Halifax Regional Municipality

Water Quality Monitoring Policy and Program Development

Prepared by:

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To:

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Project name:
Halifax Regional Municipality Water Quality Policy and Program Development

Project ref:
60617813

From:
AECOM Canada Ltd.

Date:
September 4, 2020

REPORT – FINAL

Subject: Review Report – Halifax Regional Municipality Water Quality Policy and Program Development

Dear Mr. Deacoff:

Please find attached our final report in relation to the Water Quality Policy and Program Development for the Halifax Regional Municipality.

On behalf of the AECOM team, we would like to thank Halifax Regional Municipality for the opportunity to complete this undertaking and report. Please contact me at your earliest convenience if you have any questions.

Sincerely,

AECOM Canada Ltd.

[redacted]

Nora Doran, P.Geo.
Senior Project Manager, Environment
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AECOM: 2015-04-13

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1. Introduction

1.1 Project Overview

AECOM Canada Ltd. (AECOM) was retained by Halifax Regional Municipality (HRM or Halifax) to determine the efficacy of HRM's past municipal initiatives related to water quality monitoring, to understand what other cities are doing to support healthy watersheds, and to provide advice on a potential water quality monitoring program for recommendation to Halifax Regional Council during fiscal year 2020-2021. While there is a perception that "*water quality monitoring is neither a standard nor a typical municipal function …";* Halifax has engaged in these activities historically for a variety of reasons. Through this undertaking, HRM hopes to better understand "*…1) the policy basis for a corporate water quality monitoring program, and 2) the elements, structure, proposed operations and management of such a program*". A part of this exercise is to better understand how and why other municipalities perceive water quality monitoring to be their responsibility and how the monitoring can be used to fulfill or provide the foundation for their established water resources management policies and whether their existing policies are appropriate or adequate.

The secondary goals of this undertaking include:

a. to develop suitable lake water quality monitoring objectives, which shall form the basis for the program;
b. to develop, at minimum, three alternative program frameworks that may serve to meet program objectives; and,
c. to develop order-of-magnitude costing estimates for each program framework, including start-up and annual costs.

This report summarizes the research that has been undertaken to document what other communities are doing and why, a summary of the consultation that was undertaken with government, academia, the public and other organizations, the review of existing policies and their implementation within HRM and how this review informs a policy basis for a water quality monitoring program and refines strategic monitoring objectives that supports the development of monitoring program framework options that can address management needs.

1.2 Background

Halifax, located along the south shore of central Nova Scotia, is approximately 5,490 km^2 in area, with over 1000 freshwater lakes within its jurisdiction. Increasing population growth, land development, introduction of non-native species and climate change have placed pressure on natural resources with a potential to affect lake water quality. Historically, Halifax has monitored lake water quality for a variety of purposes, with different scopes and durations. This has led to management challenges due to the inconsistency of data collection over time, and the need for reactionary approaches to address new water quality issues as they have emerged. HRM is considering the implementation of a long-term, comprehensive lake water quality monitoring program to address these management challenges.

Previous water quality studies undertaken by Halifax were driven by land development activities, public health threats and fulfillment of regulatory compliance requirements:

- Corporate Water Quality Monitoring Program (2006-2011);
- Seasonal Lake and Stream Monitoring Program (2015-2017);
- Execution of development agreements (2007-present);
- Watershed studies (2006-present);
- Supervised Beach Monitoring Program (2008-present);

- Risk management of cyanobacteria (blue-green algae) blooms (2018-present); and
- Groundwater well monitoring.

In the absence of a long-term comprehensive monitoring program, recent monitoring by HRM has been conducted on an *ad hoc* basis to respond to management issues that arise in area lakes. Concerns facing HRM in recent years, as noted in the project terms of reference have included:

- Increasing numbers of beach closures resulting from more frequent exceedances of fecal coliform thresholds established by Health Canada's Guidelines for Canadian Recreational Water Quality;
- Increasing frequency of potentially harmful blue-green algae (i.e., cyanobacteria) blooms;
- Increasing instances of nuisance aquatic plant growth, impairing safe access to lakes for swimming and boating;
- Impacts of invasive alien species (e.g., Yellow Floating Heart (*Nymphoides peltata)* in Little Albro Lake), and, more recently, Chinese Mystery Snail (*Cipangopaludina chinensis*); and
- Chloride levels in several lakes that exceed the long-term freshwater exposure guideline value, and the forthcoming federal requirements to identify Salt Vulnerable Areas and develop and implement action plans.

Reactionary monitoring is sometimes necessary; however, this type of monitoring can have several drawbacks, for example:

- It cannot always draw on cost-saving partnerships and collaborations due to time limitations;
- There is often insufficient time and resources to collect background data or response data to fully characterize conditions that consider natural in-lake and watershed-based processes;
- Sampling standards and data management procedures may not always be in line with other sampling programs;
- Quality assurance and quality control procedures may be inconsistent;
- Technical and plain language reporting for the community may not always occur; and
- Data are often not easily transferable to address other issues due to inconsistencies in monitoring approaches.

A corporate water quality monitoring program that is well developed to address specific management objectives could reduce the need for future reactionary monitoring and provide a means to identify existing and emerging concerns for management in a timely, scientifically defensible, and cost-effective manner.

1.3 Scope

The scope of work undertaken as a part of this evaluation generally includes the following:

- Review applicable background information to provide context for the project;
- Conduct a jurisdictional scan of other local and regional municipalities to identify if others have such policies and programs and to assess their relevance for application to Halifax;
- Develop, plan, and conduct consultations with local water quality stakeholders, selected in consultation with the Municipality, to help identify water quality monitoring priorities, objectives, and possible approaches;
- Develop, propose, and validate program objectives, as well as effective means by which Halifax and program stakeholders can objectively measure the success in meeting those objectives;
- Recommend strategies that HRM may pursue to achieve program objectives that it may not be able to accomplish alone, including but not limited to:
  - Academic partnerships, with individual institutions, networks, etc.
  - Inter-governmental collaboration, at local, provincial, and/or national scale

  - Private sector collaboration
  - Voluntary sector collaboration (e.g., local lake-based, community-based, and other not-for-profit organizations with shared interests in HRM lakes);
- Recommend an alternative approach to water quality monitoring requirements for Development Agreements, considering the challenges encountered; and
- Recommend suitable approaches for water quality data management, including data storage, analysis, interpretation, and dissemination, to maximize automation, expertise, and opportunities for reporting, sharing, and other beneficial uses of water quality data.

The scope of the monitoring program proposed for HRM within this report is limited to lakes. It is recognized that rivers and interconnecting channels are also important components of the aquatic environment and these too should be monitored strategically by HRM. However, the design of a monitoring program of fluvial environments needs to be very different from that of lakes unless the river sampling is being monitored at the outlet of the lake to solely characterize lake water quality. River monitoring would need to be designed to specifically characterize conditions and hydrology of a water course (e.g. headwater stream versus a controlled river versus a natural river versus a river in an urban area receiving stormwater) and consequently, river monitoring is beyond the scope of the current project.

1.4 Inter-governmental Roles for Water Resource Management

Water quality monitoring is foundational to effective water resource management. All levels of government, the private sector and the general public bear some responsibility for protecting and managing water resources, however, each has different roles and responsibilities. Water quality monitoring implemented to support water resource management, therefore, will vary by necessity depending on specific information needs of different parties.

1.4.1 Federal Government

The Government of Canada describes the broad roles and responsibilities of federal and provincial governments respecting water resource management.[1] The federal government has jurisdiction for water resources related to fisheries, navigation, federal lands, and international relations. It also shares responsibilities with provinces in other areas such as agriculture, health, and significant national water issues, supports aquatic research and technology development, and ensures national policies and standards are in place on environmental and health-related issues. Provinces have jurisdiction over waters that lie solely within their boundaries with legislative authority in respect of flow regulation, water use development, water supply, pollution control and thermal and hydroelectric power development. The Province of Nova Scotia[2] states that its role in managing and protecting surface water includes:

- *ensuring sustainable water use through several key surface water management programs,*
- *allocating available water resources amongst various users through surface water withdrawal approvals,*
- *protecting surface waters from human influences by regulating activities through required approvals,*
- *developing guidelines, standards, policies, and strategies,*
- *promoting watershed planning, stewardship, and use of best management practices (BMPs),*
- *monitoring surface waters to track trends in water quality and quantity, and*
- *developing and maintaining surface water data, maps, and publications.*

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[1] *Government of Canada, 2020.* https://www.canada.ca/en/environment-climate-change/services/water-overview/governance-legislation/shared-responsibility.html

[2] *Government of Nova Scotia, 2017. Nova Scotia Environment, Surface Water. Accessed online at:* https://www.novascotia.ca/nse/surface.water/

Federal and provincial governments typically monitor water quality to support large-scale, regional-level initiatives that support their respective and collaborative roles and responsibilities. In Nova Scotia, large-scale national programs include the Maritime Coastal Basin Long-term Water Quality Monitoring Data program, the Acid Sensitive Lakes Study and the Canadian Environmental Sustainability Indicators (CESI) Water Quality Index (WQI) program (**Section 4.1.3**).

1.4.2 Provincial Government

Nova Scotia provincial initiatives include the Automated Surface Water Quality Monitoring Program and the Nova Scotia Lake Survey Program (**Section 4.1.2**), as well as health-risk monitoring for cyanobacteria blooms. Importantly in 2010, the Province of Nova Scotia published a provincial water resource management strategy, *Water for Life*. This was a 10-year plan for guiding the management of water resources within the Province of Nova Scotia to 2020 (Nova Scotia, 2010). The strategy is said to create a framework to manage competing demands for water and protect its quality and availability for future generations. It lists the following goals:

- improve our understanding of watersheds and how they work;
- learn how much water we have and how much we are using;
- decide how and where we want our water used;
- identify how we should continue to protect water; and,
- use water in a way that is both economically and environmentally sustainable.

The intent of the water strategy was to "guide the government in the management of water for the benefit of communities, businesses, industries, First Nations, and individuals." It presents a path and strategy to help ensure that Nova Scotia is staying on "our path to sustainable prosperity" and indicates that Nova Scotia will "remain a great place to live, work, play, and do business into the future". The strategy indicates the government will carry out the water strategy using the following principles as guidelines (Nova Scotia, 2010):

- **Sustainability** - We must recognize the fundamental value of healthy water and ecosystems, and the social and economic importance of water to Nova Scotia. Today's decisions must consider tomorrow's effects, carefully balancing the water we use with the protection of natural ecosystems.
- **Stewardship** - Stewardship means conserving and protecting water. It is based on both an individual and a collective responsibility to ensure safe, healthy water for future generations.
- **Partnership and collaboration** - Water is a shared resource, and its stewardship is a shared responsibility. Everyone must participate, including all levels of government, the private sector, communities, and individual citizens.
- **Leadership** - Creating positive change in the way we manage our water will require strong leadership not only by the provincial government, but by all interested and affected parties. Accountability & Transparency Decision making should be based on evidence and open to public review.

The intent of the Water for Life strategy is reportedly to enable governments and other stakeholders to address important issues in water management on the strategy that seeks to achieve five goals for the Province, as follows:

1) Human Health • ensure safe, secure water for consumption, recreation, and livelihoods;
2) Economic Prosperity • ensure sustainable and beneficial use of water resources;
3) Ecosystem Integrity • protect, conserve, and enhance water resources and dependent ecosystems;
4) Emergency and Hazards Preparedness • minimize the effect of water-related emergencies and, hazards; and,
5) Water Monitoring and Knowledge • strengthen our understanding of provincial water resources.

The Water for Life strategy provides actions under the following four areas:

1) **Integrated Water Management** – a comprehensive approach to managing water resources including human activities and their effects on watersheds and ecosystems.
2) **Understanding the quality and quantity of water** – understanding how watersheds work, the impacts of activities on water, how much water the province has, how its being used, and the water effects of climate change.
3) **Protect the quality and quantity of our water** – protection includes addressing the needs of the natural environment as well as people both physically and economically.
4) **Engage in caring for our water**. – all people in the province need water and everyone can play a role in its management.

1.5 Policy Framework - HRM Regional Plan Context

HRM's Regional Plan, originally approved in 2006 and most recently updated as of October 2014, '*establishes long-range, region-wide planning policies outlining where, when and how future growth and development should take place between now and 2031*.' (HRM, 2014)

In the context of AECOM's current-undertaking, and specifically relating to the policy-basis for conducting a corporate water quality monitoring program, AECOM completed a review of the most-recent version of the Regional Plan (HRM, 2014) to identify:

- which policies stipulate water quality monitoring as a requirement; and,
- which polices would benefit from water quality monitoring.

It should be noted that AECOM's mandate is not a planning exercise, or in-depth review of HRM planning policies. However, existing policies are reviewed in the context of determining the basis for a corporate water quality monitoring program and whether the existing policies are appropriate or adequate in the context of supporting water resource management.

Based on AECOM's review of the Regional Plan (2019), the main sections of the Regional Plan where water quality monitoring may be required or would be of benefit include the following sections within Chapter 2 – Environment, Energy and Climate Change, which are further described below:

- Section 2.2 Greenbelting
- Section 2.3 Water Resources
- Section 2.4 Watershed Planning

In addition to the above Regional Plan sections, pursuant to Policy E-11, within the Greenbelting Section, the Halifax Green Network Plan (HGNP), is a more recent publication prepared in 2018 (HRM, 2018) that discusses water quality monitoring and it is relevant for the purpose of this undertaking.

1.5.1 Regional Plan Section 2.2 Greenbelting

HRM's Greenbelting plan aims to determine a strategy for the maintenance and distribution of parks and open space within HRM. This includes natural networks, park classifications, regional parks, municipal parks, natural areas and natural corridors, urban forests and a greenbelting and public open space priorities plan.

A key excerpt from Section 2.2 of the Regional Plan on Greenbelting is as follows:

> *HRM has a vast network of open space. While the conventional concept of open space may imply parks or untouched natural areas, the term "open space" is used here as a land use category to refer*

to several additional types of land uses with a wide range of functions. Open space is publicly or privately owned, undeveloped land or water, intended to be preserved for agricultural, forest, community form, ecological, historical, public safety, or recreational purposes. It consists of lands for natural resources, agriculture, recreation, environmentally sensitive areas, hazard prone lands, cultural landscapes, natural corridors and trails and preservation areas for potable water and waste/resource management.

Policy E-11 - this policy includes "coordinating and managing a program to research, identify and designate potential natural areas, systems and distinct landscapes, natural corridors and critical ecosystem linkages, and significant natural habitats to guide future development".

Pursuant to Policy E-11, HRM has completed the HGNP, (HRM 2018), which defines an interconnected open space system for the municipality, highlights ecosystem functions and benefits, and outlines strategies to manage open space. Specifically, the HGNP provides land management and community design direction to:

- maintain ecologically and culturally important land and aquatic systems;
- promote the sustainable use of natural resources and economically important open spaces; and
- identify, define and plan land suited for parks and corridors.

As it relates to water quality monitoring requirements and activities, the HGNP (HRM, 2018), indicates the Municipality "*does not have the capacity or expertise to identify key indicators or collect and interpret the information on a regular basis*". The HGNP indicates an intention of the Municipality to form partnerships with other organizations that are already researching and monitoring water quality, as a way to obtain water quality monitoring information. Organizations that are referenced in the HGNP include Halifax Water, Nova Scotia Environment, university researchers and non-profit and community groups. With respect to the varying approaches to monitoring, the HGNP indicates that partnerships with these organizations are important, to "*identify key variables to monitor, the Municipality's role, and how the information (generated by monitoring activities) can feed back into the Municipality's role, land use planning and other Municipal decision-making processes.*" While the HGNP indicates that partnerships with these organizations are important to the Municipality, it is not clear within the HGNP how the Municipality will use this information.

1.5.2 Regional Plan Section 2.3 Water Resources

The introduction to Regional Plan Section 2.3 has some supportive language regarding the valuation of water resources within the Region, as a potable water supply source, wildlife habitat, recreational enjoyment and aesthetic value:

"*Water, a limited and precious resource, is one of HRM's most highly valued environmental assets. Protection of this resource for potable water supply, wildlife habitat, recreational enjoyment, and aesthetic value is crucial for HRM. HRM's strategy aims to protect this resource through land use control and retention of those features that regulate water flow, mitigate flooding, reduce water pollution and protect ecological functions."*

The policies within this section of the Regional Plan relate to the protection of potable water supplies, wetlands protection, establishing riparian buffers, floodplains and coastal inundation. Relevant policies for a corporate lake water monitoring program include E-15 (protection of wetlands), E-16 to E-19 (retaining riparian buffers), and E-21 (restricting development within flood plains for designated watercourses).

1.5.3 Regional Plan Section 2.4 Watershed Planning

Regional Plan Section 2.4 offers planning policies related to new developments within the Region. The strongest linkages to requiring a water quality monitoring program are within this section of the Regional Plan. A key excerpt from Section 2.4 is as follows:

"Planning on a watershed basis will therefore be undertaken in greater detail during the creation of secondary planning strategies and upon completion of watershed studies. This Plan will seek to achieve public health standards for body contact recreation and to maintain the existing trophic status of our lakes and waterways to the extent possible."

Policy E-23 - HRM shall undertake watershed or sub-watershed studies concerning natural watercourses prior to undertaking secondary planning strategies in areas where new or additional development could adversely affect watercourses within the watershed. The studies, where appropriate, shall be designed to:

(a) recommend measures to protect and manage quantity and quality of groundwater resources;
(b) recommend water quality objectives for key receiving watercourses in the study area;
(c) determine the amount of development and maximum inputs that receiving lakes and rivers can assimilate without exceeding the water quality objectives recommended for the lakes and rivers within the watershed;
(d) determine the parameters to be attained or retained to achieve marine water quality objectives;
(e) identify sources of contamination within the watershed;
(f) identify remedial measures to improve fresh and marine water quality;
(g) identify any areas around watercourses where increased flow from development could cause flood damage to properties or environmental damage and estimate the maximum increase in flow from the area to be developed that would not cause damage to the areas identified;
(h) recommend strategies to adapt HRM's stormwater management guidelines to achieve the water quality objectives set out under the watershed study;
(i) recommend methods to reduce and mitigate loss of permeable surfaces, native plants and native soils, groundwater recharge areas, and other important environmental functions within the watershed and create methods to reduce cut and fill and overall grading of development sites;
(j) identify and recommend measures to protect and manage natural corridors and critical habitats for terrestrial and aquatic species, including species at risk;
(k) identify appropriate riparian buffers for the watershed;
(l) identify areas that are suitable and not suitable for development within the watershed;
(m) recommend potential regulatory controls and management strategies to achieve the desired objectives; and
(n) recommend a monitoring plan to assess if the specific water quality objectives for the watershed are being met.

Policy E-24 - 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

1.6 Key Points from Policy Review

1.6.1 Provincial Water Resource Strategy

In summary, while it is recognized that the Province has a jurisdiction over inland waters, the Province presents a strategy, Water for Life, that identifies a collaborative approach to the management of water for the benefit of all "*communities, businesses, industries, First Nations, and individuals.*" The strategy indicates that 'water is a shared resource and stewardship is a shared responsibility'. It recognizes water as a resource of fundamental value, with social and economic benefits to all Nova Scotians. It recognizes the importance of the sustainability of the resource, where today's actions must consider tomorrow's effects (Nova Scotia, 2010). The guiding principles for carrying out this strategy, as discussed above, were sustainability, stewardship, partnership and collaboration and finally, leadership.

The intent of the Water for Life strategy is reportedly to enable governments and other stakeholders to address important issues in water management. This includes goals within human health, economic prosperity, economic integrity, emergency and hazards preparedness and water monitoring and knowledge.

It is instructive that the Province takes a holistic approach to water management through partnership and collaboration, where water is a resource to be valued. It includes language that indicates it is a shared resource whose management and protection is a shared responsibility.

1.6.2 Regional Plan

Upon review of the key planning policies set forth in the most recent Regional Plan (HRM, 2014) and for policies in the context of those where water quality monitoring may benefit or be required, AECOM offers some comments relative to the current planning policies.

In the context of HRM's Regional Plan (2014), we note that water quality monitoring is only triggered under secondary planning strategies that look at new or expanded developments. While there are many other policies that are in place for water resource management and protection, none identify a requirement for monitoring to assess impacts from historical activities and existing infrastructure (e.g. combined sewers and storm sewers) and the absence of adequate infrastructure (e.g. older septic systems that would not meet current design requirements or have outlived their functional lifespan). The impact from historical and existing conditions needs to be documented through monitoring in order to establish priorities for restoration and mitigation to protect or restore the natural water resources.

Unfortunately, Policy E-11 does not stipulate that water quality monitoring is required even though it would clearly benefit from monitoring to inform land-use designation within the greenbelting framework to protect and preserve lakes as open spaces for ecological and recreational purposes and as potable water supplies. Equally unfortunate is the statement in the HGNP that "*others are going to monitor their water resources*" with no comment as to how HRM can support this, or ensure work completed by others, perhaps for different purposes than managing the impacts from past, present and planned urban growth, will effectively address the needs of HRM and their residents.

Similarly, policies E-15 (protection of wetlands), E-16 to 19 (retaining riparian buffers) and policy E-21 (restricting development within floodplains for designated watercourses) do not specify a requirement for water quality monitoring. A lake water monitoring program could be useful to assess the success of these type of land use controls and retention features for the protection of water quality to meet HRM's strategy.

Policies E-23 and E-24 require the use of water quality monitoring data and the requirement for a long-term water quality monitoring dataset; however, these requirements are only triggered for secondary planning purposes, where new or additional development is being assessed. Neither policy specifically addresses water quality monitoring relating to an assessment of existing conditions and recent anthropogenic influences of the urban built environment that may impact directly on the type and extent of the monitoring and mitigation requirements of the secondary plan.

2. Background Report Review

Over the past two decades, a considerable amount of work has been completed in the Halifax region related to water quality management. This work provides context for a new corporate lake monitoring program by providing information on past management issues and successes, and past monitoring activities and their findings. Several background reports were consulted in the preparation of this report, including reports on servicing studies, watershed studies for secondary planning evaluations, water resource policy and procedure evaluations, and lake-specific studies. Key background reports are provided in **Table 1**. While these reports have provided essential background information to this work, their content has not been summarized here and they will be referred to in the report where specific information or content is referenced.

Table 1: Summary of Background Reports Reviewed

Report Title	Category
AECOM 2013. Shubenacadie Lakes Subwatershed Study Final Report.	Assimilative Lake Capacity
AECOM 2013. Birch Cove Lakes Watershed Study Final Report.	Assimilative Lake Capacity
AECOM 2014. Preston Area Watershed Study Final Report.	Assimilative Lake Capacity
AECOM 2014. Sandy Lake Watershed Study Final Report.	Assimilative Lake Capacity
AECOM 2017. Surface Water Quality Monitoring – 2017 Final Report	Assimilative Lake Capacity
CBCL 2007. Consulting Services – Watershed Study Musquodoboit Harbour. Final Report.	Secondary Planning Report
CBCL 2009. Hubbards Watershed Servicing Study. Final Report.	Servicing Study Report
CBCL 2010. Musquodoboit Harbour Follow-Up Study Report. Final Report.	Secondary Planning Report
CBCL 2012. Lake Echo Watershed Servicing Study. Final Report	Servicing Study Report
CBCL 2013. Tantallon Watershed Servicing Study. Final Report.	Servicing Study Report
CBCL 2013. Porters Lake Watershed Servicing Study. Final Report.	Secondary Planning Report
CBCL 2015. Paper Mill Lake Watershed Total Phosphorus Characterization Project. Final Report.	Lake Investigation. Focus on Phosphorus
Centre for Water Resource Studies, Dalhousie University. 2016. Final Report: Paper Mill Lake Watershed Assessment.	Lake Investigation. Focus on Phosphorus
Dillon Consulting Limited. 2003. HRM Water Resource Management Study Report.	Recommended Guideline for Water Resource Management
Dillon Consulting Limited. 2006. Halifax Regional Municipality Stormwater Management Guidelines.	Recommended Guideline for Water Resource Management
Jacques Whitford. 2009. Fall River – Shubenacadie Lakes Watershed Study.	Secondary Planning Report
SNC Lavalin. 2019. Final Report: Surface Water Quality Monitoring Program, 2019 Spring Sampling Event, Bedford West, Bedford, Nova Scotia.	Development Specific Monitoring Report
Stantec Consulting Limited. 2010. Final Report: Water Quality Monitoring Functional Plan.	Recommended Guideline for Water Resource Management
Stantec Consulting Limited. 2012. An Analysis of the HRM Lakes Water Quality Monitoring Program Data (2006 – 2011). Final Report.	Water Quality Trends

Report Title	Category
Stantec Consulting Limited. 2012. Analysis of Regional Centre Lakes Water Quality Data (2006 – 2011). Final Report.	Water Quality Trends
Stantec Consulting Limited. 2013. HRM Water Quality Monitoring Protocol	Recommended Guideline for Water Resource Management
Stantec Consulting Limited. 2019. Pollution Source Control Study for Lake Banook & Lake Micmac. Final Report.	Lake Specific Evaluation
Staff Report, HEMDCC, 6 June 2013. Russell Lake Water Quality Policy Review Project	Recommended Guideline for Water Resource Management
Staff Report, Halifax Regional Council, 27 April 2010, Service Review - Water Quality Sampling	Recommended Guideline for Water Resource Management

3. Jurisdictional Reviews

A review of four (4) Canadian jurisdictions was conducted to inform recommendations for the objectives (Section 6) and framework options (Section 7) for a monitoring program based on successful municipally led lake water quality monitoring programs already. A fifth jurisdiction from the US was reviewed as this regional municipality has many similarities to HRM in that it consists of both urban core and residential and rural residential developments. Importantly, this municipality has maintained an active monitoring program through partnerships for over 25 years.

An overview of each program is provided in the sections that follow and relevant components are summarized in **Tables A-1 to A-5, Appendix A.1** according to the following topics:

- Objectives of monitoring;
- Policy and planning grounds for monitoring;
- Monitoring design;
- Costs, if available;
- Data management and analysis approach;
- Collaborations; and
- Challenges and lessons learned.

3.1 District Municipality of Muskoka – Muskoka Water Strategy

The District Municipality of Muskoka is a regional municipality in central Ontario located approximately 180 km north of Toronto and spans 6,475 square kilometres in area (km^2) **(Figure 1[4])**. It has approximately 1,600 lakes and is a popular cottaging destination. According to the District of Muskoka and based on 2016 Census information, the District of Muskoka has 60,599 year-round residents. Information published in the 2017 Second Home Study[3] by the District of Muskoka indicates there is a seasonal population of 81,907 in Muskoka, for a total population of 142,506.

Figure 1: Location of the District of Muskoka, ON

The District of Muskoka spearheads the Muskoka Water Strategy that emphasizes relationship building, resource sharing and community involvement to address water resource issues and to provide a management structure for future initiatives[4]. The Strategy is supported through the adoption of policies in the Official Plan, which includes provisions for lake and watershed monitoring under the Lake System Health Program.

Muskoka has monitored recreational water quality for 25 years with the goals to identify lakes that have surpassed acceptable water quality thresholds, identify the limits to growth for lakes and to better understand the impacts of stormwater, municipal facilities and site development on water resources. Each year, approximately 80 to 85 sites are sampled for total phosphorus (TP) and other chemical parameters[5], clarity, temperature and dissolved

[3] *The District of Muskoka. 2017 Second Home Study. Final Report. March 2018.*

[4] *https://www.muskoka.on.ca/en/district-government/Muskoka-Water-Strategy-.aspx*

[5] *Other parameters include pH, alkalinity, conductivity, dissolved organic carbon, calcium, chloride, colour, sodium, nitrogen, sulphate and metals.*

oxygen. Monitoring is conducted on a rotating basis, such that about 160 lakes are monitored every three years. The program also features the Muskoka Water Web, an online portal to communicate and share monitoring data, evaluation of monitoring results, and information on best management practices and other management resources to protect recreational water quality. This program fosters community support and leverages activities by local residents (e.g., benthic invertebrate monitoring, shoreline surveys) and provincial agencies (e.g., research initiatives, provincial monitoring programs) to further expand on information collected to assess water quality issues and identify remedial action needs. At present, the District is working to develop lake-specific monitoring and studies to address issues of cyanobacteria blooms and identify causes (i.e., nutrient enrichment from human activities, climate change) to inform development planning restrictions.

Results of the monitoring program are reported annually in a series of Lake Data Sheets and in a detailed monitoring report, and the results are further used in the preparation of a Watershed Report Card, which is published every four years. Copies of the Muskoka Watershed 2018 Report Card and an annual Lake Data Sheet and a web link to a detailed annual report are included in **Appendix A.2.**

3.2 City of Greater Sudbury Lake Water Quality Monitoring Program

The City of Greater Sudbury, Ontario, in northern Ontario has a population of 164,689[6]. The City has a large land area of 3,228 km^2 and is located approximately 400 km (4-hour drive) north of Toronto[7] (**Figure 2**). With approximately 330 lakes within its jurisdiction, including several lakes within urban centres, the City is nicknamed the 'City of Lakes'. Mining and forestry industries are prevalent within the Greater Sudbury area.

Figure 2: Location of the City of Sudbury, ON

The City's Lake Water Quality Program was implemented in 2001 to improve and protect the quality of the community's surface water through lake water quality monitoring and to encourage community engagement through lake stewardship groups and the volunteer help of residents. The program includes monitoring of various lake water and shoreline quality parameters and collaborative efforts with other City divisions, government agencies, academic researchers, lake stewardship groups, and individual residents to address problems as they arise. The program actively promotes and supports the creation of stewardship groups on individual lakes. A summary of the key components of the City of Sudbury's Lake Water Quality Program is presented in **Table A-2, Appendix A.1**.

