at halifax.ca/lakewatchers when available.

Moving forward, staff will author an annual State of the Lakes to be published in the spring of each year. As such, the next State of the Lakes report will be released in the spring of 2025, detailing the results of the 2024 sampling year. This next report will also assess and review the current sampling frequency of selected lakes.

DISCUSSION

LakeWatchers' first sampling season was in Spring 2022. GHD Ltd was hired after a competitive procurement process to coordinate the sampling of all 73 selected lakes. During this inaugural season all lakes were also sampled for metals.

In advance of the Summer 2022 sampling period, staff held training and information sessions for prospective volunteers on how to use sampling equipment, take water samples for laboratory analysis, and correctly record the data collected. The original goal had been to have 5 of 73 lakes monitored by community groups or volunteers in the first year of the LakeWatchers program, but by the end of 2022 volunteers and community organizations were involved in the monitoring of 15 lakes. In 2023 additional events and equipment training workshops were held to further boost volunteer recruitment. By the completion of the 2023 LakeWatchers sampling year, the number of lakes involving volunteers or community organizations was doubled to 30 (Figure 1, Table 1).

As of February 2024, all data collected from the 2022 and 2023 seasons was available through the Halifax Open Data portal[3], as well as Atlantic DataStream[4], an online platform for sharing water quality data in Atlantic Canada.

Moving forward, data collected as part of the LakeWatchers program will be uploaded to both HRM's Open Data portal and Atlantic DataStream bi-annually upon completion of each sampling period (i.e. Spring and Summer).

An overview of findings from the 2022 and 2023 sampling years are provided in this report. A more detailed analysis of the LakeWatchers program can be found in the "State of the Lakes" Report (Attachment A).

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[2] AECOM. 2020. Water Quality Monitoring Policy and Program Development for the Halifax Regional Municipality

[3] Halifax Data, Mapping and Analytics Hub – Open Data.

[4] Atlantic DataStream – Home Page.

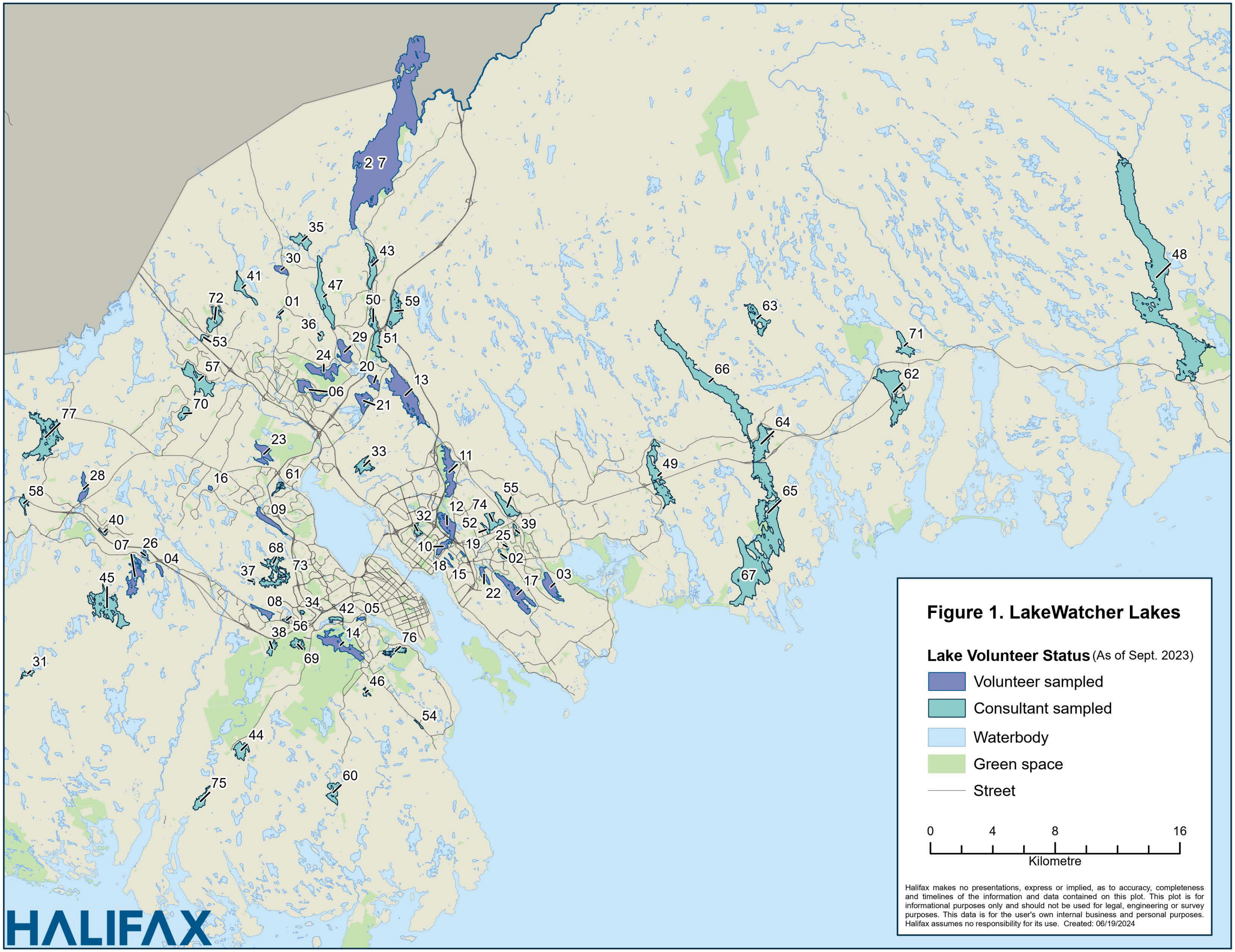


Figure 1. LakeWatcher Lakes

Table 1. Lake Names, Identifier Number and Volunteer Status for Figure 1

Number	Lake Name	Volunteer Status	Number	Lake Name	Volunteer Status
1	Barrett Lake	V*	40	Elbow Lake	C
2	Bell Lake	V	41	Fenerty Lake	C
3	Bissett Lake	V	42	First Chain Lake	C
4	Black Point Lake	V	43	Fletchers Lake	C
5	Chocolate Lake	V	44	Hatchet Lake	C
6	First Lake	V	45	Hubley Big Lake	C
7	Five Island Lake	V	46	Kidston Lake	C
8	Governors Lake	V	47	Kinsac Lake	C
9	Kearney Lake	V	48	Lake Charlotte	C
10	Lake Banook	V	49	Lake Echo	C
11	Lake Charles	V	50	Lake Thomas (North Basin)	C
12	Lake MicMac	V	51	Lake Thomas (South Basin)	C
13	Lake William	V	52	Lemont Lake	C
14	Long Lake	V	53	Little Springfield Lake	C
15	Maynard Lake	V	54	Long Pond	C
16	McQuade Lake	V	55	Loon Lake	C
17	Morris Lake	V	56	Lovett Lake	C
18	Oat Hill Lake	V	57	McCabe Lake	C
19	Penhorn Lake	V	58	Mill Lake	C
20	Powder Mill Lake	V	59	Miller Lake	C
21	Rocky Lake (Northeast Basin)	V	60	Moody Lake	C
22	Russell Lake	V	61	Paper Mill Lake	C
23	Sandy Lake (Bedford)	V	62	Petpeswick Lake	C
24	Second Lake	V	63	Pine Lake	C
25	Settle Lake	V	64	Porters Lake (Middle North)	C
26	Sheldrake Lake	V	65	Porters Lake (Middle South)	C
27	Shubenacadie Grand Lake	V	66	Porters Lake (North)	C
28	Stillwater Lake	V	67	Porters Lake (South)	C
29	Third Lake	V	68	Quarry Lake (Birch Cove)	C
30	Tucker Lake	V	69	Ragged Lake	C
31	Albert Bridge Lake	C**	70	Sandy Lake (Glen Arbour)	C
32	Albro Lake	C	71	Scots Lake	C
33	Anderson Lake	C	72	Springfield Lake	C
34	Bayers Lake	C	73	Susies Lake (Birch Cove)	C
35	Beaver Bank Lake	C	74	Topsail Lake	C
36	Beaver Pond	C	75	Whites Lake	C
37	Big Cranberry Lake	C	76	Williams Lake (Spryfield)	C
38	Blueberry Lake	C	77	Wrights Lake	C
39	Cranberry Lake	C			

* Where V represents volunteer sampled lakes
** Where C represents consultant sampled lakes

Eutrophication

Eutrophication describes a process in which lakes with naturally low nutrient levels become increasingly enriched with nutrients resulting in increased plant and algae growth. Large amounts of aquatic plant and algae growth can become a nuisance for lake users, decrease water clarity and when they die off their decomposition can deplete the water of oxygen, harming aquatic organisms.

Lakes can be classified into 'trophic states' based on the amount of nutrients in a lake's water. The CCME provides six trophic state classifications describing Canadian lakes based on concentrations of total phosphorus. This is because phosphorus is thought to be the limiting nutrient controlling the growth of aquatic plants and algae in temperate lakes, such as those found in the Halifax region[5]. Trophic state classifications can also be derived from the concentration of chlorophyll-a in lake water[6,7]. Many of the lakes within the Halifax region are oligotrophic which means they typically have low nutrient levels, low plant and algal growth and are oxygenated throughout the year. There are increasing risks that lakes could become eutrophic with higher nutrient levels leading to more plant and algal growth and periods of de-oxygenated water in the warmer summer months.

Lakes in the Halifax Regional Municipality are naturally oligotrophic, but previous work has suggested that the addition of anthropogenic nutrients, especially phosphorus, is accelerating the eutrophication process[8,9]. Many lakes within the Municipality are used for recreation, and it through this lens that people assess water quality, whether for swimming, boating, or fishing.

As lakes become more enriched with nutrients, their value for recreation decreases as plant and algae abundance increases and water clarity decreases. This issue is already affecting the recreational value of Lake Banook and Lake Micmac[10], requiring the Municipality to hire a contractor to harvest the excessive aquatic plant growth during the summer months. As such, it is important to monitor the trophic status of lakes so that proactive measures may be taken if nutrient levels are shown to be increasing over time.

During the last comprehensive lake water quality monitoring program, the HRM LWQMP (2006-2011), most lakes sampled were classified as either mesotrophic or meso-eutrophic[11] based on their 5-year average total phosphorus levels. That result suggested Halifax-area lakes were trending towards higher levels of nutrients over time. However, if the 2-year (2022-23) average total phosphorus levels from the LakeWatchers' dataset are used, most lakes would be classified as either oligotrophic or ultra-oligotrophic (Table 3). This was a surprising result, as the total phosphorus concentrations observed in 2022-23 were expected to be similar or even slightly higher than what had been previously measured during the HRM LWQMP. More than a decade has since passed between these two sampling periods and the development pressures within the watersheds of many lakes have remained consistent or in many cases increased. It is important to note that these inconsistencies were seen at lakes sampled by both volunteers and consultants.

In support of that consideration, most lakes within the 2022-23 LakeWatchers data can be classified as mesotrophic if their average summer chlorophyll-a concentrations are used instead of their average total phosphorus concentrations (Table 2). Additionally, there have been growing complaints about increasing nuisance aquatic plant growth in Halifax-area lakes, as well as many confirmed incidences of blue-green

[5] Canadian Council of Ministers for the Environment. 2004. Phosphorus, Canadian Guidance Framework for Management of Freshwater Systems.
[6] Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography. 22:361-369.
[7] Carlson, R.E. and J. Simpson. 1996. A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society. 96 pp.
[8] Clement, P. et al. 2007. Synoptic Water Quality Survey of Selected Halifax Regional Municipality Lakes on 28-29 March 2000.
[9] Clement, P.M., and Gordon, D.C. 2019. Synoptic water quality study of selected Halifax-area lakes: 2011 results and comparison with previous surveys.
[10] Stantec Consulting Limited. 2019. Pollution Source Control Study for Lake Banook & Lake Micmac.
[11] Stantec Consulting Limited. 2012. An Analysis of the HRM Lakes Water Quality Data (2006 – 2011).

algae in recent years which is suggestive of increasing eutrophication. Lastly, de-oxygenated conditions were observed at 58 of 77 lake basins during either the summer sampling of 2022 or 2023, a condition closely associated with higher nutrient levels, known as seasonal anoxia. Overall, these initial findings suggest that Halifax-area lakes are indeed trending toward higher nutrient levels over time, despite the unexpectedly low average total phosphorus results in 2022-23.

Of most concern, however, is the seasonal anoxia that was observed at many lake basins. This can lead to a process known as internal loading, which allows for nutrients, such as phosphorus, and other harmful contaminants that are trapped in lakebed sediments to be released back into the water column. Recent studies have indicated that this process is already occurring at some lakes within the HRM[12], [13] and the LakeWatchers dataset also supports that assertion. In both the summers of 2022 and 2023, most lake basins exhibiting de-oxygenated conditions also showed higher total phosphorus levels from the deepwater sample when compared to the surface water sample.

The reasons for the discrepancy between the total phosphorus data collected between 2006-11 and the LakeWatchers data collected in 2022-23 are not yet clear. One reason may simply be that the LakeWatchers dataset is still quite small, spanning only 2 years, instead of 5 years as with the previous HRM LWQMP. Other possible reasons include differences in sampling methods, timing of sampling, changes in lab techniques over time, or the degradation of samples between collection and analysis. During a future sampling event a select number of duplicate water samples will be collected for Total Phosphorus analysis. To assess whether the TP values observed in 2022-23 reflect real conditions or a source of lab discrepancy or error, a small number of duplicate samples will be collected and submitted to a second analytical laboratory for TP analysis.

Table 2. Summary of the Estimated Trophic Status' for the 77 Lake Basins sampled as part of the 2022-23 LakeWatchers Programs

Trophic State Categories	**Trophic Status based on *CCME Total P Framework***	**Trophic Status based on NALMS chlorophyll-a Framework***
	Number of Lake Basins	
Ultra-oligotrophic	35	2
Oligotrophic	32	22
Mesotrophic	9	45
Meso-eutrophic	1	6
Eutrophic	0	2
Hyper-eutrophic	0	0
TOTAL	**77**	**77**

Chloride Enrichment

Chloride enrichment, or salinization, refers to the process of a freshwater body, such as a lake, becoming saltier over time. Ambient chloride concentrations in freshwater lakes within the Atlantic region, including Nova Scotia, are normally less than 10 mg/L for inland lakes, with concentrations as high as 20 to 40 mg/L in lakes located closer to coastal areas[14]. However, de-icing and anti-icing materials made from salt (NaCl) and used for winter maintenance can readily dissolve into water and be transported to lakes and

[12] Sivarajah, B. et al. 2024. Historical gold mining increased metal(oid) concentrations in lake sediments from Nova Scotia, Canada.

[13] Doucet, C. et al. 2023. Synoptic snapshots: monitoring lake water quality over 4 decades in an urbanizing region.

[14] CCME (Canadian Council of Ministers of the Environment). 2011. Canadian water quality guidelines for the protection of aquatic life: Chloride.

watercourses by municipal stormwater systems. This has the effect of increasing concentrations of chloride in lakes beyond their naturally occurring levels.

As lake water becomes saltier it can become increasingly difficult for organisms adapted to life in freshwater, such as fish, plants, invertebrates, and plankton to survive, which can lead to an overall reduction of biodiversity. Furthermore, in some cases, elevated chloride concentrations can increase the density of lake water to such an extent that it can disrupt a lake's natural mixing cycle which regulates nutrient and oxygen levels throughout a lake. If a lake's natural mixing cycle is disrupted it can result in pro-longed de-oxygenated conditions and can exacerbate the effects of internal loading, potentially releasing nutrients and other harmful contaminants trapped in the lakebed back into the water column.

The CCME *Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FWAL)* provide guideline values for both 'long-term' and 'short-term' exposure limits designed to protect the freshwater aquatic environment. The CCME FWAL short-term exposure limit is 640 mg/L and is intended to protect most species against lethal exposure during severe but short-term events. The CCME FWAL long-term exposure limit is 120 mg/L and is intended to protect against negative impacts on aquatic ecosystem community structure and function during extended or chronic exposures.

Previous studies have indicated that many lakes within HRM, often those with the most developed watersheds, regularly have dissolved chloride concentrations above the long-term CCME guideline[15, 15].

Fortunately, none of the freshwater lakes sampled in 2022 or 2023 exceeded the CCME short-term exposure limit for dissolved chloride (this excludes Porter's Lake as it is a tidal waterbody). However, the average deepwater chloride concentrations at 10 freshwater lakes did exceed the long-term CCME FWAL guideline (>120mg/L) and a further seven lakes had values approaching the guideline (i.e. between 80 mg/L and 120 mg/L (Table 3).

These results support the findings of previous studies and illustrate that many Halifax-area lakes have chronically elevated concentrations of chloride at levels that may be interfering with their natural mixing regimes and harmful to the freshwater aquatic life that inhabit them. As with the previous studies, the lowest concentrations of chloride tended to occur in lakes with relatively undeveloped watersheds and a low density of roadways (e.g. Scots, Pine, Charlotte, Kidston). The highest values tend to occur in lakes with the most developed watersheds and densest road networks (e.g. Lovetts, Banook, Micmac, Russell).

Table 3. Summary of 17 Freshwater Lakes whose Deepwater Dissolved Chloride values approach or exceed the CCME FWAL long-term exposure guideline (**BOLD** indicates exceedance ≥120 mg/L).