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[6] *Statistics Canada, 2016 Census Profile, City of Greater Sudbury, Ontario* https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CMACA&Code1=580&Geo2=PR&Code2=47&Data=Count&SearchText=Greater%20Sudbury&SearchType=Begins&SearchPR=01&B1=All&GeoLevel=PR&GeoCode=580&TABID=1

[7] *Online reference:* https://en.wikipedia.org/wiki/Greater_Sudbury *Accessed April 1,2020*

The City's program includes three key monitoring initiatives:

- An Aquatic Vegetation Survey and Mapping Initiative to identify and track the spread of aquatic plant invasive species (e.g., Eurasian water milfoil) as well as the recovery of aquatic plant communities from historic impacts of local smelting activities and acid rain.
- A Phosphorus Monitoring Initiative that includes spring sampling of 64 lakes and summer sampling of 15 priority lakes to inform concerns regarding nutrient enrichment. Spring sampling when lakes are fully mixed provides accurate information on whole lake TP concentrations, while summer sampling provides additional information on impacts of urban drainage and potential internal nutrient loads from the sediments under anoxic conditions. Parameters monitored include TP concentrations, and depth profiles of temperature, dissolved oxygen, pH and conductivity. Results of this monitoring were usefully employed to validate and calibrate a watershed-scale lake water quality model and inform planning policies for shoreline development.
- A Shoreline Home Visit Initiative that is a confidential and one-on-one program designed to advise residents of healthy shoreline living practices that they can use to help protect, conserve, and restore the ecological health of their property, shoreline, and lake.

The City of Greater Sudbury funds a full-time Program Co-ordinator and a seasonal Lake Water Quality Field Intern. These positions are responsible for the day-to-day program and activities including water quality monitoring, shoreline home visit program, technical assistance to lake stewardship groups and the Watershed Advisory Panel. Additional duties include website content management and report writing.

Results of the monitoring program are published in an annual report prepared by the City, which is publicly available. A copy of the 2018 Annual Report is included in **Appendix A.2** for reference.

3.3 Kings County Lake Monitoring Program

The Municipality of the County of Kings (Kings County) is situated in the eastern Annapolis Valley in central Nova Scotia **(Figure 3)**. It is bordered by the Bay of Fundy to the north and its northeastern part forms the western shore of the Minas Basin. Kings County spans an area of approximately 2,100 km^2. Kings County is a productive agricultural region of Nova Scotia and has population of 60,600 according to the 2016 Census[8]. The county includes three separately incorporated towns of Wolfville, Kentville and Berwick, and two First Nations reserves. Within the southern area of the County, there are upwards of 45 lakes located on the South Mountain, south of the Annapolis and Gaspereau valleys.

Figure 3: Location of Kings County, Nova Scotia

AECOM conducted an interview with Will Mushkat-Robinson, Land-use Planner and the current Program Manager of the Lake Monitoring Program, on April 2, 2020. According to Mr. Mushkat-Robinson, the program became an active multi-stakeholder annual program in 1997. It initially included routine monitoring of six to seven lakes within the eastern area of the

[8] StatsCanada. Online Reference. Accessed April 1, 2020. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CD&Code1=1207&Geo2=PR&Code2=01&SearchText=Kings&SearchType=Begins&SearchPR=01&B1=All&type=0

municipality, and later expanded to include a total of 13 lakes within the municipality as a result of concerns of community residents. To date, the program has been in operation for 23 years and is volunteer-run and municipally funded.

The Kings County Lake Monitoring Program was initiated after the Municipality initiated some testing as a result of longstanding community concerns regarding lakeshore development. (Robinson-Mushkat, W., pers comm., 2020). A multi-stakeholder group spearheaded by municipal staff was formed in 1994 and included representatives of all three levels of government as well as local community groups (e.g., Aylesford Lake Property Owners Society and Lake George Property Owners Society) and the development community. The group's objective was to implement a tool that 'could be used to determine the extent of development that could exist around a given Kings County lake, while maintaining its water quality at acceptable levels.'[9] The tool was to be used by the Municipality in a land-use planning context. According to Mr. Robinson-Mushkat, the water quality monitoring data is collected to present a long-term trend and picture and has successfully provided scientific and evidence-based planning policy within the region. For example, in 2008, changes were made to the land-use bylaw and land-use strategy to include more stringent policies relating to setbacks, lot sizes, site plan approval requirements and building envelope requirements based on monitoring. In addition, he commented that the Lake Monitoring Program has been a successful educational tool to inform residents on what steps they can take as property owners to ensure they are not contributing to deterioration of lake health. Kings County uses a location-based community consultation platform called Placespeak™ to share information. Kings County has published several information and education resources for volunteer and community members that are hosted on their Lake Water Monitoring Placespeak™ site, including an Algae Monitoring Field Sheet, a Lake Development Brochure and a Water Sampling Handbook. Copies of these publications are included in **Appendix A.3.**

A graphic summarizing the program purpose, goals and process is provided as **Figure 4.**

Program Overview - The King's County Lake Monitoring program is a volunteer-based lake monitoring program, that is municipally funded. That is, samples are collected by volunteers, however; the municipality funds the program administration including laboratory analysis, data interpretation and reporting. Water quality sampling is conducted monthly from May to October in a total of thirteen (13) lakes. The volunteers collect the samples, typically on the third Sunday of each month, using equipment and supplies provided by the Municipality. On the day following the sample collection, the Kings County Lake Monitoring Program student coordinator collects the water samples from each of the volunteers and submits them to the QEII Hospital in Halifax, NS for laboratory for analysis. During each sampling event, the volunteers also

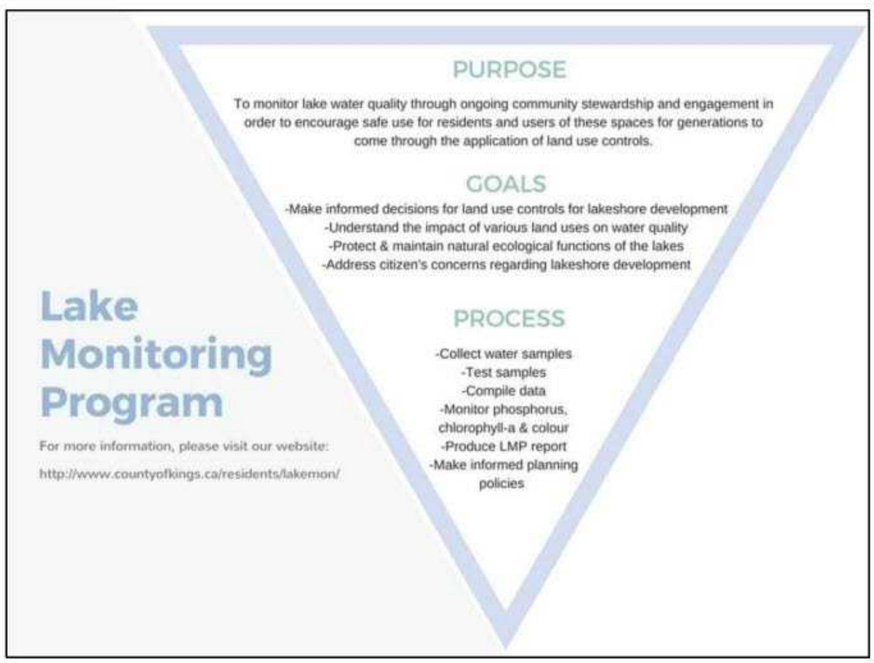

Figure 4: Kings County Lake Monitoring Program – Purpose, Goals and Processes

[9] *Kings County Website Online Reference https://www.countyofkings.ca/residents/services/planning/lake/program.aspx Accessed April 1, 2020.*

collect field data and make field observations, and document them on a field sheet that is submitted to the Municipality. Community volunteers are also provided with winter logbooks to document observations such as when does the lake freeze or thaw, whether the lake is used for winter ice fishing, or recreational activities (ice hockey, skating, snowmobiling), etc., over the winter months.

Kings County engages an external consultant to analyze and prepare a report on the lake water monitoring program results on an annual basis. Based on information presented in Marty (2018), the report includes a report-card type summary for each of the lakes that are monitored within the program. A copy of the 2017 Monitoring Report by Marty (2018) is included in **Appendix A.2**. It includes an interpretation of the monitoring results and report-card style, lake by lake summary for the 2017 sampling year

Kings County Lakeshore Capacity Model -The Municipality adopted a phosphorus loading model in 1997, the Kings County Lakeshore Capacity Model (KCLCM) and included modelling of 18 lakes within study area. The model was derived in 1995 by Horner and Associates Limited, in collaboration with Michael Michalski Associates and Rayment Walton. In 2009, the Centre for Water Resources Studies at Dalhousie University and Stantec Consulting Ltd. undertook a review of the KCLCM model, volunteer monitoring program, the monitoring framework and related land use planning policies. (CWRS and Stantec, 2009). The model was developed to assist with assessing long term trends and analysis of the data. Data collected through monitoring can be used to assist with model calibration and also to assist with future predictions as it relates to lake carrying capacity and informing decisions relating to future development.

A summary of the key components of the Kings County Lake Monitoring Program is presented in Table A-3, **Appendix A.1.**

3.4 Carleton River Watershed Lake Quality Monitoring Program

Background: The Carleton River Watershed Lake Water Quality Program Steering Committee was formed as a result of the initiatives of several individuals in the Municipalities of Argyle, Clare and Yarmouth and groups in the region concerned about water quality issues in the Carleton River watershed and surrounding area (**Figure 5**). According to the Municipality of the District of Yarmouth[10] the idea for forming a Steering Committee began in October 2012 at a workshop held by Nova Scotia Environment in Yarmouth, NS. NSE had concerns at the time with addressing recommendations from water quality surveys and reports on several lakes located within the Carleton, Meteghan and Sissiboo River watersheds carried out between 2008 and 2010 which showed many of the lakes to be seriously degraded as a result of nutrient over-enrichment. A recommendation had been made to design and implement a long-term water quality monitoring program in this area. According to the Municipality of Yarmouth, an existing model of a volunteer-based water quality monitoring program ongoing in Kings County was presented at the workshop by NSE as an example of a model which could be adopted in the Carleton area.

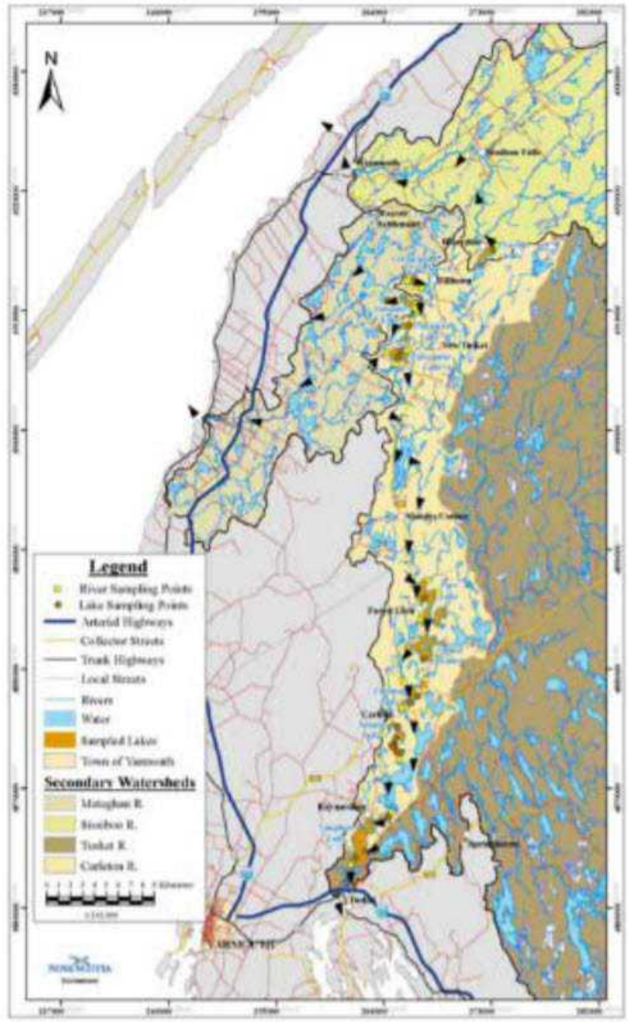

Figure 5: Map of the Carleton-River Watershed Monitoring Area (from Brylinsky, 2012)

Program Details: The Carleton River Watershed Lake Quality Monitoring Program was implemented in 2008 and includes annual monitoring of more than 14 lakes in the Carleton River, Meteghan River and Sissiboo River watersheds in Nova Scotia (**Figure 5**). The program was initiated by the Province of Nova Scotia to determine the source of nutrients from within the watershed contributing to cyanobacteria blooms affecting lakes in the area. When nutrient sources were found to be derived from local agriculture, aquaculture, residential development and mink farming operations, a collaborative, multiple stakeholder steering committee was formed to undertake lake water quality monitoring. The Carleton River Watershed Area Water Quality Monitoring Steering Committee is hosted by the Municipality of the District of Yarmouth and includes representation from municipal government, environmental non-government organizations and provincial departments, private industry and the community coordinator. The Committee generally meets twice a year, in the spring and fall, to plan the annual water sampling program and to review and report on the results of the program. Since 2016, the program has been completely volunteer-led.

The water quality monitoring program includes monitoring at several locations in the study lakes including the inlet, mid-lake, nearshore, shoreline and outlets for physical and chemical parameters and cyanobacteria and microcystin.

[10] *Municipality of the District of Yarmouth. Online Reference. https://www.district.yarmouth.ns.ca/index.php/community/community-organizations-programs/224-carleton-river-watershed Accessed April 4, 2020.*

Funding and Collaboration Summary – according to Sollows (2018), the following summarizes the funding and monitoring program collaborations and contributions for the 2017 sampling season:

- **Funding:** the study was primarily funded by NSE, with supplementary funding from the Nova Scotia Salmon Association's Adopt-a-Stream program, Municipality of the District of Yarmouth, Municipality of Argyle, and Tusket River Environmental Protection Association.
- **Human Resources:**
  - **Private Industry** – Stantec Consulting Ltd. completed field work relating to monitoring summer parameters and related reporting in all lakes except Raynards, Salmon, and Kegeshook.
  - **Other Provincial Departments:** NS Fisheries and Aquaculture conducted sampling at on Provost, Nowlans, Placides, and Porcupine Lakes. Technical advice was provided by Darrell Taylor of NSE.
  - **Industry Association:** Technical advice provided by Jim Mullen of Nova Scotia Mink Breeders' Association.
  - **Volunteers –** lake monitoring activities were conducted by eight (8) volunteers living on or near specific lakes, through the coordination of a volunteer coordinator.

A copy of the 2017 Monitoring Report by Stantec (2017) is included in **Appendix A.2,** along with a reported on the supplemental 2017 results, by Sollows (2018).

3.5 Minneapolis – St. Paul Minnesota

Minneapolis-St. Paul is a major metropolitan area within east central Minnesota (**Figure 6**[11]). The area is commonly known as the Twin Cities, after the two largest cities, Minneapolis as the most populous city in the state and its neighbour to the east, St. Paul with a combined population of approximately 4 million spread over 28,422 square kilometres.

Figure 6: Map of Minneapolis-St. Paul, MN

The Minnesota Legislature directed the Metropolitan Council for Minneapolis – St. Paul to prepare a metropolitan development guide that included a plan for the region's wastewater collection and treatment system, along with supporting policies and goals. The Policy Plan, which has evolved, was also prepared in response to another statute requiring the Council to adopt a water resources plan and federal requirements for a regional management plan to address pollution from point sources and nonpoint sources. The Metropolitan Council is responsible for ensuring that waste treatment management and urban stormwater management policies are in place to protect water quality in the region. In addition, the Council, in cooperation and consultation with many partners, fills gaps in monitoring and assessment of the water quality of area lakes, rivers and streams. The Council works closely with communities and watershed organizations as they prepare their local water plans and watershed management plans, providing technical assistance related to surface water management and water quality issues and conditions in the region (MSP, 2015).

The Metropolitan Council was required to minimize the adverse impacts of growth, including adverse impacts on the environment. At the outset, this required the Council to conduct an assessment of the waters (lakes, streams, and rivers) in the metro area that have been polluted or that have the potential for water pollution caused by non-point sources. The monitoring data collected by the Council, its partners, and citizen volunteers

[11] *Trip Maps – Online Reference http://tripsmaps.com/minneapolisst-paul-map.html . Accessed April 4, 2020.*

are used to identify pollution problems, support regional planning efforts, and meet federal and state regulations. Most of the lake monitoring efforts focus on the assessment of eutrophication. The broad "outcomes" in a policy plan titled "2040 Water Resources Policy Plan" (MSP, 2015) are: stewardship, prosperity, equity, livability, and sustainability. These outcomes provide policy direction for this Policy Plan.

- **Stewardship** advances the Council's longstanding mission of orderly and economical development by responsibly managing the region's natural and financial resources and making strategic investments in our region's future.
- **Prosperity** is fostered by investing in infrastructure and amenities that make our region competitive in attracting and retaining successful businesses, a talented workforce, and strong economic opportunities.
- **Equity** means connecting all residents to opportunity and creates viable housing, transportation, and recreation options for people of all races, ethnicities, incomes, and abilities so that all communities share the opportunities and challenges of growth and change.
- **Livability** focuses on the quality of our residents' lives and experiences in the region, and how places and infrastructure create and enhance the quality of life that makes our region a great place to live.
- **Sustainability** seeks to protect our regional vitality for generations to come by preserving our capacity to maintain and support our region's well-being and productivity over the long term.

The region's lakes, streams, and wetlands together form a system that discharges into the region's major rivers which provide drinking water for the urban core, recreational uses, and other activities that support the region's economy and quality of life. The Council includes **accountability** as a principle of the plan which is fulfilled through the commitment to monitoring and evaluating the effectiveness of the programs and policies.

Monitoring has continued since 1980 and with its partners, the Council monitors and assesses the condition of approximately 200 lakes per year and 21 stream sites. The Council works closely with State agencies on coordinating and filling gaps in monitoring and assessment activities for the major rivers which includes an additional 22 river sites each year. The Council's volunteer program, the Citizen Assisted Monitoring Program (CAMP), was formalized in 1993. This highly successful program collects data on the lakes each year through the efforts of trained, dedicated volunteers and their local sponsors. The year 2013 was the 21st year of the Council's volunteer program, with 118 citizen volunteers participating in the CAMP. Through the dedicated efforts of the volunteers and local partners a total of 175 lake-sites on 159 lakes were monitored in 2013 through the CAMP. Three of the lakes monitored by the CAMP also were monitored by Metropolitan Council staff (but for different parameters), so the total number of lakes monitored by the Metropolitan Council's lake monitoring program was 162 in 2013 (MSP, 2015). Even at 175 lakes, this remains a small subset of the 950 lakes in the Twin Cities metro area of Minneapolis – St. Paul.

3.6 Summary of Jurisdictional Review

AECOM reviewed five (5) jurisdictions/ municipalities that undertake lake monitoring programs in response to or external to senior government initiatives. All the jurisdictions reviewed have extensive experience in lake monitoring and can provide potentially valuable lessons for Halifax in developing its program. A brief summary is provided in **Table 2** below for a comparison of the physical and social settings of the various jurisdictions reviewed and to highlight some of the most relevant lessons learned from these jurisdictions that may be instructive.

Table 2: Summary of Setting Characteristics for All Jurisdictions Reviewed as Compared to Halifax

Setting Characteristic Relative to Halifax	Muskoka	Sudbury	Kings County	Carleton River	Minneapolis – St. Paul
Total population	smaller	smaller	smaller	smaller	larger
Seasonal residences	large				
Dominant urban core	no	yes	no	no	yes
Suburban areas	no	yes	no	no	yes
Rural/natural areas	yes	yes	yes	yes	no
Attributes of Monitoring Program					
Required by senior governments	no	no	no	no	yes
Financially supported by senior governments	no	no	no	partly	partly
Monitoring managed by municipality	yes	yes	yes	yes	yes
Municipal staff support	yes	yes	yes	limited	yes
Data managed locally	yes	yes	yes	yes	yes
Periodic reporting	annual	annual	annual	annual	annual
Volunteer monitoring	yes	yes	yes	yes	yes
Number of years of operation	25	19	23	8	40
Number of lakes monitored	160	64	13	14	>200
Other programs (shorelines, lake capacity)	yes	yes	yes	no	yes

The commonalities amongst programs are important and include:

- recognition of a need to monitor, protect and manage their natural resources;
- primarily funded, organized and controlled by the municipality for the benefits of the communities;
- frequent reporting to the communities
- direct involvement of the public in monitoring and sharing of information;
- support for the monitoring program through complementary initiatives; and,
- a long-term commitment on the part of the municipality.

4. Stakeholder Consultation

AECOM conducted one-on-one consultations with representatives from local universities, federal, provincial and municipal government agencies, and a group-consultation with community and recreation-based user groups. These consultations were held between December 13, 2019 and February 6, 2020. The objective of these consultations was to share information on the project objective and mandate, and to seek feedback from individuals and organizations with water quality expertise. In particular, the AECOM team sought to engage water quality specialists from external organizations, to determine where opportunities for partnership and collaboration may exist as it relates to an HRM-led corporate water quality monitoring program and as it relates to potential strategies that HRM may pursue to achieve program objectives that HRM may not be able to accomplish on its own.

4.1 Individual One on One Consultations

Individual meetings were held between AECOM team members and representatives from various organizations as listed in **Table 3**.

Table 3: Summary of Stakeholder Meetings – One-on-One Consultation Participants

Organization Category	Organization	Name	Title and Area of Focus
Academic	Dalhousie University	Rob Jamieson	Professor and Canada Research Chair in Cold Water Engineering. Centre for Water Resources
		Lobke Rottveel	Graduate Student in Dr. Shannon Sterling's Group at Centre for Water Resources Studies
	Saint Mary's University	Linda Campbell	Senior Research Fellow, Environmental Science Department. Dynamic Environment & Ecosystem Health Research Group.
Federal Government	Environment and Climate Change Canada	Denis Parent	Water Quality Specialist, Water Quality Monitoring and Surveillance. Advisor for Atlantic Water Network.
Provincial Government	Nova Scotia Environment – Sustainability and Applied Science Division	Andrew Sinclair	Senior Surface Water Quality Specialist. Advisor for Atlantic Water Network.
		Jennifer Rocard	Manager, Water Resources
		Elizabeth Kennedy	Director - Industrial Management & Water/Wastewater
Municipal Government	Halifax Regional Municipality	Shannon O'Connell	Program Engineer, Infrastructure Policy & Standards
		Cameron Deacoff	Water Resources Specialist and Project Manager
Private Sector	Atlantic Water Network	Emma Wattie	Director

A summary of meeting discussion points is presented in the following sub-sections, ordered by meeting date.

4.1.1 Halifax Regional Municipality – Infrastructure Planning Division

AECOM representatives met with Shannon O'Connell, Program Engineer within the Infrastructure Policy and Standards group within HRM's Infrastructure and Planning Department, along with Cameron Deacoff, Water Resources Specialist and HRM Project Lead. The meeting was held by teleconference on Friday December

13, 2019. The objective of the meeting was to share information on the recent efforts by HRM with regards to stormwater management.

Follow up correspondence from Ms. O'Connell to the AECOM team provided a summary of the current direction for stormwater work on behalf of HRM. The current-day activities within HRM Engineering come from several places including the following:

- The Integrated Stormwater Policy Draft Framework (approved by HRM Council in Dec 2017 and by the Halifax Water Board of Commissioners in January 2018);
- The HRM Regional Plan (2014); and,
- A settlement hearing on a Utility and Review Board matter, where an agreed upon outcome was that Halifax Water and HRM would work together to develop Joint Design and Construction standards for stormwater management that would focus on the quality of stormwater runoff.

Below are some policies and successes that are in-preparation, according to Ms. O'Connell:

- The "Joint Stormwater Standards" were developed by HRM and Halifax Water. The draft standards focus on new, large-scale developments on private property, and require that stormwater infrastructure be used to retain the first inch of rainfall on site, as well as remove 80% total suspended solids (TSS). These standards will be enforced by a new by-law (described below) and will be triggered with development permits.
- A new by-law is in-preparation titled "By-Law Respecting Grade Alteration and Stormwater Management" and is expected to come into force in 2020. The Joint Stormwater Standards will be attached as an appendix to that by-law and enforced accordingly.
- As part of the Municipal Design Guidelines (Red Book) update, a chapter on updated stormwater standards that apply to public right-of-way will be included. These standards will also focus on reducing the quantity and improving the quality of stormwater runoff using Green Infrastructure. This is expected to be completed in September 2020.
- HRM has begun to incorporate green infrastructure in new projects such as the "Prince Albert Road Diet", a lane reduction project and the "Spring Garden Road" project. These projects are expected to be constructed in 2021. These pilot projects will help HRM demonstrate working methods for managing stormwater runoff quantity and quality. It is anticipated that some testing and monitoring will be set up at one or both of these projects to collect data on the treatment effectiveness of the green infrastructure.
- HRM is working with Halifax Water regarding the second stage of daylighting Sawmill Creek. As part of the Dartmouth Cove project, the intent is to narrow the northern end of Alderney Drive to maximize the daylighting that can be done in this area.

4.1.2 Nova Scotia Environment

The objectives of this consultation were to further understand the priorities of NSE, existing programs, policies and procedures as they relate to water resources, and to identify opportunities for collaboration and funding support for lake water quality monitoring. The following questions were prepared by the AECOM team and were posed to NSE representatives to help facilitate the discussion held on February 4, 2020.

- What are the water quality monitoring priorities for NSE?
- What is the Province's role with respect to surface water resource management within HRM? What will the role be moving forward given NSE priorities and limitations?
- Regarding setting targets or objectives (WQ) for water bodies – is this done? What parameters? What are the targets? How are they evaluated or measured?
- Our role for HRM is to assess and advise them on a monitoring strategy for water resources within the municipal boundaries. Municipalities that we have worked with and are familiar with, believe that they are

not mandated or required in legislation to protect and monitor the water resources and yet at the same time frequently have vocal community support to do so. What are your thoughts on this?

- When does the Province step in with regards to water quality issues?
  - Blue/green algae and/or other issues related to climate change? If yes, when does NSE – surface water resources participate? Or is the effort led by the Provincial Health Department?
  - Contamination issues?
  - How else and when else is the Province involved?
- Opportunities for Collaborating
  - Where the Department pays for the analytical services associated with the Lake Survey Program with NSDFA, are there other opportunities for this type of collaboration?
  - Does the Department collaborate with other academic institutions with respect to surface water resources?

The following sections summarize the discussion held during this meeting and is organized by key topic discussed.

Water Monitoring Priorities - NSE representatives described having two (2) long-term priorities for water quality monitoring within the Province. This includes the Automated Surface Water Quality Monitoring Program which collects water quality information on an hourly basis at 5 locations across the Province[12], and the Nova Scotia Lake Survey Program, which inventories lake water chemistry and lake morphometrics (e.g. depth, volume, and stratification) [13]. Within the lake survey program that is jointly run with the Nova Scotia Department of Aquaculture, NSE shared that there are ten (10) lakes that are sampled per year and approximately 600 lakes have been sampled in the past 50 to 60 years.

NSE shared that they have a mandate to represent different regions and different uses with regards to surface water resources.

Funding – on the topic of funding support, it was shared that NSE hopes to expand their efforts, however; they work with a limited budget and generally support two to three research projects per year. They are currently involved in projects involving phosphorus and blue-green algae both driven by complaints and health-risks. NSE has provided funding towards water quality sampling for the Carleton River watershed within the Municipality of Yarmouth, NS. NSE indicated they are also supporting on-going research with Centre for Water Resources Studies (CWRS) at Dalhousie University on the development of a watershed assessment tool to identify and manage lakes at risk for Harmful Algae Blooms, with applications at a regional scale as a screening tool. As described in McCarron *et. al.* (2019) "*this type of risk assessment tool would aid in generating regional or Province-wide risk assessments of lake eutrophication. The identification of high-priority lake watersheds would allow the Province to efficiently prioritize their resources for managing lakes across the Province. The risk assessment tool would also guide municipalities and watershed stewardship groups in establishing monitoring programs and land-use management plans in watersheds of interest.*"

Decisions for funding support are made on a project-by-project basis. For NSE to provide funding support, the project must be applicable to water resource management in the Province as a whole.

Data Management – Data collected by NSE are published/uploaded to the Nova Scotia Open Data Catalogue[14], generally within one year of sample collection and data is typically uploaded during the winter months. NSE is currently looking into adjusting the data presentation format. NSE also shares the results of their sampling activities with the Atlantic DataStream, an open-access platform for sharing information on

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[12] Reference: https://novascotia.ca/nse/surface.water/automatedqualitymonitoring.asp#figure01

[13] Reference: https://novascotia.ca/nse/surface.water/automatedqualitymonitoring.asp#figure01

[14] Reference: https://data.novascotia.ca/

freshwater health in the Atlantic Provinces[15]. Atlantic DataStream is discussed further in Section 4.1.6 and Section 9.1. NSE commented that the Atlantic DataStream dataset is publicly available and as such, it keeps individuals and organizations accountable.

Blue-green algae – Nova Scotia adopts a health-risk approach to its protocol for sampling, notifications and imposing restrictions related to cyanobacteria blooms in lakes that are drinking water sources and recreational lakes (McCarron et. al., 2019). Briefly, an NSE Inspector is deployed to visually assess a report of suspected cyanobacteria bloom activity. NSE has different protocols for responses to blue-green algae response, depending on whether the surface water body is used as a municipal or registered drinking water supply, or whether it is used for recreational purposes. Given the focus of this report is primarily for surface water used for recreational purposes, according to McCarron *et al.*, 2019, for recreational waters, the Canadian Recreational Water Quality Guidelines are applied to determine when an advisory is issued. When NSE receives a report of a bloom, an inspector conducts a site visit to collect information on the users of the water body to assist with the public health risk assessment. If the inspector suspects a cyanobacteria bloom is occurring, a sample is collected and sent to the NS Department of Health for confirmation via laboratory analysis. If a cyanobacteria bloom is confirmed, notification protocols are triggered and the lake is posted, banning all activity. For recreational lakes, NSE does not have a policy in place for lifting a ban due to health risks from cyanobacteria once one is in place.

As it relates to NSE's involvement with water quality monitoring within the Province, NSE conducts long-term lake water quality monitoring in the Province and is a partner in active studies in the Carleton River and Mattatall Lake watersheds which have experienced cyanobacteria blooms occurring over two or more years.

Provincial Role in Monitoring and Maintaining Water Quality - During AECOM's February 4, 2020 consultation discussion with NSE, staff indicated that it is the Province's goal to have water available such that it can be used safely by members of the public. The Province has legislation that enables participation and allows other jurisdictions such as HRM to step in with regards to water resource management. Under provincial legislation, the Province regulates and enforces the release of a deleterious substance to water. In this case, releases of deleterious substances can come from point sources and non-point sources. There is a complaint process that can be acted upon however enforcement can be challenging for non-point sources as it can be difficult to attribute the cause of water quality impairment to a specific source or entity.

The Province provides support through provision of technical guidance to watershed planners, municipalities, and various provincial departments. NSE representatives indicated they are supportive of multi-stakeholder watershed management. There is a desire for such as an outcome-based management of the resource. Representatives of NSE, HRM and Halifax Water meet on a regular basis to discuss shared interests, issues, concerns and topics related to water resource management.

There may be future opportunities to make a recommendation for provisions under the Statements of Provincial Interest Regulations under Section 193 and subsections 194(2) and (5) of the *Municipal Government Act*, to include a statement of provincial interest on reference points on water quality and resource management.

On the topic of future stormwater quality guidelines, it was shared that the Province must be mindful of all municipalities and cannot impose restrictions that may be relevant to one but a burden to other municipalities. However, when changes are imposed at the Provincial level to municipalities, in general, a one-year period of advanced notice must be given.

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[15] *Atlantic DataStream website; accessed March 29, 2020; https://atlanticdatastream.ca/en/about*

4.1.3 Environment and Climate Change Canada

AECOM personnel met with Mr. Denis Parent of Environment and Climate Change Canada (ECCC) on February 4, 2020. ECCC conducts water quality monitoring in Nova Scotia as part of national programs for ECCC including the Maritime Coastal Basin Long-term Water Quality Monitoring Data program[16]) and the Acid Sensitive Lakes Study[17]

The Maritime Coastal Basin program includes river sites selected based on land use and to provide spatial coverage. Of the 13 sites monitored under this program in Nova Scotia, two stations are located within the HRM jurisdiction, the Little Sackville River at Middle Sackville and Sackville River at Bedford. Water quality has been monitored approximately monthly at these stations since 2006 to include a comprehensive suite of nutrients, metals, major ions, and other physical-chemical variables. At the Little Sackville River station, continuous measurements of pH, temperature, conductivity, dissolved oxygen and dissolved oxygen % saturation, are measured on an hourly basis. Continuous water quality monitoring has taken place at this station since 2006[18].

There are 3 flowing river systems and 4 lakes within Nova Scotia that are monitored by ECCC for water quality purposes in accordance with the minimum requirements for the Canadian Environmental Sustainability Indicators (CESI) Water Quality Index (WQI) program[19]. Mr. Parent noted that the 2016 to 2018 dataset was recently published.

Within Nova Scotia, Mr. Parent also noted that Parks Canada conducts some water quality monitoring activities.

4.1.4 Dalhousie University – Centre for Water Resources Studies

4.1.4.1 *Lobke Rottveel – Dr. Shannon Sterling Hydrologic Research Group*

On February 5, 2020 AECOM team representatives met with Ms. Lobke Rottveel, a graduate student within Dr. Shannon Sterling's research group within the Centre for Water Resources Studies at Dalhousie University. Ms. Rottveel's research focus is, 'Global patterns of Aluminum in Freshwaters". Her research has focused primarily on the effects of aluminum in freshwater bodies on the Atlantic Salmon population across Nova Scotia. She is also involved in a project with Halifax Water on lake acidification. Dr. Sterling is the Director of Dalhousie Hydrology Research Group and an Associate Professor in the Department of Earth Sciences within the Faculty of Science of Dalhousie University. Ms. Rottveel was asked to meet with AECOM representatives due to her knowledge and experience of research activities within Dr. Sterling's research group and also her experience working with water quality data management.

Key points taken from this meeting are as follows:

- As part of the research on the effects of aluminum in freshwater bodies on Atlantic Salmon, Dalhousie collects samples twice a year (spring and fall) from sixteen (16) rivers across Nova Scotia, which would be

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[16] *((https://open.canada.ca/data/en/dataset/b42b8484-95a2-4654-ad83-ebb2aa8407e3)*

[17] *(https://open.canada.ca/data/en/dataset/ac4d7703-1dee-4eb9-b71d-65bcd5427157*

[18] *(https://open.canada.ca/data/en/dataset/b42b8484-95a2-4654-ad83-ebb2aa8407e3).*

[19] CESI https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/water-quality-canadian-rivers.html#Classification

used as a representation of the watershed. ECCC collects these samples six (6) times a year. The parameters that are collected are general water quality parameters.
  - Dalhousie is interested in water quality monitoring data for water bodies within HRM where there would be Atlantic Salmon (i.e., Sackville River).
  - Ms. Rottveel's group uses water quality data obtained from the ECCC database.
- In relation to acidification, Dalhousie currently has a global freshwater acidification research base, and are looking for more data to add to it. There may be an overlap in this data in areas where HRM would be interested in sampling.
- In relation to water quality data management, Lobke Rottveel uses Python™, a 'high-level general programming language" [20], for the management of water quality data, where customized programming scripts are used for data management and the data is quality controlled.
  - Relating to the subject undertaking for HRM, Ms. Rottveel offered to show HRM representatives the scripts that she writes for her research purposes, that may be applicable for HRM.
  - Using this method, Ms. Rottveel shared that generation of data interpretation figures and tables are generated easily, for reporting purposes.

4.1.4.2 Dr. Rob Jamieson

AECOM team members met with Dr. Rob Jamieson on February 6, 2020. Dr. Jamieson is Professor and Canada Research Chair in Cold Regions Ecological Engineering with the Department of Civil and Resource Engineering at Dalhousie University. Dr. Jamieson is a well-known researcher on Nova Scotia lakes and a frequent advisor to HRM. He stated he found the 2006 to 2011 lakes water quality data collected by HRM to be a "gold mine". He was, though, unaware that additional data had been collected on behalf of HRM from 2014 to 2017 and indicated he would pursue these data. He stated that the data are of scientific value as they are rigorously collected and are directly related to lakes and to development.

He identified the need for HRM to invest in lake monitoring and resource management now as it would save money in the future by preventing limnological impacts such as presently afflicting Lakes Banook and Micmac. He suggested that Banook Lake could be used as a case study to illustrate how an absence of monitoring and managing the watershed has resulted in degradation of the resource and reduced economic benefit and value of the resource and surrounding properties. The lost real and intrinsic value of Lake Banook and its shoreline can only be overcome now at much greater cost compared to monitoring and protecting the resource historically.

Dr. Jamieson is continuing to work on Powder Mill Lake where algal blooms were a problem for a few years but have not recurred subsequently. He is also involved in a study within the Lake Mattatall area of Nova Scotia. Other work discussed included research relating to the development of a watershed and lake assessment tool to identify and manage risks for harmful algae blooms.

With respect to funding, Dr. Jamieson noted that he welcomes opportunities to work with the Province and HRM as he can leverage their funding through research organization grants.

4.1.5 Saint Mary's University

4.1.5.1 Dr. Linda Campbell

AECOM team representatives met with Dr. Linda Campbell, Senior Research Fellow within the Environmental Science Department at Saint Mary's University on February 5, 2020. The meeting was held at Dr. Campbell's office on campus. Dr. Campbell is a member of the Dynamic Environment & Ecosystem Health Research (DEEHR) group at Saint Mary's. The meeting discussion was three-fold: sharing the mandate and goal of this

[20] *Source: https://www.python.org/*

study, seeking to understand Dr. Campbell's research area of focus, and to help identify future potential areas for input and collaboration. Key discussion points are included below:

- Dr. Campbell provided information on her research area, as it relates to historical mining impacts and invasive species. A summary of the DEEHR team's research evaluating environmental and industrial issues within Nova Scotia, as presented on the DEEHR group website[21] is as follows:
  - Historically-contaminated sites – Dr. Campbell's group is studying the bioaccumulation and distribution of arsenic and mercury in living organisms across the Province to assess the potential risk of gold mine tailing wastes to aquatic ecosystems. Dr. Campbell has completed investigations within Lake Charles and within the Barry's Run area of Dartmouth, NS as it relates to the former Montague Gold Mine operations.
  - Non-native Species – Dr. Campbell provided information on her groups research on the non-native species, the Chinese mystery snail, as it relates to its presence in Nova Scotia and within the Lake Loon area of Dartmouth, NS. Dr. Campbell shared a draft poster presentation by graduate student, Sarah Kingsbury, with the AECOM team members, "Case study of Chinese mystery snail, *Cipangopaludina chinensis*, to evaluate potential applications of freshwater monitoring program datasets in Nova Scotia" (Kingsbury, et.al., 2020). As Ms. Kingsbury evaluated freshwater quality data as a part of her investigation, the meeting discussion was focused to the available datasets and monitoring parameters. Recommendations in the poster related to future water quality monitoring programs, were as follows:
    - Standardize the sampling effort. We recommend that all measured and non-measured parameters be carefully considered with respect to their ecological significance and relationships with other frequently measured parameters. A list of recommended water quality monitoring parameters could be published to unify water quality monitoring efforts.
    - Consistent spatial and temporal sampling program. We recommend a set of lakes and watercourses in different regions of Nova Scotia be prioritized and sampled regularly on a rotating basis with a consistent temporal schedule. These data should be shared with research groups and other stakeholders so all efforts can be aligned.
    - Support community/NGO groups to collect sonde/probe data consistently and regularly with a standardized list of priority parameters. This work is already underway through the Atlantic Water Network (https://atlwaternetwork.ca/). Regular consultations and workshops should be held to ensure all water quality sampling are in accord with local priorities and are complementary with other regions of Nova Scotia.
    - Training could be offered to community groups for water sample collection and preservation. These samples could be collected and sent to a Nova Scotia Government laboratory for analysis when funding becomes available.
- Dr. Campbell provided meeting follow-up correspondence with the AECOM team pertaining to Dr. Campbell and Ms. Kingsbury's recommendations for minimum sampling requirements for future water quality monitoring programs in a tiered approach, as follows:
  - Tier 1: Google Maps & Geographical Features -- available from government maps (morphology, landscape, boat access, roads, wetlands, etc.)
  - Tier 2: Basic water quality parameters available in most water quality multiparameter sondes and pocket testers: pH, conductivity, temperature, dissolved oxygen, (turbidity if available). They noted that salinity measurements from sondes is not recommended because how it is calculated internally in the sonde software varies with software and manufacturer and is always calculated from specific conductivity results. Specific conductivity is more consistent and can be used to calculate salinity post-measurement in spreadsheets calculations.

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[21] *Online Reference: http://www.ap.smu.ca/~lcampbel/research.html; Accessed March 28, 2020*

- Tier 3: Minimum laboratory analyses - phosphorus, nitrogen, chlorophyll, calcium, E-coli, chloride (for road salt). Detection limits are important – phosphorus (P) is typically naturally low in NS lakes, and if non-detects are common, then there needs to be infrastructure for more appropriate monitoring of P.
- Tier 4: Toxicant laboratory analyses for specific cases - arsenic (as a part of an ICP MS scan) and mercury, Microcystin-LR and anatoxin-a algal toxins. Especially if legacy gold mine tailing sites may be an issue (elevated As and Hg), which is already documented for parts of HRM and for lakes that are prone to regular bloom events.

Further, Dr. Campbell recommended including reference lakes as a necessary component of monitoring programs, where "problem lakes" need a comparison dataset to help with tracking issues. Dr. Campbell recommended the Blue Mountain - Birch Cove Lakes Wilderness Area as an opportunity for establishing a couple of reference lake sites in collaboration with community groups.

4.1.6 Atlantic Water Network

AECOM met with Emma Wattie, Director of the Atlantic Water Network (AWN), on February 5, 2020. The meeting was an in-person meeting held at Saint Mary's University. The AWN is a privately funded organization that provides equipment, training, and resources for water quality monitoring organizations and communities throughout Atlantic Canada.[22] Ms. Wattie provided information on that programs and support that is offered by AWN. Key information points are as follows:

- AWN is the regional-lead on Atlantic DataStream, an open-access hub for water quality data. Atlantic DataStream is a free, open-access data portal for water quality data. The portal stores water quality data of several of AWN's community partners. Atlantic DataStream is funded by a private charitable organization, The Gordon Foundation.
- AWN is also a regional partner for the Atlantic AquaHacking Challenge, a technology competition aimed at engaging young entrepreneurs and tech talent for innovative water solutions.
- AWN provides support to community groups by providing free access to its Environmental Monitoring Equipment Bank program, which lends calibrated water quality monitoring equipment to community organizations, similar to a library loan program. According to the AWN website, the Equipment Bank program is funded by TD Friends of the Environment, Environment and Climate Change Canada, Saint Mary's University Department of Geography and Environmental Studies and the Community Based and Environmental Monitoring Network.

4.2 Group Consultation – Community and Lake-Based User Groups

On February 5, 2020 AECOM hosted a stakeholder consultation meeting with local community and lake-based user groups. AECOM team representatives N. Doran, D. Gregor and J. Shea facilitated the meeting, which was also attended by HRM staff Jim Hunter, Environmental Performance Officer, and Thea Langille, Principal Planner – Rural Policy & Planning Applications.

The lake stewardship and community groups and representatives that attended the stakeholder meeting are included in **Table 4.** During the stakeholder meeting, it was brought to AECOM's attention that there were additional local and rural community and lake-based user groups from across HRM that could have been invited to participate. It should be noted that it was not AECOM's intention to exclude these groups in the stakeholder meeting. Due to the short duration of the subject study, a limited group of community and lake-based stakeholders were initially invited to participate in the meeting. During the time leading up to the meeting, additional groups who became aware of the meeting and asked to attend, were invited to-do so. Future efforts to engage community and lake-based user groups should include all known groups within HRM.

[22] *Atlantic Water Network Website; https://atlwaternetwork.ca/ Accessed March 27, 2020.*

A summary and key points from the meeting and feedback provided by participating lake-user and community groups is summarized in the sections to follow. At the start of the meeting, each community group was given the opportunity to introduce themselves and provide some details on their group. Participant introductions are appended to the full meeting minutes and both are included within **Appendix B**.

Table 4: Summary of Community and Lake-User Group Meeting Participants

No.	Community Association
1	Banook Area Residents Association (BARA)
2	Lake Charles Residents Group
3	Lake Mic Mac Residents' Association
4	Oathill Lake Conservation Society (OLCS)
5	Portland Estates and Hills Residents Association (PEHRA)
6	Sackville Rivers Association (SRA)
7	Shubenacadie Watershed Environmental Protection Society (SWEPS)
8	Williams Lake Conservation Company
9	Atlantic Division Canoe Kayak Canada

4.2.1 Community Group Profile Questionnaire

As part of the meeting with local community and lake-based user groups, in advance of the meeting, AECOM sent out a questionnaire to each group with select questions with the goal to gain a better understanding of each organization. The questionnaire was a data gathering exercise to understand if the groups are currently completing monitoring activities, and if so, details were sought on:

- frequency of monitoring;
- information that is collected;
- funding of these monitoring activities;
- how these data are shared/reported/interpreted;
- the coordination mechanism involved for monitoring information collection (i.e. sampling guide/manual, how many people are involved, etc.);
- additional lake management initiatives conducted by the organization; and
- any improvements that could be made to their sampling program.

A copy of the blank questionnaire is included in **Appendix B**. Responses were received from six (6) groups and this information is included in **Appendix B**. In addition to questionnaire responses, two groups (BARA and OLCS) submitted additional information which is also included in **Appendix B**. Key information submitted as responses to community profile questionnaires from the participating stakeholder groups is summarized in **Table 5**.

Table 5: Summary of Lake- User and Community Groups – Profile Responses

Group Name	Why Formed	Information Collected, Frequency	Funding	How Information is shared/reported/interpreted Coordination Mechanism for monitoring details	Additional Lake Management Initiatives	Improvements that could be made to their program
Lake Mic Mac Residents Association	Concern with the deterioration of our lake quality New organization formed within the past 6 months. Have a Steering Committee and Executive in-place, have developed an association charter with goals focused on lake health, education and coordination	Have not undertaken monitoring activities to-date and do not see this as a mandate of their organization Organization is trying to understand the data from existing sources.	No funding. No membership fees and are entirely volunteer. This group would like to be in a position to assist other organizations, on a volunteer basis with monitoring activities	n/a	n/a	n/a

Oathill Lake Conservation Society	Group organized due to the decline in the overall health of the lake including:
	• the loss of amphibians and eels
	• heavy stocking of rainbow trout in a put and take fishery, open year-round and creating an imbalance in the natural food web. Stocking attracted large numbers of fisherman in the days after stocking, causing damage to riparian areas.
	• user conflicts between anglers and swimmers and other recreational users
	• the final trigger was a sewage spill from an unknown source that closed the lake.
		<u>Information Collected:</u>
		• YSI and other sensors collect water quality information on a routine basis:
		  ○ YSI (pH, temp, DO-DO%, SPC, conductivity, salinity)
		  ○ Date, time, location, crew, depth
		  ○ Secchi disc reading
		• Water samples sent for chemical and biological analysis once or twice per year, if funds are available.
		  ○ AGAT – standard water analysis and metals scan. Coliforms in summer months.
		  ○ Timing for sample collection determined based on changes observed in YSI data. Surface and depth samples collected as required to identify source of the change.
		• Group works with Provincial fisheries to maintain an ecologically sound trout stocking program
		• Ad hoc observations on fish and wildlife use of the lake
		• Ad hock observations of recreational use of the lake
		• Ad hoc observations on road salting
		• Monitor activities in the riparian area
		• Monitoring invasive plant species in the riparian area
		<u>Frequency:</u>
		• During ice-free seasons, bi-weekly vertical profiles of the lake in 3 locations
		• Sample several storm sewer outfalls in the lake
		• During winter months, profiles and outfall sampling are repeated when it is safe to go on the ice.
			1) Volunteer basis
			2) Apply for grants for maintenance activities
			3) Member dues
				<u>Data Shared/ Reported/ Interpreted:</u>
				• On Excel sheets, emailed to volunteers
				• Access via Society web page
				• Atlantic DataStream
				<u>Coordination Mechanism, Number of People Involved, Guide/SOP for Data Collection?</u>
				• Volunteer
				• Varies, about 10
				• Data is collected using the standards from St. Mary's University Community Based Monitoring / Atlantic DataStream
					• Lake restoration – during ice free seasons, we operate an Aquago to circulate the water and improve oxygen levels in the lake leading to better trout habitat and less internal cycling of nutrients
					• Have had good success down to depth of 5 m and are making changes to extend this down to the deepest part of the lake, 8.5 m.
					• Have installed a storm water pond with vegetation to remove nutrients from one of the storm drain outfalls
					• Removal of invasive plants in the riparian areas
					• Provide access to the lake
					• Garbage clean up
					• Facebook, web page and yearly newsletter, public/ community awareness
						• Need some base funding to maintain equipment (YSI and Aquago) and funding to pay for water sample analysis at the lab.
						• Need coliform sampling as we have a lot of swimmers
						• The lake does not turn over in the spring most years due to road salt build up in the deep water. We need a solution.
						Oathill Lake Conservation Society also provided a report, on Recommendations for HRM's Lake and Watercourse Policy.
						Recommendations are grouped into four (4) main themes
						• Public Education
						• Storm Water Treatment
						• Maintenance and Development Policy; and,
						• Monitoring and Research
						A copy of this report is included in Appendix B of this report

Portland Hills and Estates Residents Association / Morris and Russell Lakes	• PEHRA has been in the community for 25 years. PEHRA was formed in 1990 as the Portland Estates Residents' Association (PERA) and changed its name in Fall 2007 to reflect the growth of the community and its widened mandate. • The association acts as an environmental watchdog, organizes community events (e.g. clean-ups, skating parties, summer	<u>Monitoring Activities</u> • Due to limited resources, monitoring only includes testimonial observations by residents • It is the group's position that due diligence monitoring is the responsibility of the elected governments and regulatory agencies, to either conduct analytical monitoring and study themselves or to provide resources to community groups to conduct the activity.	None. PEHRA is non-profit fully funded by paying memberships	<u>Data Shared/ Reported/ Interpreted:</u> • Association website and social media sites • Information shared within PEHRA committees to regulatory authorities, when required and to elected members	• Primarily are focused on public education through social media, information, signage, news, presentations, events, and outreach to regulatory authorities and elected officials. • In the past, PEHRA has conducted tree planting and worked Clean	• Analytical monitoring program to collect data frequently to assess lake condition and understand the impacts of human and weather-related events on the lake. Information to inform the residents and stakeholders about the human health and environmental

Group Name	Why Formed	Information Collected, Frequency	Funding	How Information is shared/reported/interpreted Coordination Mechanism for monitoring details	Additional Lake Management Initiatives	Improvements that could be made to their program
Conservation Committee	picnics, dances), and has built an extensive trail system. • To keep residents informed through our website and through quarterly newsletters delivered to all community households. • In the Fall of 2018 PEHRA formed a subcommittee of our Environment Committee to respond to the concerns of residents about significant negative changes in the conditions of Morris and Russell Lakes. The committee was named the Morris and Russell Lakes Conservation Committee.	Information Collected: • Testimonial observations of stream and lake conditions, e.g., weed growth, odours, algae blooms, sediment loads, suspicious activity. Frequency: • Based on lake usage, or during specific events (e.g., discoloration of the streams or lakes, swimmers itch, etc.)			Foundation to support Stream Restoration projects.	conditions of the lakes and streams. • Environmental study of the lakes and streams to understand the conditions, sources of impacts, and possible mitigation measures. • A source of resources and a multi governmental collaborative effort for the community group, either in the form of direct or indirect funding or human resources from the various government stakeholders.
Shubenacadie Watershed Environmental Protection Society (SWEPS)	SWEPS is a non-profit community-based organization concerned with the quality of life in the environment in the Shubenacadie Watershed. Their main focus is the headwaters of the Shubenacadie Watershed, concerned with water quality, habitat protection and trail construction.	Information Collected: • Quarterly water quality monitoring of lakes and streams in the watershed. • Water quality parameters collected using a YSI and water samples are collected and are sent to an external lab for additional testing. Frequency: Based on lake usage, or during specific events (e.g., discoloration of the streams or lakes, swimmers itch, etc.)	Typically, from external grants	Data Shared/ Reported/ Interpreted: • Information is posted on their website and data is shared with anyone who requests it. Coordination Mechanism, Guide/SOP for Data Collection? • Monthly meetings are held to plan activities. • Organization has equipment for testing which includes a basic standard operating procedure.	• Stream restoration • Habitat management • Monitoring of biodiversity • Maintenance of associated trails	None provided.

Sackville Rivers Association	Group formed as a group of concerned community members over the state of the Sackville River.	Information Collected:
		• River water quality data at nine (9) locations across the Sackville River Watershed. Data collected bi-weekly during summer months and otherwise once per month.
		• Biological data in the form of fish abundance is collected at several locations on a periodic basis.
		• SRA has a comprehensive Quarterly water quality monitoring of lakes and streams in the watershed.
		  ○ Lake sampling for Sandy Lake, McCabe. Sampling in Webber and Big Sandy lake to be initiated this year (2020)
		  ○ Lake and stream parameters: pH, temperature, dissolved oxygen, salinity and conductivity. Measurements taken at depth in lakes.
		  ○ Fish abundance collected by electrofishing
		• Water quality parameters collected using a YSI and water samples are collected and are sent to an external lab for additional testing.
			Funded through general revenues, primarily donations.	Data Shared/ Reported/ Interpreted:
				• Data is shared via Atlantic DataStream and St. Mary's University Atlantic Water Network.
				• Most recent comprehensive data review and interpretative report was in 2016.
				Coordination Mechanism, Guide/SOP for Data Collection?
				• Board of Directors established a monitoring plan, which is implemented by the SRA coordinator and summer work crew.
					None.	• Continued stream sampling with increased parameters – nutrients and contaminants
						• Better characterization of fish populations
						• Rain induced runoff sampling
						• Lake water quality measurements
						• Invertebrate sampling.

Williams Lake Conservation Co.	Ongoing stewardship of lake and its shores for maintenance of water quality and local ecology.	Information Collected: • Annual monitoring of minerals (iron, manganese and mercury in particular. *E-coli and coliform bacteria* – three (3) times per year.	WLCC funds	Data Shared/ Reported/ Interpreted: • Executive meetings and membership meetings	Lakeside monitoring Community education	• Moratorium on lakeside development pending complete environmental review of lake health and watershed stress

Group Name	Why Formed	Information Collected, Frequency	Funding	How Information is shared/reported/interpreted Coordination Mechanism for monitoring details	Additional Lake Management Initiatives	Improvements that could be made to their program
	Area extends to parkland and backlands.	• Ecological monitoring • Water flow, conductivity, (dissolved) oxygen		Coordination Mechanism, Guide/SOP for Data Collection? • Annual general meeting report • Newsletter report	Engaging Council members	• A responsive department in HRM that enforces existing bylaws affective riparian zones, watersheds, roads • Review of lake and lakeside ecology.

In summary, based on the responses received, when asked why they decided to organize as a group, most groups indicated they organized because they were concerned about the quality of the life and environment within their lakes. Some of the organizations have been established for several years (i.e., Sackville Rivers Associations (SRA), Shubenacadie Watershed Environmental Protection Society (SWEPS), Banook Area Residents Association (BARA), Oathill Lake Conservation Society (OLCS), Williams Lake Conservation Company (WLCC)), and some newer groups have formed over recent years (Lake Charles, Lake Mic Mac Resident's Association, Morris and Russell Lakes Conservation Committee (sub-committee of Portland Estates and Hills Residents Association (PEHRA)).

Most of the groups are currently undertaking monitoring activities at their lakes or in the case of SRA, watercourses. In general, activities include monitoring (mainly during the ice-free seasons) ranging from bi-weekly to annually. The YSI is used to collect water quality parameters (i.e. temperature, dissolved oxygen, salinity, conductivity, pH, etc.). Some groups monitor specific data relevant to their lakes (i.e. metals, nitrates, phosphates, etc.), and if funding is available, some groups complete sampling for metals scans and coliform samples and submit these for analysis at a qualified laboratory. PEHRA's monitoring activities, due to limited resources, include testimonial observations by residents, and Lake Mic Mac Residents Association have not undertaken any monitoring activities to date.

For those groups currently undertaking monitoring activities, funding is sought through external grants, membership dues, donations, while members undertake activities on a volunteer basis. None of the participating groups indicated they receive funding from provincial or municipal sources.

Four groups (BARA, SWEPS, SRA, and Oathill Lake Conservation Society) are currently sharing their data on Atlantic DataStream. Others are sharing their data through group webpages and will send their data to volunteers and those who ask for it.

The coordination mechanism involved for some of the monitoring programs involve meetings where a Board of Directors or group members will come together to establish a monitoring plan, which would then be implemented by volunteers within the group. However, it is noted that not all groups undertake monitoring activities.

Other lake management initiatives communicated by the participating groups include stream and lake restoration, habitat management, monitoring of biodiversity, removal of invasive plants in riparian areas, garbage cleanup, maintenance of associated trails, community education, engaging council members, and social media (web page, Facebook, yearly newsletters).

When asked what each group would like to implement that would improve their program, the following responses were received:

- Monitor more often, with more sites, and a larger suite of collected data across more water quality parameters (including coliform sampling, invertebrate sampling, rain-induced runoff sampling).
- Monitoring of lakeside development pending a complete environmental review of lake health and watershed stress.
- Frequent collection of data to assess lake condition and understand the impacts of human and weather-related events at each lake. Information to inform the residents and stakeholders about the human health and environmental conditions of the lakes.
- Base funding: to maintain equipment (e.g. YSI™ water quality meters and in the case of OLCS a solar-powered devise, an Aquago, that is equipped with a propeller to draw water from depth and to surface to promote mixing) and to pay for lab fees associated with water sample analysis.
- A responsive department within HRM that enforces existing bylaws affecting watersheds, riparian zones, and roads.
- A source of resources and a multi-governmental collaborative effort for the community groups, either in the form of direct or indirect funding or human resources from the various government stakeholders.

4.2.2 Break-out Group Discussion and Focused Questions

During the second half of the meeting, meeting participants were divided into two (2) separate groups with the intention of mixing meeting participants from individual lake stewardship groups. An AECOM representative was also present to help facilitate the group discussions. A series of questions were posed to each group and responses were captured by a designated meeting note-taker. The questions posed to each group were as follows:

1. What do you see as the Water Quality Monitoring Priorities in HRM?
2. How can HRM collaborate and coordinate with community and lake user-based groups?
3. What can Community and Lake-User Based Organizations offer to HRM to Assist/Support HRM in Achieving their Mandate?
4. Do you have knowledge of other Municipalities within Canada that conduct Municipal-led Monitoring?
5. How can HRM more effectively Communicate Information relating to Water Resources?