Lake name	Spring 2022 (mg/L)	Summer 2022 (mg/L)	Spring 2023 (mg/L)	Summer 2023 (mg/L)	2022-23 Average
Lovetts Lake	**260**	**200**	**270**	**190**	**230**
Lake Banook	**240**	**240**	**180**	**200**	**215**
Lake Micmac	**240**	**220**	**220**	**120**	**200**
Russell Lake	**220**	**180**	**190**	**170**	**190**
Oathill Lake	**190**	**160**	**180**	**170**	**175**
Bayers Lake	**190**	**170**	**170**	76	**151.5**
Governors Lake	**150**	**150**	**120**	**120**	**135**
Penhorn Lake	**140**	**130**	**130**	**130**	**132.5**
First Lake	**140**	**120**	**120**	**120**	**125**

[15] Bermarija, T. et al. 2023. Assessing and predicting Lake Chloride Concentrations in the Lake-Rich Urbanizing Halifax Region, Canada.

Bissett Lake	**140**	110	**150**	100	**125**
Settle Lake	**150**	**130**	110	57	111.8
Cranberry Lake	**160**	**110**	**120**	44	108.5
Chocolate Lake	57	**160**	**120**	89	106.5
Albro Lake	110	110	100	86	101.5
Maynard Lake	91	94	87	89	90.3
Morris Lake	100	93	90	69	88
Rocky Lake	93	98	74	56	80.3

Bacteria Contamination
The 2022-23 results for *E. coli*, measured in 'colony forming units' per 100 ml (CFU/100ml), were generally quite low and routinely not present at detectable levels, especially during the spring sampling. Overall, only five samples (less than 1%) from a total of 616 collected during the 2022-23 LakeWatchers Program were found to exceed Health Canada's *Guidelines for Canadian Recreational Water Quality* (2023)[16] for primary contact activities (≥235 CFU/100ml), such as swimming.

This is an encouraging result and suggests that most HRM lakes do not routinely suffer from high *E. coli* counts leading to unsafe swimming conditions. However, this outcome is in contrast with the increasing number of municipal beach closures observed in recent years resulting from high *E. coli* counts. Higher *E. coli* counts at municipal beaches are most likely related to warmer water temperatures in the shallower water closer to the shoreline and their proximity to terrestrial sources of possible *E. coli* contamination. Such sources could be the improper disposal of canine fecal waste around beaches, preferential use of a beach area by waterfowl, or a nearby municipal stormwater outfall or other run-off, to name a few. Nevertheless, the extremely low number of detected exceedances for *E. coli* during the 2022-23 LakeWatchers sampling suggests the issue is not widespread and predominantly confined to nearshore beach locations.

Recommendations

The initial results of the 2022-23 LakeWatchers Program have largely supported the findings of previous studies and suggest that many Halifax-area lakes are at increased risk of eutrophication and may also suffer from chloride enrichment. These water quality concerns are primarily related to urban development as nutrients, such as phosphorus, and salts used for de-icing in the winter are dissolved in rain or meltwater and delivered to lakes and streams by the municipal stormwater system.

To address these key water quality concerns, staff recommend three initial actions to help mitigate the flow of nutrients, salts and other contaminants to Halifax-area lakes.

1) Initiate a review of the Municipality's current Salt Management Plan guided by the Syntheses of Best Practices of Road Salt Management [17].

The municipal Winter Operations team has implemented innovations and upgraded equipment in recent years to help reduce overall salt use, such as Direct Liquid Application (also known as brining) and the introduction of pre-wet systems but is faced with a difficult situation with more frequent freeze-thaw events and changing weather patterns due to climate change.

The Municipality last reviewed best management practices related to road salt in 2011[18] out of concern for

[16] Health Canada. 2023. Guidelines for Canadian Recreational Water Quality: Indicators of Fecal Contamination.
[17] Transportation Assoc. of Canada (TAC). 2013. Syntheses of Best Practices Road Salt Management.
[18] Stantec Consulting Ltd. 2011. Road Salt – Review of Best Management Practices.

lake water quality[19]. It was recommended at that time that the Municipality develop and implement a road salt reduction plan, [20]. Though improvements have been made and implemented from the plan, newer data suggests that additional salt vulnerable areas could be identified by staff, along with accompanying tactics to handle increased chloride levels in these areas.

2) Investigate policy options for setbacks for new stormwater discharge locations into natural waterbodies and consider options for naturalization and/or Low Impact Development (LID) features at existing stormwater discharge locations around priority lakes.

The Municipality protects riparian areas recognizing their ability to buffer impacts to surface water features, however, there are many locations throughout the municipality where the stormwater system discharges directly into lakes, streams, and rivers. This direct discharge of stormwater contributes nutrients, salts, and other contaminants to our lakes and streams with no treatment or buffering.

By developing policy options requiring stormwater discharge locations to be setback from natural waterbodies, the flow of nutrients, salts, and other contaminants can be mitigated by infiltration and uptake by vegetation. For lakes located within already densely developed watersheds, staff can identify locations where naturalization could be used to buffer the impacts of stormwater into lakes. Additionally, staff recommend prioritizing the implementation of green infrastructure such as bioswales, naturalized stormwater ponds, or tree trenches, for locations where naturalization is not possible and where increased treatment of stormwater is desired.

3) Ask the Mayor to write a letter to Province of Nova Scotia's Minister of Environment and Climate Change and Halifax Water supporting the development of Provincial stormwater Quality Standards.

As stated above, the direct discharge of stormwater contributes nutrients, salts and other contaminants to our lakes and streams with no treatment or buffering. Currently, there are no standards or guidelines that regulate the quality of stormwater in Nova Scotia. As lakes and other freshwater bodies are the jurisdiction of the province, provincial regulation is needed to mandate water quality objectives for stormwater entering natural water bodies. One of the six 'actions for tomorrow' listed within the provincial Water Resource Management Strategy[21] (2010) is to "Update current guidance for stormwater management and sediment control to improve protection of water quality from land development activities."

It is recommended that the Mayor write a letter to Province of Nova Scotia's Minister of Environment and Climate Change supporting the development of provincial stormwater quality standards as part of updating the current guidance for stormwater management, consistent with the provincial Water Resource Management Strategy[21].

When possible, new lakes may be added to the LakeWatchers' current roster of 73 lakes prioritizing those in areas of the Municipality with data gaps, as identified by a data sufficiency analysis completed by the Atlantic Water Network. The decision to add new lakes will also be informed by the level of community involvement, volunteer commitment and public use.

FINANCIAL IMPLICATIONS

Anticipated costs associated with the programmatic changes listed above are incorporated into the current operating budget for 2024/25. As the number of lakes that are monitored by volunteers continues to grow,

[19] Environment & Sustainability Standing Committee. 2012. Road Salt Impacts on Lakes.
[20] Stantec Consulting Ltd. 2012. Review of Lake Water Quality (with respect to potential road salt impacts).
[21] Province of Nova Scotia. 2010. Water for Life: Nova Scotia's Water Resource Management Strategy.

this decreases the number of lakes that must be sampled by consultants and will free up operating budget to cover the costs of additional laboratory analysis for any new lakes that are added to the program.

RISK CONSIDERATION

The risks associated with implementing the proposed recommendations in this report are low.

Implementing the proposed recommendations will help to improve the water quality delivered to Halifax-area lakes. The primary risks to Halifax-area lakes and other freshwater bodies of continued development without considering adaptive management measures and policies are outlined in the Discussion section of this report.

COMMUNITY ENGAGEMENT

Community engagement and participation are core to the LakeWatchers program as volunteers and community groups are encouraged to actively take part and conduct water quality sampling on Halifax-area lakes.

Community engagement began in 2022 with equipment training workshops held online due to pandemic restrictions and resulted in volunteer involvement at 15 lakes that year. With the ending of pandemic restrictions, four in-person equipment training workshops were held in the summer of 2023 which resulted in the number of lakes with a dedicated, trained team of volunteers doubling to 30.

On November 22, 2023, staff hosted a volunteer appreciation event at the Fairbanks Interpretive Centre in Shubie Park, where initial results of the LakeWatchers program were shared with attendees. All volunteers were also mailed a handwritten thank-you card for their participation in the program.

ENVIRONMENTAL IMPLICATIONS

The results of the proposed recommendations could improve lake water quality and preserve the ecology and current recreational uses of Halifax-area lakes. If no action is taken, the risks to Halifax-area lakes as a result of eutrophication and chloride enrichment will continue and could increase.

ALTERNATIVES

The Environment & Sustainability Standing Committee or Halifax Regional Council could request that the motion be split in accordance with Administrative Order 1 section 90, to consider each recommendation separately for voting purposes to pass or defeat specific recommendations. The recommendations could be passed independently of each other; however, this is not recommended by staff as outlined in the discussion section of this report.

LEGISLATIVE AUTHORITY

Halifax Regional Municipality Charter, SNS 2008 c 39:

7A The purposes of the Municipality are to (a) provide good government; (b) provide services, facilities and other things that, in the opinion of the Council, are necessary or desirable for all or part of the Municipality; and (c) develop and maintain safe and viable communities.

79A (1) Subject to subsections (2) to (4), the Municipality may only spend money for municipal purposes if (a) the expenditure is included in the Municipality's operating budget or capital budget or is otherwise authorized by the Municipality; (b) the expenditure is in respect of an emergency under the *Emergency Management Act*; or (c) the expenditure is legally required to be paid.
Part VIII Planning and Development
Policy E-24 Regional Municipality Planning Strategy:

HRM may consider preparing a water quality monitoring protocol to provide guidance for water quality monitoring plans accepted by HRM under clause (n) of policy E-23 and any other monitoring programs to be undertaken for HRM by landowners.

ATTACHMENTS

Attachment A State of the Lakes Report 2022-23

Report Prepared by: Chris Kennedy, Water Quality Monitoring Program Coordinator, Property, Fleet & Environment 902 476-1853

"ATTACHMENT A"

LakeWatchers State of the Lakes Report

2022-2023 SAMPLING YEARS

HalifACT Acting on Climate Together

LakeWatchers

Table of Contents

Glossary

Anoxia – Anoxia, or anoxic conditions, refers to a condition of very low to no dissolved oxygen within the water column.

Bacterial contamination – Bacterial contamination generally refers to elevated *E. coli* and other fecal coliform bacteria levels whose presence may indicate the water is contaminated by human or animal wastes.

Baseline conditions - Baseline conditions are established through an analysis of the current situation to identify the starting points for a program or project. In other words, it represents the initial condition from which all later changes (trends) can be measured against.

Chemocline – The chemocline is a layer in a body of water that separates a fresh upper layer from a deeper layer containing higher concentrations of dissolved minerals and/or gases.

Chloride enrichment - Chloride enrichment, or salinization, refers to the process of a freshwater body, such as a lake, becoming saltier over time. In temperate regions, de-icing and anti-icing salt materials (NaCl) used for winter maintenance can readily dissolve into water and be transported by urban runoff to lakes and watercourses by municipal storm sewers. This has the effect of increasing concentrations of chloride in lakes beyond their naturally occurring levels.

Chlorophyll-a - Chlorophyll-a is the primary green pigment found in most plants that allows for photosynthesis, the process by which plants convert sunlight into the energy they need to grow and survive.

Enteric pathogen - Enteric pathogens are harmful bacteria and other organisms that can infect the gastrointestinal tract of humans resulting in illness. Common examples include salmonella, shigella and *E. coli*.

Eutrophication - Eutrophication describes the process in which nutrients accumulate in a body of water, resulting in an increased growth of aquatic plants and algae. In temperate locations, such as Nova Scotia, this process is thought to be limited by phosphorus concentrations. Although eutrophication is a natural process, human-caused or 'cultural eutrophication' is far more common and is characterized by a more rapid process caused by a variety of polluting inputs entering lakes from their surrounding watershed.

Fetch – Fetch or fetch length refers to the distance across a body of water over which wave-generating winds can blow.

Internal Loading - Internal loading is a process that occurs in lakes and reservoirs when nutrients or other contaminants are re-introduced into the water from the lake sediment. Along with external loading, when nutrients or contaminants come from terrestrial sources, internal loading can lead to lake eutrophication and result in other contaminants re-entering the lake's water.

Lake basin – Although the term 'lake basin' has many definitions, for the purposes of this report, the term refers to the deepest spot of a lake.

Lake turnover (see Figure 2) - From late spring through early fall, some lakes in temperate climates experience thermal stratification, a phenomenon wherein lakes separate into three distinct thermal layers. The warming of the surface of the water by the sun causes water density variations and initiates thermal stratification. Cooler, denser water settles to the bottom of the lake. A layer of warmer water floats on top. A thin middle layer (or thermocline) separates the top and bottom layers and is characterized by a rapid change in water temperature. This separation is often strong enough to resist mixing of the layers by the wind.

The most extreme thermal stratification occurs within lakes during the warm summer months. During fall turnover, the warmer layer cools, sinks and falls below the thermocline, resulting in mixing. Thermal stratification of a lake depends on the lake's depth, shape and size. Some small, shallow lakes may not experience seasonal thermal stratification because the wind mixes the entire lake. Other lakes have a combination of geographic location and water depth that regularly produces thermal stratification.

Meromixis - Most deep lakes follow a seasonal cycle of stratification and complete mixing (see 'Lake turnover'). Meromixis is a condition in which a lake does not mix completely.

Nutrient – Nutrients are substances that provide nourishment essential for growth and the maintenance of life.

Primary production - Primary production is the process by which organisms make their own food from inorganic sources. Most primary producers are terrestrial and aquatic plants, as well as algae.

Run-off – Run-off is any water, either from rain or outdoor water use, that drains from rooftops, driveways, sidewalks and roads and that doesn't soak into the ground, instead flowing into lakes and streams. Most urban run-off is discharged from municipal stormwater systems.

Thermal Stratification - Thermal stratification describes the process by which lakes form separate and distinct thermal layers during the extreme warmer and colder months of the year because of the difference in water density at different temperatures.

Trophic state/status - Trophic state can be defined as the total weight of living biological material (biomass) in a waterbody at a specific location and time.

Introduction

Lake management is a shared responsibility between all levels of government, the private sector and community stakeholders. Monitoring water quality is an essential component for any type of environmental management. The municipality has a role to play in lake management, with several municipal services that are dependent on water quality, such as beach recreation, or that can impact water quality, such as land management.

It has been more than a decade since the last municipal water quality monitoring program, the Lakes Water Quality Monitoring Program (WQMP), was suspended.

Regional Council approved a new program to begin in 2022 after extensive consultation and a jurisdictional scan of other municipal lake monitoring programs. The result was LakeWatchers, a hybrid program that works with consultants, volunteers and local lake associations to monitor 73 lakes across the municipality. Sampling takes place twice a year in the spring and summer.

In Spring 2022, the LakeWatchers Coordinator worked with consultants to monitor all 73 lakes. The initial goal for the summer sampling was to have five lakes sampled by volunteers or community groups. Over the spring and summer months, the LakeWatchers Coordinator recruited existing organizations as well as individual volunteers to become LakeWatchers Stewards. Several training sessions were held to give residents hands-on experience with equipment and to engage potential volunteers on the full scope of the program. In 2022, 15 lakes were sampled by community groups or volunteers from across the region. In 2023, the number of groups conducting lake monitoring expanded to 30. This is the first State of the Lakes report based on data collected in the 2022 and 2023 seasons.

BACKGROUND

The Halifax Regional Municipality has over one thousand lakes. These lakes are invaluable for many reasons, including water supply, recreation and wildlife habitat. Urban and suburban development imposes various stressors on lakes and their watersheds, making careful environmental planning and management necessary for maintaining an acceptable level of water quality in developed areas, rural areas and regions undergoing development. Proper lake management requires a scientific understanding of the natural processes that control lake properties, the types and concentrations of pollutants being added, their origin and their impacts on important lake processes.

Efforts to understand, protect and manage watershed health at the municipal level dates back to the Halifax Regional Municipality's Water Resources Management Study (2003), which recommended that the municipality establish a lake water quality monitoring program.

The WQMP program started in 2006 with the monitoring of 52 lakes and over the course of the program expanded to include up to 73 waterbodies by 2011 (Stantec, 2012). Unfortunately, the WQMP was suspended after the 2011 sampling season, with some additional monitoring of selected lakes carried out by contractors (AECOM) between 2015 and 2017.

In 2019, Regional Council, the Regional Watersheds Advisory Board (RWAB) and concerned members of the community requested that a lake monitoring program be reinstated. That shift was spurred by a recognition that the municipality is the level of government closest to residents and with responsibilities for planning, parks and recreation, community enjoyment and wellbeing, and environmental sustainability.

On June 29, 2021, Regional Council approved a relaunch of a detailed lake water quality monitoring program based on recommendations made in an AECOM report (2020). This motion was passed unanimously.

PURPOSE

The main goal of the State of the Lakes Report is to provide a 'snapshot' of the health of lakes within the Halifax Regional Municipality, especially in relation to the identified issues of eutrophication, chloride enrichment and bacterial contamination.

The purpose of LakeWatchers as a water quality monitoring program is to establish baseline conditions, identify trends, answer questions, address key concerns and meet legislated requirements.

In the absence of a long-term comprehensive monitoring program, recent monitoring by municipal staff has been conducted on an ad hoc basis to respond to water quality issues as they arise in certain lakes (e.g., the First Lake Pollution Study, the request for a Kearney Lake management plan and the Lake Micmac and Lake Banook Pollution Control Study and related nuisance aquatic weeds removal). As such, the water quality monitoring the municipality engaged in tended to be reactive rather than proactive.

Water quality concerns facing the municipality in recent years have included:

- increasing numbers of beach closures resulting from exceeding the fecal coliform thresholds established by Health Canada's Guidelines for Canadian Recreational Water Quality
- increasing frequency of potentially harmful cyanobacteria (i.e., blue green algae)
- increasing instances of nuisance aquatic plant growth impairing safe access to lakes for swimming and boating
- chloride levels in several lakes that exceed federal guideline values (Doucet et al., 2023; Kanabar 2021; Stantec 2012; Clement et al., 2007)
- increasing instances and impacts of invasive species (e.g., Yellow Floating Heart *[Nymphoides peltate]*, Carolina fanwort *[Cabomba Carolina]*, Chinese Mystery Snail *[Cipangopaludina chinensis]* and Louisiana crayfish *(Procambarus clarkii)*

This report provides an initial assessment and establishes a baseline for the water quality and health of the 73 lakes (inclusive of 77 total lake basins) monitored as part of the LakeWatchers Water Quality Monitoring Program.

In 2022 and 2023, the LakeWatchers Program sampled at 73 lakes across the municipality. Most lakes had samples collected from their deepest basin and primary outlet. However, multiple deep basins were sampled at two of the 73 lakes due to their size or topography. These were Thomas Lake (two sampled basins), which is divided by Highway 102, and Porters Lake (four sampled basins), which is very large and divided into 4 distinct sections. Consequently, LakeWatchers samples have been collected from a total of 73 lakes but include data for 77 basins in total.

VOLUNTEER ACKNOWLEDGEMENT & APPRECIATION

The LakeWatchers program is proud to acknowledge the contributions of the many volunteers who have participated in the collection of the data presented in this report. Thank you to all volunteers, past and present, who have supported the launch of the program and generously provided their time to make it possible to sample all lakes within a short amount of time.

LIMITATIONS

This report focuses on the assessment of water quality at 73 lakes within the Halifax region that have been sampled as part of the LakeWatchers Monitoring Program in 2022 and 2023, the program's first two years of operation (Figure 1). As the LakeWatchers dataset only spans two years, identifying overall trends in water quality is not yet appropriate. Instead, to strictly assess the water quality data collected at each lake, laboratory results were compared to established Canadian Council of Ministers of the Environment (CCME), Health Canada and the Nova Scotia Department of Environment and Climate Change (NSECC) water quality guidelines.

Key Water Quality Concerns

Anthropogenic, or human-caused, activities on land can impact the water quality of lakes throughout the municipality. LakeWatchers was created to address water quality impacts that are likely to result from land use practices that directly affect the ability of lakes to provide valued services (e.g., recreation at public beaches). The municipality can control or manage these impacts through implementation of municipal policies, land-use by-laws, as well as informed community planning and programming. The following lake water quality concerns were selected by reviewing previous research and background studies, through community consultation, by referencing other water quality monitoring programs and via consultation with local and regional water resource managers (AECOM 2020).

- Eutrophication
- Chloride enrichment (or salinization)
- Bacteria contamination

The sections that follow provide a brief overview and discussion of the key water quality issues of most direct concern for municipal lakes. Discussion will address how these water quality issues may affect recreational uses and the ecological health of lakes within the municipality and the potential implications of climate change on municipal lakes. For more information on key water quality concerns and others not listed below, please see DataStream's Water Quality Guide or Atlantic Water Network's Knowledge Hub.

EUTROPHICATION

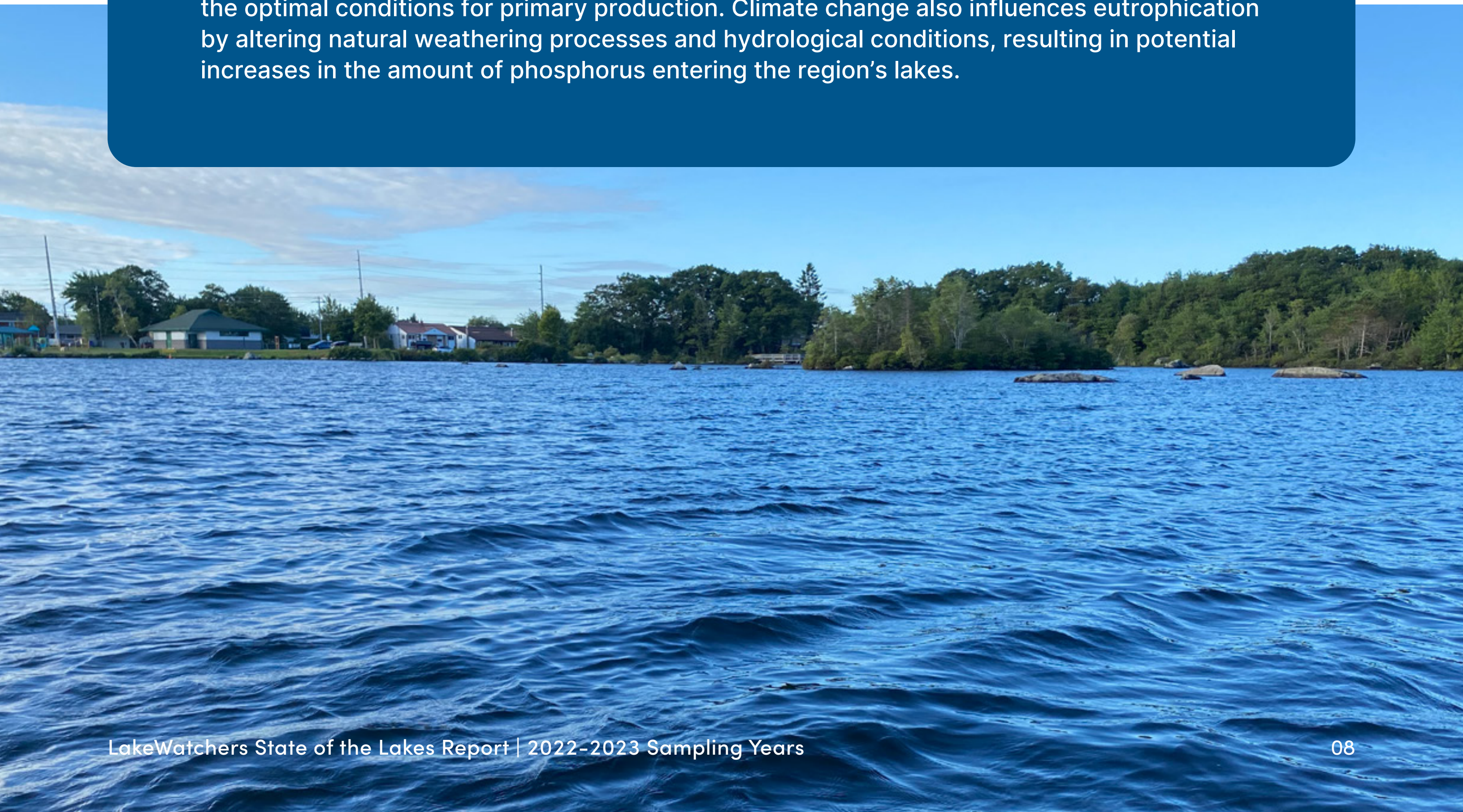
Eutrophication refers to the process of increased primary production, or in other words, increased growth and abundance of aquatic plants and algae. This is generally caused by the addition of nutrients that are needed for the growth of those aquatic plants and algae. In temperate, freshwater lakes, such as those found within the region, phosphorus is generally considered to be the limiting nutrient that most frequently controls primary production (Janus and Vollenweider 1981; Vollenweider and Kerekes 1982).

There are many human activities on land that can contribute to increased phosphorus in lakes. These include point sources such as wastewater treatment plants and combined sewer overflows, but also some less obvious sources such as failing septic systems or urban runoff carried to lakes in stormwater systems.

Eutrophication can result in substantial changes to the plants, algae and other organisms that inhabit a lake and can directly impair water quality for human uses. Recreational impairments of concern for municipal lakes include:

- boating and swimming interference caused by excessive plant and algae growth in the nearshore and shallower areas
- health hazards to swimmers and other beach users caused by potentially toxin-producing cyanobacteria
- poor aesthetics due to reduced water clarity and odour issues
- reduced angling opportunities resulting from long-term decreases in deep-water oxygen concentrations and in extreme anoxic conditions, possible fish kills

Climate change can contribute to eutrophication in several ways: it can cause physical changes in lakes like warmer surface waters and lengthen the growing season. This creates the optimal conditions for primary production. Climate change also influences eutrophication by altering natural weathering processes and hydrological conditions, resulting in potential increases in the amount of phosphorus entering the region's lakes.



CHLORIDE ENRICHMENT

Chloride enrichment, or salinization, refers to the process of increasing concentrations of chloride and other ions in lakes and other waterbodies beyond their naturally occurring levels. This is generally caused by salty run-off being directed or otherwise reaching and contaminating freshwater bodies, such as lakes, rivers and streams.

Elevated concentrations of chloride can alter the community composition of fish, invertebrates and plankton, and reduce the overall biodiversity of aquatic species (CCME 2011). In extreme cases, high chloride concentrations can increase the density of water to such an extent that it prevents lakes from mixing, a condition known as meromixis. This lack of mixing can result in extremely low oxygen levels, or a condition called anoxia, at lower depths of the lake and can impact habitat quality and availability for aquatic organisms that require oxygen to breathe and carry out their life functions. Additionally, low oxygen levels at the lakebed can result in the release of nutrients and other pollutants bound to sediments, a process known as internal loading, and can contribute to eutrophication and the release of potentially harmful contaminants.

Increasing concentrations of dissolved chloride beyond what would occur naturally is also harmful to organisms adapted to life in freshwater; it becomes increasingly difficult for freshwater fish, plants, insects and many other organisms to survive, leading to biodiversity loss. The CCME *Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FWAL)* provide guideline values for both 'long-term' and 'short-term' exposure limits designed to protect the freshwater aquatic environment.

The CCME FWAL short-term exposure limit is 640 mg/L and is intended to protect most species against lethal exposure during severe but short-lived events. The CCME FWAL long-term exposure limit is 120 mg/L and is intended to protect against negative impacts on aquatic ecosystem community structure and function during extended exposures (CCME 2011).

Past studies have indicated that many lakes within the municipality are regularly found to have dissolved chloride concentrations above the long-term CCME guideline of 120 mg/L (Doucet et al., 2023; Bermarija et al. 2023; Clement and Gordon 2019; Stantec 2012; and Clement et al. 2007).

Climate change is likely to increase the intensity and frequency of extreme winter events, requiring an increased use of de-icing materials for safe winter maintenance. Warmer winters with a greater number of freeze-thaw events may also require more de-icing materials to treat icy conditions.

BACTERIAL CONTAMINATION

Bacterial contamination of freshwater bodies refers to the detectable presence of microorganisms such as viruses, bacteria and parasites that can cause intestinal illness (i.e. enteric pathogens) within that waterbody. The presence of enteric pathogens almost always indicates that a source of fecal material is reaching the waterbody.

There has been increasing concern over the total number and length of beach closures in recent years within the municipality because of detected levels of *E. coli* and enterococci exceeding the Health Canada's *Guidelines for Canadian Recreational Water Quality (2023)*.

Lakes may become impacted by fecal material containing enteric pathogens from numerous sources, including:

- discharged sewage
- treated and untreated wastewater effluent
- stormwater runoff from urban, suburban and agricultural areas
- industrial processes
- wild or domesticated animal droppings
- fecal shedding by swimmers

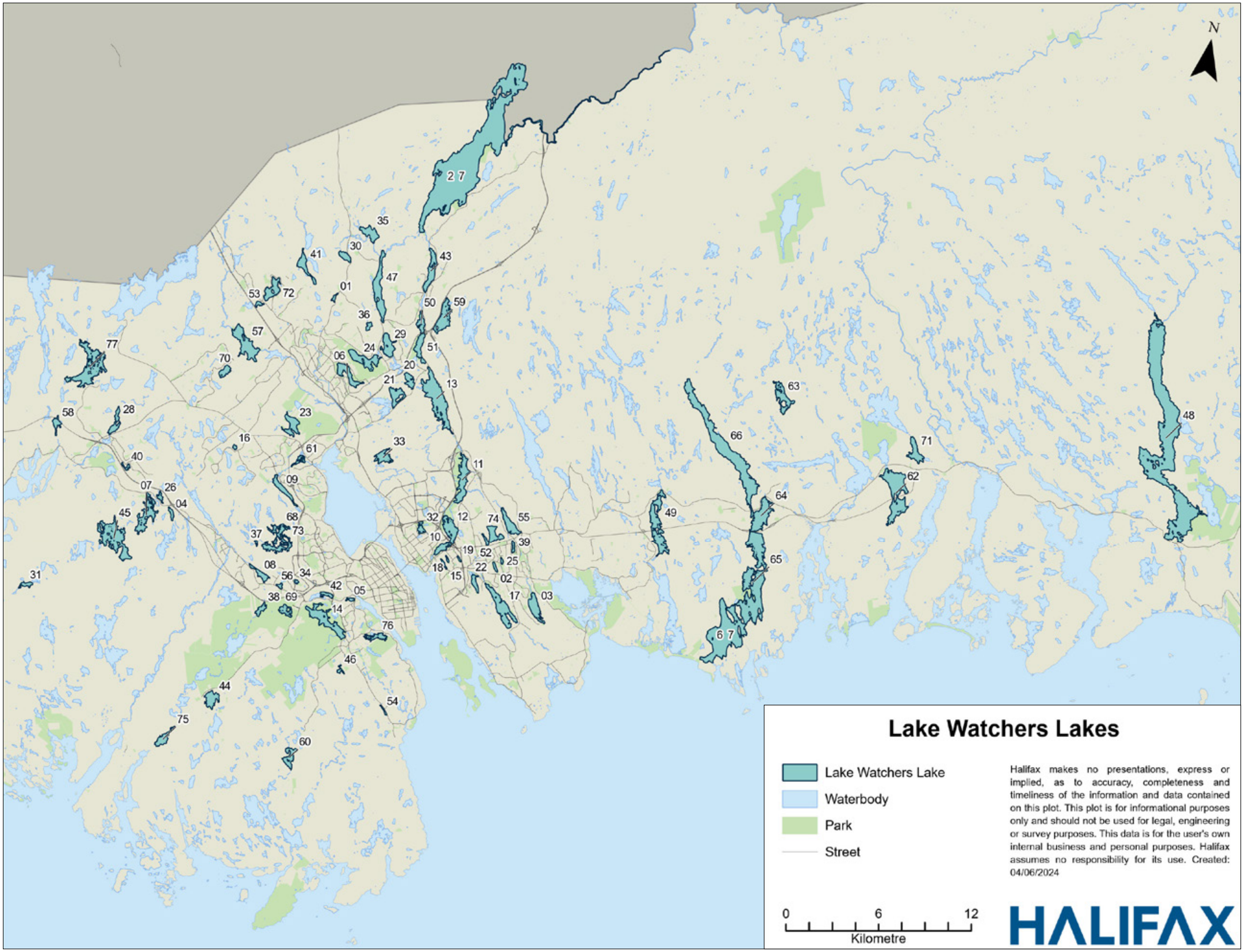
The effects of climate change, such as a lengthening of the growing season and warming surface water temperatures, are likely to increase the risk of elevated bacterial contamination becoming more common and widespread in municipal lakes.

Water Quality Sampling Methodology

LAKE SELECTION

73 lakes in the region were identified for consideration in the LakeWatchers Water Quality Monitoring program based on vulnerability to human activities at a sub-watershed scale and informed by the following (Figure 1):

- lake-specific land uses and development designations
- beneficial uses (e.g., public beaches, recreation)
- past water quality monitoring results and documented concerns related to eutrophication, chloride enrichment and bacteria contamination



Number	Lake Name
01	Barrett Lake
02	Bell Lake
03	Bissett Lake
04	Black Point Lake
05	Chocolate Lake
06	First Lake
07	Five Island Lake
08	Governors Lake
09	Kearney Lake
10	Lake Banook
11	Lake Charles
12	Lake MicMac
13	Lake William
14	Long Lake
15	Maynard Lake
16	McQuade Lake
17	Morris Lake
18	Oat Hill Lake
19	Penhorn Lake
20	Powder Mill Lake
21	Rocky Lake (North East Basin)
22	Russell Lake
23	Sandy Lake (Bedford)
24	Second Lake
25	Settle Lake
26	Sheldrake Lake
27	Shubenacadie Grand Lake
28	Stillwater Lake
29	Third Lake
30	Tucker Lake
31	Albert Bridge Lake
32	Albro Lake
33	Anderson Lake
34	Bayers Lake
35	Beaver Bank Lake
36	Beaver Pond
37	Big Cranberry Lake
38	Blueberry Lake
39	Cranberry Lake
40	Elbow Lake
41	Fenerty Lake
42	First Chain Lake
43	Fletchers Lake
44	Hatchet Lake
45	Hubley Big Lake
46	Kidston Lake
47	Kinsac Lake
48	Lake Charlotte
49	Lake Echo
50	Lake Thomas (North Basin)
51	Lake Thomas (South Basin)
52	Lemont Lake
53	Little Springfield Lake
54	Long Pond
55	Loon Lake
56	Lovett Lake
57	McCabe Lake
58	Mill Lake
59	Miller Lake
60	Moody Lake
61	Paper Mill Lake
62	Petpeswick Lake
63	Pine Lake
64	Porters Lake (Middle North)
65	Porters Lake (Middle South)
66	Porters Lake (North)
67	Porters Lake (South)
68	Quarry Lake (Birch Cove)
69	Ragged Lake
70	Sandy Lake (Glen Arbour)
71	Scots Lake
72	Springfield Lake
73	Susies Lake (Birch Cove)
74	Topsail Lake
75	Whites Lake
76	Williams Lake (Spryfield)
77	Wrights Lake

Figure 1. LakeWatchers Lakes

The assessment process resulted in the selection of 73 lakes (including 77 basins). These were broken down into three distinct groups, as identified by AECOM (2020). Class A Lakes have a high vulnerability to water quality impacts from human stressors related to land-use. Class B Lakes are considered moderately vulnerable to human stressors. The third grouping, “reference lakes,” are relatively unaffected by local land uses or other human stressors. They are also unlikely to be impacted in the future due to their isolation, the protection of their watershed, or other factors. A complete list of lakes, the communities they are located in, the geographic coordinates for sampling locations and their approximate depths are provided in Appendix A. The dates each lake was sampled and who completed the sampling (volunteers, the consultants or a combined team) are provided in Appendix B.