Once completed, the two (2) groups came together to share and discuss responses in a round table setting. A summary of the compiled key responses from meeting participants is summarized in **Table 6.** These responses are reproduced directly from feedback from attendees and do not necessarily reflect the position of AECOM or the authors of this report.

Table 6: Summary of Group Break-Out Questions and Compiled Responses

Question 1: What do you see as the Water Quality Monitoring Priorities in HRM?
Overall lake health / quality of the lake: this was the most common response from the stakeholders as the highest water quality monitoring priority within HRM. The responses included issues such as phosphorus loading, urban development, *E. coli*, blue-green algae, sediment issues, weeds, salt loading from roads, hard surface runoff and overall lake health. **Enforcement of existing bylaws / following standardized guidelines**: another common response heard from the stakeholders was around the enforcement of existing bylaws, federal/provincial regulations, and development plans. Additional noteworthy responses were as follows: • Following standardized guidelines while completing sampling; • Climate change effects; • Human health issues; • Stress modelling by lake; • Watershed mapping; and • Storm water control.
Question 2: How can HRM Collaborate and Coordinate with Community and Lake-User Based Groups?
Committed HRM office: one of the top responses from the meeting participants was around the development or set up of a separate office within HRM that would be a committed, responsive body to all lake health issues. The meeting participants would like to see this as an office where each group could work and communicate regularly with, including collaboration with regular meetings and information exchange. The meeting participants would also like to see HRM take a lead on standardizing the monitoring methods and data to be collected from the lakes, including sampling forms and standard operating practices. **Provide funding:** another top response from the meeting participants was for HRM to provide funding to each group. Examples included lab funding and budgets for groups to do regular testing, providing lake specific grants to allow for summer students from local universities to help, and to sponsor citizen-based science efforts in the communities.

Additional noteworthy responses were as follows:

- Effective regional watershed advisory board;
- Lot user charges to be allocated to monitoring as it relates to development;
- Regional breakout of lake stewardship groups to be led by HRM councillors; and
- Consult all stakeholders across HRM.

Question 3: What can Community and Lake-User Based Organizations offer to HRM to Assist/Support HRM in Achieving their Mandate?

Provide expertise / volunteer: the response from the meeting participants with what they could offer to HRM to assist and support HRM was clear – they would be able to provide volunteer support and guidance. There is a will to do something within these groups, and they would be able to provide "salary free" sampling (that is, sampling services whereby the person who collects the sample is not financially compensated, therefore the samples are collected only 'at cost', of the laboratory analysis itself), help to identify problems by providing day to day observations, advise on current lake issues and suggestions for improvement, and provide a local point of contact for each lake.

Question 4: Do you have knowledge of other Municipalities within Canada that conduct Municipal-led Monitoring

The following examples were given of other municipalities that conduct municipal-led monitoring within Canada:

- Hamilton, ON – blue green algae and groundwater testing;
- Muskoka ON, Halliburton, ON, Lake Simcoe, ON;
- Newfoundland - live water monitoring program (i.e., real-time monitoring ; and
- Quebec - municipalities have programming as well.

Question 5: How can HRM more effectively Communicate Information relating to Water Resources?

Reporting: Publish periodic or annual reports detailing water quality by watershed. Community groups to be able to review and provide feedback respecting the technical information presented in these reports and speak up with respect to the results of these reports.

Centralized website: Centralized website – needs to be easily accessed.

Open data sources: Open-data sources where groups can access and upload data; or consistently use Atlantic DataStream.

Communication: Direct communication and education between HRM and those on the lake. Improve the 311.

Question 6: Is Implementing more effective Mitigation Programs more important than Monitoring?

The group consensus was no. The meeting participants made it clear that they believe that one cannot exist without the other. Mitigation must be effective, you cannot just stop monitoring once you theoretically address the problem, and without monitoring, it would be difficult to justify anything. Enforcement should exist for both mitigation and monitoring programs.

4.3 Summary of Key Points from Stakeholder Meetings

Table 7 below provides a summary of key comments from the stakeholder meetings between AECOM representatives and government, academic, local and community-based groups.

Table 7: Summary of Key Comments from Stakeholder Meetings

Discussion Comments	Gov		Academic			Local		Explanatory Notes	Key Observations from Interviews
	NSE	ECCC	RJ	LR	LC	ADS	LBCG		
Making data accessible and readily available	X	X			X			NSE data available on Open Data NS and working with Atlantic DataStream, King's County issues annual report card, Sudbury and Carleton River Watershed prepares an annual report, Muskoka prepares a report card every 4 years, NSE and ECCC provide their data to ADS. Lake-based and community groups seeking data accessible. Some groups use ADS.	HRM does not have an active forum currently to make data available to the public. However, we understand some historical data has been recently uploaded to ADS. Future water quality data collected by or on behalf of HRM should be made available to the public.
Interviewee plays an advisory role to HRM	X		X					NSE provides advice as needed, however mainly regarding development monitoring and recreational monitoring. NSE plays an active role with monitoring for blue green algae only with respect to drinking water. Dr. Rob Jamieson provides advisory expertise, generally on a project basis.	HRM should continue to engage and leverage advisory input from external water resource professionals.
Multi-stakeholder approach to monitoring/managing recreational lakes	X						X	NSE provides technical support, agriculture and Municipal Affairs are relevant but limited involvement.	HRM should continue to support multi-stakeholder management of water resources.
NSE undertakes initiatives with special funding for projects that are considered as "pilot projects" within a single municipality but relevant to all municipalities	X							Province does not directly support a single municipality even though HRM is unique.	Municipal representatives should continue to pursue provincial support for management needs that may be unique to HRM as the only municipality in the Province with an extensive urban built environment.
Leveraging funds students/researchers to fill knowledge gaps	X		X	X	X			Academics also support this. 2:1 leverage on all funds using Natural Sciences and Engineering Research Council (NSERC).	Support for graduate students to address specific issues that require further investigation should be considered by HRM. HRM should continue to pursue financial and technical support through leveraging funding opportunities and research.
NSE suggests a different vision, rather than setting specific standards, should set broader outcomes to be met	X							NSE vision would be broader and rather than setting water quality objectives (e.g. TP) that broader management goals or outcomes would be desirable (i.e. maintaining trophic state based on multi-parameter-based objectives).	
NSE provides limited guidance on storm water management policies and this is under review	X							This is almost exclusively relevant for HRM within the Province.	NSE should be prepared to address issues highly relevant to HRM over and above other municipalities. NSE should be fully aware of the discussions between HRM and Halifax Water so that they can fully support these efforts.
ECCC does not collaborate with municipalities but does undertake projects relevant to municipalities - e.g. new guidelines for metals in SW		X						At present, these projects are not specifically located within HRM.	

Discussion Comments	Gov		Academic			Local		Explanatory Notes	Key Observations from Interviews
	NSE	ECCC	RJ	LR	LC	ADS	LBCG		
Chemical monitoring plan for emerging contaminants and metals		X						Provides guidance to municipalities	
Canadian Environmental Sustainability 2017-2018 report just published		X						Perhaps relevant sections to HRM	
Little Sackville River automated sampling program only work within HRM - 2006 to present		X						Connections relevant with Sackville River Association monitoring activities which seems to be focused on spot monitoring with YSI instruments (pH, SC, Temp, DO)	
Reporting of HRM data in open data format and provide summary reports (report cards) to users and public		X	X	X		X	X	Dr. Jamieson was not aware of HRM sampling on lakes between 2015-2017 and yet had used earlier data extensively.	Another demonstration of how critical making data available to the community including researchers is critical to the success of a monitoring program. Future water quality data collected by or on behalf of HRM should be made available to the public.
Certification of samplers by providing training and standardized procedures including equipment calibration		X	X			X	X		
Legacy contamination from mining - Hg, methyl-Hg, arsenic					X			Some relevance to HRM sampling - possible issues with respect to liability as a result of using students on projects.	
E. coli should be a basic component of monitoring					X		X		
Concern about placing public data into a quasi-private entity (i.e. Atlantic DataStream) that owns the data but may not exist if funding expires			X					This was the one concern expressed re. using Atlantic DataStream as the main storage and retrieval system.	
Blue - Green algae							X	HRM spending considerable money on this with little support from senior governments.	
Consistent funding for laboratory analysis of water samples							X		
Strategic sampling plan based on objectives of sampling - huge differences across HRM			X				X		
More cost-effective to monitor and mitigate in advance rather than trying to restore after serious impact (e.g. Banook and Micmac)			X				X		
Awareness of all activities - HRM should fund a periodic "workshop" to bring academics, agencies and public user groups together to develop cooperation and awareness			X		X	X	X		

Notes: NSE = Nova Scotia Environment; ECCC = Environment and Climate Change Canada; RJ: Dr. Rob Jamieson; LV: Lobke Rottveel; LC: Dr. Linda Campbell; ADS = Atlantic DataStream; LBCG: Lake-based and community groups.

5. Stormwater Management and Development Agreements

5.1 Current Status - Stormwater Management

Managing stormwater within HRM has principally been the purview of the Halifax Regional Water Commission, also known as Halifax Water (2016). The design criteria contained in Halifax Water (2016) illustrate the more common aspects encountered in the design of stormwater systems. Any stormwater system within the core service boundary of HRM shall be designed to achieve the following objectives:

i. to prevent loss of life and to protect structures and property from damage due to a major storm event;
ii. to provide safe and convenient use of streets, lot areas and other land during and following rain and snow melt events;
iii. to adequately convey stormwater flow from upstream sources;
iv. to mitigate the adverse effects of stormwater flow, such as flooding and erosion, on downstream properties;
v. to preserve natural water courses;
vi. to minimize the long-term effect of development on receiving watercourses; and,
vii. to provide safe, accessible outlet.

Only items v and vi above make any direct reference to the protection of the natural water systems and the broader and long-term implications of stormwater on the natural receiving waters which is the focus of this document. It is noted in Halifax Water (2016) that the guidance therein is to provide minimum design standards which should not hinder the application of newer practices or carefully evaluated innovative approaches to stormwater management. This will be the focus of **Section 7.2**, whereas this section will consider the recent development of a more comprehensive approach to stormwater management within HRM.

5.1.1 Current Stormwater Management Planning

A stormwater management plan (SWMP) under Halifax Water (2016) is to be prepared and included as part of the submission for any land development to deal with stormwater and drainage issues related to the development. At a minimum the stormwater management plan will include the design criteria for the 1 in 5, 1 in 10 and 1 in 100-year events as per the "Design and Construction Specifications, Section 6.0 (Stormwater System) where applicable".

Two levels of stormwater drainage systems are considered. The minor stormwater drainage system typically consists of lot grades, ditches, back yard/side yard swales, roof leaders, foundation drains, gutters, catch basins (and other inlet structures), manholes, stormwater systems and culverts. The minor system is required to be designed to convey the 1 in 5 year storm without surcharge (Halifax Water, 2016). It follows that the major stormwater drainage system is designed to cover the downstream portion and to convey the 1 in 100 year storm event. The major systems include natural streams, valleys, swales, man-made channels, roadways, ponds, and watercourses. Halifax Water (2016) further notes that existing water and drainage courses shall be left in their natural state and alterations to watercourses and wetlands are subject to approval of Nova Scotia Environment (NSE). Interestingly, the next paragraph adds that "*Not withstanding the above {the flow routes} shall be sized to convey the appropriate storm event*" (Halifax Water, 2016).

As specified in Halifax Water (2016) the SWMP is to include drainage plans and detailed runoff calculations. Included in the runoff calculations will be information showing sub-watersheds, rainfall abstraction, antecedent moisture conditions and schematization of the system for pre- and post-development and all stormwater management alternatives. The product of the calculations will show the main steps of the calculations and the peak discharge at key points in the system.

The SWMPs are required to be an integral part of overall site design and development thereby requiring the development of an erosion and sediment control plan (ESCP) consistent with applicable municipal and provincial regulations and guidelines (Halifax Water, 2016; NSE, 1988). The ESCP is required to include both short-term measures applicable during construction and long-term measures after completion of development. Existing topography and vegetation shall be considered in the site design and cut and fill operations should be minimized. Site design shall consider minimizing if not preventing surface water flows across or from the construction site through considering the following at a minimum:

- Construction staging to expose a minimum area of the site for the minimum time;
- Interception & diversion ditches to direct clear water around the construction site;
- Stable diversion berms;
- Sediment traps;
- Covering or seeding of topsoil or other soil stockpiles;
- Isolated stripping of land being developed;
- Vegetation screens or buffers;
- Filter bags in catch basins (during construction only); and,
- Settling ponds.

Halifax Water (2016) also recommends long-term environmental protection measures shall include designs to minimize erosion and sediment flow, protect outfall areas, minimize disruption of natural water courses, utilize wetlands for natural filtration, and provide for ground water recharge when possible. Although required to follow the ESCP Handbook, HW does not provide specific details or objectives regarding erosion control and protecting the natural environment are not provided and are presumably left up to the developer.

5.1.2 Development of Stormwater Management Services

Prior to 2007, wastewater and stormwater services in Halifax were not regulated services pursuant to the *Public Utilities Act* ("PUA") but were furnished by the Municipality (HRM) and none of the wastewater and stormwater services provided by HRM were subject to the jurisdiction of the Nova Scotia Utility and Review Board (NSUARB) (NSUARB, 2017). In 2007, at the request of HRM and HRWC, the *Halifax Regional Water Commission Act* was amended, in part, such that the *PUA* applies to both the Commission and any water, wastewater or stormwater facility or system owned, operated, managed or controlled by the Commission for service to the public and therefore is deemed to be a public utility within the meaning of that Act. Thus, the Legislature of the Province of Nova Scotia determined, as a matter of public policy, that HRWC may operate a wastewater and stormwater system and that such a system would be subject to regulation by the Board pursuant to the PUA. At that time HRWC then agreed to assume responsibility for the wastewater system and stormwater system and by Motion of Council dated May 29, 2007, HRM agreed to transfer to HRWC its wastewater system and stormwater assets pursuant to a Transfer Agreement dated June 12, 2007.

In due course, HRWC developed for approval of the NSUARB (NSUARB, 2017) a Cost of Services (COS) Manual for stormwater which included a cost to HRM, like any other stormwater customer. This charge was based on the surface area of the rights of way owned by HRM. HRM argued unsuccessfully before the NSUARB, that the transfer of wastewater and stormwater services to HRWC was done in the public interest and the levied charges defeats or violates the public interest. In turn the NSUARB found that public confusion was the result of the manner in which HRM chose to fund its stormwater rate obligation which was added as a specific charge to the tax bill. The Board clearly indicated that while it is up to HRM how they choose to bill their users for a stormwater user charge, the proposed HRWC rates and the methodology for determining these rates for Site Related Flow Charges for residential and non-residential customers are reasonable and appropriately address the related revenue requirements, and accordingly, ordered that the charges be implemented (NSUARB, 2017).

Importantly, in 2017 the Board approved the proposed HRWC stormwater service charge exemptions and the stormwater credit program as developed by HRWC for non-residential customers, including HRM. The intent of this credit program was to encourage stormwater users including HRM to pursue BMPs to reduce their loading to the stormwater system by managing stormwater to the extent possible on their own sites, including roadways. The approved credits to the stormwater service charges are to have the following characteristics:

a) Available to any customer who pays the non-residential rate;
b) Available to HRM;
c) The credit range is 30% to 50% of the normal stormwater charge for the property;
d) To earn the minimum credit, the private stormwater management system must be sufficient to handle a one-in-five year storm. Any private system that does not achieve this minimum is not eligible for a credit;
e) Customers that share a private stormwater management system are proportionally eligible to receive the credit;
f) The credit is not available for those customers that discharge to a combined sewer; and
g) There is no credit for any private stormwater management system based solely on the treatment of stormwater quality.

Further, the Board accepted the proposal that in order to be eligible for the credit, a customer must apply annually and confirm that the stormwater management system has been maintained and cleaned and that HRWC can check compliance. In short, a Settlement Agreement between HRM and HRWC encourages the adoption of stormwater BMPs with a stormwater credit system as presented in **Table 7**. Some issues that still need to be clarified in the Settlement Agreement include:

- What BMPs are eligible under the stormwater credit system;
- How stormwater detention facilities/BMPs designed to standards other than those identified in Section 1 of the Settlement Agreement will be assessed;
- Stormwater credit application requirements, including:
  - Application form format;
  - Frequency of application;
  - Supporting documentation;
  - Operation and maintenance requirements to ensure stormwater credit system compliance;
  - How often HRWC staff will inspect stormwater detention facilities/BMPs to ensure compliance with the stormwater credit system;
  - Enforcement actions;
  - How properties that share stormwater detention facilities/BMPs will be allocated stormwater credits;
  - The billing cycle for stormwater credits;
  - How HRWC will make residential customers aware of the opportunity and requirements to take advantage of the stormwater credit system;
  - How a residential customer could apply to switch to non-residential status; and,
  - If a residential customer has not maintained the private system, how they will be charged for the coming billing period.

Halifax Water has proposed five levels of credit matching the specific storm return periods (5-, 10-, 25-, 50-, and 100-year). The designs would ensure that that specific return period flow and all lesser flows are discharged at a rate not exceeding the 5-year pre-development flow. **Table 8** from NSUARB (2017) gives information on the five credit levels. Vol/Vol5 is the outcome of an example calculation for a one-hectare detention pond for a 100% impervious parking area and is the storage volume ratio of the designed pond volume to the minimum 5-year level 1 credit storage volume. The storage increments are similar and the credit increments are each 5%. The Level 5 credit for detaining the 100-year storm would provide a 100% credit of the credit available charge (i.e. all of the credit available charge is given as credit not the total charge).

Table 8: Stormwater Management Credit System Adopted between HRM and Halifax Water

Credit Level	Year Storm	Released as PreDev	% Credit	Vol/Vol5 (%)
1	5	5	30	100
2	10	5	35	130
3	25	5	40	170
4	50	5	45	201
5	100	5	50	233

This NSUARB decision has led HRM and HW to the Integrated Stormwater Management Policy Framework discussed in Section 5.2.3.

5.1.3 An Integrated Stormwater Management Policy Framework

Since 2013, HRM and Halifax Water have been working on developing an integrated stormwater management policy framework (ISMPF) (Halifax, 2017). The ISMPF has now been approved by the HRM Council in December 2017 and by the Halifax Water Board of Commissioners in January 2018 (pers. comm., O'Connell, S. 2019) The stormwater policy gives specific regard to the following outcomes:

- Prevent loss of life and property damage due to major storms events;
- Efficient and effective work management processes, with a clear delineation of responsibilities between the Municipality and Halifax Water;
- Safe and convenient use of streets and other land areas before, during, and after storm events; and,
- Mitigation of the long-term impacts of development on natural systems and downstream properties.

To address these outcomes, the ISMPF is structured around four main issues or themes:

- A capital investment strategy for stormwater infrastructure to be based on a flood risk assessment of areas prone to flooding;
- Ownership and maintenance of stormwater systems wherein work management rules have been documented to reflect the responsibilities of the Municipality and Halifax Water;
- Land development practices (see further discussion below); and,
- Drainage on private properties has led to business processes between the Municipality and Halifax Water that triage and respond to complaints.

In the context of this report, further consideration of the proposed land development management practices is warranted. In brief, HRM carries responsibility for reviewing land development applications and approving subdivision grading and stormwater management plans, whereas; Halifax Water's role is to review and approve the design of stormwater systems that will be owned and operated by Halifax Water. Halifax Water, as noted above, focuses largely on managing "*peak discharge*"; whereas HRM policies are broader, relating to watershed planning, floodplain protection, and development standards such as best management practices, wetland protection and riparian buffers, as addressed within the Regional Plan (2014). Better integration of these responsibilities is the goal of the ISMPF and HRM and Halifax Water have worked together to develop a program for stormwater quality which would include the development and administration of joint design and construction standards, and the possible development of a credit for water quality as part of best management practices described in the stormwater credit program.

As noted in the Halifax (2017) report, significant regulatory gaps exist relating to development standards and approvals. HRM has relevant policies that are evolving with site specific development agreements that attempt to predict and minimize the numerous land-based impacts associated with urbanization without controls, including water quality impacts. HRM recognizes that watersheds are the fundamental unit for understanding impacts on water resources, and that water, soil, vegetation, and habitat are all connected. Managing impacts at the source will help to address the downstream impacts that are historically the purview of Halifax Water. To further this, the Regional Plan requires watershed studies in advance of secondary planning in order to establish *"… background water quality, predict impacts of development on water quality, influence community design, and provide a framework to monitor impacts"*. Ideally, these watershed-based studies, including land suitability analyses, will have a direct influence on community and site design which will mitigate the impacts of the development through avoidance of steep slopes and erosion prone soils, protect floodplains, provide adequate riparian buffers, map, avoid and protect wetlands and other significant natural features. In short, the report concludes that *"… There is growing evidence to suggest that a stormwater by-law which regulates site design features promote control of stormwater at source is more effective than public infrastructure at protecting water resources"* and this is being reflected in the development of the "*Joint Stormwater Standards*".

Some policies related to the Joint Stormwater Standards that are currently under development (pers. comm., O'Connell, S., 2019) include:

- The draft standards developed focus on large scale developments on private property. The requirements in these standards indicate that a new property must retain the first inch of rainfall on site, as well as remove 80% TSS, using green stormwater infrastructure. These standards will be backed by a new by-law (described in the next bullet point) and will be triggered with development permits;
- A new by-law is in the works with respect to grade alteration and stormwater management which will include as an appendix, the joint stormwater standards developed between HRM and Halifax Water enforced by the by-law. This work is expected to be completed in 2020;
- As part of the Municipal Design Guidelines (Red Book) update, a chapter on updated stormwater standards that apply to public right of way will be included. These standards will also focus on reducing the quantity and improving the quality of stormwater runoff using Green Infrastructure. This is expected to be completed in September 2020; and,
- HRM has begun to incorporate green infrastructure into new road upgrade projects. The objective of these pilot projects will help demonstrate working methods for managing stormwater runoff quantity and quality and will incorporate testing and monitoring to collect locally relevant data on the effectiveness of mitigation and best management practices.

5.2 Development Agreements – Existing and Planned

Progress is being made in the development and implementation of the ISMPF. Much of the progress from the HRM side has come from the site-specific development agreements that have been negotiated with proponents in advance of development projects. These will be briefly reviewed here with emphasis on the monitoring requirements of the development agreements in order to show the evolutionary nature of the monitoring programs from monitoring receiving lake water quality to the incorporation of managing water quality and quantity issues on site through stormwater mitigation measures.

Through development agreements with HRM, it has become standard practice to undertake baseline, construction and post-construction water quality monitoring on previously undeveloped lands. As noted by Stantec (2010), consistency is lacking in relation to data collection methods and the timing of sampling events. In addition, the initial agreements focused on monitoring of the receiving waters often some distance downstream of the construction activity which made it difficult to attribute a change detected in the monitoring to a specific action or oversight of the developer. These early agreements did not sufficiently detail requirements to manage water quality and quantity leaving the development site. This fortunately has evolved with the newer development agreements. An overview of the progression of development agreements has been provided for Russell Lake Development West, Morris Lake, the Bedford West Secondary Planning Strategy the Port Wallace Secondary Planning Strategy and the River Lakes Secondary Planning Strategy in Section 1.1 of **Appendix C**

5.3 Monitoring Associated with Future Developments

The evolution of stormwater management over the past 20 years is evident in the discussion in the discussion above. Gradually there has been a migration away from the objective of preventing "*loss of life and to protect structures and property from damage due to a major storm event*" (Halifax Water, 2016) as discussed to an increasing emphasis on better control of stormwater at source and simultaneously protecting the natural environment from both quantity and quality perspectives. This has been in part implemented through development policies that apply to specific growth areas within the Region as well as the adoption of initiatives to document background water quality, predict impacts of development on water quality, influence community design, and provide a framework to monitor impacts within the Regional Plan. The ongoing development of the Joint Stormwater Standards under the integrated stormwater management policy framework between HRM and Halifax Water will support the management of stormwater and the protection of the natural environment. Nevertheless, HRM and Halifax Water will need to address the long-term maintenance of BMPs and LID technologies on public property.

However, in the context of this report, a challenge remains for elaborating on the policies and framework for lake water quality monitoring. Observations based on the Bedford West Secondary Planning Strategy as well as the other documents reviewed in **Appendix C**, provide guidance for maximizing the benefits that could be expected from secondary planning strategy monitoring programs. These are built on the assumption that a lake monitoring framework as discussed and presented in **Section 7** of this report, is implemented.

Significant lessons can be learned for the design of future development agreement monitoring programs. Importantly, the success of a monitoring program for development agreements depends on a clear objective that directly links impacts of development to effects on receiving waters. Consistency and transparency, to the greatest extent possible, are essential to gain the support of the developers by demonstrating that all are treated fairly, and they have full, advanced awareness of expectations. Transparency also assures this and has the added benefit of demonstrating to the community that Halifax is protecting the natural water systems from development impacts. For example, this was an objective of the River-Lakes PNLA, whereby developer applicants were required to prepare and submit technical documents (i.e. phosphorus net loading assessments, erosion and sediment control plans and stormwater management plans), specific to the development demonstrating there would be no net increase in phosphorus exported from the site, in advance of any development agreements being issued. The PNLA was presented as a policy available to all.

Importantly, it is concluded here that development agreement-based monitoring programs should be restricted to establishing existing conditions and effectively measuring impacts of the development and the benefits of the BMPs and LID practices incorporated into the development plan. Development agreements should not be conflated into the lake monitoring programs. Accordingly, it is proposed that HRM consider that:

> **Any monitoring program designed to assess the impact of development or the effectiveness of mitigation measures including BMPs and LID should not be used as a replacement of well-planned and ongoing lake monitoring programs. Development agreement monitoring programs must be used to measure the effectiveness of these planning initiatives in order to demonstrate their benefits.**

For development agreement monitoring initiatives to be effective, sufficient expertise and technical support at the municipal level is necessary to adequately design, evaluate and assess, and provide both technical and plain language reports on monitoring programs undertaken within development agreements. The municipality needs to assure timely consideration of applications from an impact monitoring perspective when negotiating development agreements and to ensure timely and adequate documentation of the value of the monitoring program. The Municipality should:

> **Enhance the staff complement to ensure sufficient resources are available to provide the necessary input to the design of the monitoring program. The staff may also provide the technical and plain language reporting or provide effective oversight of this reporting by others as reporting is critical to obtaining the ongoing support from HRM Council, citizens and developers;**
>
> **If reporting is to be contracted out, HRM staff need to ensure that expectations are clearly specified and followed, and that preceding reports and data are effectively considered, and analytical methodologies are consistent and relevant to the available data and the purpose of the monitoring.**

Finally, and it is worth repeating again, the monitoring data and reporting must be shared in a timely and effective manner both satisfying technical quality as well as providing plain language documentation of the effectiveness of the monitoring program and how these monitoring programs are benefiting the broader environment (i.e. lakes) and the people of the entire community. Lake associations and environmental interest groups need access to this information. Critically, HRM Council and the citizens of the municipality must be provided with the opportunity of understanding the outcomes of this monitoring and how this investment is benefitting all in the community through plain language reporting. Reporting is essential and is discussed further below in Section 8.4.

5.3.1 Policy Overview

To date, the policies that have been implemented for new development agreements have tended to be standalone policies addressing a specific location or addressing an evolutionary understanding of appropriate requirements to protect the environment. This approach satisfies technical experts and aligned community groups but what seems to be lacking is the philosophical understanding that provides a "value proposition" for the community as a whole. A value proposition or statement for the community development agreements and even water resource monitoring in general, must go beyond protecting the environment. Rather, it must demonstrate how socio-economic and cultural community values are protected and enhanced through specific environmental policies related to ongoing and future developments.

The Province of Nova Scotia published a provincial water resource management strategy (see Section 1.4.2) (Nova Scotia, 2010). This was a 10-year plan for guiding the management of water resources within the Province of Nova Scotia to 2020. The strategy is said to create a framework to manage competing demands for water and protect its quality and availability for future generations. The intent of the water strategy was to "*guide the government in the management of water for the benefit of communities, businesses, industries, First Nations, and individuals*." It presents a path and strategy to help ensure that Nova Scotia is staying on "*our path to sustainable prosperity*" and indicates that Nova Scotia will "*remain a great place to live, work, play, and do business into the future*". The strategy indicates the government will carry out the water strategy using the following principles as guidelines (Nova Scotia, 2010):

- **Sustainability** - We must recognize the fundamental value of healthy water and ecosystems, and the social and economic importance of water to Nova Scotia. Today's decisions must consider tomorrow's effects, carefully balancing the water we use with the protection of natural ecosystems.
- **Stewardship** - Stewardship means conserving and protecting water. It is based on both an individual and a collective responsibility to ensure safe, healthy water for future generations.
- **Partnership and collaboration** - Water is a shared resource, and its stewardship is a shared responsibility. Everyone must participate, including all levels of government, the private sector, communities, and individual citizens.
- **Leadership** - Creating positive change in the way we manage our water will require strong leadership not only by the provincial government, but by all interested and affected parties. Accountability & Transparency Decision making should be based on evidence and open to public review.