MONITORING PROGRAM

The LakeWatchers Monitoring Program consists of bi-annual sampling conducted during the Spring (April and May) and Summer (August) to collect water quality data from two different ‘seasons’ of a lake, in the spring following lake turnover and again during summer stratification (Figure 2). This includes collecting lake water samples for laboratory analysis and measuring physical parameters such as temperature, pH, dissolved oxygen and specific conductance (or conductivity) directly in the field using a handheld water quality meter.

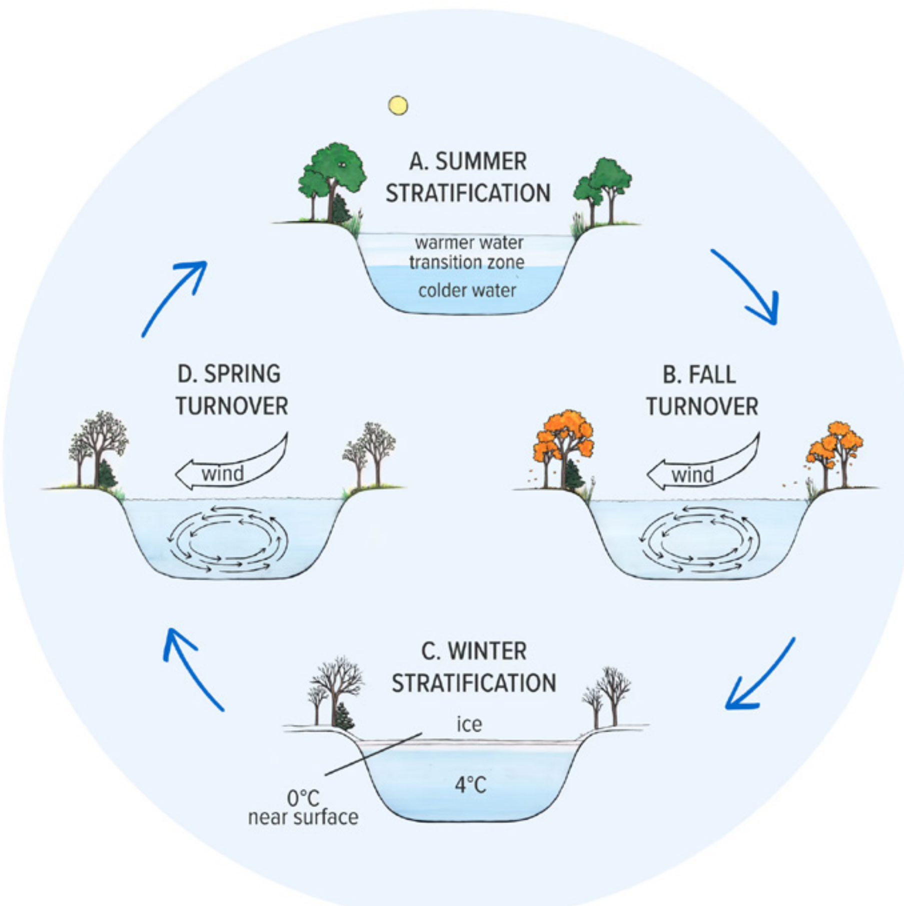


Figure 2. Seasonal Lake Mixing for a Typical Lake - Illustration provided courtesy of Atlantic DataStream

Water quality samples collected for laboratory analysis were analyzed for parameters that address the key water quality concerns, eutrophication, chloride enrichment and bacteria contamination. Total Phosphorus (TP) and chlorophyll-a (Chl-a) were assessed to investigate eutrophication risk. Dissolved chloride concentrations were assessed to investigate chloride enrichment risk. *E. coli* levels were assessed to investigate issues regarding bacterial contamination. An analysis for metals and other elements was also conducted during the inaugural LakeWatchers sampling event in the spring of 2022.

During monitoring, water quality samples are collected, and other measurements taken at both the primary outlet and deep-water basin locations for each lake. At the deep-water basin location, water quality samples are taken at just below the lake's surface and from just above the lake bottom. These are referred to in this report as the 'shallow sample' and the 'deep sample', respectively. An example is provided below (Figure 3), and the program's sampling components are outlined in Table 1.

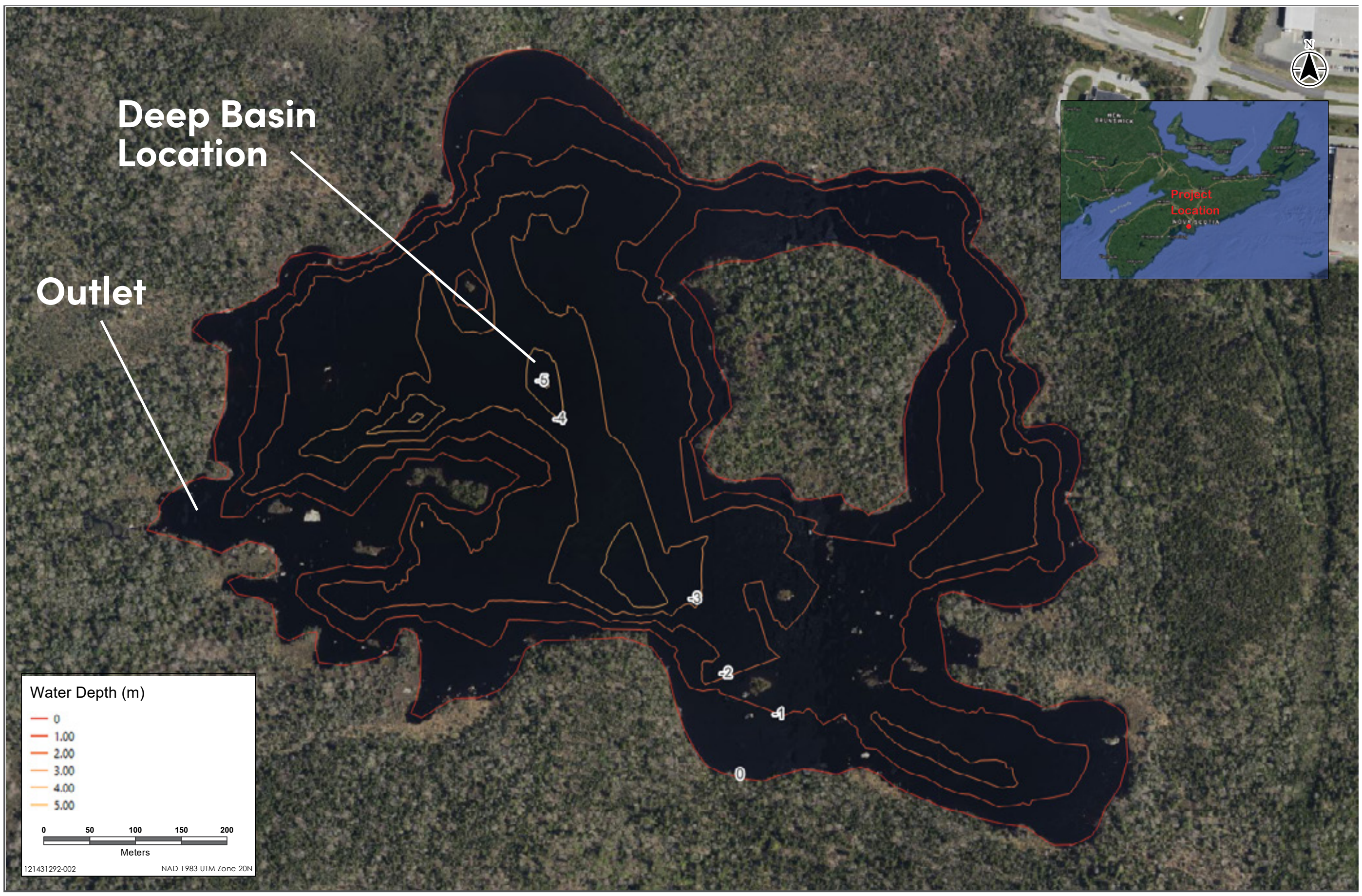


Figure 3. Example of lake sampling locations in Ragged Lake.

Table 1. Summary of water quality analysis conducted at each sampling location for each lake in 2022-23.

	Total Phosphorus	Dissolved Chloride	*E. coli*	Chlorophyll-a	Metals suite*
Deep sample	✓	✓	✗	✓	✓
Shallow sample	✓	✗	✓	✓	✗
Outlet sample	✓	✓	✓	✓	✗

*Analysis for metals was completed in the Spring of 2022 only and not in subsequent sampling events.

Approach to Analysis

As the LakeWatchers Water Quality Monitoring Program is intended to provide baseline conditions and to assess water quality in terms of both recreational use and environmental sustainability, the following federal and provincial guidelines were used for the assessment.

Canadian Council of Ministers of the Environment (CCME) Guidelines for the Protection of Freshwater Aquatic Life (FWAL)

- The CCME FWAL guidelines were developed to provide a science-based benchmark for a nationally consistent level of protection for aquatic life in Canada.

CCME Phosphorus Framework

- The CCME Phosphorus (P) Framework outlines the natural phosphorus ranges recommended by the CCME for the designation of trophic status within Canadian lakes and rivers.

Health Canada (HC) Guidelines for Canadian Recreational Water Quality, Third Edition

- The Health Canada guidelines consider the human health risks associated with "primary contact activities" like swimming, bathing/wading, windsurfing and waterskiing, and secondary contact activities like canoeing or fishing, in natural waterbodies.

Nova Scotia Tier 1 Environment and Climate Change (NSECC) Environmental Quality Standards for Surface Water

- The provincial Numerical Environmental Quality Standards guidelines (EQS) are based on the assessment and management of risks posed to humans, ecological receptors, and environmental processes.

The above-listed guidelines were used to assess the results of the past two years of lake water quality sampling where applicable (i.e. some parameters do not have guideline values). For each measured parameter, the question is: **over the course of the LakeWatchers monitoring program (2022-23), did water quality in a lake meet or exceed the guideline value for the measured parameter?**

For example, the CCME protection of FWAL guidelines for arsenic is 5 µg/L. If arsenic levels in a lake are detected at a concentration of less than 5 µg/L, the guideline is considered to have been met, and therefore freshwater aquatic life can be said to be protected from the negative effects of higher concentrations of arsenic. On the contrary, if arsenic levels are detected at or above a concentration of 5 µg/L, the guideline is considered to have been exceeded and freshwater aquatic life are at risk of experiencing the negative effects of arsenic exposure.

Field Results

The following sections introduce and describe the results of the physical parameters measured in the field from each of the lakes monitored through the LakeWatchers program.

SECCHI DEPTH

Secchi depth is measured as the depth at which a Secchi disc is no longer visible when lowered into water from the shaded side of a boat, and the point at which it reappears after raising it. Secchi depth measurements can be used to estimate the amount of algae in the water and are based on the idea that algal particles disrupt the penetration of light into the water column (Figure 4). Secchi depth has been measured in lakes and oceans for over a hundred years. While there are other more expensive and technologically advanced ways to measure water clarity, Secchi depth remains a standard and inexpensive method that is still in use today.

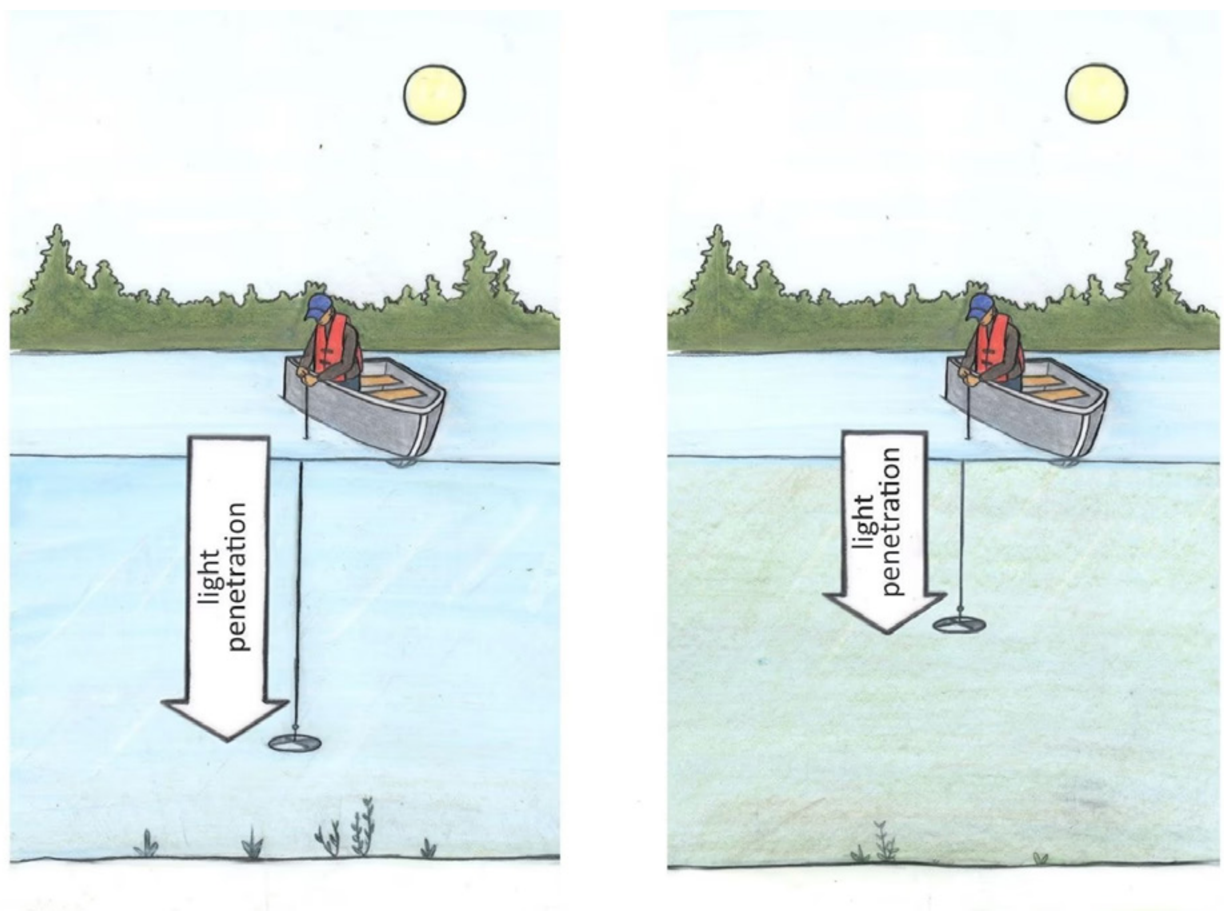


Figure 4. Example of different Secchi depth measurements due to differences in light penetration. Illustration provided courtesy of Atlantic DataStream

Health Canada's *Guidelines for Canadian Recreational Water Quality* includes guidelines for water clarity based on observed Secchi Depth measurements. According to Health Canada, a recreational swimming area should have water that is sufficiently clear such that a Secchi disc is visible at a minimum depth of 1.2 m. Clear water is important so that swimmers can estimate depth and see subsurface hazards, and it allows for lifesaving in emergency situations by allowing first responders to detect submerged swimmers.

Over the past two years of water quality sampling, there have been 30 occasions where the minimum Secchi Depth of 1.2 m was not met (Table 2). Two thirds of these occasions were during the summer 2023 sampling period, primarily in August following historic rainfall on July 21 and July 22.

Table 2. Summary of Secchi Depth Results for the 2022-23 LakeWatchers Program

Sampling Period	Range of Secchi Depths	Lowest	Highest	Other lakes with a measured Secchi Depth < 1.2 m
Spring 2022	1.0 to 9.1 m	Blueberry Lake (1.0m) and Elbow Lake (1.0m)	First Chain Lake (9.1m)	Long Pond (1.1m)
Summer 2022	0.8 to 6.9 m	Long Pond (0.8m)	Shubenacadie Grand Lake (6.9m)	Blueberry Lake (0.9m), Big Cranberry Lake (0.9m), Fenerty Lake (0.9m), Moody Lake (1.1m), and Black Point Lake (1.1m)
Spring 2023	0.9 to 10.8 m	Ragged Lake (0.9m)	First Chain Lake (10.8m)	none
Summer 2023	0.5 to 12.2 m	Blueberry Lake (0.5m) and Albert Bridge Lake (0.5m)	First Chain Lake (12.2m)	Ragged Lake (0.6m), Moody Lake (0.6m), Black Point Lake (0.7m), Whites Lake (0.7m), Sheldrake Lake (0.7m), Five Islands Lake (0.8m), Big Cranberry Lake (0.8m), Long Pond (0.8m), Hubley Big Lake (0.9m), Lake Echo (0.9m), Porters Lake (North) (0.9m), Fenerty Lake (1.0m), Beaver Pond (1.0m), Porters Lake (Mid North) (1.0m), Porters Lake (Mid South) (1.0m), McCabe Lake (1.0m), Long Lake (1.0m), and Elbow Lake (1.1m)

TEMPERATURE

Surface water temperatures during the spring sampling period ranged from 8.2°C to 18.9°C in 2022, and 7.4°C to 13.9°C in 2023. Higher springtime surface temperatures were generally found in smaller, shallower lakes (e.g. Black Point, Blueberry, Bayers) that lose their ice cover earlier and have more time to warm up. In contrast, larger lakes tend to hold their ice cover longer and simply have more water volume to resist spring warming. Surface water temperatures during the summer sampling ranged from 21.4°C to 26.4°C in 2022, and 20.0°C to 24.4°C in 2023.

2023 was the hottest year on record since recording began in 1850. This increase in global temperatures produced record-breaking global sea surface temperatures across much of the world and chronic drought in many places. When it comes to the impact of climate change and global heating on freshwater, there has been a documented increase in the risk of eutrophication and cyanobacteria blooms.

Earlier ice-out in the spring allows for an elongated growing season for plants and algae, including potentially harmful cyanobacteria. Warmer overall surface water temperatures can strengthen and prolong a lake's summer stratification period, which could disrupt ecological processes and contribute to eutrophication risk.

pH

Potential of hydrogen or pH is a measure of the hydrogen ion concentration in water. A pH reading of 7 represents neutral conditions, while lower values indicate acidic conditions and higher ones indicate alkaline conditions. Due to the bedrock geology of Halifax, lakes in this region are naturally acidic and it is likely that most lakes would have had pH values below 6.0 prior to European settlement (Clement et al. 2007).

A lake's pH is an important parameter to monitor for both recreational and biological reasons. Health Canada's *Guidelines for Canadian Recreational Water Quality* includes guidelines for pH values as both alkaline and acidic waters may cause eye irritation for primary contact users. To protect against the risk of eye irritation, the pH of recreational water is recommended to be in the range of 5.0 to 9.0. There were no lakes during the 2022-23 sampling that measured a surface pH greater than 9.0 and only a few lakes that measured a surface pH below 5.0 (Table 3).

Table 3. Summary of pH values detected below Health Canada's guideline to protect against the risk of eye irritation (≤5.0) for the 2022-23 LakeWatchers Program

Spring 2022	Summer 2022	Spring 2023	Summer 2023
First Chain Lake (4.69) Ragged Lake (4.76) Big Cranberry Lake (4.98)	First Chain Lake (4.42) Ragged Lake (4.90)	Big Cranberry Lake (4.41) First Chain Lake (4.76) Ragged Lake (4.87) Susies Lake (4.88)	Big Cranberry Lake (4.55) First Chain Lake (4.68) Albert Bridge Lake (4.96)

Similarly, the CCME *Water Quality Guidelines for the Protection of Freshwater Aquatic Life* provides a long-term value of 6.5 to 9.0 to protect freshwater organisms (Figure 5). Average surface pH values ranged from 4.68 in First Chain Lake (the most acidic) to 8.1 in First Lake (the most alkaline). The lowest values are generally found in lakes with relatively undisturbed or protected watersheds (e.g. Ragged Lake, Big Cranberry Lake, First Chain Lake). The highest values are generally found in lakes with densely developed watersheds (e.g. First Lake, Lake Banook, Albro Lake). Overall, a total of 25 lakes had average surface pH values below the CCME FWAL Guideline of 6.5, as illustrated in Figure 6 below.

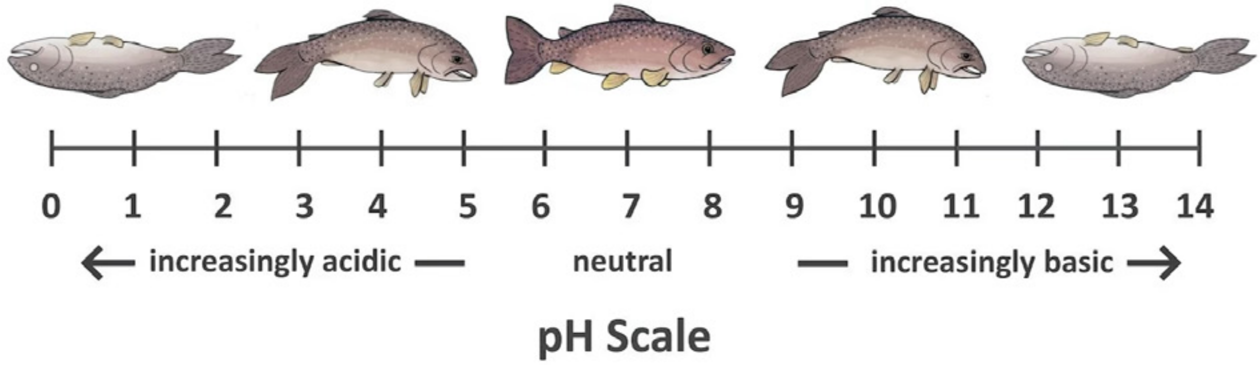


Figure 5. pH scale illustrating the preferred range for many species of freshwater fish and other aquatic organisms. Illustration provided courtesy of Atlantic DataStream

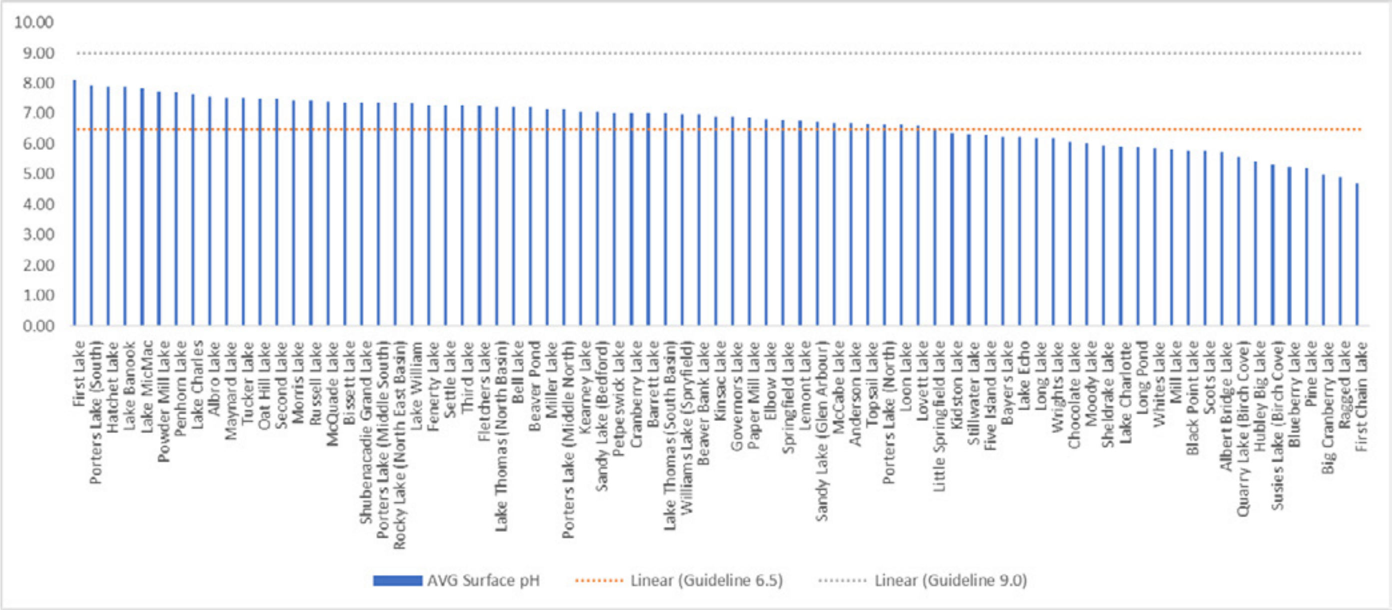


Figure 6. Average surface pH values for all sampling locations versus CCME FWAL Guidelines

SPECIFIC CONDUCTANCE (SPC)

Specific conductance (SPC) is a measure of the total dissolved ions present in a water sample. It is a measure of the material that is dissolved into water allowing for an electrical current to be passed through it. Specific conductance differs from conductivity in that it is a standardized measure of the electrical conductance of 1 cubic centimeter of a solution at 25 °C. By measuring for specific conductance, rather than conductivity, we can more readily compare values taken from each lake because it accounts for varying temperatures.

A wide range of specific conductance readings were observed in the surface waters of the municipality's lakes. Excluding the four basins in Porter's Lake due to its tidal influence, the highest reading was 1.0 micro siemens/centimeter (µS/cm) at Lovett Lake in spring 2023, while the lowest readings were 0.0066 µS/cm at Oathill Lake and 0.0067 at Whites Lake in spring 2022. As was found in previous studies (Kanabar 2021, Clement et al., 2007, Doucet et al., 2023), the lakes with consistently low SPC have relatively undisturbed watersheds (e.g. Big Cranberry Lake, Pine Lake, Scots Lake, Wrights Lake). These more natural levels are the result of wind-blown sea salt and the weathering of bedrock and soil, which dissolves minerals into the water. Excluding Porters Lake, the highest values were found in lakes with highly developed watersheds (e.g. Lake Banook, Lake Micmac, Bayers Lake, Lovetts Lake) where the use of road salt for winter road safety is prevalent and can enter lakes through stormwater runoff, causing SPC to rise.

DISSOLVED OXYGEN

Dissolved oxygen is a measure of the amount of oxygen dissolved in water. Dissolved oxygen levels in lakes depend on various factors, including fetch length (for wind action), aquatic plant density, water temperature, ice cover length and lake depth, among many others. Fish and other aquatic animals depend on this oxygen to breathe, so if dissolved oxygen levels become too low, fish and other aquatic organisms may not be able to survive.

The levels of dissolved oxygen that are considered too low can vary, but the CCME *Water Quality Guidelines for the Protection of Freshwater Aquatic Life* provides minimum levels of 6.0 mg/L to sustain most species of fish during their early life stages and 5.5 mg/l to sustain most species of fish at later life stages (Figure 7).

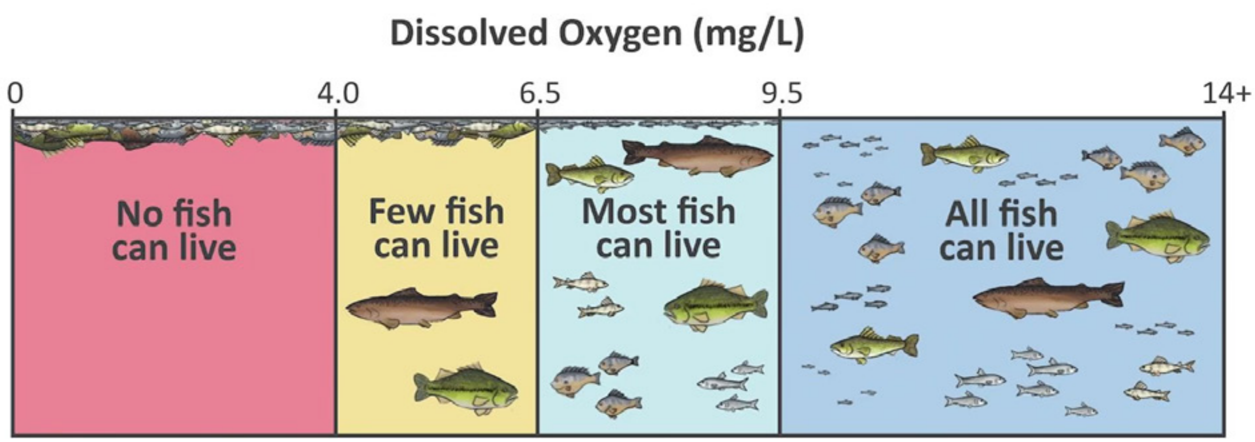


Figure 7. Dissolved oxygen levels (mg/L) and its effect on fish diversity and survival - Illustration provided courtesy of Atlantic DataStream

The surface waters of all 73 lakes sampled had dissolved oxygen levels above the more stringent CCME FWAL Guideline of 6.0 mg/L. During both the spring sampling events in 2022 and 2023, DO levels in surface waters ranged from a low of 9.41 mg/L (Kidston Lake) to a high of 14.58 mg/L (Settle Lake). During both the summer sampling events in 2022 and 2023, dissolved oxygen levels ranged from a low of 6.21 mg/L (Long Pond) to a high of 9.8 mg/L (Settle Lake).

However, in temperate lakes like those found in the Halifax region, dissolved oxygen levels throughout a lake are often subject to a process known as 'thermal stratification' (Figure 8). Lakes that undergo thermal stratification tend to develop three distinct thermal layers by mid-to-late summer that prevent or slow mixing between them:

- **the Epilimnion**, the top layer of water, is warmed by the sun and oxygenated by wave action
- **the Thermocline (or Metalimnion)** is the middle layer which slows or prevents mixing
- **the Hypolimnion**, the colder bottom layer, extends to the floor of the lake

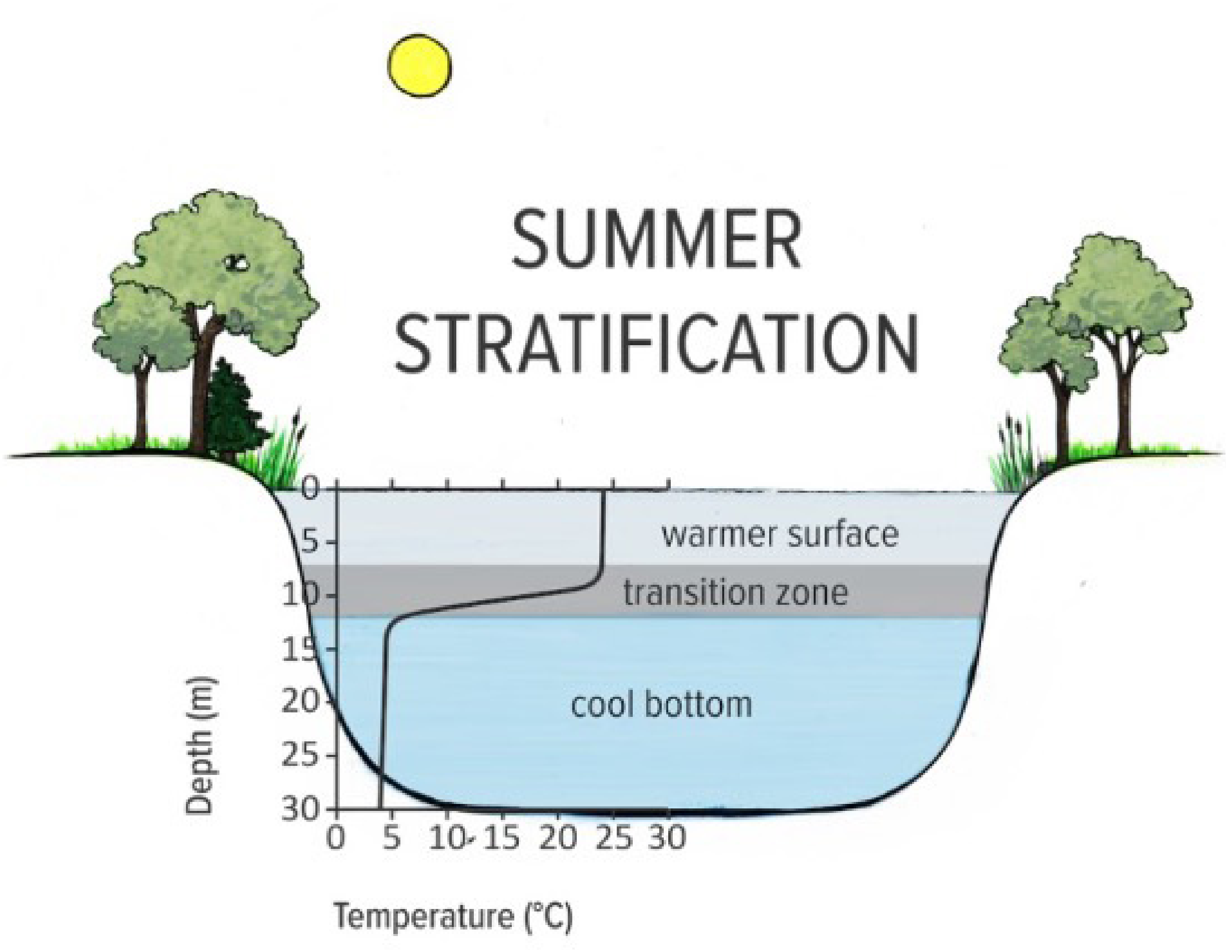


Figure 8. Typical Thermal Stratification of a Temperate Lake in Mid-summer. Illustration provided courtesy of Atlantic DataStream

Once stratified into these layers, dissolved oxygen in the bottom layer (hypolimnion) will often gradually decrease as it is breathed by fish or used by other organisms that inhabit this layer. As mixing with the oxygenated upper layer (epilimnion) is slowed or prevented by the middle layer (thermocline), the bottom layer can become de-oxygenated over time. This process is known as 'hypolimnetic dissolved oxygen depletion.' Over time, depending on the strength and duration of the stratification, dissolved oxygen can become depleted at lower depths of a lake in a condition known as 'anoxia' (≤ 1.0 mg/L).