These are amazingly similar to the broad "outcomes" in the policy plan prepared by the Minneapolis – St. Paul Regional Council titled "2040 Water Resources Policy Plan" (MSP, 2015). The policy outcomes include:

- **Stewardship** advances the Council's longstanding mission of orderly and economical development by responsibly managing the region's natural and financial resources, and making strategic investments in the region's future;
- **Prosperity** is fostered by investing in infrastructure and amenities that make the region competitive in attracting and retaining successful businesses, a talented workforce, and strong economic opportunities;
- **Equity** means connecting all residents to opportunity and creates viable housing, transportation, and recreation options for people of all races, ethnicities, incomes, and abilities so that all communities share the opportunities and challenges of growth and change;
- **Livability** focuses on the quality of our residents' lives and experiences in the region, and how places and infrastructure create and enhance the quality of life that makes our region a great place to live; and,
- **Sustainability** seeks to protect regional vitality for generations to come by preserving the capacity to maintain and support the region's well-being and productivity over the long term.

Consequently, we recommend that:

> **HRM Council should consider adopting an overarching policy toward development within the region that addresses broad social policy objectives where one measurement of accountability of the HRM Council will be the effective implementation and reporting of the achievements of development agreement environmental monitoring plans. This broad policy document will need to integrate all of the individual policies adopted for development agreements and provide a comprehensive statement for all of the individual policies such that Council and residents can clearly understand the objective(s) and know that these actions are contributing to the socio-economic sustainability of the community as a whole.**

6. Monitoring Goal and Objectives

6.1 Introduction

The responsibility for implementing water resource management within the bounds of HRM, by default, lies with local governments. This has been evidenced with examples from other jurisdictions, all of which (Muskoka, Sudbury, King's County, Carleton River and Minneapolis – St. Paul) have taken the lead to protect and manage their natural resources from impacts within their jurisdictional control. Commonly, this control is affected through land-use planning for current and future developments but frequently includes taking responsibility for old infrastructure (e.g. historic dams or out-dated approaches to managing stormwater). Generally, however, municipalities may undertake initiatives to understand and perhaps mitigate impacts from beyond their direct jurisdictional responsibilities (e.g. climate change) but do not become directly involved in addressing the driving forces behind these, leaving that role to senior levels of government. Municipalities also have responsibilities through the provision of municipal services including drinking water treatment and supply, wastewater treatment and stormwater management.

HRM LAKE WATER QUALITY MONITORING PROGRAM GOAL

TO PROVIDE SCIENTIFICALLY SOUND AND RELEVANT INFORMATION FOR MUNICIPAL MANAGEMENT, PLANNING AND POLICY DECISIONS TO PROTECT WATER RESOURCES

In Halifax, land-use planning is under the jurisdiction of HRM. The role of development agreements and how these are evolving to better protect water resources has been discussed in Section 5. Halifax Water is responsible for the operation and management of infrastructure providing water and wastewater. The recent integrated stormwater management policy framework (ISMPF) is a joint effort between HRM and Halifax Water to manage stormwater services. HRM has conducted monitoring sporadically both from the perspective of lake monitoring as well as from monitoring required as part of development agreements but a focused objective to this monitoring has been absent which in turn has impacted its effectiveness. As noted in Section 1.4, water quality monitoring is conducted federally and provincially in Nova Scotia and monitoring, and research is undertaken by academia. However, all of these monitoring programs have different areas of focus and are not sufficiently detailed or aligned with the needs of HRM to meet decision making needs for water resource management at the local level. At the same time, there is hesitancy within HRM and undoubtedly, within the community in general, to jump into the cost and responsibility of a program that many perceive as the responsibility of other government jurisdictions.

The task of this section is to present an effective lake water quality monitoring program for consideration by HRM. However, a broad base of support at the community level for water resource monitoring is imperative. As discussed with respect to development agreements in Section 5, it is not sufficient to set policies solely in environmental terms or in this case to set a water resource monitoring objective in these terms, there must be a clear link made to the fulfillment of the broad community based social policy objectives. Just as was described for the development agreements, a broad objective statement committing HRM to the sustained development of the community is critical to long term protection of its natural water resources that define the Region. This document needs to fully integrate monitoring of the water resources as a tool by which HRM is held accountable to sustaining the community. As has been commented upon, taking samples is only one component of accountability. Reporting on results and demonstrating to the community that their interests and investments are being protected by these actions, is essential. It is within this context that the lake monitoring program(s) proposed here has been developed. If the monitoring program is to be a success, it has to be viewed as an investment for the long term in the community, rather than a cost.

6.2 Lake Monitoring Program

A lake water quality monitoring program is intended to provide knowledge and understanding of the health of aquatic ecosystems to guide effective management, planning and policy decisions by HRM. A corporate monitoring program, therefore, should collect data and information related to relevant water quality concerns that can be used to assess impacts from land use activities that are managed by Halifax, with the objectives to:

- Establish baseline and reference conditions;
- Determine long-term trends;
- Determine compliance with guidelines for recreational use and for the protection of aquatic life;
- Detect emerging issues and threats;
- Measure response to remedial measures and planning decisions;
- Support development of lake water quality or contaminant loading models;
- Establish water quality management targets; and
- Assess and manage risk.

A future corporate lake water monitoring program for Halifax, should be designed to achieve all of the objectives listed above.

6.3 Key Water Quality Concerns

Human activities can result in water quality issues in lakes. For HRM's purposes, water quality monitoring should address those water quality issues and concerns that are likely to result from land use practices that HRM can control or manage through implementation of municipal policies, planning and programming or that directly affect HRM's ability to provide valued services (e.g., public beaches). The lake water quality concerns identified from policy direction in HRM's regional plan, a review of background studies, consultation with water resource managers and the evaluation of development agreements include:

- Eutrophication;
- Chloride enrichment;
- Bacteria contamination; and
- Invasion of non-native aquatic species.

Climate change and its potential to exacerbate water quality issues is also of concern and requires consideration in the development of a monitoring program but it is recognized that HRM will be only influencing mitigation of climate induced impacts while direct controls are largely outside of their responsibility.

The sections that follow provide a brief overview of the key water quality issues of most direct concern for HRM, how they may affect recreational uses and the ecological health of lakes within HRM, and the potential implications of climate change on these lakes.

6.3.1 Eutrophication

Eutrophication is the process of increased primary production and is generally caused by the enrichment of nutrients needed for the growth of aquatic plants and algae. Phosphorus is the limiting macro-nutrient that most frequently controls primary production and can be readily controlled from anthropogenic sources. Therefore, management of TP is commonly considered as the best means to control eutrophication in temperate lakes such as those in HRM. Excessive phosphorus inputs to lakes can cause nuisance growth of aquatic plants and algae that affect the ecology, aesthetic quality and recreational value of lakes.

Phosphorus enters surface water from the atmosphere (e.g., by precipitation, and deposition of dust), stream and overland flow, and groundwater, with lake concentrations regulated by local geology, land-use, lake morphometry, soil type and depth, and human activity (Dillon et al. 1993). Human activities contributing to increased phosphorus in lakes include point sources such as domestic and industrial sewage treatment plants, stormwater outfalls and combined sewer overflows, and non-point sources such as septic systems, and runoff from agriculture, forest harvesting and developed lands.
Eutrophication causes substantial changes in biota that directly impair water quality for human uses. Recreational impairments of concern for HRM lakes include:

- Poor aesthetics due to reduced water clarity, and taste and odour issues;
- Health hazards to bathers caused by Harmful Algal Blooms (HABs) that produce potent toxins;
- Boating and bathing interference caused by nuisance macrophyte weed and algae growth in nearshore and shallow areas; and
- Reduced angling opportunities resulting from long-term decreases in deep-water oxygen concentrations with consequences for coldwater fish habitat and in extreme anoxic conditions, possible fish kills.

- Climate change can contribute to eutrophication through alteration of weathering processes and hydrological conditions that increase the transport of phosphorus to lakes, and by causing physical changes in lakes that optimize conditions for primary production (e.g., lengthening of the growing season, warmer waters) and favour bloom-forming algae including HABs (e.g., warmer surface water and increased thermal stability of the water column). Furthermore, warmer surface water and longer growing seasons alter nutrient dynamics in lakes by increasing the rate of decomposition and recycling of phosphorus, and by increasing the potential for deep-water anoxia and the resultant release of nutrients in sediments.

6.3.2 Chloride Enrichment

Elevated chloride levels can alter the community composition of fish, invertebrates and plankton, and reduce the richness and abundance of aquatic species. In extreme cases, high chloride concentrations can increase the density of bottom water to such an extent that it prevents lakes from mixing (called meromixis). Meromixis can cause anoxia that leads to impacts on habitat for aquatic biota and the release of nutrients and other chemicals from sediments (i.e., internal loading) that can contribute to eutrophication.

De-icing and anti-icing salt materials used for winter maintenance of roads, parking lots, driveways and walkways are the primary sources of chloride to lakes. Other common sources of chloride in urban centres include dust suppressants and water treatment salt (for water softening).

Chloride in salting materials is readily dissolved in water and transported overland by surface runoff and to lakes and water courses via storm sewers during melt events or infiltrated into soils, thus potentially contaminating groundwater. Dry salt can also be transported as windblown dust and re-deposited on land or water. As such, salt loading to lakes occurs primarily in winter and spring during melt conditions but can continue through the summer and fall via discharge of contaminated groundwater, dry deposition to the lake surface, diffuse runoff that mobilizes dry salt from land surfaces, and flushing of contaminated water bodies in the catchment including stormwater ponds.

- Climate change is likely to increase the intensity and frequency of extreme winter events requiring the use of more salting materials for safe winter maintenance. Moreover, generally warmer winters with a greater number of freeze-thaw events may increase the use of more salting materials to treat ice conditions.

6.3.3 Bacteria Contamination

Fecal pathogens produced by humans and warm-blooded animals including viruses, bacteria and protozoans can cause a health risk to bathers from recreational body contact with contaminated water, beach sand and sediments. Health risks to humans due to fecal contamination at beaches is typically assessed using *Escherichia coli* as a fecal bacteria indicator, although other coliform bacteria measures have also been used.

Fecal pathogens are introduced to the aquatic environment in runoff from urban and agricultural areas, discharge from infrastructure including wastewater treatment facilities, combined sewer overflows, and ineffective septic tank systems, and activities of humans, pets and wildlife in and around the water (Halliday and Gast, 2001). Once introduced, fecal pathogens can be transported between shorelands and water (swash zone) by wave action, within water bodies with currents, and also be released from shallow sediments and aquatic plant refugia that can harbour pathogens (Halliday and Gast, 2001).

There is concern over an increasing number of beach closures within HRM in recent years due to high levels of *E. coli*, and the risk that bacteria contamination could worsen, become more widespread and impair other recreational uses of the lakes

6.3.4 Aquatic Invasive Species

Aquatic invasive species (AIS) are plants, animals, and micro-organisms that are introduced into a new aquatic ecosystem and have harmful consequences for the natural resources in the native aquatic ecosystem and/or the human use of the resource[23]. Some consequences of AIS include:

- stress on natural ecosystem functions and processes that reduce biodiversity and impair fish and fish habitat;
- littering and fouling of beaches and docks affecting recreational usage;
- damage to infrastructure such as hydroelectric and drinking water filtration facilities; and
- damage to fisheries, shipping, aquaculture, and tourism.

The introduction and spread of AIS in freshwater bodies most commonly occur through recreational and commercial boating, the use of live bait, the aquarium/water garden trade, live food fish, unauthorized introductions and transfers, and canals and water diversions[21]. Climate change can make aquatic habitats more vulnerable to AIS. For example, as water temperatures rise, more non-native species can survive the winter in Canadian waters. In addition, native aquatic species that are already stressed due to climate change may be less able to out compete AIS for available resources.

Federal and provincial legislation has been enacted to address AIS. The 2015 Aquatic Invasive Species Regulations under the *Fisheries Act* (SOR/2015-121) prohibit the importation, possession, transportation, and release of AIS, and give the provincial Minister of Fisheries and Aquaculture authorization to prevent, control, and eradicate of AIS in Nova Scotia. In Nova Scotia, AIS species subject to the federal regulations include:

- species set out in the regulations [grass carp (*Ctenopharyngodon idella*), bighead carp (*Hypophthalmichthys nobilis*), silver carp (*H. molitrix*), black carp (*Mylopharyngodon piceus*), zebra mussel (*Dreissena polymorpha*) and the quagga mussel (*D. bugensis*)]; and
- any other aquatic species in a body of water frequented by fish where the aquatic species is not indigenous and may harm fish, fish habitat or the use of fish.

[23] *Canadian Council of Fisheries and Aquaculture Ministers Aquatic Invasive Species Task Group, 2004. Canadian Action Plan to Address the Threat of Aquatic Invasive Species. Accessed from: https://www.dfo-mpo.gc.ca/species-especes/publications/ais-eae/plan/index-eng.html#glossary.*

The Live Fish Possession Regulations (N.S. Reg. 212/2012) under Section 81 of the *Fisheries and Coastal Resources Act* in Nova Scotia prohibit the unlawful possession of live fish to help to address the long standing and serious threat of AIS introductions from this pathway to native species in Nova Scotia.

In addition to legislation, the federal government leads several initiatives to address issues with AIS in Canadian waters. In 2004, the *Canadian Action Plan to Address the Threat of Aquatic Invasive Species*[21] was launched, and the Department of Fisheries and Oceans Canada (DFO) leads the *Aquatic Invasive Species Science Program* and the *Aquatic Invasive Species National Core Program*. DFO hosts an online resource tool, *Aquatic Invasive Species*[24], on regulations, information and collaboration for reducing the spread of AIS. These and other federal plans and programs recognize the need to collaborate with other jurisdictions including lower levels of government, industry, non-government organizations, Aboriginal peoples and other stakeholders to achieve successful outcomes. Key roles for collaborators include spreading public awareness of AIS and measures to prevent AIS introductions and assisting DFO with early detection and monitoring to control the spread of introduced AIS through reporting of sightings. Citizens are encouraged by the DFO to report potential AIS sightings and offer the following guidance[25]:

- Identify the species;
- Do not return the species to the water;
- Note the exact location (GPS coordinates) and the observation date;
- Take photos; and
- Take note of identifying features.

Freshwater AIS are known to occur in Nova Scotia and include smallmouth bass (*Micropterus dolomieui*) and chain pickerel (*Esox niger*), which have had an impact on native sportfish species, in particular, speckled trout or brook trout (*Salvelinus fontinalis*)[26]. Other non-native species identified include yellow floating heart (*Nymphoides peltate*) in Little Albro Lake and the Chinese mystery snail (*Cipangopaludina chinensis*).

6.4 Focus Lakes for Monitoring

There are more than 1,000 lakes within the HRM jurisdiction[27] **(Figure 7)**. Not all of these lakes are equally vulnerable to water quality issues as lakes will be more or less susceptible to water quality degradation based on the degree and type of human activities in the watershed, but also the physical characteristics of lakes and their watersheds. Selection of lakes to include those that have been or could be susceptible to water quality issues of concern is advisable for a corporate water quality monitoring program to make the best use of available resources.

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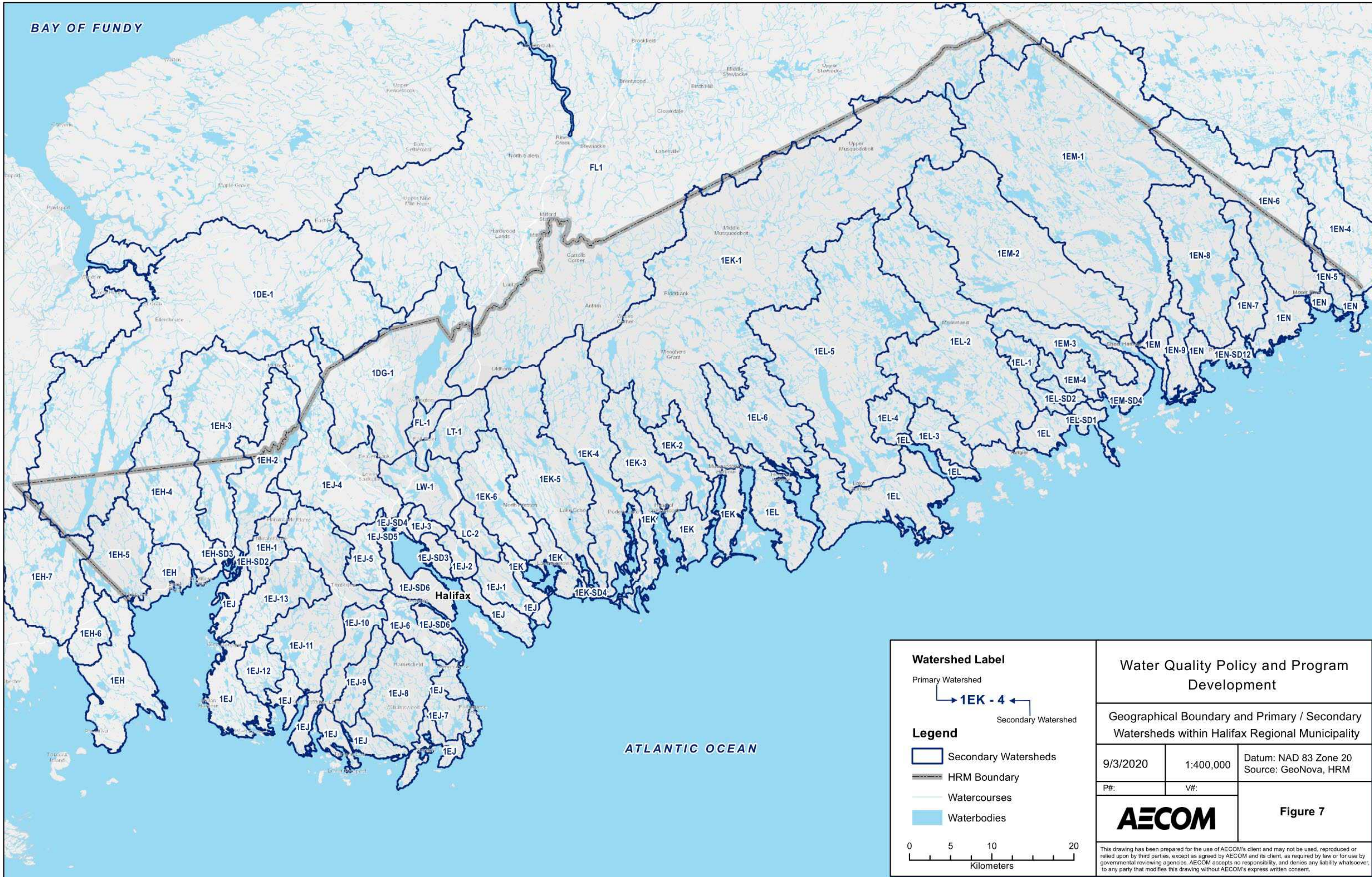
[24] *Fisheries and Oceans Canada. Aquatic Invasive Species. Accessed online at: https://www.dfo-mpo.gc.ca/species-especes/ais-eae/index-eng.html*

[25] *Fisheries and Oceans Canada. Early detection and monitoring for aquatic invasive species. Accessed online at: https://www.dfo-mpo.gc.ca/species-especes/ais-eae/early-detection-precoce/index-eng.html*

[26] *Nova Scotia Fisheries and Aquaculture, undated. New Regulations to Address the Threat of Aquatic Invasive Species: Live Fish Possession Regulations. Accessed from: https://novascotia.ca/fish/sportfishing/resource-management/ais/FCRA-QandA.pdf*

[27] *Halifax website: https://www.halifax.ca/about-halifax/energy-environment/lakes-rivers*


BAY OF FUNDY
ATLANTIC OCEAN
Halifax
FL1
FL-1
LT-1
LW-1
LC-2
1DE-1
1DG-1
1EH-3
1EH-2
1EH-4
1EH-5
1EH-7
1EH-6
1EH
1EH-1
1EH-SD3
1EH-SD2
1EJ-4
1EJ-SD4
1EJ-SD5
1EJ-3
1EJ-5
1EJ-SD3
1EJ-2
1EJ-1
1EJ-SD6
1EJ-13
1EJ-10
1EJ-6
1EJ-11
1EJ-12
1EJ-9
1EJ-8
1EJ-7
1EJ
1EK-1
1EK-2
1EK-3
1EK-4
1EK-5
1EK-6
1EK-SD4
1EK
1EL-1
1EL-2
1EL-3
1EL-4
1EL-5
1EL-6
1EL-SD1
1EL-SD2
1EL
1EM-1
1EM-2
1EM-3
1EM-4
1EM-SD4
1EM
1EN-4
1EN-5
1EN-6
1EN-7
1EN-8
1EN-9
1EN-SD12
1EN
Watershed Label
Primary Watershed
1EK - 4
Secondary Watershed
Legend
Secondary Watersheds
HRM Boundary
Watercourses
Waterbodies
0
5
10
20
Kilometers
Water Quality Policy and Program Development
Geographical Boundary and Primary / Secondary Watersheds within Halifax Regional Municipality
9/3/2020
1:400,000
Datum: NAD 83 Zone 20
Source: GeoNova, HRM
P#:
V#:
AECOM
Figure 7
This drawing has been prepared for the use of AECOM's client and may not be used, reproduced or relied upon by third parties, except as agreed by AECOM and its client, as required by law or for use by governmental reviewing agencies. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without AECOM's express written consent.

6.4.1 Methodology for Lake Selection

Lakes within HRM were identified for consideration in an HRM monitoring program based on vulnerability to human activities at a sub watershed scale and informed by lake specific land use 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.

The vulnerability of secondary watersheds in HRM was previously assessed by Stantec (2010) to consider risks from land use, relative vulnerability based on lake area to watershed area ratios, and susceptibility to erosion and to acid rock drainage impacts due to the Halifax Formation. The assessment was conducted for each of the secondary watersheds within HRM with the exception of the Shubenacadie Headwater Lakes' watersheds (i.e., Lake Charles, Lake William, Lake Thomas, Lake Fletcher, and Grand Lake), which were assessed using water quality modeling results from a study by Jacques Whitford (2009). The results of the analysis were used to classify the sub watersheds as High Vulnerability (Tier I), Moderate Vulnerability (Tier II) and Low Vulnerability (Tier III). These classifications were then refined by Stantec (2009) on a lake-by-lake basis to consider:

- Greenfield/Master Plan Areas;
- Commercial/Industrial Zoning;
- Watershed Advisory Board Areas of Concern;
- Public Beach/Swimming Designation;
- Public Drinking Supply;
- Areas of Engineering Concern (e.g., identified sewer and stormwater overflow areas); and
- Existing Monitoring Program.

The approach to assessing vulnerability classes developed by Stantec (2009) was generally adopted in the present evaluation but updated to reflect new information collected since that study and to focus further on the key water quality concerns (eutrophication, chloride enrichment, bacteria contamination and, aquatic invasive species). Some key changes and updates included:

- **Lakes within the Halifax Formation bedrock.** While susceptibility to acid rock drainage can be a concern for water quality, this issue is not managed by HRM and is not likely to significantly influence the key water quality concerns. The vulnerability class of sub watersheds on the Halifax Formation was therefore reduced (i.e., from Tier I to Tier II, or from Tier II to Tier III) as appropriate.
- **Wetlands and small water bodies (<2 ha).** The present study focuses on lakes, therefore small water bodies that function as wetlands that would require a different monitoring approach were removed from the list.
- **Rivers.** The present study focuses on lakes, therefore; rivers are not included in the development of the monitoring framework. Similar to wetlands and small water bodies, rivers, as flowing water systems, also require a very different monitoring approach to be meaningful and as such they were also removed from the list and are not considered as part of this program.
- **Priority lakes.** Priority lakes were identified for each of the key water quality issues of concern, and included:
    - **Priority Eutrophication Lakes** - lakes with elevated surface water TP concentrations during the ice-free period that are indicative of eutrophic conditions (i.e., >20 µg/L) based on a high-level review of monitoring data from select sources, and lakes with documented past issues with algal blooms or nuisance aquatic plant growth.
    - **Priority Chloride Enrichment Lakes** – lakes with elevated spring surface water chloride concentrations (i.e., >100 mg/L) that are approaching the Canadian Water Quality Guideline (CWQG) of 120 mg/L for long-term exposure for freshwater aquatic life, based on a high-level review of monitoring data from select sources.

- **Priority Bacteria Contamination** – lakes with municipal beaches where HRM provides supervision due to human health risks from recreational body contact with water.

It should be noted that while aquatic invasive species are a key water quality concern within HRM, we suggest that the monitoring or management of AIS within HRM's geographical boundary is outside of HRM's water resource management purview. Rather, we suggest that HRM could assist with public education and awareness through active community engagement. **However, management activities should be the responsibility of and undertaken by DFO.**

Key roles for HRM could include assisting with spreading public awareness of AIS and measures to prevent AIS introductions, as well as assisting DFO with early detection and monitoring to control the spread of introduced AIS through reporting of sightings. HRM could encourage citizen to support DFO with respect to reporting potential AIS sightings and provide the following guidance:

- Identify the species;
- Do not return the species to the water;
- Note the exact location (GPS coordinates) and the observation date;
- Take photos;
- Take note of identifying features; and,
- Contact DFO to report an AIS.

6.4.2 Resultant List of Lakes to be Monitored

The resultant list of lakes proposed for consideration in a water quality monitoring program for HRM includes lakes considered to have High Vulnerability (Class A) and Moderate Vulnerability (Class B) to water quality impacts from human stressors related to land use. Reference lakes and priority lakes (**Table 9)** are also identified. Reference lakes are those that have not already been impacted by local or land use human stressors and are not likely to be impacted in the future due to protection of their watershed, isolation or other factors. Priority lakes are those impacted by human activities resulting in eutrophication due to elevated TP or chloride enrichment due to road salt applications. Lakes considered to have Low Vulnerability (Class C) are excluded from the list as these are not considered to be essential to the lake monitoring program at this time but may be added to the program at some future time.

Table 9 provides a list of lakes for monitoring based on this review of priorities and concerns within HRM. These lists are also presented in **Appendix D,** along with corresponding secondary watersheds and additional rationale for selection, as follows:

Table D-1: Class A Lakes - High Vulnerability Lakes
Table D-2: Class B Lakes - Moderate Vulnerability Lakes
Table D-3: Priority Eutrophication Lakes
Table D-4: Priority Chloride Enrichment Lakes
Table D-5: Priority Bacteria Contamination – Beach Monitoring Lakes
Table D-6: Reference Lakes

Table 9: List of HRM Lakes for Monitoring and Associated Vulnerability Classes and Priority Concerns

Vulnerability Class[1] / Reference Lake	Lake	2° Watershed	Priority Eutrophication[2]	Priority Chloride Enrichment[2]	Priority Bacteria Contamination (Beaches)[3]
Class A – High Vulnerability	Albro	1EJ-AL	yes	yes	yes
	Banook	1EJ-2	yes	yes	yes
	Bell	1EJ-1	yes		
	Charles	LC-2	yes		yes
	Chocolate	1EJ-P		yes	yes
	Cranberry	LC-2	yes	yes	
	Five Island	1EJ-13			
	Fletchers	FL-1			
	Governors	1EJ-P	yes	yes	
	Kearney	1EJ-5			Yes
	Kidston	1EJ-6			Yes
	Long Pond	1EJ-6			Yes
	Loon	LC-2			
	Maynard	1EJ-2			
	McQuade	1EK-2			
	Micmac	1EJ-2	yes	yes	
	Morris	1EJ-1		yes	
	Oathill	1EJ-2		yes	
	Paper Mill	1EJ-5	yes		yes
	Penhorn	1EJ-2		yes	yes
	Russell	1EJ-1	yes		
	Sandy (Bedford)	1EJ-4	yes		yes
	Settle	1EJ-1		yes	
	Springfield	GL-1	yes		yes
	Williams (Spryfield)	1EJ-P			yes
Class B – Moderate Vulnerability	Albert Bridge	1EJ-13			
	Anderson	1EJ-3			
	Barrett	GL-1			
	Bayers	1EJ-6			
	Beaver Bank	GL-1			
	Beaver Pond	GL-1			
	Bissett	1EJ-1	yes	yes	
	Black Point	1EJ-13			
	Charlotte	1EL-5			yes
	East River Sheet Harbour	1EM-1			yes
	Echo	1EK-5			yes
	Elbow	1EH-1			
	Fenerty	GL-1	yes		
	First	LW-1			yes
	First Chain	1EJ-6			
	Hatchet	1EJ-9			yes
	Hubley Big	1EJ-13			
	Kinsac	GL-1			
	Lamont	1EJ-1			
	Little Springfield Lake	1EJ-4			
	Long	1EJ-6			
	McCabe	1EH-2			
	Mill	1EH-2			
	Miller	LT-1			
	Moody	1EJ-8			
	Petpeswick	1EK-3			yes
	Porters (North)	1EK-4			
	Porters (Middle)	1EK-4			
	Porters (South)	1EK-4			yes

Vulnerability Class[1] / Reference Lake	Lake	2° Watershed	Priority Eutrophication[2]	Priority Chloride Enrichment[2]	Priority Bacteria Contamination (Beaches)[3]
	Powder Mill	LW-1			
	Quarry (Birch Cove)	1EJ-5			
	Rocky (North East Basin)	LW-1			
	Sandy (Glen Arbour)	1EJ-4	yes		
	Scots	1EK-2			
	Second	LW-1			
	Sheldrake	1EJ-13			
	Shubenacadie Grand	GL-1			yes
	Stillwater	1EH-1			
	Susies (Birch Cove)	1EJ-5			
	Third	LW-1			
	Thomas (North Basin)	LT-1			
	Thomas (South Basin)	LT-1			
	Tucker	GL-1			
	Whites	1EJ-10			
	William	LW-1			
	Wrights	1EH-2			
Reference Lakes	Big Cranberry	1EH-1			
	Topsail	1EJ-1			
	Ash	1EJ-5			
Summary	**Total Priority Lakes**		**14**	**11**	**20**
	Total Class A Lakes		25		
	Total Class B Lakes		46		
	Total Reference Lakes		**3**		
	Total Lakes		74		

Notes:

1 - Class A is High Vulnerability and Class B is Moderate Vulnerability;

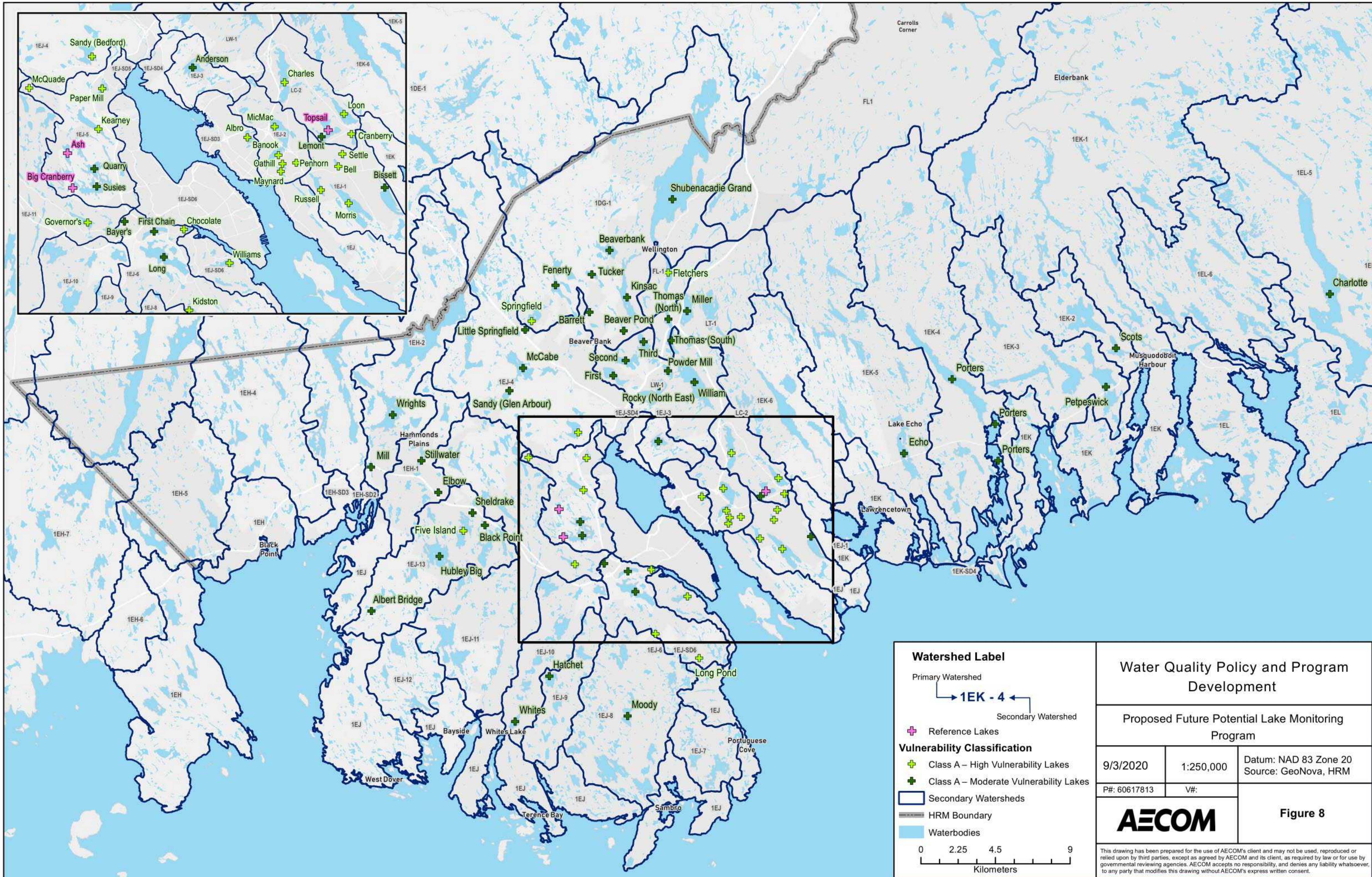
2 – Priority Eutrophication and Priority Chloride Enrichment lakes were identified based on a high-level assessment of limited water quality data and documented water quality issues. The lack of identification as a priority does not imply that a lake does not have water quality issues.