By the time of summer sampling in August, most of the lake basins sampled showed strong thermal stratification. For instance, in 2022, 62 of the 77 lake basins sampled exhibited moderate to strong thermal stratification. Similarly in 2023, 64 of the 77 lake basins sampled exhibited moderate to strong thermal stratification. This finding suggests that most lakes in the Halifax region become thermally stratified in most years. Weak or absent stratification tended to occur in shallower lakes with greater exposure to wind, while stronger thermal stratification was generally found in deeper lakes and those that have less wind exposure, such as those with smaller surface areas relative to their maximum depth and lakes with irregular shapes.

This is an important finding, as many of the lakes that exhibited strong to moderate thermal stratification also exhibited hypolimnetic dissolved oxygen depletion leading to anoxia. In fact, anoxic conditions were observed at 58 of 77 lake basins during either the summer sampling of 2022 or 2023, while 36 lake basins exhibited anoxic conditions during both summer sampling periods. This is concerning because anoxic conditions near the lakebed can lead to the release of nutrients, such as phosphorus, and other harmful contaminants trapped in the lakebed in a process known as internal loading. Anoxic layers ranged from as small as 0.5 m to as large as 16 m at First Lake.

Laboratory Results

The following sections introduce and describe the results of the laboratory analysis of the water samples collected from each of the lakes for the LakeWatchers program.

TOTAL PHOSPHORUS (TP)

In Canada, the Canadian Council of Ministers of Environment (CCME) developed national guidelines for eutrophication management which rely on Total Phosphorus as the key indicator of trophic state in freshwater systems (CCME 2004). In this guideline, the concentration of TP is used to estimate the trophic state of a given lake. These trophic states and the anticipated conditions that accompany them in temperate lakes are summarized in Table 4.

Table 4. A list of possible changes that might be expected in a temperate lake as the amount of algae changes along the trophic state gradient.

Trophic State	Expected TP range (CCME 2004)	Expected Chlorophyll-a range*	Anticipated lake conditions*
Ultra-oligotrophic	<4 µg/L	< 0.95 µg/L	Clear water, usually oxygenated throughout, even deep stratified layers, such that salmonids (e.g. trout) can survive.
Oligotrophic	4 – 10 µg/L	0.95 to 2.6 µg/L	
Mesotrophic	10 – 20 µg/L	2.6 to 7.3 µg/L	Moderately clear water, increasing probability of hypolimnetic anoxia during summer resulting in loss of salmonids. Invasive smallmouth bass and chain pickerel may dominate.
Meso-eutrophic	20 – 35 µg/L	7.3 to 20 µg/L	
Eutrophic	35 – 100 µg/L	20 to 56 µg/L	Anoxic hypolimnia, nuisance macrophyte and harmful algal blooms possible. Low water clarity may discourage swimming and boating. Bass will dominate.
Hyper-eutrophic	>100 µg/L	> 56 µg/L	Large anoxic hypolimnia, nuisance macrophyte and harmful algal blooms are likely (detected or not). Bass will dominate and summer fish kills are possible.

*Adapted from A Coordinator's Guide to Volunteer Lake Monitoring Methods (North American Lake Management Society – Carlson and Simpson 1996)

To classify the trophic state of a lake, the average of all surface total Phosphorous (TP) results collected during the 2022-23 sampling seasons was calculated and related to the CCME Phosphorous Framework, the same as was done for the previous WQMP (2006-11). These trophic state classifications were then compared to those calculated from the WQMP. The current LakeWatchers Program and the previous WQMP conducted monitoring at 73 waterbodies, however, sufficient data for comparison only exists for 48 lakes that were included in both programs.

Using the CCME Phosphorous Framework, of the 48 lakes included in both programs, the majority were classified as mesotrophic or meso-eutrophic based on data collected during the 2006-2011 period. In contrast, most lakes were classified as either oligotrophic or ultra-oligotrophic, with only six being classified as mesotrophic, based on the data collected during 2022-23. The disagreement between these two datasets was unexpected and the cause is currently unclear. One reason may be that the LakeWatchers dataset is still quite small, spanning only two years, instead of the five year span of the previous WQMP.

Despite the unexpectedly low average total phosphorus results in 2022-23, basins that exhibited anoxic conditions during the summer sampling generally showed higher total phosphorus levels at depth when compared to the surface.

Overall, 67 of 77 lake basins sampled as part of LakeWatchers were classified into the ultra-oligotrophic and oligotrophic categories of the CCME Phosphorus Framework based on surface TP results collected in 2022-23. Only 10 were classified as mesotrophic or meso-eutrophic (Table 5).

Table 5. Summary of the Estimated Trophic Status for the 77 Lake Basins sampled as part of the 2022-23 LakeWatchers Program

Trophic State Categories	Trophic Status based on *CCME Phosphorous Framework*	Trophic Status based on NALMS chlorophyll-a Framework*
	Number of Lake Basins	
Ultra-oligotrophic	35	2
Oligotrophic	32	22
Mesotrophic	9	45
Meso-eutrophic	1	6
Eutrophic	0	2
Hyper-eutrophic	0	0
TOTAL	**77**	**77**

*Carlson and Simpson 1992

CHLOROPHYLL-A

Along with total phosphorus, the concentration of chlorophyll-a in surface water can also be used to estimate the overall productivity or trophic status of a lake system (Carlson 1977, Carlson and Simpson 1992). The concentration of chlorophyll-a in the surface water of a lake during the summer months represents a direct measure of the amount of algae growing within a lake's waters and is seen by some as the most accurate predictor of trophic status (Carlson 1977, Carlson and Simpson 1992). However, chlorophyll-a can be less reliable as it is based on fewer samples (summer only). By contrast, TP represents a measure of the amount of nutrients available for algae and plant growth and can therefore be seen as a less direct indicator of lake productivity.

Algae are important because they form the base of the food chain, but too much algae can upset natural processes. Under certain conditions, algae can grow quickly and create a bloom that can cover lakes or make the water look greener than normal. When algae die, naturally occurring lake bacteria decompose the algal cells, which consumes oxygen from the water. This can result in low oxygen levels or even anoxia, which can be harmful to fish and other aquatic life. Some species of cyanobacteria can also produce harmful toxins. Algal blooms and associated fish die-offs tend to only occur in lakes that are considered eutrophic or hyper-eutrophic.

Like the CCME Phosphorus Framework, the North American Lake Management Society (NALMS) provides a gradient of chlorophyll-a concentration ranges and their anticipated trophic statuses (Table 4).

Overall, based on the NALMS chlorophyll-a gradient, only 24 (31%) of lake basins were classified as ultra-oligotrophic or oligotrophic, while 51 (66%) were classified as mesotrophic or meso-eutrophic (Table 5).

DISSOLVED CHLORIDE

Once released into the environment, chloride does not break down. This can result in the chloride concentrations in a lake increasing over time and remaining high long after its initial introduction. Elevated chloride concentrations in freshwater systems can result in negative impacts to lakes such as the disruption of a lake's natural mixing cycle, as well as biodiversity loss from chloride toxicity.

Elevated levels of dissolved chloride can disrupt a lake's natural mixing cycle by concentrating in a lake's deeper water, making it significantly denser than the fresh water above. This denser, saltier deep layer of water can become so dense that it can resist the seasonal mixing cycle of many lakes (Figure 2) which can result in prolonged anoxic conditions that can lead to fish kills. Persistent anoxic conditions can trigger the release of sediment-bound phosphorus and other harmful elements (i.e. arsenic, mercury, etc.) from the lakebed itself, in a process known as internal loading. Internal loading can become a major contributor of available nutrients to a lake's water column and can increase a lake's eutrophication risk.

According to the CCME (2011), ambient chloride concentrations in lakes within the Atlantic region, including Nova Scotia, are normally less than 10 mg/L for inland lakes, with concentrations as high as 20 to 40 mg/L in lakes located closer to coastal areas. Excluding the four basins sampled within Porters Lake (as it is a tidal waterbody), a wide range of chloride values were found among the 73 remaining freshwater lake basins assessed, ranging from 4.0 mg/L (Lake Charlotte – summer 2022) to 270 mg/L (Lovetts Lake – spring 2023). The three reference lakes (Pine, Big Cranberry and Topsail) selected to represent natural lake conditions in the region had average deepwater dissolved chloride values of 4.5 mg/L, 12.2 mg/L and 13.0 mg/L, respectively. Only 14 other lakes sampled had values below that of Topsail Lake (13.0 mg/L), while 28 lakes had values at least four times greater. As with previous studies, the lowest concentrations of chloride consistently occurred in lakes with relatively undeveloped watersheds (e.g. Scots, Pine, Charlotte, Kidston) while the highest values were consistently found in lakes with the most developed watersheds and densest road networks (e.g. Banook, Penhorn, First, Lovetts).

Fortunately, the CCME short-term exposure limit for dissolved chloride of 640 mg/L was not observed to be exceeded at any of the 73 freshwater lakes during sampling in 2022 or 2023. This value was exceeded at all four basins sampled within Porter's Lake, but this was expected because the lake is subject to a tidal influence. However, average deepwater chloride concentrations at ten freshwater lakes did exceed the long-term CCME FWAL guideline (>120mg/L) and a further seven lakes had values approaching the guideline, i.e. between 80 mg/L and 120 mg/L (Table 6). This result suggests that many other lakes within the municipality may have chronically elevated deepwater chloride concentrations that often exceed or approach the CCME long-term exposure guideline for the protection of freshwater aquatic life.

Table 6. Summary of 17 Freshwater Lakes whose Deepwater Dissolved Chloride Results approach or exceed the CCME FWAL long-term exposure guideline (BOLD indicates exceedance ≥120 mg/L).

Lake name	Spring 2022 (mg/L)	Summer 2022 (mg/L)	Spring 2023 (mg/L)	Summer 2023 (mg/L)	2022-23 Average
Lovetts Lake	260	200	270	190	230
Lake Banook	240	240	180	200	215
Lake Micmac	240	220	220	120	200
Russell Lake	220	180	190	170	190
Oathill Lake	190	160	180	170	175
Bayers Lake	190	170	170	76	151.5
Governors Lake	150	150	120	120	135
Penhorn Lake	140	130	130	130	132.5
First Lake	140	120	120	120	125
Bissett Lake	140	110	150	100	125
Settle Lake	150	130	110	57	111.8
Cranberry Lake	160	110	120	44	108.5
Chocolate Lake	57	160	120	89	106.5
Albro Lake	110	110	100	86	101.5
Maynard Lake	91	94	87	89	90.3
Morris Lake	100	93	90	69	88
Rocky Lake	93	98	74	56	80.3

E. COLI

E. coli results collected during the spring sampling periods of 2022 and 2023 were generally low or not detectable (i.e. present at levels below the ability of lab testing to detect). This was expected, as lakes are still relatively cold and biological activity is generally lower than during the warmer summer months. There was one unusual exceedance of Health Canada's *Guidelines for Canadian Recreational Water Quality* at the outlet sample for Sandy Lake (in Bedford) during the spring of 2023. It is possible that the sample was inadvertently contaminated during or after sampling, however.

Similarly, during the summer sampling periods of 2022 and 2023, *E. coli* results were generally low or not detectable, and only 4 of 73 lakes had at least one result that exceeded the recently updated Health Canada *Guidelines for Canadian Recreational Water Quality* (<235 *E. coli* CFU/100ml). These four lakes were Bell Lake and Springfield Lake in 2022, and Kidston Lake and Lovetts Lake in 2023.

TRACE METALS

A trace metals analysis was conducted at each of the 77 lake basins during the inaugural LakeWatchers sampling event in the spring of 2022 from the deep-water sample. Metals are a diverse group of elements that can occur naturally in water or enter waterbodies from human activities.

Some of these metals are required in very small (trace) amounts by organisms that live in water, such as iron or zinc, but at higher concentrations many of these elements can be toxic. Some metals, such as mercury, are toxic to living things in any amount.

Metals do not degrade naturally, but they can change form and move between water and sediments in aquatic systems. The CCME FWAL guidelines exist for only a fraction of the metals analyzed, such as arsenic, mercury and uranium. Where a CCME FWAL Guideline for a particular metal was not available, the Nova Scotia Tier 1 Environment and Climate Change (NSECC) Environmental Quality Standards for Surface Water (EQS-SW) were used to assess for exceedances instead.

For the complete list of trace metals results see Appendix C.

ARSENIC

Though detectable levels of arsenic were found in 11 lakes, the only lake that exceeded the CCME FWAL guideline of 5.0 µg/L was Lake Charles, with a concentration of 13 µg/L. The two lakes to which Lake Charles flows into, Lake William and Lake Micmac, had arsenic concentrations of 3.1 µg/L and 2.4 µg/L, respectively.

Elevated levels of arsenic are found in these waterbodies as the result of historic gold mining operations between the 1860s and 1940s in the Montague area that left significant quantities of arsenic-rich tailings in areas immediately upstream from these lakes (Sivarajah et al., 2024).

LEAD

The Nova Scotia Tier 1 EQS-SW guideline for lead is 1.0 µg/L.

Detectable levels of lead were found in 12 of 77 lake basins sampled ranging from a low of 0.55 µg/L (Morris Lake and Long Lake) to a high of 2.4 µg/L at Ragged Lake. Only two lakes had levels of lead that exceeded the Nova Scotia Tier 1 EQS-SW, these were Ragged Lake (2.4 µg/L) and Wrights Lake (1.4µg/L).

MAGNESIUM

Neither the CCME FWAL or the Nova Scotia Tier 1 EQS-SW provide a guideline for magnesium.

Magnesium was detected at all 77 lake basins sampled in the spring of 2022. A wide range of values were detected in municipal lakes ranging from a low of 230 µg/L at Big Cranberry Lake to a high of 820,000 at Porters Lake – south basin, where it is highly influenced by tidal seawater.

MANGANESE

The Nova Scotia Tier 1 EQS-SW guideline for manganese is 430 µg/L.

Manganese was found at detectable levels in all 77 lake basins sampled ranging from a low of 6.0 µg/L (Kidston Lake) to a high of 2900 µg/L (Porters Lake – middle north basin). There were only two exceedances, at the middle-north basin (2900 µg/L) and the north basin (840 µg/L) of Porters Lake.

MERCURY

The CCME FWAL guideline and the Nova Scotia Tier 1 EQS-SW guideline for mercury is 0.026 µg/L.

Mercury was not detected at any of the 77 lake basins assessed in the spring of 2022.

URANIUM

The CCME FWAL guideline for long-term exposure and the Nova Scotia Tier 1 EQS-SW for uranium is 15 µg/L. The CCME FWAL guideline for short-term exposure is 33 µg/L.

Uranium was found to be present at above detectable levels in 22 of 77 lake basins sampled ranging from a low of 0.11 µg/L (Williams Lake, Lake Charles and Kearney Lake) to a high of 2.0 µg/L (Porters Lake – middle north basin). None were found to be above the CCME FWAL or the Nova Scotia Tier 1 EQS-SW guidelines.

Discussion

Over the past two years, the LakeWatchers program has collected an enormous amount of data regarding the health and water quality for 73 lakes (inclusive of 77 basins) across the Halifax Regional Municipality. Despite this relatively short timeframe, when assessed alongside the previous WQMP data, the LakeWatchers data highlights a few potential concerns for lakes within the municipality.

The total phosphorus (TP) results observed in 2022-23 were inconsistent with what was expected, based on the data collected during the previous WQMP (2006-11). It was expected that surface TP results collected in 2022-23 would be similar or higher than those observed during the previous WQMP. This is because urban and suburban run-off and development pressures, the primary sources of added phosphorus to lakes, have either stayed constant or increased during the past decade.

Overall trends in surface TP concentrations tended to correspond between datasets, though. For example, a lake with elevated TP relative to the WQMP dataset also tended to have elevated TP relative to the LakeWatchers dataset, despite the differences in absolute values.

The trophic status estimates provided by the LakeWatchers surface TP results also did not show close alignment between the observed chlorophyll-a concentrations for the same 2022-23 period. In fact, the LakeWatchers chlorophyll-a results provided trophic status estimates that were more consistent with the estimates provided by the surface TP values observed in the 2006-2011 WQMP.

With only two years of data, it is impossible to determine whether the unexpectedly low TP values represent real lake conditions, the result of a small sample size, or an issue with sampling and/or analysis.

Potential issues which may explain the disagreement between the datasets include:

- differences in sampling techniques, methodologies or equipment used in sample collection
- possible degradation of samples between collection and laboratory analysis
- possible deviation from the phosphorus-limited model assumed for municipal lakes
- advances in analytical methods used by labs

To begin identifying whether the TP values observed in 2022-23 reflect real conditions or a lab discrepancy, municipal staff recommend that a select number of duplicate samples be collected and submitted to a second analytical laboratory for TP analysis during a future sampling event and the results compared.

The most concerning results were the elevated concentrations of deepwater dissolved chloride observed in many of the 73 freshwater lakes sampled, combined with the large number of lakes exhibiting anoxic conditions at their lakebeds during the August sampling. While anoxic conditions within the hypolimnion (bottom lake layer) is not itself a symptom of elevated dissolved chloride, these conditions can strengthen and extend the duration of seasonal thermal stratification, which can worsen hypolimnetic dissolved oxygen depletion and lead to prolonged periods of anoxia at the lakebed surface.

As stated previously, prolonged periods of anoxia at the lakebed can result in a process known as 'internal loading' by creating conditions favorable for the release of previously sediment-bound nutrients and other harmful contaminants from the lakebed back into the water column. This process has already been documented in some of the municipality's lakes (Doucet 2022, Doucet et al. 2023, Bermarija et al. 2023, and Sivarajah et al. 2024) and the LakeWatchers dataset supports the assertion that internal loading is occurring. In both summer 2022 and 2023, most of the lake basins exhibiting de-oxygenated conditions also showed higher total phosphorus levels from the deepwater sample when compared to the surface water sample.

Additionally, the observed concentrations of dissolved chloride in many of the 73 freshwater lakes sampled as part of LakeWatchers are likely leading to a reduction of biodiversity. Some species, especially those that form the basis of the food web, such as invertebrates and microorganisms, cannot tolerate increasing salinity. This is especially concerning for those lakes whose deepwater chloride concentrations consistently exceeded the CCME FWAL guideline for long-term exposure.

There were very few instances of *E.coli* (CFU/100ml) detected above the Health Canada's *Guidelines for Canadian Recreational Water Quality* during the 2022-23 sampling events for the LakeWatchers program. Out of a total of 616 samples collected, only five (less than 1%) were found to exceed the federal guideline. This outcome is in contrast with the increasing number of municipal beach closures observed in recent years resulting from high *E. coli* counts. Higher *E. coli* counts at municipal beaches are most likely related to warmer water temperatures in the shallower water close to the shoreline and the proximity of this water to terrestrial sources of *E. coli* contamination. Sources could include the improper disposal of canine feces around beaches, use of a beach area by waterfowl or a nearby municipal stormwater outfall or other run-off.

The extremely low number of detected exceedances for *E. coli* during the 2022-23 LakeWatchers sampling suggests the issue is predominantly confined to nearshore beach locations and not widespread.

Conclusion

The data collected as part of the 2022-23 LakeWatchers program has helped to establish baseline conditions for 73 lakes across the region. From this baseline, future changes to these lakes can be measured and trends detected. This information can be used to guide adaptive management efforts and inform future planning considerations with the aim to improve and maintain lake water quality within the municipality. Going forward, the LakeWatchers program will produce an annual “State of the Lakes” report based on the results of the past year’s sampling analysis.

LakeWatchers included three reference lakes to be representative of natural baseline conditions: Big Cranberry Lake, Pine Lake and Topsail Lake. Of the remaining 70 lakes, those that deviated most from the reference lakes’ baseline conditions tended to be those with the most developed watersheds and densest road networks, and therefore the most area covered by impervious surfaces (e.g. pavement, asphalt, etc). Lakes with the lowest pH, lowest chloride concentrations, lowest trace metal concentrations and lower estimated trophic states were generally located in less developed watersheds with catchment areas consisting of more natural land cover, such as forested lands (i.e., watersheds with less area covered by impervious surfaces).

Because most lakes with poorer water quality outcomes are in more heavily developed watersheds, findings indicate that the impacts of development, and the resulting increase in impervious surfaces within a watershed area, is the most likely predictor of declining lake water quality in the municipality.

The first two years of LakeWatchers have been a success by many measures, considering that

- data has been consistently collected at all 73 targeted lakes included in the program
- volunteer uptake in the program has grown significantly and steadily from each sampling event to the next, with 30 of the 73 LakeWatchers lakes completed by volunteers during summer 2023
- the standardized methods used by volunteers, municipal staff and hired consultants allow for easy comparison between lakes and provide data on key water quality concerns in the region
- the data being collected as part of the LakeWatchers program is shared publicly on the Halifax Open Data Portal and on Atlantic DataStream

Assessment of the program has led to the following changes being implemented, starting in 2024:

- Field collected water-quality measurements will be changed from recording every 0.5 m to every 1 m in lakes with a depth more than 5 m. In deeper lakes, volunteers found recording at 0.5 m intervals to be difficult and discouraging. Since water quality parameters did not change dramatically at 0.5 m intervals, this level of precision was deemed to be unnecessary.
- A select number of duplicate water samples will be collected for Total Phosphorus analysis to identify whether the TP values observed in 2022-23 reflect real conditions or a source of lab discrepancy or error. A select number of duplicate samples will be collected and submitted to a second laboratory for TP analysis.
- Volunteers will, when possible, record the actual GPS coordinates of the location that sampling occurred and the maximum depth encountered. In the field, it is often difficult to navigate to the exact sampling location because of GPS inaccuracy or because waves and wind drift make it challenging to keep a boat in one location when sampling. The actual locations sampled may not match the deepest part of the lake as recorded and sampling equipment may reach the bottom of a lake earlier than predicted. To account for this variation, volunteers will record the specific sampling coordinates and lake depth sampled.
- *E. coli* sampling is suspended for the spring sampling period and, moving forward, will resume only during the summer sampling period in August. In late April and early May, water temperatures are typically not warm enough to support bacteria populations dangerous to human health and people are not typically engaged in primary contact recreational activities (e.g., swimming). As a result, spring *E. coli* testing will be removed from the program but will continue during the summer sampling period.

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Appendix A

LAKE NAMES, COMMUNITIES, COORDINATES OF SAMPLING LOCATIONS AND APPROXIMATE DEPTHS

Lake Name	Community Name(s)	Primary Outlet Coordinates	Deepwater Coordinates	Approximate Depth
Class A Lakes – High Vulnerability Lakes (25)				
Albro Lake	Dartmouth	44° 41' 08" N 63° 34' 37" W	44° 41' 18" N 63° 34' 39" W	6 m
Bell Lake	Dartmouth	44° 40' 19"N 63° 30' 24"W	44° 40' 24" N 63° 30' 31" W	8 m
Chocolate Lake	Halifax	44° 38' 19" N 63° 37' 14" W	44° 38' 20" N 63° 37' 24" W	13 m
Cranberry Lake	Cole Harbour/ Dartmouth/ Westphal	44° 41' 22" N 63° 29' 51" W	44° 41' 22" N 63° 29' 50" W	3 m
Five Island Lake	Hubley	44° 39' 32" N 63° 48' 41" W	44° 39' 59" N 63° 48' 19" W	9 m
Fletchers Lake	Fall River/ Fletchers Lake/ Wellington	44° 51' 23" N 63° 37' 02" W	44° 50' 52" N 63° 36' 41" W	8 m
Governor Lake	Lakeside/ Timberlea	44° 38' 51" N 63° 42' 46" W	44° 38' 29" N 63° 41' 55" W	14 m
Kearney Lake	Bedford/ Halifax/ Timberlea	44° 42' 12" N 63° 42' 15" W	44° 41' 42" N 63° 41' 49" W	26 m
Kidston Lake	Halifax	44° 35' 53" N 63° 37' 14" W	44° 35' 42" N 63° 37' 16" W	6 m
Lake Banook	Dartmouth	44° 40' 29" N 63° 33' 44" W	44° 40' 50" N 63° 33' 20" W	12 m
Lake Charles	Dartmouth/ Waverley	44° 42' 31" N 63° 33' 14" W	44° 43' 18" N 63° 32' 49" W	26 m
Lake Micmac	Dartmouth	44° 41' 03" N 63° 33' 01" W	44° 41' 23" N 63° 33' 26" W	7 m
Long Pond	Herring Cove	44° 34' 32" N 63° 34' 29" W	44° 34' 32" N 63° 34' 33" W	6 m
Loon Lake	Lake Loon / Westphal	44° 42' 37" N 63° 30' 50" W	44° 42' 15" N 63° 30' 26" W	5 m
Maynard Lake	Dartmouth	44° 40' 05" N 63° 33' 00" W	44° 40' 12" N 63° 33' 05" W	12 m
McQuade Lake	Hammonds Plains	44° 42' 51" N 63° 44' 33" W	44° 42' 52" N 63° 44' 39" W	7 m
Morris Lake	Cole Harbour/ Dartmouth/ Eastern Passage/ Shearwater	44° 38' 53" N 63° 29' 21" W	44° 39' 02" N 63° 29' 42" W	12 m
Oathill Lake	Dartmouth	44° 40' 33" N 63° 33' 08" W	44° 40' 23" N 63° 32' 59" W	9 m
Paper Mill Lake	Bedford	44° 42' 52" N 63° 41' 03" W	44° 42' 56" N 63° 41' 07" W	6 m
Penhorn Lake	Dartmouth	44° 40' 26" N 63° 32' 19" W	44° 40' 32" N 63° 32' 27" W	9 m

Lake Name	Community Name(s)	Primary Outlet Coordinates	Deepwater Coordinates	Approximate Depth
Class A Lakes – High Vulnerability Lakes (25)				
Russell Lake	Dartmouth	44° 40' 02" N 63° 31' 18" W	44° 39' 57" N 63° 31' 30" W	9 m
Sandy Lake	Bedford	44° 44' 25" N 63° 42' 25" W	44° 44' 13" N 63° 42' 06" W	21 m
Settle Lake	Dartmouth/ Cole Harbour	44° 40' 39" N 63° 30' 16" W	44° 40' 42" N 63° 30' 17" W	8 m
Springfield Lake	Middle Sackville	44° 48' 58" N 63° 44' 03" W	44° 48' 45" N 63° 44' 18" W	4 m
Williams Lake	Halifax	44° 37' 11" N 63° 35' 18" W	44° 37' 12" N 63° 35' 30" W	20 m
Class B – Moderate Vulnerability Lakes (49)				
Albert Bridge Lake	Glen Margaret/ French Village/ Seabright	44° 36' 27" N 63° 53' 53" W	44° 36' 35" N 63° 53' 20" W	12 m
Anderson Lake	Bedford/ Waverley	44° 43' 19" N 63° 37' 23" W	44° 43' 33" N 3° 37' 15" W	24 m
Barrett Lake	Beaver Bank	44° 49' 04" N 63° 41' 05" W	44° 48'55" N 63° 41' 14" W	6 m
Bayers Lake	Beechville	44° 38' 32" N 63° 40' 09" W	44° 38' 31" N 63° 40'17" W	2 m
Beaver Bank Lake	Beaver Bank Lake/ Kinsac	44° 51' 04" N 63° 39' 50" W	44° 51' 25" N 63° 39' 59" W	8 m
Beaver Pond	Windsor Junction	44° 48' 14" N 63° 39' 20" W	44° 48' 02" N 63° 39' 15" W	8 m
Bissett Lake	Cole Harbour	44° 38' 51" N 63° 27' 36" W	44° 39' 12" N 63° 28' 06" W	9 m
Black Point Lake	Hubley	44° 39' 50" N 63° 47' 00" W	44° 40' 08" N 63° 47' 09" W	2 m
Blueberry Lake	Beechville	44° 37' 04" N 63° 41' 52" W	44° 37' 25" N 63° 41' 38" W	3 m
Elbow Lake	Stillwater Lake	44° 41' 29" N 63° 50' 06" W	44° 41' 29" N 63° 50' 06" W	2 m
Fenerty Lake	Beaver Bank	44° 50' 24" N 63° 43' 14" W	44° 50' 02" N 63° 43' 13" W	9 m
First Lake	Lower Sackville	44° 46' 01" N 63° 39' 05" W	44° 46' 24" N 63° 39' 56" W	24 m
First Chain Lake	Beechville	44° 38' 19" N 63° 38' 17" W	44° 38' 19' N 63° 38' 40" W	12 m
Hatchet Lake	Brookside/ Hatchet Lake	44° 33' 36" N 63° 43' 04" W	44° 33' 56" N 63° 43' 25" W	21 m
Hubley Big Lake	Hubley	44° 38' 41" N 63° 49' 56" W	44° 38' 11" N 63° 48' 54" W	14 m
Kinsac Lake	Beaver Bank/ Fall River/ Kinsac/ Wellington/ Windsor Junction	44° 50' 49" N 63° 39' 07" W	44° 49' 12" N 63° 39' 01" W	18 m
Lake Charlotte	Lake Charlotte/ Upper Lakeville	44° 47' 18" N 62° 55' 53" W	44° 51' 42" N 62° 59' 36" W	44 m
Lake Echo	Lake Echo/ Mineville	44° 42' 23" N 63° 22' 21" W	44° 43' 19" N 63° 23' 11" W	11 m
Lake William	Waverley	44° 44' 54" N 63° 33' 58" W	44° 46' 19" N 63°35' 13" W	26 m

Lake Name	Community Name(s)	Primary Outlet Coordinates	Deepwater Coordinates	Approximate Depth
Class B – Moderate Vulnerability Lakes (49)				
Lemont Lake	Dartmouth	44° 41' 13" N 63° 31' 13" W	44° 41' 21" N 63° 31' 16" W	6 m
Little Springfield Lake	Middle Sackville/ Upper Sackville	44° 48' 01" N 63° 45' 04" W	44° 48' 05" N 63° 45' 02" W	7 m
Long Lake	Beechville/ Halifax	44° 37' 03" N 63° 37' 45" W	44° 37' 32" N 63° 38' 57" W	26 m
Lovett Lake	Beechville	44° 38' 19" N 63° 41' 14" W	44° 38'15" N 63° 41' 00" W	7 m
McCabe Lake	Hammonds Plains/ Lucasville/ Middle Sackville	44° 46' 36" N 63° 45' 06" W	44° 46' 24" N 63° 45' 09" W	16 m
Mill Lake	Head of St. Margarets Bay	44° 42' 02" N 63° 53' 40" W	44° 42' 23" N 63° 53' 46" W	8 m
Miller Lake	Fall River	44° 48' 30" N 63° 36' 01"W	44° 48' 42" N 63° 35' 29" W	13 m
Moody Lake	Harrietsfield/ Williamswood	44° 31' 54" N 63° 38' 41" W	44° 32' 07" N 63° 38' 46" W	13 m
Petpeswick Lake	East Chezzetcook/ Gaetz Brook/ Musquodoboit Harbour/ West Petpeswick	44° 46' 18" N 63° 12' 12" W	44° 46' 16" N 63° 11' 44" W	22 m
Porters Lake (North basin)	Porters Lake	44° 44' 18" N 63° 18' 26" W	44° 46' 02" N 63° 19' 59" W	24 m
Porters Lake (mid-North basin)	Porters Lake	44° 43' 34" N 63° 18' 10" W	44° 44' 32" N 63° 17' 45" W	11 m
Porters Lake (mid-South basin)	Grand Desert/ Middle Porters Lake/ Seaforth/ West Chezzetcook/ West Porters Lake	44° 42' 07" N 63° 16' 59" W	44° 43' 20" N 63° 17' 58" W	7 m
Porters Lake (South basin)	East Lawrencetown/ Seaforth/ Three Fathom Harbour/ West Porters Lake	44° 39' 28" N 63° 17' 35" W	44° 39' 27" N 63° 18' 37" W	10 m
Powder Mill Lake	Waverley	44° 46' 18" N 63° 36' 24" W	44° 46' 34" N 63° 36' 43" W	12 m
Quarry Lake	Halifax	44° 40' 24" N 63° 41' 09" W	44° 40' 15" N 63° 41' 30" W	8 m
Ragged Lake	Beechville	44° 37' 25" N 63° 40' 52" W	44° 37' 30" N 63° 40' 35" W	5 m
Rocky Lake (North East basin)	Lakeview/ Waverley	44° 46' 08" N 63° 37' 32" W	44° 45' 54" N 63° 37' 20" W	4 m
Sandy Lake	Glen Arbour	44° 45' 41" N 63° 45' 44" W	44° 45' 23" N 63° 46' 06" W	8 m
Scots Lake	Musquodoboit Harbour	44° 47' 21" N 63° 10' 22" W	44° 47' 22" N 63° 10' 45" W	18 m
Second Lake	Lower Sackville/ Windsor Junction	44° 47' 05" N 63° 38' 19" W	44° 46' 48" N 63° 39' 21" W	13 m
Sheldrake Lake	Hubley	44° 40' 31" N 63° 48' 00" W	44° 40' 33" N 63° 47' 49" W	7 m
Shubenacadie Grand Lake	Grand Lake/ Oakfield/ Wellington	44° 55' 33" N 63° 34' 15" W	44° 55' 52" N 63° 35' 18" W	40 m
Stillwater Lake	Stillwater Lake/ Upper Tantallon	44° 42' 33" N 63° 50' 48" W	44° 42' 38" N 63° 50' 56" W	17 m
Susies Lake	Halifax	44° 40' 06" N 63° 41' 26" W	44° 39' 34" N 63° 41' 40" W	12 m

Lake Name	Community Name(s)	Primary Outlet Coordinates	Deepwater Coordinates	Approximate Depth
Class B – Moderate Vulnerability Lakes (49)				
Third Lake	Fall River/ Windsor Junction	44° 47' 15" N 63° 37' 45" W	44° 47' 30" N 63° 37' 57" W	24 m
Thomas Lake (North basin)	Fall River	44° 48' 57" N 63° 36' 43" W	44° 48' 43" N 63° 36' 37" W	6 m
Thomas Lake (South basin)	Fall River/ Waverley	44° 48' 13" N 63° 36' 32" W	44° 47' 26" N 63° 36' 24" W	14 m
Tucker Lake	Beaver Bank	44° 50' 27" N 63° 41' 21" W	44° 50' 21" N 63° 41' 13" W	19 m
Whites Lake	Whites Lake	44° 31' 51" N 63° 45' 28" W	44° 31' 56" N 63° 45' 18" W	9 m
Wrights Lake	Head of St. Margarets Bay/ Upper Hammonds Plains/ Upper Tantallon	44° 43' 59" N 63° 53' 39" W	44° 44'13" N 63° 53' 01" W	19 m
Reference Lakes (3)				
Big Cranberry Lake	Halifax	44° 39' 42" N 63° 42' 35" W	44° 39' 33" N 63° 42' 35" W	4 m
Pine Lake	Porters Lake	44° 48' 05" N 63° 18' 00" W	44° 48' 33" N 63° 18' 06" W	20 m
Topsail Lake	Dartmouth	44° 41' 21" N 63° 31' 07" W	44° 41' 42" N 63° 31' 03" W	7 m