3 – Priority Bacteria Contamination denotes the lakes where an HRM-supervised beach is situated and bacteria concentrations must be monitored to confirm water quality meets Canadian Council of the Ministers of the Environment (CCME), body-contact recreation guidelines.

It is recognized that this list may be reviewed and revised based on the specific monitoring framework implemented by HRM and its specific monitoring goals. Periodic review within the framework will also be a necessity to maintain the relevance of the list to changing priorities, development pressures and community concerns. This should be a formal process within the monitoring program led by HRM with involvement from the community and experts in the field. For example, specific lakes may be targeted to inform planned municipal salt management strategies. The vulnerability classification and identification of priority lakes may also be refined based on a more thorough examination of water quality indicators (e.g., to consider other eutrophication indicators) including an assessment of trends, and to consider monitoring data from other sources. Increased phosphorus loads from human sources may not have caused some lakes to become eutrophic; but may be causing a shift in the natural trophic status, altering ecological conditions. Lakes in transition between trophic states may be of equal or greater priority than an existing eutrophic lake and changing transitional lakes to a higher class should always be a consideration.

Three reference lakes have been identified – Ash, Big Cranberry and Topsail lakes. They are selected based on the fact that they have not been impacted by land based human activities and are not anticipated to be impacted in the reasonably foreseeable future. Trends or changes in reference lakes will therefore be indicative of external (i.e. non-local land-based factors) that also may be influencing the monitoring lakes.

An overview map of the lakes to be included in a future water quality monitoring program is included as **Figure 8.** Maps showing the individual lakes to be monitored and the corresponding sub-watershed area, is included in **as Figures D-1** to **D-10 in Appendix D.**



Water Quality Policy and Program Development

Proposed Future Potential Lake Monitoring Program

9/3/2020	1:250,000	Datum: NAD 83 Zone 20 Source: GeoNova, HRM
P#: 60617813	V#:	

AECOM

Figure 8

7. Monitoring Program Frameworks

7.1 Methodology / Approach / Considerations

Through this study, AECOM has completed a series of tasks including 1) a comprehensive review of past lake water monitoring and water resource evaluations, 2) a comprehensive review of lake monitoring programs for 5 comparable jurisdictions, and 3) a consultation with water resource professionals within the provincial and federal government departments, as well as a small group of lake-stewardship / community volunteer groups. The results of these undertakings form the basis for the series of frameworks for lake monitoring program presented here.

Historical efforts and practices have informed the need for a core lake water quality monitoring program that meets a series of management objectives. Specifically, monitoring should only be conducted if it can be expected to meet a management objective. Concurrently, any future core lake monitoring program must be cost-effective, maximize collaboration and partnerships with other user groups and water resource professionals and can be maintained on a long-term basis. Importantly, future monitoring results must be interpreted by qualified professionals and reported to the public in a plain-language format that can be easily understood. Accordingly, this information should be used to guide land use planning and maintenance decisions within the Municipality. As noted in Conrad (2007):

> *No matter how much monitoring we do, we will not change anything if we can not deliver the results to inform choices, decisions, and policies. Science alone is not well equipped to model and understand future changes and scientists are even less equipped to reach decision-makers. The community serves a role and a purpose here.*

Despite having completed past undertakings relating to the monitoring of water resources, HRM, 'does not use this information to understand the health and sustainability of the Region's natural environment.' (HRM, 2018). Other organizations within the region monitor water quality and quantity (e.g. Halifax Water, NSE, university researchers and non-profit and community groups), and HRM 2018 indicates a desire to continue to evaluate and establish partnerships with these and other organizations on a go forward basis for completing monitoring activities. In recent years, there has been significant progress locally within HRM with increased participation of community-based water quality monitoring activities. There is a desire by HRM to retain and maximize these contributions in the form of data collection, in-kind efforts and knowledge and expertise brought by these groups and individuals in the operation of a future program.

Three (3) monitoring program frameworks are proposed for consideration by HRM. These frameworks address the strategic monitoring objectives as they relate to key water quality concerns and in recognition that some HRM lakes may be impaired or may be vulnerable to water quality degradation. The frameworks are centered around a core long-term lake monitoring program; the design of the core program includes elements that apply to all frameworks. The frameworks differ with respect to the selection and number of lakes monitored, who conducts the monitoring, and cost. However, all three (3) frameworks share the same core program elements such as program design, frequency and timing, and parameters and collection methods.

It is recommended that HRM's Beach Monitoring Program continue as designed and form part of each of the monitoring frameworks proposed here or the final framework selected by HRM for implementation. The existing Beach Monitoring Program provides a scientifically-sound approach to monitor bacteria and cyanobacteria for confidently assessing and responding to potential health risks to bathers at municipal beaches in a timely manner.

Details of the core monitoring and the frameworks (excluding the Beach Monitoring Program) are provided in the sections that follow and address key elements for a monitoring program including:

- Monitoring Design
- Sample Size, Frequency and Timing
- Parameters
- Data Collection Methods
- Program Partnership and Collaboration Strategies
- Operations and Management
- Quality Assurance
- Program Evaluation and Reporting
- Cost

A summary of the key elements of the core monitoring and the three frameworks is provided in **Table 10**.

Table 10: Summary of Core Water Quality Monitoring Elements

Element	Description
	Core Monitoring Elements (Applicable to All Frameworks)
Design	• a single, fixed station in a central deep lake location • additional stations for lakes with complex morphometry/distinct basins

Frequency and Timing	• 2-year rotation (Framework 1 and 3) Annual Program (Framework 2)
	• Number of sampling events dependent on lake vulnerability classification
	• Class A – High Vulnerability Lakes have 2 sampling events per year at each lake
	  o once in spring during mixed-water column conditions
	  o once at the end of summer
	• Class B – Moderate Vulnerability Lakes are sampled once per year at each lake:
	• once in spring during mixed water column conditions (ahead of thermal stratification)

Parameters and Collection Methods	**Routine:**
	• Secchi depth
	• Lake depth
	• Field measurements
	  o Full water column profiles (temperature, pH, dissolved oxygen concentration, specific conductivity)
	• Laboratory Analysis
	  o TP (low-level detection limit) (euphotic zone composite)
	  o Chlorophyll α (euphotic zone composite)
	Supplemental (if triggered)[1]:
	• TP (1 metre off bottom, end of summer sampling only)
	• Chloride (1 metre off bottom)
	
	Observational:
	• Aquatic invasive species incidental sightings
	• Algae bloom incidental sightings
	• Ice-on and ice-off dates
	Other water quality related observations (e.g., nuisance aquatic plant growth, unusual visual appearance of water or odours)

Operations and Management	• HRM responsible for program coordination and management, provision of equipment, data verification, analysis and management, reporting

Quality Assurance	• Implementation of a Quality Assurance Plan to include:
	  o monitoring protocols for collecting samples
	  o only accredited laboratories be used for chemical analysis
	  o data review and management protocols
	  o methods for handling suspect data or outliers
	• randomized duplication of samples

Program Evaluation and Reporting	Annually:

Element	Description		
	• Overview Report on monitoring activities and summarizing data by lake (i.e., trends, relative to guidelines/targets) After Two Years Following Program Start-Up: • Detailed Program Report that addresses monitoring objectives with recommendations for management needs/policy and planning considerations on a lake-by-lake basis and on a regional basis • Water Quality Report Card that concisely documents water quality in HRM lakes using appropriate metrics based on a scientific assessment with presentation appropriate for public understanding • Monitoring Program Framework Review to identify and resolve program issues, improve programming based on new information (e.g., reclassify lakes, address new or emerging concerns, identify trigger monitoring requirements) • Determine frequency of subsequent program reports		
Framework-Specific Monitoring			
Element	Framework 1	Framework 2	Framework 3
Sample Size	Class A Lakes (2 events per year) Class B Lakes (spring only) Reference Lakes Total Number of Lakes: ~74	Priority Eutrophication Lakes Priority Chloride Enrichment Lakes Total Number of Lakes: ~23	Class A Lakes (2 events per year) Class B Lakes (spring only) Reference Lakes Total Number of Lakes: ~74
Operations and Management (Monitoring Staff)	• HRM staff led • Community support for lakes with community volunteers; monitoring by HRM staff to be reduced over time with progressively more volunteer commitment • Observational information from residents or other stakeholders	• Community-led with HRM support for lakes without community volunteers; monitoring by HRM staff to be reduced over time with progressively more volunteer commitment • Observational information from residents or other stakeholders	• HRM staff is responsible for all aspects of program operation and management, including monitoring activities. • Observational information from residents or other stakeholders
Cost Responsibility	• HRM funded with in-kind support from volunteers (to conduct monitoring, provide equipment if available)	• HRM funded with in-kind support from volunteers (to conduct monitoring, provide equipment if available)	• HRM funded and implemented

Note: 1. Additional parameters or sampling may be triggered based on the results of field parameters measured during a specific sampling event, to further assess water quality issues and inform potential modeling exercises. This is further described in **Section 7.2.3**

7.2 Proposed HRM Core Water Quality Monitoring Program

7.2.1 Overview

The proposed core water quality monitoring program is a regional scale monitoring program designed to maximize collection of pertinent data and the number of lakes that can be monitored to address the key water quality concerns and management issues facing HRM while making effective use of resources. The core program is based on widely accepted and proven approaches used by several other jurisdictions (e.g., District Municipality of Muskoka's Lake System Health Program (Section 3.1), City of Greater Sudbury's Lake Water Quality Monitoring Program (Section 3.2), King's County Lake Monitoring Program (Section 3.3), the Carleton River Watershed Lake Quality Monitoring Program (Section 3.4), the Minneapolis – St. Paul, Minnesota Water Resources Policy Plan (Section 3.5) as well as the Province of Ontario's Lake Partner Program[28] which has not been discussed here. This core water quality monitoring program can meet all HRM monitoring program objectives.

More complex or different monitoring approaches can be warranted to more thoroughly investigate water quality issues, but these approaches are best designed and implemented on a lake-by-lake basis. These types of focused lake monitoring approaches need to consider the specific issue at hand and the individual characteristics of the lake in question and are therefore best developed as part of a lake management plan specifically designed and costed to fulfill the objectives of the plan. Lake-specific management plans and their application to meet HRM's water resources management needs are discussed in **Section 7.4**.

The core monitoring program applies the same general design and parameter list across lakes. This allows for consistent collection, analysis and reporting of data between and within lakes.

7.2.2 Core Monitoring Program Design, Frequency and Timing

The core monitoring design is focused and includes monitoring of a single, fixed station in a central deep lake location, once in spring during mixed-water column conditions and once at the end of summer. The lakes to be monitored in spring and/or at the end of summer varies according to different frameworks and individual characteristics of lakes (i.e., vulnerability class, priority for water quality concern, triggers based on monitoring observations) (see **Sections 7.3**). Monitoring is conducted on a two-year rotational basis, such that each lake is monitored every other year.

Under spring mixed conditions, that is in advance of thermal stratification, most water quality parameters are uniform throughout the lake and hence concentrations of parameters of interest are representative of the whole lake (i.e., a single sample is equivalent to a volume-weighted average concentration).

End-of-summer monitoring provides an indication of water quality changes since spring that can be used to further assess trophic state and factors influencing or influenced by primary production, as well as impacts from chloride enrichment on lake mixing. Eutrophic conditions in lakes at the end of the summer growing season are typically associated with an increase in TP concentration, higher concentrations of algal pigments, a significant reduction in dissolved oxygen levels in deep water, and lower surface water pH in comparison to spring. Meromixis in lakes is indicated by higher water temperature near the lake bottom that is characteristic of the presence of a monimolimnion (i.e., a deep dense layer that is prevented from mixing at least once per year) (**Figure 9**[29]).

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[28] *Dorset Environmental Science Centre, 2020. Lake Partner Program. https://desc.ca/programs/LPP*

[29] *LakeAccess. 2006. Seeing below the surface. www.lakeaccess.org. Three Rivers Park District, MN and University of Minnesota-Duluth, Duluth, MN 55812*

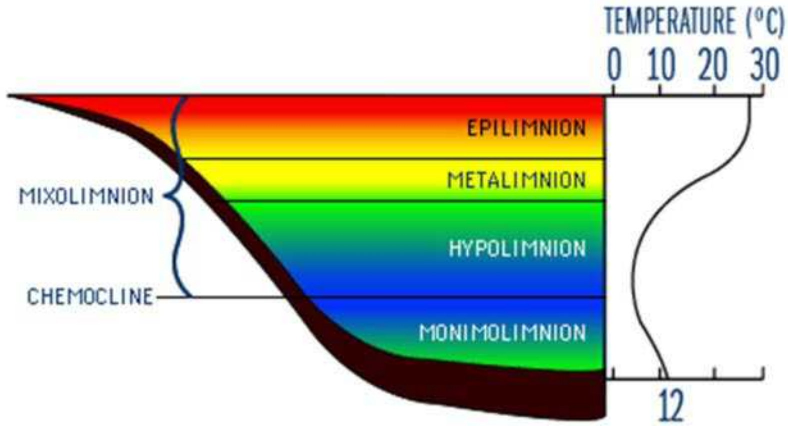

Figure 9: Stratification of a Meromictic Lake (from Lake Access, 2006)

While a single sampling location is proposed here, additional sampling locations may be necessary for lakes with complex morphology that prevents whole lake mixing, such as basins that are physically separated from the main body of the lake (i.e., by narrows or islands), and basins that have significant inlets or point sources that cause a disproportionate inflow of water with different chemical composition than the lake as a whole. Additional sampling locations should therefore be considered on a lake-by-lake basis. Some lakes which are difficult to access other than on foot may also be sampled at their outlet (e.g. Ash Lake). In such a case, sampling will be limited to surface water samples with no profiling.

7.2.3 Core Parameters and Data Collection Methods

Routine monitoring parameters are selected that provide strong indicators of eutrophication and chloride enrichment that can be compared against numerical objectives and targets. Routine parameters include:

- Secchi depth;
- Lake depth at the sampling location;
- Profiles of field measurements at 1-m depth intervals from the lake surface to 1-m off the lake bottom for standard parameters (i.e., temperature, pH, dissolved oxygen concentration, specific conductivity); and
- TP concentration and Chlorophyll α (as a euphotic zone composite).

Additional parameters or sampling that may be triggered to further assess water quality issues and inform potential modeling exercises, include:

- Chloride concentration – to be analyzed in a discrete sample collected at one metre off the lake bottom (1 MOB) - triggered if dissolved oxygen concentration is less than 1 mg/L and specific conductivity exceeds 450 microsiemens per centimeter (µS/cm) at 1 MOB in spring. This specific conductivity is approximately equivalent to the CWQG for chloride concentration of 120 mg/L for the protection of aquatic life from chronic exposure (see ***Chloride Enrichment*** section below).
- TP concentration (1 MOB) – to be analyzed in a discrete sample collected at 1 MOB – triggered if dissolved oxygen concentration is less than 1 mg/L at 1 MOB at end-of-summer.

The rationale for the selection of the routine and triggering additional parameters for the assessment of eutrophication and chloride enrichment is described in the following sections.

7.2.3.1 Eutrophication

A combination of indicators is proposed to characterize the trophic status of lakes and identify potential issues with eutrophication including TP, chlorophyll α, water clarity (as Secchi depth) and supporting field parameters. The use of multiple indicators recognizes that a single indicator may not capture potential issues and that lakes respond individualistically to nutrient enrichment depending on a host of physical and hydrological conditions. For example, it is possible that a lake can suffer from algal bloom activity at relatively low nutrient levels, or without an apparent increase in surface water nutrients. Monitoring for nutrients alone, therefore, would not be adequate in this situation to identify issues with algae blooms.

Total phosphorus is a useful indicator of trophic status considering ease of collection and reproducibility of analysis. Phosphorus, the primary nutrient that controls primary production in most lakes, can occur in many forms. Algae can only take up dissolved (soluble) reactive inorganic phosphorus, called orthophosphate (PO_4^{3-}). In well oxygenated water, orthophosphate typically occurs in low concentrations and makes up only about 5% of the TP. Orthophosphate is difficult to measure because it is extremely labile (i.e., can rapidly change chemical form) and it tends to be overestimated by laboratory analysis at low concentrations. Patterns in orthophosphate can help to determine sources of phosphorus, particularly loads released from benthic environments or inputs from sewage (e.g., septic systems) that typically have a high but variable proportion of orthophosphate. TP is the total mass of all phosphorus in water and includes dissolved and particulate forms. TP provides an overall assessment of available phosphorus (recognizing that all phosphorus can potentially be converted to orthophosphate) and is less variable and more confidently measured in the laboratory than orthophosphate.

Samples measuring algal abundance using Chlorophyll are proposed. Chlorophyll *a* is produced by all algae and is an indicator of total algae. Analysis of phycocyanin, produced only by cyanobacteria may be added as enhanced sampling in lakes where HABs are a concern.

Secchi depth is a measure of water clarity and is often strongly related to algal abundance, where Secchi depth decreases with increasing algal biomass. Secchi depth also provides a measure of the depth of the water column that has enough light for photosynthesis, that is, the euphotic zone. The euphotic zone is defined as two times the Secchi depth.

Other field measures of water quality can be used in conjunction with TP and algal pigments to more fully assess algal and nutrient dynamics in lakes. Physical profiles provide information on thermal stability and mixing patterns of the water column that affect nutrient cycling and availability as well as information on habitat availability for algae and aquatic life.

7.2.3.2 Chloride Enrichment

Specific conductivity is selected as an indicator of chloride concentration in lakes as a cost-effective means to track chloride enrichment. In freshwater bodies without significant point sources of pollution or seawater influence, conductivity is strongly related to chloride concentration. This relationship is exemplified in HRM lakes where the relationship between chloride concentration and specific conductivity in spring (May and June) is statistically significantly (linear regression, $df = 166$, $p < 0.001$) based on 167 observations from 76 lakes monitored between 1984 and 2016 (**Figure 10**). Specific conductivity can therefore be confidently used to predict spring chloride concentrations using this relationship, where:

$$\text{Chloride Concentration (mg/L)} = 0.268 \times \text{Specific Conductivity } (\mu\text{S/cm}) - 6.938 \quad (1)$$

Chloride concentration in lakes is often highest in winter due to salt loads that enter lakes with mid-winter thaw events. Concentrations typically decline over the spring, summer and fall with dilution from rain and runoff, but continued loading can occur as salt remaining in the watershed continues to be washed into lakes or with inputs of salt-contaminated groundwater. Spring monitoring of specific conductivity, therefore, is expected to provide information on maximum chloride concentrations due to cumulative winter salt loads and hence the maximum concentration that would be expected to occur in lakes over the growing season.

Chloride-induced meromixis needs to be confirmed by direct analysis of chloride concentration. This is required because specific conductivity near the lake bottom is significantly influenced by concentrations of other ions that are released from sediment under reducing conditions at low oxygen concentration. Some lakes, however, may have naturally low oxygen concentration near the lake bottom in spring due to the shape of the basin (i.e., very deep lakes with small surface area) that can prevent, limit, or delay water column mixing (and re-oxygenation of bottom water) in spring. For coastal lakes, sea water intrusion (e.g., caused by extreme weather events) can also cause elevated conductivity and meromixis. Analysis of chloride concentration in bottom water where meromixis is suspected is therefore included in the monitoring program to differentiate between natural oxygen depletion or chloride enrichment from human sources. Analysis of other ions is required to differentiate confidently between sea water influence and human sources of chloride, but this is not a component of the core program.

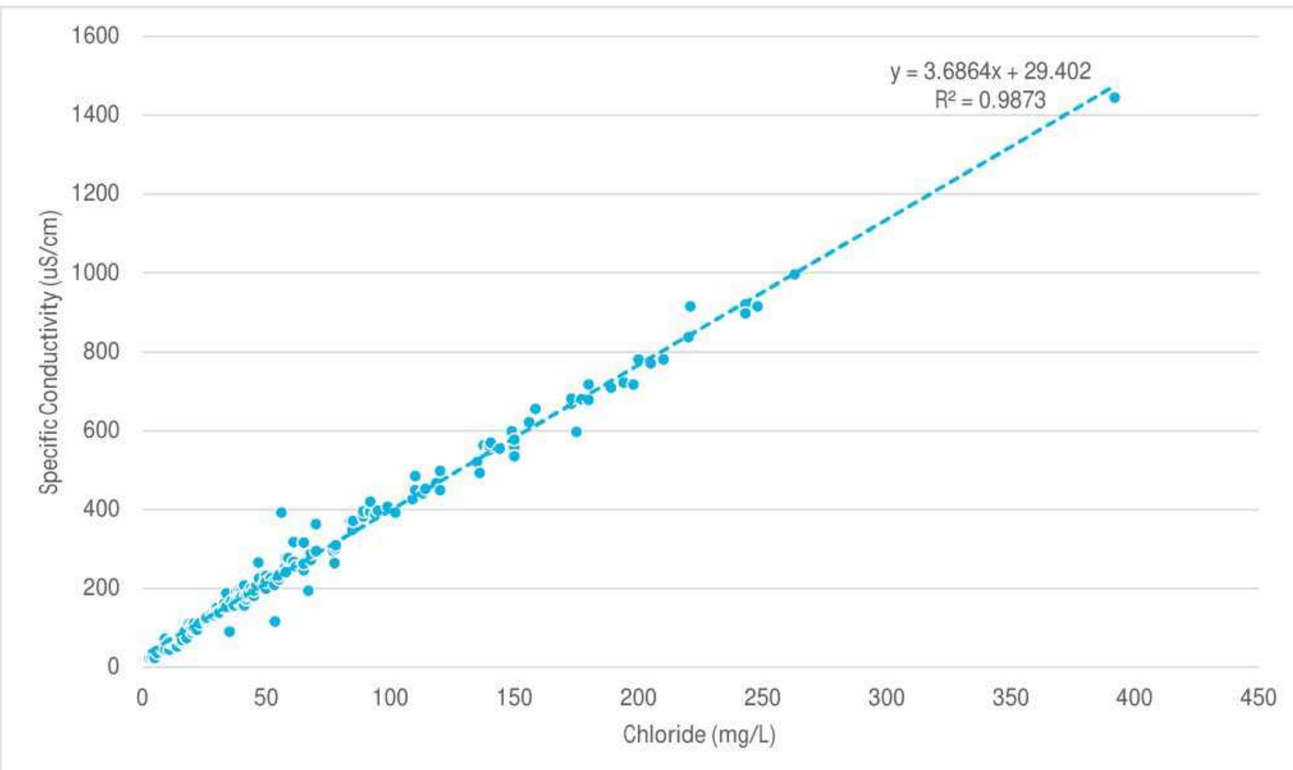

Figure 10: Relationship between Chloride Concentration and Specific Conductivity in HRM Lakes

7.3 Proposed Water Quality Monitoring Frameworks

Three (3) monitoring program frameworks, all built on the core monitoring program, are proposed for consideration. Framework 1 combines the core regional scale monitoring led by HRM and builds on the existing community-based monitoring activities. Framework 2 is a community-based monitoring program that leverages active participation of volunteers to conduct monitoring and is focused to provide long-term monitoring of lakes that are most vulnerable to eutrophication and chloride enrichment. Framework 3 implements the core monitoring at a regional scale in HRM and is led by HRM without integrating the community-based support.

Table 11 summarizes the sampling schedule by month, by Framework option. Framework 1 and Framework 3 only differ by the proposed organizations to be involved in conducting the sampling efforts, where Framework 1 includes community participation and Framework 3 does not. In both cases, lakes evaluated as highly vulnerable (Class A) and lakes evaluated as moderately vulnerable (Class B) are sampled during the spring months between April and mid-May, during spring-mixed conditions. In both cases, during the summer when thermal stratification occurs, which in Nova Scotia is typically during mid August, the lakes evaluated as highly vulnerable (Class A) are sampled again. For Framework 2, a reduced number of lakes are proposed for sampling and they are limited to those lakes that have been classified as either priority eutrophication lakes or lakes with priority chloride enrichment. Lakes with priority eutrophication or chloride enrichment, also have overall classifications as highly or moderately vulnerable (i.e. Class A or B). Priority eutrophication and chloride enrichment, are defined in **Section 6.2.2**, and repeated as follows:

- **Priority Eutrophication Lakes** - lakes with elevated surface water TP concentrations during the ice-free period that are indicative of eutrophic conditions (i.e., >20 µg/L) based on a high-level review of monitoring data from select sources, and lakes with documented past issues with algal blooms or nuisance aquatic plant growth.
- **Priority Chloride Enrichment Lakes** – lakes with elevated spring surface water chloride concentrations (i.e., >100 mg/L) that are approaching the Canadian Water Quality Guideline (CWQG) of 120 mg/L for long-term exposure for freshwater aquatic life, based on a high-level review of monitoring data from select sources.

Table 11: Summary of the Schedule of Sampling by Framework

Month/ Description	Jan - Mar	Apr	May	Jun	Jul	Aug	Sept - Dec	Sampling Effort by
Framework 1		Class A Lakes Class B Lakes Reference Lakes				Class A Lakes Reference Lakes		HRM + Community
Framework 2		Priority Eutrophication Lakes Priority Chloride Enrichment Lakes				Priority Eutrophication Lakes Priority Chloride Enrichment Lakes		Community + HRM
Framework 3		Class A Lakes Class B Lakes Reference Lakes				Class A Lakes Reference Lakes		HRM Only

Note: 1. Class A = Highly Vulnerable lakes; Class B = Moderately Vulnerable lakes

2. Class A Lakes and Class B Lakes include the select lakes with priority eutrophication and/or priority chloride enrichment concerns

In some cases, access limitations may prevent collection of a deep-station sample and in this case, a surface sample would be collected at the lake outlet.

7.3.1 Framework 1 – Coordinated Regional and Community Focused Monitoring

Framework 1 combines the core regional scale monitoring led by HRM and builds on the existing community-based monitoring activities. This framework is ideally suited to provide information on overall water quality of HRM lakes spanning the range of land use practices and development pressures. It also is most suitable to support lake water quality and contaminant loading models, providing the necessary range of data to calibrate and validate the models. Finally, monitoring lakes across a broader geographical area and spanning a range of land use can provide insights on regional scale stressors on lake water quality (e.g., climate change, acidification) that may be influencing water quality. This approach provides monitoring for a large number of lakes allowing for a regional assessment of lake water quality while maximizing support from volunteers. The municipality maintains "ownership" to avoid issues with data capture and quality, data sharing, and associated financial support. Avoiding these issues can reduce potential for data gaps or third-party concerns if the data are used to make planning decisions (e.g., enhanced development controls required for developers based on data collected as part of the program). Finally, this approach provides consistency for budgeting purposes. This approach builds on the existing commitments and knowledge of community associations and volunteers. It provides opportunities for maximizing a return on the funding commitments and builds partners both for monitoring and supporting the communication of the benefits and outcomes of the program.

The existing beach monitoring program implemented by HRM would continue. A summary of the public beaches included in HRM's monitoring program is included as **Table D-6. Appendix D.** A summary of the program elements for Framework 1 is included in **Table 12.**

Lakes

Monitoring is conducted at all lakes that are classed as highly vulnerable (Class A) or moderately vulnerable (Class B) to eutrophication and chloride enrichment due to human activities in the watershed and reference lakes (**Tables D-1, D-2 and D-3, Appendix D**). Class A lakes and reference lakes are monitored in spring and at end-of-summer, and Class B lakes are monitored in spring only.

Frequency

Monitoring is conducted on a two-year rotational basis, such that each lake is monitored every other year. Increased monitoring frequency to annual monitoring could be considered based on volunteer availability to conduct the monitoring, or the need to advance data collection to address management needs.

Operations and Management

HRM staff is responsible for all aspects of program operation and management, including coordination of volunteers and monitoring activities, and the provision of training. It is also expected that HRM staff take the lead with monitoring activities with volunteer monitoring supplementing the core program. As the program progresses, and more volunteers are recruited, HRM's role in monitoring may be reduced but their coordination and information synthesis and reporting requirements would increase.

Table 12: Summary of Framework 1 Program Elements

<table>
<tr><th colspan="2">Framework 1-Specific Monitoring</th><th>Core Monitoring Program Elements</th></tr>
<tr><td>Sample Size</td><td>Class A Lakes
Class B Lakes (spring only)
Reference Lakes
Total Number of Lakes: ~74</td><td rowspan="5"><u>Routine:</u>
• Secchi depth
• Lake depth
• Field measurements
  o Full water column profiles (temperature, pH, dissolved oxygen concentration, specific conductivity)
• Laboratory Analysis
  o TP (low-level detection limit) (euphotic zone composite)
  o chlorophyll α (euphotic zone composite
<u>Supplemental (if triggered {Section 7.2.3}):</u>
• TP (1 metre off bottom, end of summer sampling only)
• Chloride (1 metre off bottom, summer sampling only)

<u>Observational:</u>
• Aquatic invasive species incidental sightings
• Algae bloom incidental sightings
• Ice-on and ice-off dates

Other water quality related observations (e.g., nuisance aquatic plant growth, unusual visual appearance of water or odours)</td></tr>
<tr><td>Design</td><td>• a single, fixed station in a central deep lake location
• additional stations for lakes with complex morphometry/distinct basins</td></tr>
<tr><td>Frequency and Timing</td><td>• 2-year rotation
• Class A – High Vulnerability Lakes have 2 sampling events per year at each lake
  o once in spring during mixed-water column conditions
  o once at the end of summer
• Class B – Moderate Vulnerability Lakes are sampled once per year at each lake:
  o once in spring during mixed water column conditions (ahead of thermal stratification</td></tr>
<tr><td>O&M (Monitoring Staff)</td><td>• HRM-led with community support for lakes with community volunteers; monitoring by HRM staff to be reduced over time with progressively more volunteer commitment
• Observational information from residents or other stakeholders</td></tr>
<tr><td>Cost Responsibility</td><td>• HRM funded with in-kind support from volunteers (to conduct monitoring, provide equipment if available)</td></tr>
</table>

7.3.2 Framework 2 – Community Focused Monitoring Program

Framework 2 is community-based monitoring program that leverages active participation of volunteers to conduct monitoring and is focused to provide long-term monitoring of lakes that are most vulnerable to eutrophication and chloride enrichment. However, it does mean that there will be gaps in the program that may place the desired outcomes of the municipality in jeopardy and limits the ability of the municipality to direct the program and its outcomes.

Many municipalities have successfully included partnerships with volunteers in their monitoring programs to leverage funds, data and effort (e.g., Kings County Lake Monitoring Program, **Section 3.3** and Carleton River Watershed, **Section 3.4** and Minneapolis – St. Paul, Minnesota**, Section 3.5**). These examples of community-based monitoring programs demonstrate that concerns regarding data quality due to monitoring conducted by multiple individuals can be alleviated by a well-designed and co-ordinated monitoring framework with clear delegation of responsibilities (technical and monetary), adequate training, and established quality control measures for data collection and verification.

As demonstrated by the stakeholder consultation, there are several interested and commited community groups that actively monitor lakes and rivers in HRM, collect observational data, and conduct stewardship activities. Academic researchers also often conduct monitoring and have used past HRM monitoring data to support their research activities. Partnerships opportunities should be explored to gain assistance from academia for monitoring activities (e.g., student participation) in exchange for data sharing. Leveraging support from these groups for monitoring can reduce costs and take advantage of local knowledge of lakes and water quality issues. HRM should consider providing technical support and financial contributions to these community based monitoring groups to provide training, enhance their effort, make the monitoring more consistent and consolidate data and provide information to the broader community.

The existing beach monitoring program implemented by HRM would continue. A summary of the public beaches included in HRM's monitoring program is included as **Table D-6. Appendix D.** A summary of the program elements for Framework 2 is included in **Table 13.**

Lakes

Monitoring is conducted at selected priority lakes with existing community associations or those for which HRM can develop volunteer support for. The priority lakes include lakes with existing concerns related to eutrophication and/or chloride enrichment (**Tables D-4 and D-5, Appendix D**) and lakes that can be monitored by a committed non-government organization (e.g., a lake or watershed association, a community group, etc.), academic researchers or other government agency (i.e., federal or provincial).

A drawback of including only priority lakes is that the monitoring program would not be able to identify water quality issues that potentially arise in other lakes, there may be gaps in the priority lakes that are monitored and consistency and quality of the monitoring may be impacted with reduced HRM involvement.

Frequency

Monitoring is conducted on a minimum two-year rotational basis, such that each lake is monitored every other year. However, increased monitoring frequency will likely be provided based on volunteer availability to conduct the monitoring, or the need to advance data collection to address management needs.

Operations and Management

To be effective, HRM staff must be responsible for all aspects of program operation and management, including coordination of volunteers and monitoring activities, and the provision of training and the encouragement or establishment of community-based monitoring groups where they do not exist. In the interim, HRM staff would conduct monitoring activities to supplement volunteer monitoring to ensure that lakes are monitored if volunteers are not available. As the program progresses, and more volunteers are recruited, HRM's role in monitoring may be reduced but their coordination and information synthesis and reporting requirements would increase.

Table 13: Summary of Framework 2 Program Elements

Framework 2-Specific Monitoring		Core Monitoring Program Elements

Sample Size	Priority Eutrophication Lakes
	Priority Chloride Enrichment Lakes
	Total Number of Lakes: ~19
		Routine:
		• Secchi depth
		• Lake depth
		• Field measurements
		  ○ Full water column profiles (temperature, pH, dissolved oxygen concentration, specific conductivity)
		• Laboratory Analysis
		  ○ TP (low-level detection limit) (euphotic zone composite)
		  ○ Chlorophyll α (euphotic zone composite)
		
		Supplemental (if triggered {Section 7.2.3}):
		• TP (1 metre off bottom, end of summer sampling only)
		• Chloride (1 metre off bottom, end of summer sampling only)
		
		Observational:
		• Aquatic invasive species incidental sightings
		• Algae bloom incidental sightings
		• Ice-on and ice-off dates
		
		Other water quality related observations (e.g., nuisance aquatic plant growth, unusual visual appearance of water or odours)

Design	• a single, fixed station in a central deep lake location • additional stations for lakes with complex morphometry/distinct basins	

Frequency and Timing	• 2 sampling events per year at each lake
	  ○ once in spring during mixed-water column conditions
	  ○ once at the end of summer	

O&M (Monitoring Staff)	• Community-led with HRM support for lakes without community volunteers; monitoring by HRM staff to be reduced over time with progressively more volunteer commitment • Observational information from residents or other stakeholders	
Cost Responsibility	• HRM funded with in-kind support from volunteers (to conduct monitoring, provide equipment if available)	

7.3.3 Framework 3 – Regional Scale Water Quality Monitoring

Framework 3 implements the core monitoring at a regional scale in HRM. This framework is ideally suited to provide information on overall water quality of HRM lakes spanning the range of land use practices and development pressures. It also is suitable to support lake water quality and contaminant loading models, providing the necessary range of data to calibrate and validate the models. Finally, monitoring lakes across a broader geographical area and spanning a range of land use can provide insights on regional scale stressors on lake water quality (e.g., climate change, acidification or recovery from same) that may be influencing water quality. Volunteer monitoring would likely continue but with no direct coordination by HRM.

The existing beach monitoring program implemented by HRM would continue. A summary of the public beaches included in HRM's monitoring program is included as **Table D-6. Appendix D.** Program elements for Framework 3 is summarized in **Table 14.**

Lakes

Monitoring is conducted at lakes that are highly vulnerable (Class A) or moderately vulnerable (Class B) to eutrophication and chloride enrichment due to human activities in the watershed and reference lakes (**Tables D-1 D-2, and D-3, Appendix D**). Class A lakes and reference lakes are monitored in spring and at end-of-summer, and Class B lakes are monitored in spring only.

Operations and Management

HRM staff is responsible for all aspects of program operation and management, including monitoring activities. This approach is consistent with several other municipalities with a corporate water quality monitoring program (City of Greater Sudbury, District Municipality of Muskoka) (**Section 3**), where there is a preference to maintain "ownership" to avoid issues with data capture and quality, data sharing, and associated financial support. Avoiding these issues can reduce potential for data gaps or third-party concerns if the data are used to make planning decisions (e.g., enhanced development controls required for developers based on data collected as part of the program). Finally, this approach provides consistency for budgeting purposes.

Table 14: Summary of Framework 3 Program Elements

<table>
<tr><th colspan="2">Framework 3-Specific Monitoring</th><th>Core Monitoring Program Elements</th></tr>
<tr><td>Sample Size</td><td>Class A Lakes (spring and summer)
Class B Lakes (spring only)
Reference Lakes
Total Number of Lakes: ~74</td><td rowspan="5"><u>Routine:</u>
• Secchi depth
• Lake depth
• Field measurements
  ○ Full water column profiles (temperature, pH, dissolved oxygen concentration, specific conductivity)
• Laboratory Analysis
  ○ TP (low-level detection limit) (euphotic zone composite)
  ○ Chlorophyll α (euphotic zone composite)

<u>Supplemental (if triggered {Section 7.2.3}):</u>
• TP (1 metre off bottom, end of summer sampling only)
• Chloride (1 metre off bottom, end of summer sampling only)

<u>Observational:</u>
• Aquatic invasive species incidental sightings
• Algae bloom incidental sightings
• Ice-on and ice-off dates

Other water quality related observations (e.g., nuisance aquatic plant growth, unusual visual appearance of water or odours)</td></tr>
<tr><td>Design</td><td>• a single, fixed station in a central deep lake location
• additional stations for lakes with complex morphometry/distinct basins</td></tr>
<tr><td>Frequency and Timing</td><td>• 2-year rotation
• Class A – High Vulnerability Lakes have 2 sampling events per year at each lake
  ○ once in spring during mixed-water column conditions
  ○ once at the end of summer
• Class B – Moderate Vulnerability Lakes are sampled once per year at each lake:
  ○ once in spring during mixed water column conditions (ahead of thermal stratification</td></tr>
<tr><td>O&M (Monitoring Staff)</td><td>• HRM staff
• Observational information from residents or other stakeholders</td></tr>
<tr><td>Cost Responsibility</td><td>• HRM funded</td></tr>
</table>

7.4 Lake-Specific Management Plans and Triggered Monitoring

Additional monitoring based on specific lakes with known water quality issues may be required. This monitoring would be developed based on lake specific management plans that would define the scope of the monitoring, approach and costs. AECOM cannot define which lakes would be included nor can the specific elements of the lake specific plan be laid out here. Lake specific plans would be developed based upon a review of data that may identify issues, public concerns or external development pressures. Issues that might be considered could include trophic state transition due to increased loadings of TP or planned major developments or changes to land use within the watershed of a lake which would require more intensive baseline condition and effects monitoring, Lake management plans would be developed under the direction of HRM with input from the community lake associations if they exist, academics and professionals in the field. For example, based on general knowledge of past and recent undertakings, a lake management plan is warranted for Lake Banook, where ongoing aquatic weed harvesting, and extensive lake-specific studies have been undertaken; however, in the absence of an overall plan for the management of the lake. Another example could be Paper Mill Lake, which has had past cyanobacteria blooms and been the subject of past lake-specific undertakings; however, in the absence of an overall lake management plan. Monitoring specifics and costs and the sharing of the workload among HRM, the community, academia and others would be addressed in the plan and is beyond the scope of this report.

In addition, the core monitoring program may identify special needs that require further investigation. This **triggered monitoring** derived from management considerations for an individual lake would be based on a set of management threshold criteria and the monitoring program would be designed to address these criteria. A trigger might be recognition in complex lakes that discrete portions of the lake are more sensitive than the open lake which is currently being monitored or the increased frequency in a lake of HABS. Again, the triggered monitoring would be led by HRM but would include cooperation with academia and community groups as appropriate. Costing for this work would be specific to the task. While setting these criteria is beyond the scope of this undertaking, lake specific monitoring that may be triggered as a result of the review of the results of the core monitoring program could include the areas identified in **Table 15.**

Table 15: Summary of Some Conditions Resulting in Trigger Monitoring and Monitoring Responses

Trigger Monitoring Cause / Monitoring Response	Upward trend in TP	Upward trend in chlorophyll a	Exceed TP guideline	Exceed chlorophyll a Target	Harmful Algal Bloom	Upward trend in chloride	Upward trend in conductivity	Exceed Chloride Guideline	Exceedance E. coli
Phytoplankton, taxonomy, biomass (during and following bloom)				X	X				
Cyanotoxin				X	X				
Stormwater monitoring	X		X			X	X	X	X
E. coli source tracking (e.g., other near-shore sampling)									X
Immediate response to confirm observation					X				X
End of summer or fall mixing monitoring, if not already done.	X	X	X			X	X		
If septic systems thought to be problematic, add shoreline *E. coli*	X	X	X	X					X
Seasonal Monitoring (winter, fall, summer)	X	X	X	X				X	
Reclassify (move up to a higher vulnerability classification or to a Priority lake for monitoring)	X	X	X	X	X	X	X	X	X

8. Program Operation

8.1 Partnerships and Collaborative Strategies

Partnerships and collaboration with community groups, university programs, students, and other parties are recommended as part of the core program to enhance the monitoring program, leverage funding and promote stewardship and research that contribute to HRM's management goals. These strategies include:

- Creation of an HRM lake stewardship community committee to be led by HRM, to unite lake stewardship, community groups and HRM and to serve as a forum for communicating and sharing information relating to the management and protection of water resources, such as:
  - Communicating standard operating procedures for water quality monitoring activities conducted by volunteer groups.
  - Promoting collection and reporting of observational information to enhance core monitoring including:
    - Aquatic invasive species - incidental sightings
    - Algae bloom - incidental sightings
    - Ice-on and ice-off dates
    - Other water quality related observations (e.g., nuisance aquatic plant growth, unusual visual appearance of water (e.g. turbidity plumes or sheens) or odours)
  - Educating the public and key community leaders on HRM lake issues and on ongoing HRM water resource activities and actions to address them.
  - Communicating roles and responsibilities for other government departments.
  - Gaining community assistance to foster wider public participation in best management practices for protecting and improving water quality (e.g., lawn care, shoreline rehabilitation, septic system maintenance and inspection, prevention of AIS introduction and spread).
  - Engaging HRM Councillors and other municipal engineering and planning representatives.
- Establishing a grant program for lake stewardship groups to apply for funding associated with projects/equipment/training deemed important and relevant by HRM. HRM should allocate a budget for this on an annual basis (this is discussed further in **Section 10 - Program Costing**).
- Establishing an ongoing annual budget to be set-aside for leveraging funding opportunities associated with academic researchers for the purpose of lake-specific investigations, and/or investigations associated with key water concerns relevant on a region-wide basis.
- Continue to participate and support provincial and federal government initiatives.

Partnerships to directly assist with field monitoring activities in a community-focused program led by HRM can be an effective strategy to leverage resources. This approach is considered in Framework 1 and Framework 2.

8.2 Operations and Management

8.2.1 Staffing Needs – Frameworks 1 and 3

To implement the comprehensive program outlined under either Frameworks 1 and 3, it is recommended that HRM establish a full-time position for a dedicated HRM lake water quality Program Manager. It is further recommended that the Program Manager be supported by a full-time program assistant and these full-time personnel would be supported by seasonal staff members who are responsible for field monitoring as may be necessary as well as working with the volunteer teams. The Program Manager's position is expected to be mapped to the Energy and Environment division. Suggested responsibilities of the Program Manager could include but not necessarily be limited to:

- Responsible for the oversight and delivery of the HRM lake water quality monitoring activities including sample collection, validation, data management, and documentation.
- Responsible for establishing and chairing a municipal-led committee of lake stewardship representatives. The Program Manager would be a point of contact for lake stewardship groups relating to water quality initiatives within HRM. This could include educational and training initiatives, information exchange to establish collaboration opportunities, and serve as a forum for communicating standardized water quality sampling and monitoring procedures for the Region, field observation and data collection initiatives and documentation.
- Responsible for assessment/evaluation of monitoring data collected by others (volunteers, community representatives, etc.), against an established set of criteria. Only if the data meets the criteria, will it be incorporated into HRM's data management system.
- HRM Lead for surface water resources and internal point of contact with other HRM departments. In particular, the Regional Planning, Current Planning and, Infrastructure Planning of the Planning & Development business unit.
- Responsible for the QA/QC management and operation of a data management system for water resource data for HRM
- Responsible for preparing and producing reports and report card publications to communicate results of the monitoring activities.
- Responsible for content and sharing of information on a centralized website / web page dedicated to the HRM lake water quality program.
- Additional responsibilities relating to ongoing water resource efforts within the municipality includes but is not limited to:
  - Contract administration and program oversight as a part of ongoing remediation/management efforts within HRM lakes (i.e. weed harvesting program within Lake Banook)
  - Municipal lead for HRM's Beach Monitoring Program.
- Responsible for future undertakings such as:
  - Conducting data analysis to determine lakes requiring trigger monitoring for future program
  - HRM internal lead for lake management plans, where required.

The Program Assistant would support all of these functions with key responsibilities including training seasonal staff, volunteers, maintaining equipment, monitoring and other assignments depending upon specific skills and abilities of the staff person.

8.2.2 Staffing Needs – Framework 2

Staffing needs for Framework 2 are similar to those of Frameworks 1 and 3, however they are reduced in that a Program Assistant would not be required for Framework 2. However, to leverage the community-based efforts proposed in Framework 2, it is recommended that HRM establish a full time Program Manager position. Seasonal sampling for those lakes where community volunteers have not been identified, would be sampled by the Program Manager and a seasonal staff member (i.e. field technician), where health and safety regulations require two (2) individuals in a boat. The seasonal staff member would also provide support to the coordination and sample gathering activities associated with the community-led volunteer sampling. The Program Manager's position is expected to be mapped to the Energy and Environment division. Suggested responsibilities of the Program Manager are similar to those recommended for Frameworks 1 and 3, listed above.

8.2.3 Community Involvement

Frameworks 1 and 2 propose and we recommend leveraging support from volunteers from the community and lake-base stewardship groups for those lakes where groups are already established. Both frameworks propose utilizing community-based volunteers to conduct the field activities including collecting the scheduled samples during each of the spring and summer sampling events, along with collection of associated field observations. These frameworks utilize and empower members of the community who have a strong interest, commitment and knowledge pertaining to the lakes in their area. It is also anticipated that community members will be helpful contributors for observational data collection such as incidental sightings of aquatic invasive species and algae blooms, ice-on and ice-off dates and other water quality observations. As was said earlier, this approach builds on the existing commitments and knowledge of community associations and volunteers. It provides opportunities for maximizing a return on the funding commitments and builds partners both for monitoring and supporting the communication of the benefits and outcomes of the program. As we noted above, and it is worth repeating here that *"No matter how much monitoring we do, we will not change anything if we can not deliver the results to inform choices, decisions, and policies. Science alone is not well equipped to model and understand future changes and scientists are even less equipped to reach decision-makers. The community serves a role and a purpose here."* (Conrad, 2007)

The proposed programs outlined in Frameworks 1 and 2 consider participation by the community groups listed in **Table 16**, as applicable based on the lakes being proposed to be sampled.

Table 16: Community Groups Considered for Participation in Frameworks 1 and 2

Group Name
Banook Area Residents' Association
Eastern Shore Group[1]
Five Island Lake Estates Homeowners' Association
Friends of Blue Mountain - Birch Cove Lakes Society
Hubley Area Community Group[1]
Lake Charles Community Group
Lake Micmac Residents Association
Oathill Lake Conservation Society
Portland Estates and Hills Residents Association
Sandy Lake Conservation Association
Springfield Lake Group[1]
Shubenacadie Watershed Environmental Protection Society
Westwood Hills Residents Association
Williams Lake Conservation Company

Note: 1. AECOM has information that suggests there are established community groups within these communities, however the group name or details for these groups is not known. Future efforts to confirm whether viable community-groups exist in these communities in support of future monitoring efforts will require confirmation

8.2.4 In-Kind Service Arrangements

All three (3) proposed program frameworks recommend continuing to engage members of the local Nova Scotia academic community. It has been already said that academic researchers also often conduct monitoring and have used past HRM monitoring data to support their research activities. Partnership opportunities should be explored to gain assistance from academia for monitoring activities (e.g., student participation) in exchange for data sharing. HRM should also consider partnerships with academia for research-related activities that may be applicable to the municipality, or applicable to lakes with similar vulnerability classifications. From a review of past initiatives, academia has been typically involved for lake-specific investigations, where required. We recommend that funds should be set aside on an annual basis to plan for future undertakings whereby these collaborations are expected, and funds invested by the Municipality can be essentially doubled or tripled through project-specific collaboration with academics/student researchers through NSERC match or other funding opportunities. It is also suggested that HRM should be involved in future collaborations with other groups including academics, agencies and public user groups, to help develop cooperation and awareness.

8.2.5 Contract Service Arrangements

All three (3) proposed program frameworks recommend program operation and management by HRM through the hiring of a full-time program manager. Additional resources are recommended, depending on the framework that is chosen. Depending on the education and experience of the future direct hires by HRM, additional support by way of paid service arrangements will likely be required. However, the type and scope of additional support that may be needed will be determined based on the skills and expertise of the future program manager and/or program assistant. For example, the future program manager may have expertise and experience conducting surface water sampling programs and a strong understanding of water resources, however, they may not have the limnological educational and experience background needed for data interpretation. This expertise could be contracted out to limnology consultants or consulting academics. Similarly, the program assistant may have experience with data management and therefore, data management support from external organizations may be unnecessary. Each recommended framework assumes that HRM will conduct the day to day management and supervision of the program, however external expertise is likely needed for execution of additional program functions. Examples could include, but are not limited to the following:

- Technical review and advisory expertise in relation to data interpretation;
- Expertise and support for data management strategies;
- Technical review and advisory expertise with reporting activities (i.e. annual report, report cards); and,
- Advisory support for establishing a community-led monitoring program.

8.2.6 Equipment Needs

The standard equipment required to conduct the sampling includes:

- Secchi disk – 20-cm diameter
- Water quality multimeter – hand-held meter with a 20-m long cable assembly equipped with temperature, dissolved oxygen, pH, conductivity,
- Calibration solutions for field equipment if purchased
- Tube sampler – to collect euphotic zone composite samples
- Discrete depth sampler –thief sampler (e.g., Kemmerer or Van Dorn sampler) to collect water samples at a discrete depth
- Boat, motor, trailer and truck (purchase or lease or contract)
- Field safety equipment
- Laboratory-issued sample jars - for collection of chemical parameters (i.e., TP, chlorophyll α and chloride)
- Incidentals – underwater camera, field book, disposable gloves

The sampling equipment can be purchased or rented from environmental equipment supply companies.

8.3 Quality Assurance

A quality assurance and quality control (QAQC) plan is essential to a successful monitoring program to ensure that data are of adequate quality to meet the project objectives and to avoid potential loss of data due to sampling errors, malfunctioning equipment, data transcription errors, loss or breakage of samples in transit to the laboratory, etc. A QA/QC plan should be developed to include:

- Detailed field data collection protocols otherwise referred to as standard operating procedures;
- Field equipment specifications, and operations and maintenance needs;
- Standardized field sheets;
- Water sample packaging and transportation protocols; and,
- Screening methods to identify data outliers.

To ensure quality, chemical analysis should be performed at accredited laboratories. The analysis of TP should be conducted at low level (Method Detection Limit ≤2 µg/L). Laboratory Certificates of Analysis should be reviewed in a timely manner so that issues with the analyses can be resolved (e.g., to flag unusual or suspect results that may need to be reanalyzed by the lab). All laboratory documentation should be compiled and archived for future reference including Chain of Custody, Certificates of Analysis, and individual digital results files that maintain information on detection limits.

Data review standards are discussed in relation to data management in **Section 10**.

8.4 Program Evaluation and Reporting

Review and evaluation of the monitoring program should be undertaken periodically to determine if the program met or will continue to meet decision needs for HRM, to correct issues or challenges faced during implementation, and to incorporate changes that reflect improved understanding of the system or new and enhanced monitoring techniques and additional water quality variables. This evaluation should consider all aspects of the program including:

- Monitoring objectives (e.g., whether they met and will continue to meet HRM decision-making needs);
- Key water quality concerns (e.g., whether they will continue to encompass key issues for HRM lakes);
- Lakes monitored (e.g., whether the list of lakes and classifications were appropriate to meet program goals);
- Monitoring program design (e.g., issues with lake access, ability to sample lakes within set timeframes, health and safety concerns, need for alternate data collection methods, need for additional sampling locations);
- Data quality (e.g., whether there were issues with suspect data or outliers);
- Partnerships and collaborative strategies (e.g., participation in the Lake Stewardship Community Committee, success in developing partnerships or collaborations with other government or academic groups);
- Program operation and management (e.g., need for additional resources);
- Cost (e.g., budget issues); and
- Data management (e.g., storage and access to data).

To inform the program evaluation, it is recommended that HRM obtain input from other municipal departments and agencies (i.e., Halifax Water), as well as from partners or collaborators. This can be achieved by a questionnaire, tailored to obtain feedback on specific elements of the program. It is also recommended that the Program Manager maintain a log of monitoring program successes and challenges, and comments or feedback obtained over the course of the program that can be brought forward into the evaluation.

The program findings and water quality information generated as a part of the program should be disseminated such that the information can be used by the other divisions of the Planning and Development business unit of HRM. We understand there are three (3) formal divisions of the Planning and Development Business Unit that each play active roles regarding water resource management, as follows:

- Regional Planning – planning policy development;
- Current Planning – the application of planning policy to new developments;
- Infrastructure Planning – engineers and engineering technologists who regulate development within the Development Engineering program area and the staff involved in water policy development, programming, projects and operations that form a part of the Energy and Environment program area.

The program should be evaluated two years following program start-up. It is recommended that the evaluation be completed as a component of the detailed monitoring program report so that findings from the monitoring can be used in the evaluation and recommendations made in that report. These will be carried through into the plain language and administrative reports. After the initial two-year period following program start-up, reporting and program evaluation frequencies should be re-assessed to determine optimum frequencies.

9. Water Quality Data Management

9.1 Use of Historical Data and Data Collected by Others

To make effective decisions with regards to water resources and land use planning within the Region, it is important for HRM to manage and be in control of its own program. As noted in Section 6.1, monitoring programs conducted by other organizations such as academia or volunteers are collected for specific purposes and focus, which may or may not be aligned with the needs of HRM to make water management decisions at the local level. HRM should collect its own data for its own purposes and the data (and water resources) need to be managed accordingly. The establishment of an HRM lake water quality monitoring program is a good start at establishing a monitoring program for this purpose and this is the focus of this report. However, this program can and should be supplemented with valuable water quality information collected in the past by or on behalf of HRM. Water quality information collected by others, however, should only be used by HRM, if the information meets a minimum set of data integrity and quality criteria, which should be defined and established as a part of a future undertaking.

While there are many other organizations collecting information and HRM has a plethora of information from past undertakings, this information is not being used effectively by HRM. This information is valuable scientific information that could be used to assist HRM in decision making and land-use planning practices. To be useful, historical data collected by or on behalf of HRM needs to be compiled, synthesized and managed in one database. In our view, HRM needs to take control of managing a dataset of information for its own purposes, so this data can be used effectively to inform programs and decisions.