Appendix B

SAMPLING DATES AND SAMPLING TEAM

Consultant Team	(orange)
Collaborative (Consultant + Volunteer)	(blue)
Community-led Team	(green)

Lake Name	Spring 2022	Summer 2022	Spring 2023	Summer 2023
Class A Lakes – High Vulnerability Lakes (25)				
Albro Lake	April 27	August 15	April 18	August 10
Bell Lake	May 6	August 15	April 17	August 4
Chocolate Lake	May 2	August 18	April 19	August 10
Cranberry Lake	April 28	August 12	April 18	August 8
Five Island Lake	May 2	August 15	April 17	August 23
Fletchers Lake	May 4	August 17	April 20	August 9
Governor Lake	May 2	August 26	April 26	August 16
Kearney Lake	May 4	August 18	April 24	August 29
Kidston Lake	April 29	August 19	April 20	August 9
Lake Banook	April 27	August 16	April 18	August 14
Lake Charles	April 29	August 16	April 18	August 10
Lake Micmac	April 27	August 16	April 18	August 14
Long Pond	May 3	August 18	April 19	August 9
Loon Lake	April 25	August 12	April 17	August 8
Maynard Lake	April 26	August 16	April 18	August 23
McQuade Lake	May 9	August 24	April 19	August 10
Morris Lake	April 26	August 22	May 10	August 31
Oathill Lake	April 28	August 28	April 23	August 28
Paper Mill Lake	April 29	August 23	April 19	August 11
Penhorn Lake	April 26	August 12	April 18	August 21
Russell Lake	April 28	August 22	May 11	September 7
Sandy Lake (Bedford)	May 4	August 22	April 21	August 14
Settle Lake	May 5	August 12	April 18	August 15
Springfield Lake	May 3	August 18	April 19	August 8
Williams Lake	May 2	August 19	April 19	August 9
Class B – Moderate Vulnerability Lakes (49)				
Albert Bridge Lake	May 12	August 22	April 21	August 23
Anderson Lake	May 12	August 16	April 24	August 10
Barrett Lake	May 5	August 24	April 25	August 16
Bayers Lake	May 25	August 26	April 21	August 11
Beaver Bank Lake	May 9	August 24	April 25	August 16
Beaver Pond	May 9	August 26	April 26	August 16
Bissett Lake	May 5	August 25	April 27	August 17
Black Point Lake	May 13	August 16	April 17	August 14

Class B – Moderate Vulnerability Lakes (49)				
Blueberry Lake	May 25	August 25	April 26	August 23
Elbow Lake	May 12	August 29	April 20	August 10
Fenerty Lake	May 5	August 24	April 25	August 21
First Lake	May 10	August 16	April 25	August 22
First Chain Lake	May 19	August 26	April 28	August 21
Hatchet Lake	May 6	September 1	May 2	August 16
Hubley Big Lake	May 12	August 24	April 26	August 16
Kinsac Lake	May 5	August 19	April 21	August 9
Lake Charlotte	May 17	August 25	April 27	August 17
Lake Echo	May 16	August 30	May 3	August 22
Lake William	May 3	August 22	April 20	August 1
Lemont Lake	May 6	August 15	April 17	August 8
Little Springfield Lake	May 3	August 18	April 19	August 8
Long Lake	May 11	August 24	April 26	August 11
Lovett Lake	May 3	August 15	April 18	August 14
McCabe Lake	May 10	August 18	April 17	August 8
Mill Lake	May 13	August 29	April 20	August 10
Miller Lake	May 4	August 17	April 20	August 9
Moody Lake	May 11	September 1	April 19	August 23
Petpeswick Lake	May 16	August 30	May 3	August 22
Porters Lake (North basin)	May 16	August 23	April 25	August 15
Porters Lake (mid-North basin)	May 16	August 23	April 25	August 15
Porters Lake (mid-South basin)	May 13	August 23	April 25	August 15
Porters Lake (South basin)	May 13	August 23	April 25	August 15
Powder Mill Lake	May 5	August 22	April 28	August 15
Quarry Lake	May 16	August 25	May 4	August 16
Ragged Lake	May 18	August 25	April 26	August 21
Rocky Lake (North East basin)	May 16	August 18	April 19	August 13
Sandy Lake (Glen Arbor)	May 13	August 24	April 18	August 14
Scots Lake	May 16	August 30	May 4	August 22
Second Lake	May 5	August 15	April 26	August 14
Sheldrake Lake	May 13	August 15	April 17	August 14
Shubenacadie Grand Lake	May 3	August 26	May 3	August 14
Stillwater Lake	May 12	August 24	April 26	August 25
Susies Lake	May 16	August 25	May 4	August 16
Third Lake	May 9	August 30	April 28	August 25
Thomas Lake (North basin)	May 4	August 17	April 20	August 14
Thomas Lake (South basin)	May 4	August 17	April 20	August 14
Tucker Lake	May 10	August 19	April 25	August 16
Whites Lake	May 11	September 1	May 2	August 16
Wrights Lake	May 12	August 29	April 20	August 10

Reference Lakes (3)				
Big Cranberry Lake	May 11	August 22	May 4	August 16
Pine Lake	May 26	August 23	April 24	August 15
Topsail Lake	May 6	August 15	April 17	August 8

Appendix C

COMPLETE LIST AND RESULTS FOR TRACE METALS

ALUMINUM

The Nova Scotia Tier 1 EQS-SW guideline for aluminum is 5 µg/L at pH below 6.5, no guideline is provided for pH above 6.5.

Detectable levels of aluminum were found in 76 of 77 lake basins ranging from a low of 16 µg/L at Lake Banook to a high of 1300 µg/L at First Chain Lake. Interestingly, aluminum was not detected at Porters Lake – Middle North basin.

ANTIMONY

Antimony was not detected at any of the 77 lake basins assessed in the spring of 2022.

ARSENIC

Detectable levels of arsenic were found in 11 lakes, but only exceeded the CCME FWAL guideline of 5.0 µg/L in Lake Charles which had a concentration of 13 µg/L. The two lakes to which Lake Charles flows into, Lake William and Lake Micmac, had arsenic concentrations of 3.1 µg/L and 2.4 µg/L, respectively.

Elevated levels of arsenic are found in these waterbodies because of historic gold mining operations between the 1860s and 1940s in the Montague area which left significant quantities of arsenic rich tailings in areas immediately upstream from these lakes (Sivarajah et al., 2024).

BARIUM

The Nova Scotia Tier 1 EQS-SW guideline for barium is 1000 µg/L.

Detectable levels of barium were found in 75 of 77 lake basins ranging from a low of 3.2 µg/L at Big Cranberry Lake to a high of 41 µg/L at Lovetts Lake. Barium was not detected at 2 of the 4 basins sampled at Porters Lake; the south and middle-south basins.

BERYLLIUM

The Nova Scotia Teir 1 EQS-SW guideline for beryllium is 0.15 µg/L.

Detectable levels of beryllium were found in 6 of 77 lake basins sampled, from highest to lowest there were, First Chain Lake (0.31 µg/L), Chocolate Lake (0.15 µg/L), Scots Lake (0.14 µg/L), Pine Lake (0.14 µg/L), Big Cranberry Lake (0.11 µg/L), and Lovetts Lake (0.10 µg/L).

BISMUTH

Neither the CCME FWAL, nor the Nova Scotia Tier 1 EQS-SW provide a guideline for bismuth.

Bismuth was not detected in any of the 77 lake basins sampled in the spring of 2022.

BORON

The CCME FWAL guidelines for boron are 1500 µg/L and 29000 µg/L for long-term and short-term exposure, respectively.

Boron was only detected at one lake, Porters Lake, but it was detected at all four basins sampled. As Porters Lake is subject to a tidal influence, it is not purely a fresh waterbody, and so comparison to the CCME FWAL guideline is not ideal. Nevertheless, the concentration of boron exceeded the CCME FWAL guideline for long-term exposure at 3 of the 4 basins; the middle-south basin (3100 µg/L), the middle-north basin (2500 µg/L), and the south basin (2500 µg/L).

CADMIUM

The Nova Scotia Tier 1 EQS-SW guideline for cadmium is 0.09 µg/L.

Cadmium was found to be present at detectable levels in 37 of 77 lake basins sampled through the LakeWatchers Program ranging from a low of 0.01 µg/L at Oathill Lake to a high of 0.14 µg/L at First Chain Lake. Five lakes were found to have concentrations of cadmium above the Nova Scotia EQS-SW guidelines, these were from highest to lowest; First Chain Lake (0.14 µg/L), Bayers Lake (0.13 µg/L), Lovetts Lake (0.13 µg/L), Chocolate Lake (0.12 µg/L), and Sheldrake Lake (0.092 µg/L).

CALCIUM

Neither the CCME FWAL, nor the Nova Scotia Tier 1 EQS-SW provide a guideline for calcium.

Calcium was detected at all 77 lake basins sampled in the spring of 2022. A wide range of values were detected in municipal lakes ranging from a low of 380 µg/L at Big Cranberry Lake to a high of 27,000 at Porters Lake – middle south basin.

CHROMIUM

The Nova Scotia EQS-SW guideline for chromium (total) is 8.9 µg/L.

Chromium was only detected in 1 of 77 lake basins sampled; Cranberry Lake at a concentration of 1.4 µg/L.

COBALT

The Nova Scotia Tier 1 EQS-SW guideline for cobalt is 1.0 µg/L.

Cobalt was detected at 8 of the 77 lake basins sampled ranging from a low at Bayers Lake (0.61 µg/L) to a high at First Chain Lake (7.3 µg/L). Four lakes were found to have concentrations of cobalt above the Nova Scotia EQS-SW guidelines including, First Chain Lake (7.3 µg/L), Chocolate Lake (6.0 µg/L), Porters Lake – north basin (1.3 µg/L), and Long Lake (1.1 µg/L).

COPPER

The Nova Scotia EQS-SW guideline for copper is 2.0 µg/L.

Detectable levels of copper were found in 70 of 77 lake basins sampled ranging from a low of 0.54 µg/L (White Lake & Five Islands Lake) to a high of 12 µg/L (Big Cranberry Lake). 15 lakes had detectable levels of copper above the Nova Scotia EQS-SW guideline including Big Cranberry Lake (12 µg/L), Albro Lake (5.4 µg/L), Bayers Lake (4.8 µg/L), Elbow Lake (4.2 µg/L), Sandy Lake – Glen Arbour (3.9 µg/L), Lake Charlotte (3.5 µg/L), Sheldrake Lake (3.1 µg/L), Pine Lake (3.1 µg/L), Black Point Lake (3.0 µg/L), Ragged Lake (2.7 µg/L), First Chain Lake (2.5 µg/L), Susies Lake (2.4 µg/L), Bissett Lake (2.1 µg/L), Lake Thomas – south basin (2.0 µg/L), and Oathill Lake (2.0 µg/L).

IRON

The Nova Scotia Tier 1 EQS-SW guideline for iron is 300 µg/L.

Detectable levels of iron were found in 68 of 77 lake basins sampled ranging from a low of 53 µg/L at Third Lake to a high of 3400 µg/L at Porters Lake – north basin. 8 lakes had levels of iron that exceeded the Nova Scotia Tier 1 EQS-SW, these were Porter Lake – north basin (3400 µg/L), Ragged Lake (830 µg/L), Wrights Lake (570 µg/L), McCabe Lake (480 µg/L), Little Springfield Lake (440 µg/L), Beaver Pond (390 µg/L), Lake Charlotte (350 µg/L), and Long Lake (330 µg/L).

LEAD

The nova Scotia Tier 1 EQS-SW guideline for lead is 1.0 µg/L.

Detectable levels of lead were found in 12 of 77 lake basins sampled ranging from a low of 0.55 µg/L (Morris Lake and Long Lake) to a high of 2.4 µg/L at Ragged Lake. Only 2 lakes had levels of lead that exceeded the Nova Scotia Tier 1 EQS-SW, these were Ragged Lake (2.4 µg/L) and Wrights Lake (1.4µg/L).

MAGNESIUM

Neither the CCME FWAL, nor the Nova Scotia Tier 1 EQS-SW provide a guideline for magnesium.

Magnesium was detected at all 77 lake basins sampled in the spring of 2022. A wide range of values were detected in municipal lakes ranging from a low of 230 µg/L at Big Cranberry Lake to a high of 820,000 at Porters Lake – south basin.

MANGANESE

The Nova Scotia Tier 1 EQS-SW guideline for manganese is 430 µg/L.

Manganese was found at detectable levels in all 77 lake basins sampled ranging from a low of 6.0 µg/L (Kidston Lake) to a high of 2900 µg/L (Porters Lake – middle north basin). There were only two exceedances, both at basins within Porters Lake; middle-north basin (2900 µg/L) and the north basin (840 µg/L).

MERCURY

The CCME FWAL guideline and the Nova Scotia Tier 1 EQS-SW guideline for mercury is 0.026 µg/L.

Mercury was not detected at any of the 77 lake basins assessed in the spring of 2022. \

MOLYBDENUM

The CCME FWAL guideline and the Nova Scotia Tier 1 EQS-SW guideline for molybdenum is 73 µg/L.

Molybdenum was not detected at any of the 77 lake basins assessed in the spring of 2022.

NICKEL

The Nova Scotia Tier 1 EQS-SW guideline for nickel is 25 µg/L.

Nickel was found at detectable levels in 7 of 77 lake basins sampled ranging from a low of 2.5 µg/L (Little Springfield Lake) to a high of 20 µg/L (First Chain Lake).

POTASSIUM

Neither the CCME FWAL, nor the Nova Scotia Tier 1 EQS-SW provide a guideline for potassium.

Potassium was found at detectable levels in 76 of 77 lake basins sampled in the spring of 2022, the only exception being at Hatchet Lake. A wide range of values were detected ranging from a low of 150 µg/L at Big Cranberry Lake to a high of 250,000 µg/L at Porters Lake – middle south basin.

SELENIUM

The Nova Scotia Tier 1 EQS-SW guideline for selenium is 1.0 µg/L.

Selenium was only detected at 1 of the 77 lake basins sample; Hatchet Lake (970 µg/L).

SILVER

The CCME FWAL guideline for long-term exposure and the Nova Scotia Tier 1 EQS-SW for silver is 0.25 µg/L.

Silver was not detected at any of the 77 lake basins sampled in the spring of 2022.

SODIUM

Neither the CCME FWAL, nor the Nova Scotia Tier 1 EQS-SW provide a guideline for sodium.

Sodium was found at detectable levels in 76 of 77 lake basins sampled in the spring of 2022, the only exception being at Hatchet Lake. A wide range of values were detected ranging from a low of 2400 µg/L at Big Cranberry Lake to a high of 6,900,000 µg/L at Porters Lake – middle south basin.

STRONTIUM

The Nova Scotia Tier 1 EQS-SW guideline for strontium in 21,000 µg/L.

Strontium was found at detectable levels in all 77 lake basins sampled during the spring of 2022. A wide range of values for strontium were detected ranging from a low of 2.8 µg/L at Big Cranberry Lake to a high of 16,000 µg/L at Hatchet Lake.

THALLIUM

The CCME FWAL guideline and the Nova Scotia Tier 1 EQS-SW for thallium is 0.8 µg/L.

Thallium was not detected at any of the 77 lake basins sampled in the spring of 2022.

TIN

Neither the CCME FWAL, nor the Nova Scotia Tier 1 EQS-SW provide a guideline for tin.

Tin was not detected at any of the 77 lake basins sampled in the spring of 2022.

TITANIUM

Neither the CCME FWAL, nor the Nova Scotia Tier 1 EQS-SW provide a guideline for titanium.

Titanium was found at detectable levels in 25 of 77 lake basins sampled in the spring of 2022. A wide range of values were detected ranging from a low of 2 µg/L at Settle Lake to a high of 12 µg/L at Wright's Lake.

URANIUM

The CCME FWAL guideline for long-term exposure and the Nova Scotia Tier 1 EQS-SW for uranium is 15 µg/L. The CCME FWAL guideline for short-term exposure is 33 µg/L.

Uranium was found to be present at above detectable levels in 22 of 77 lake basins sampled ranging from a low of 0.11 µg/L (Williams Lake, Lake Charles and Kearney Lake) to a high of 2.0 µg/L (Porters Lake – middle north basin). None were found to be above the CCME FWAL or the Nova Scotia Tier 1 EQS-SW guidelines.

VANADIUM

The Nova Scotia Tier 1 EQS-SW for vanadium is 120 µg/L.

Vanadium was not detected at any of the 77 lake basins sampled in the spring of 2022.

ZINC

The Nova Scotia Tier 1 EQS-SW guideline for Zinc is 7 µg/L.

Zinc was found to be present at above detectable levels in 24 of 77 lake basins sampled ranging from a low of 5 µg/L (Topsail Lake) to a high of 45 µg/L (Chocolate Lake). The Nova Scotia Tier 1 EQS-SW guideline was exceeded at 13 lake basins including Chocolate Lake (45 µg/L), First Chain Lake (36 µg/L), Lovetts Lake (35 µg/L), Bayers Lake (32 µg/L), Governors Lake (23 µg/L), Long Lake (12 µg/L), Stillwater Lake (11 µg/L), Quarry Lake – Birch Cove (10 µg/L), Williams Lake (10 µg/L), Lake Charles (9.7 µg/L), Susies Lake –Birch Cove (9.7 µg/L), Ragged Lake (8.8 µg/L), and Sheldrake Lake (8.2 µg/L).

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