9.2 Recommendations from Previous Undertakings

Recommendations for water quality data management approaches for data storage, analysis, interpretation and dissemination have been put forward in past undertakings. Recommendations relevant to water quality data management presented in AECOM 2013 included a recommendation for standardizing relating to:

- Storage of data in a secure searchable database;
- Consistent and routine data verification and validation;
- Verification and validation of all historical data as feasible;
- Inclusion of detection limits along with actual data; and
- Integration of data results periodically by updating of water quality models.

A discussion of recommended categories for database inclusion, as presented in Stantec 2010 included:

- Site name and location (including GPS coordinates);
- Sample date, time and weather (including precipitation in previous 24 hours);
- Collection depth of water sample (including whether or not the sample was a composite);
- All water chemistry parameters (including full name, units of measure, detection limits, and results);
- Relevant water quality guidelines (project-specific targets and/or national guidelines);
- All in situ water quality parameters (including full name, units of measure and results);
- Field treatment (e.g., filtering), storage time, preservative type;
- Lab methodology;
- QA/QC procedures for data verification; and,
- Ability to detect and identify outliers in the data.

Stantec 2010 presented the results of a review of the intended functions of a database management system based on discussions with other municipalities regarding their own water-based data management practices. This informed some key recommendations for the identification of several key requirements for a water quality database for HRM, including the following:

- Accessible to all stakeholders;
- Allows queries to be run to extract focused datasets;
- User friendly interface;
- Integrated (or at least compatible) with GIS mapping system;
- Compatible with mainstream data management software for the purposes of exporting and sharing with the public (*e.g.,* Microsoft Excel);
- Allow basic statistical analyses or be compatible with programs that include statistics packages (*e.g.,* Microsoft Excel, Systat); and
- Potential database systems that HRM can consider for implementation: WaterTrax™, Access, Oracle, ENVIRODAT (CCME 2006).

9.3 Summary of Feedback from Consultations for this Project

Feedback relating to data management we received as a part of the consultations conducted by AECOM in February 2020 included the following:

- Making data accessible and readily available;
- Reporting of HRM data in open data format and provide summary reports (report cards) to users and public;
- Concern about placing public data into a quasi-private entity that owns the data but may not exist if funding expires;
- Centralized website – needs to be easily accessed;
- Open data sources where groups can access and upload data; and/or
- Consistently use Atlantic DataStream.

9.4 Use of Atlantic DataStream

As discussed in Sections 4.1 and 4.2, Atlantic DataStream is an open-access platform for sharing water quality information and has recently received growing support and increased participation from the local NS water resource community. During this study we heard from federal and provincial representatives that water quality data collected by these organizations locally, is also shared and published on the Atlantic DataStream Platform. Locally, there are a growing number of community-groups that also share water quality data collected by their organizations on this platform. Concern was expressed by one representative of the long-term sustainability of Atlantic DataStream, given it is funded by a private entity, The Gordon Foundation, whose funding may not be viable or secure on a long-term basis. However, the overall feedback on the use of Atlantic DataStream from individuals and groups consulted by AECOM was quite positive.

DataStream, the parent organization to its regional partner, Atlantic DataStream, recently published its open data standard, which is a documented data standard for the DataStream platform. This open data standard is based on systems previously developed by the United States Environmental Protection Agency (USEPA) and the United States Geological Survey (USGS). According to a February 2020 news release[30], the data standard is incorporated into the DataStream digital infrastructure so that data are organized and described in a standardized way.

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[30] https://atlanticdatastream.ca/en/article/datastream-publishes-open-data-standard. *Accessed May 2, 2020.*

DataStream is an "online, open access platform for sharing water data. It is built with communities, policy-makers and researches in mind, and designed to make it easy for diverse monitoring and research groups to share, visualize and download data." DataStream's Open Data Schema -- a model based on the WQX standard for the Exchange of Water Quality Data. DataStream is free to use and allows users to query, visualize, and download data in this standardized format.

DataStream also has a policy on its practices for management of data. A copy of this policy is included in **Appendix E.**

As it relates to the subject study, HRM is encouraged to use data reported on Atlantic DataStream as a part of a future monitoring program. However, we suggest that this information should be used with caution. Issues documented in past reports and consultations involve varying data collection and data reporting methods. While having an expanded dataset through the use of data reported within Atlantic DataStream would be a benefit to HRM, this data should only be incorporated into an HRM-managed database system, should it meet a set of minimum data management quality assurance and quality control requirements or thresholds. For example, data documentation information is important for accurate interpretation of results. Information such as sample collection coordinates, sample type (i.e. grab sample versus composite sample), sample depth (surface sample, within 1 metre off bottom, euphotic zone), laboratory detection limits, laboratory analysis method, etc. are all important. Similarly, familiarity of the organization that collected the data is also important to help discern that sample collection procedures are acceptable to HRM's QA/QC criteria. However, through growing support and increased standardization, the use of data contributed by community-based organizations and government organizations in a standard platform could greatly benefit an HRM-managed program.

HRM is encouraged to continue to support Atlantic DataStream by publishing data collected on its behalf onto the Atlantic DataStream platform, and it is encouraged to use data reported within DataStream, should the information meet a minimum set of QA/QC requirements. However, this information should be used to supplement an HRM-owned and operated data management system. As discussed earlier, monitoring programs conducted by others have different areas of focus and are not sufficiently detailed or aligned with the needs of HRM to meet decision making needs for water resource management at the local level. An HRM-led data management system is needed to meet these decision-making needs at the local level. The use of Atlantic DataStream does not replace the need for HRM to manage its own program or dataset.

9.5 Potential Software Solutions

A future water quality monitoring program will require a suitable system for the organization, management and storage of water quality data management. From our experience, there are a variety of software solutions that are in-place for water resource professionals. There are a variety of options with associated start-up costs, ongoing maintenance and management considerations. For the purpose of this study, software products offered by two (2) companies will be highlighted; EQuIS by Earthsoft and EnviroData by Geotech Computer Systems Inc. Recently, other municipal and provincial entities within Nova Scotia have issued request for information (RFI) tenders for water quality data management solutions. Halifax Water issued an RFI in February 2020 and NSE and Nova Scotia Department of Energy and Mines, issued a similar RFI in April 2020. HRM is encouraged to consult with these organizations for information sharing purposes and to identify potential opportunities for economies of scale and overall database management.

9.5.1 EQuIS

Earthsoft's EQuIS (Environmental Quality Information System) is an environmental data management system. It consists of a suite of software applications to support the complete environmental data workflow including sampling planning, field data collection, data checking, data validation, reporting and visualization (**Figure 11).**

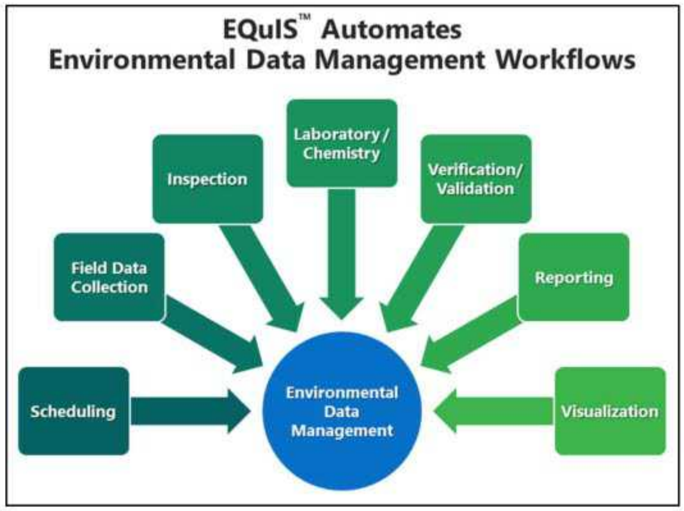


Figure 11: EQuIS Automated Workflows

EQuIS Professional is a desktop application that is typically used by trained data managers and scientists for importing and editing data, with advanced data analysis and modeling, providing ultimate power and flexibility. EQuIS Enterprise is a web-based application that is typically used by managers, auditors, executives, and laboratories.

EQuIS automates many workflows and tasks so that data handling and input is kept to a minimum. For example, EQuIS Collect is a user-friendly app that enables the easy gathering of environmental data for EQuIS on a smart phone, tablet, or computer. The field data is then uploaded to EQuIS with the Enterprise EQuIS Data Processor (EDP) which enforces data rules and ensuring the integrity of the data **(Figure 12).** Similarly, the laboratory can transmit laboratory results directly to EQuIS via the EquIS Data Processor, requiring no data entry.

Loading of data is automated with EQuIS Enterprise. This includes both field data collected through the mobile app and lab data. No mediator required as field staff and laboratories can load the data directly into EQuIS via Enterprise EDP (EQuIS Data Processor). EDP acts as a "traffic cop" by verifying and validating the data before allowing it to be securely uploaded.

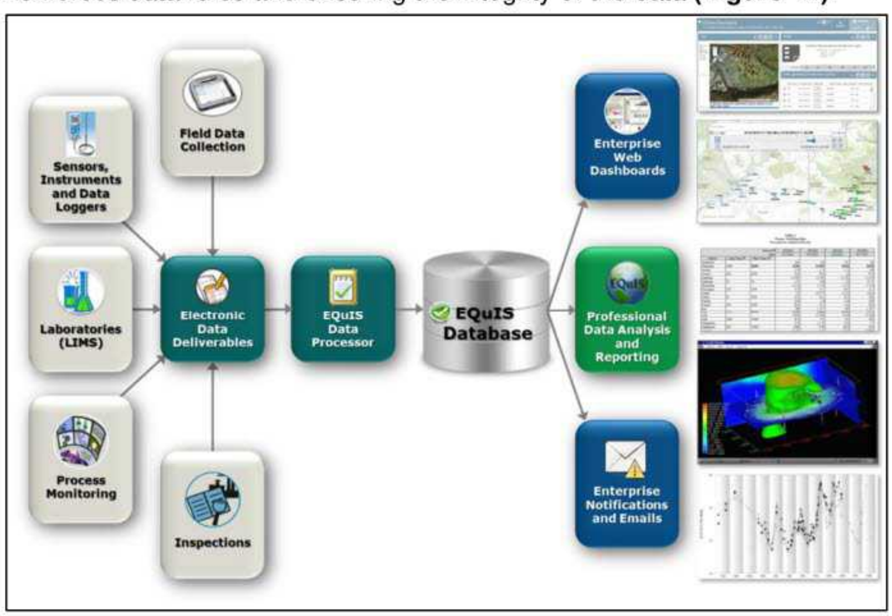


Figure 12: EQuIS Data Management Workflow

EQuIS offers a limnology specific software application, EQuIS™ Lake Watch, which is a lake and reservoir monitoring software. LakeWatch "manages and analyzes freshwater data, provides trend changes over time and reports trophic (nutrient) level of the water." A sample EQuIS™ LakeWatch dashboard is shown in **Figure 13.**

A summary of key features of the EQuIS^{TM} Lake Watch is listed below. Marketing materials from EQuIS are included in **Appendix E.**

Store. Relational Database:

- Database is structured in a logical hierarchy by waterbody, station, and sample date
- Configure and select your own monitored variables
- Database structure reduces tedious analysis

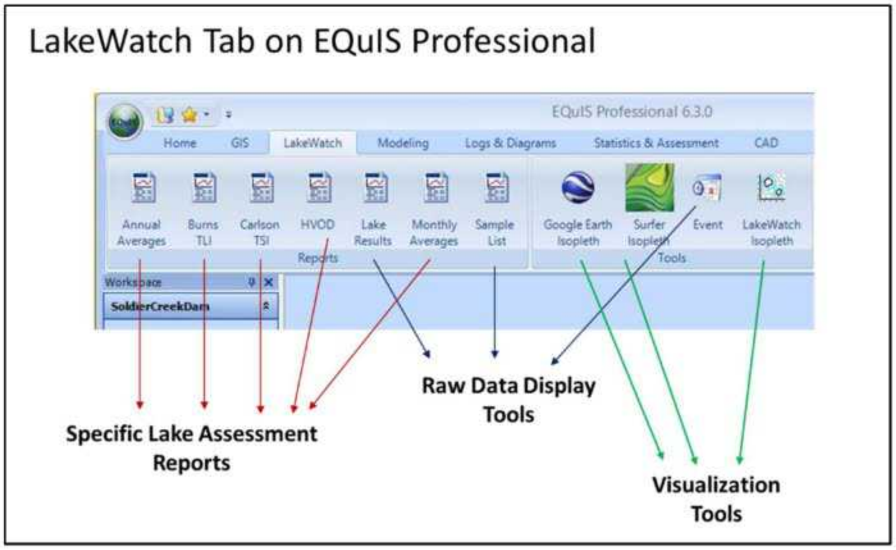


Figure 13: Example Dashboard for EQuIS^{TM} Lake Watch

Visualize. Data Profiling:

- See how any individual variable changes over time – season, year, etc.
- Interrogate data at the click of a button and profile it graphically
- Plot any variable against another over a data range

Analyze. Trend Evaluation:

- Compile a dataset for analysis by selecting a set of monitored variables for a waterbody over any time period
- Isolate data from different thermal layers
- Show true, deseasonalized trends over time

Report. Preformatted Output:

- Report the trophic level of a waterbody against an index and see the trophic level trend with time
- Change the look and feel of graphics to suit your reporting
- Copy and paste your graphs into other applications and resize them without loss of clarity

As it relates to a potential application for HRM, EQuIS Collect (mobile and computer app) could be used by field staff and also representatives from lake-based and community user groups. Field staff can upload field data and observations, and community representatives could be provided with an EQuIS Collect login (i.e. one per user group), such that supplemental data and field observations could be reported to HRM automatically. The EQuIS EDP is an intermediary step between the EQuIS Collect User and the Client Data Manager, such that Client Data Manager can vet what information gets imported into the database, ahead of the actual import.

Earthsoft's operates a business partner program, where Earthsoft partners with numerous consultants who can provide implementation and support services for EQuIS software products. At present, there are a total of eight (8) consultants that are members of this program[31].

[31] *Earthsoft Business Partner Program.* *https://earthsoft.com/about/business-partner-program/.*

EQuIS Reporting

1. EQuIS Reports can generate statistics information of Mean, UCL, Median, Standard Deviation, Coefficient of Variation, Skewness, Minimum, Maximum, Count (n), Mann-Kendall S (**Non-parametric method**), Trend analysis (at 80% confidence, 90% confidence, 95% confidence, 99% confidence) and Sen Slope (**Non-parametric method**), etc.
2. EQuIS can generate a trend chart which includes a time series chart of either actual data or averaged data, its polynomial trend and a regression analysis chart:
   - A scatter chart with polynomial trend line (top chart below)
   - A scatter-line chart with linear regression lines (bottom chart below)

9.5.2 EnviroData

EnviroData is a data management program application that is made by Geotech Systems Inc. Similar to EQuIS, discussed above, it is a relational database management system that allows for centralized data storage and incorporates sample planning, importing, validation, analysis and reporting features. **(Figure 14**)

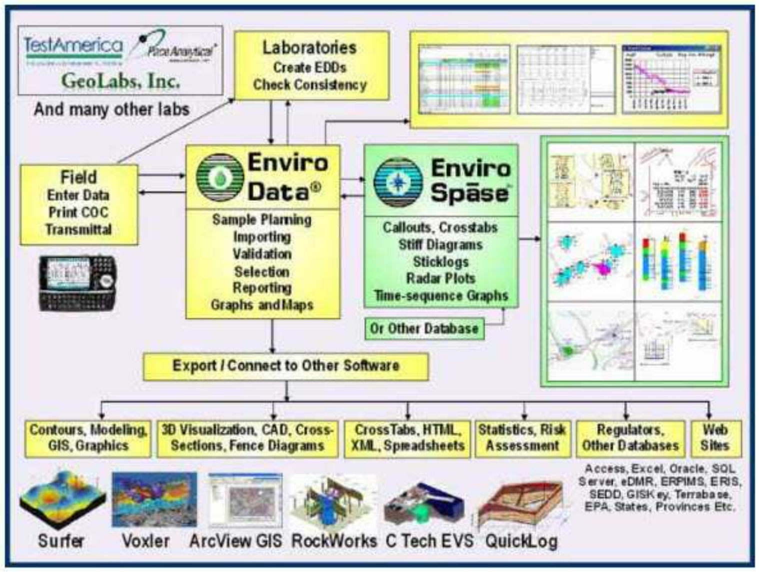


Figure 14: EnviroData Overview

EnviroData can store and display field and laboratory data for water, soil and air. It has a field and laboratory data interface, offers data validation functions and has a user-friendly selection screen that integrates graphing mapping and reporting.

EnviroData uses Microsoft Access for its user interface and data is stored in the database backend, which can be sourced by Access, SQL Server or Oracle. Since Microsoft Access is an open-source software product, it can be easily customized. EnviroData has the capability to transfer data directly from laboratories, efficiently and accurately using electronic data deliverables. EnviroData also has an interface with ArcGIS and has a companion product called EnviroSpase, which allows data to be shared within GIS-based maps.

EnviroData's features include the following:

- Storage of water, soil, air, etc. information;
- Field, lab, and operating data;
- Chemistry, geology, biology, engineering;
- Centralized data storage;
- Data integrity enforced;
- Sample planning, labels, Chain of Custody (COCs);
- Verification and validation;
- Graphs and maps;
- Reports and limits, statistics;
- Access front-end; and
- Access, SQL Server, or Oracle backend.

9.6 Hosting Options

Both EQuIS and EnviroData have multiple capabilities for software installations and hosting. Both software solutions can be purchased and used either as standard installed programs, or as cloud-based programs. With standard installed applications, the database management system is a stand-alone program that is installed locally, whereas cloud-based do not require the software to be saved or installed locally, and it is accessed via a cloud, web-based environment. Stand-alone programs would likely require in-house IT support for installation, whereas cloud-based systems would not.

10. Program Costing

10.1 Program Costing Frameworks

Table 17 presents a summary of the estimated annual costs by comparison for each of the proposed monitoring frameworks. Since Frameworks 1 and 3 are proposed on a 2-year rotational basis for the estimated 74 total lakes to be monitored, estimated costs for the program start-up, along with the first two (2) years of sampling are put forward. Framework 2 proposes monitoring a reduced number of lakes, approximately 23, on an annual basis and costs for the second year of operation are included for completeness. It should be noted that the costing summarized in **Table 16** does not include the costs associated with delivery of HRM's beach monitoring program which we recommended be undertaken within each framework.

Table 17: Summary of Estimated Annual Costs - All Frameworks[1]

Budget Item Description	Framework 1 – Coordinated Regional and Community Focused Monitoring (CAD$)	Framework 2 – Community Focused Monitoring Program (CAD$)	Framework 3 – Regional Scale Water Quality Monitoring (CAD$)
Start Up Costs	**21,750**	**21,750**	**18,250**
Year 1 – Spring Sampling – Personnel, Expenses & Laboratory Costs	15,235	11,044	13,837
Year 1 – Summer Sampling – Personnel, Expenses & Laboratory Costs	9,296	9,908	8,651
Full Time Salary Costs	133,000	85,000	133,000
Ongoing Costs	9,500	9,500	8,500
Grant Program	7,500	5,000	7,500
Consulting and Research (reduced for first year)	50,000	30,000	50,000
Year 1 -Total Cost	**224,531**	**150,452**	**221,489**
Start Up + Year 1 Costs	**246,281**	**172,202**	**239,739**
Year 2 - Spring Sampling - Personnel, Expenses & Laboratory Costs	15,361	11,044	14,331
Year 2 - Summer Sampling - Personnel, Expenses & Laboratory Costs	9,704	9,908	9,059
Full Time Salary Costs	133,000	85,000	133,000
Ongoing Costs	9,500	9,500	8,500
Grant Program	7,500	7,500	7,500
Consulting and Research	75,000	45,000	75,000
Year 2 - Total Cost	**250,065**	**167,952**	**247,390**
Grand Total (Startup + Year 1 + Year 2)	**496,346**	**340,154**	**487,129**

Note: 1. Costs are presented based on 2020 costs with no adjustments for inflation and do not include administrative overhead burden costs associated with hiring employees directly by HRM.

Framework 1 (Coordinated Regional with Community) and Framework 3 (Regional Scale by HRM), have the largest scope of work and by extension have the highest costs, estimated as $246,281 and $239,739 each respectively for the program start up and first year of operation. Framework 2 has a smaller scope, and by extension, its costs are lower, with startup and year one costs of $172,202.

For all frameworks AECOM recommends HRM lead the program operation and management. Frameworks 1 and 3 assume that two (2) full time staff are hired, a Program Manager and Program Assistant. HRM led sampling activities are assumed to be conducted by the Program Assistant and a seasonal field technician, proposed to be hired for a four (4) – month term between May and September. The Program Manager is assumed to be able to assist with sampling for periods when the field technician is not available.

Both Framework 1 and Framework 2 involve the establishment of community-led monitoring, which will require some start-up costs. It is for this reason that Framework 1 is slightly more expensive than Framework 3, in the short-term. Also, because sampling effort is assumed to be direct hires by HRM, these costs are assumed to be sunk costs over the sampling season. For Frameworks 1 and 2, while there is a cost saving to HRM by not directly conducting the sample collection at all lakes, there will be increased costs in coordination of volunteers and for collection of samples from each of the volunteers, following each sampling event. As noted earlier, the benefits of a community-led monitoring program extend far beyond dollars and cents.

10.2 Framework Costing Summaries

A breakdown of the estimated costs for Framework 1 – Coordinated Regional and Community Focused monitoring is included in **Table F-1**, **Appendix F**. A proposed schedule of sampling, along with the suggested community groups that could participate in the Framework 1 sampling is included as **Table F-2, Appendix F.**

A breakdown of the estimated costs for Framework 2 – Community Focused Monitoring of Priority Lakes, is included in **Table F-3 Appendix F**, along with **Table F-4**, **Appendix F**, which outlines the proposed schedule of lakes to be sampled, along with the suggested community groups that could participate in the sampling.

A breakdown of estimated costs for Framework 3 – Regional Scale Water Quality Monitoring is included in **Table F-5, Appendix F**, along with **Table F-6**, **Appendix** F, which outlines the proposed schedule of lakes to be sampled by HRM. In this case, the proposed schedule of lakes to be sampled, along with the proposed year of sampling, based on an overall two-year rotation, is the same as Framework 1, with the exception that HRM would be completing all of the sampling.

10.3 Overview of Costs Categories and Assumptions

Start Up Costs – For all Frameworks, we have estimated there will be program startup costs. This includes the purchase of a boat, motor and trailer, associated licensing and registration costs, a ballpark estimate for data management software start up (to be verified with a supplier) and costs associated with preparing equipment-kits for community-based monitoring groups. Equipment could include Secchi discs, and sampling equipment supplies. We have assumed that the key pieces of equipment will be purchased and thus there will be limited operational costs. If it is desirable, HRM can rent most of the equipment from suppliers. This will reduce some capital costs but will increase the annual operating costs. In general, continuous use of equipment for 4 to 6 weeks twice a year will justify purchasing over renting equipment.

Full Time Staff – For all Frameworks, we have assumed that HRM will hire direct staff for program operation and management. That is, the staff will become HRM employees. For cost estimation purpose, estimates of the raw salary costs to be paid to the employees have been included for cost estimation purposes. There is no overhead burden assumed in any of the direct costs of salaries to HRM. Frameworks 1 and 3 assume two (2) staff hires, including a Program Manager and Program Assistant. Framework 2 has a smaller sampling scope and it is suggested that only a Program Manager is needed for this option. In all cases, we suggest HRM hire a seasonal staff person to help coordinate the water sampling activities.

Ongoing Costs - It has been assumed there will be ongoing costs associated with program operation. This includes costs such as annual boat inspection and maintenance and insurance and, on-going license and upgrade costs for data management software licensing. Additional costs may be incurred over time with increasing the number of community groups involved or by replacing equipment with time. A budget has also been estimated for health and safety training of new employees, as may be required.

Other Costs - Other costs include budget allocation for provision of consulting services (i.e. limnology expertise), the establishment of an annual grant program for community groups to apply for funding for water resource equipment or endeavors that may be approved by HRM, and lastly for an annual set-aside for collaborations with academia whereby funds contributed by HRM can be doubled or tripled through fund matching programs available to academia and research projects.

Seasonal Costs - for each of the proposed Frameworks the details of the estimated laboratory, personnel and expenses associated with the sampling activities are estimated by sampling event. In all cases, it is assumed that sampling effort by HRM will be completed by a seasonal hire, along with one of the full-time staff members. The details pertaining to the schedule of sampling for analysis is specific to each of the Frameworks. Where supplemental analysis, depending on the field conditions observed, we have included an assumed number of samples that will be required. For Frameworks 1 and 3, where community groups are involved with sampling, it is assumed that the community groups will absorb the sample collection costs including boating costs and sampling effort. Following sample collection by the community volunteers, HRM staff will need to coordinate sample pick-up from each of the volunteer groups and submit the samples to an accredited laboratory for analysis. These costs have been estimated.

Lake Management Plans and Targeted Monitoring – budget for these items have not been incorporated into these framework budgets. While these are important components to the overall success of the lakes monitoring program, they will vary by scope and duration and will therefore need to be budgeted individually and separately from this monitoring program.

11. Recommendations and Implementation Considerations

11.1 Recommendations

AECOM was retained by HRM to review past municipal initiatives related to water quality monitoring, to understand what other cities are doing to support healthy watersheds, and to provide advice on a potential water quality monitoring program for recommendation to Halifax Regional Council during fiscal year 2020-2021. While there appears to be a perception generally within HRM that water quality monitoring is neither a standard nor a typical municipal function; HRM has engaged in these activities historically. Through this undertaking, HRM hopes to better understand how and why other municipalities perceive water quality monitoring to be their responsibility and how the monitoring can be used to fulfill or provide the foundation for their established water resources management policies and whether their existing policies are appropriate or adequate.

The primary goal of this undertaking was to develop, refine, and present recommendations for 1) the policy basis for a municipally-led lake water quality monitoring program, and 2) the elements, structure, proposed operations and management of such a program. Secondary goals include:

- to develop suitable lake water quality monitoring objectives, which shall form the basis for the program;
- to develop, at minimum, three alternative program frameworks that may serve to meet program objectives; and,
- to develop order-of-magnitude costing estimates for each program framework, including start-up and annual costs.

Some things that have been learned that support the need for HRM to implement a lake monitoring program include:

- The Province views the water as a shared resource and its stewardship is a shared responsibility where all levels of government, the private sector, communities and individual citizens must participate;
- The five municipal jurisdictions reviewed (2 in Nova Scotia, 2 in Ontario and one in Minnesota, USA) all share large natural water resources within their area, and while different approaches have been pursued, each has accepted the monitoring and management of their surface water resources as a municipal responsibility that benefits the entire community;
- The consultation that was undertaken with government, academia, the public and other organizations demonstrated a strong and supportive interest in an HRM led lake monitoring program that is consistent and leverages the advantages that can be attained working with lake stewardship groups and academia and other governments and organizations;
- The review of existing policies and their implementation within HRM and how this review informs a policy basis for a water quality monitoring program and refines strategic monitoring objectives that supports the development of monitoring program framework options identified, among other things, that HRM has a number of related policies but lacks an overarching policy toward development within the region that addresses broad social policy objectives; and,
- Any monitoring program designed to assess the impact of development or the effectiveness of mitigation measures should not be used as a replacement of well-planned and ongoing lake monitoring programs.

Based on this foundation, it is evident that a corporate lake monitoring strategy would be beneficial to the community and the sustainability and socio-economic well-being of the Region. AECOM has presented three frameworks for consideration for proceeding with a lake monitoring strategy based on this review and provides the following recommendations (**Table 18**) for the consideration of HRM.

Table 18:Summary of Recommendations for Consideration by HRM Regarding the Establishment of a Municipally Led Lake Monitoring Program

Ref #	TOC Item #	Topic	Summary of Observation	Recommendation
A. Program Wide Recommendations				
A1	7.2	Core Water Quality Monitoring Program for HRM	The responsibility for implementing water resource management within the bounds of HRM, by default lies with local governments. This has been evidenced with examples from other jurisdictions, all of which (Muskoka, Sudbury, King's County, Carleton River and Minneapolis – St. Paul) have taken the lead to protect and manage their natural resources from impacts within their jurisdictional control. Commonly, this control is affected through land-use planning for current and future developments but frequently includes taking responsibility for old infrastructure (e.g. historic dams or out-dated approaches to managing stormwater).	A core water quality monitoring program is recommended for HRM that addresses those water quality issues and concerns that are likely to result from land use practices that HRM can control or manage through implementation of municipal policies, planning and programming or that directly affect HRM's ability to provide valued services (e.g., public beaches). The lake water quality concerns identified from policy direction in HRM's regional plan, a review of background studies, consultation with water resource managers and the evaluation of development agreements include: • Eutrophication; • Chloride enrichment; • Bacteria contamination; and • Invasion of non-native aquatic species Climate change and its potential to exacerbate water quality issues is also of concern and requires consideration in the development of a monitoring program but it is recognized that HRM will be directly influencing mitigation of climate induced impacts while direct controls are largely outside of their responsibility. Three (3) core monitoring program frameworks are proposed for consideration. Framework 1 combines the core regional scale monitoring led by HRM and builds on the existing community-based monitoring activities. Framework 2 is community-based monitoring program that leverages active participation of volunteers to conduct monitoring and is focused to provide long-term monitoring of lakes that are most vulnerable to eutrophication and chloride enrichment. Framework 3 implements the core monitoring at a regional scale in HRM and is led by HRM without integrating the community-based support.
A2	1.6	Policy Review	Water quality monitoring is conducted federally and provincially in Nova Scotia and monitoring, and research is undertaken by academia.	All of these monitoring programs have different areas of focus and are not sufficiently detailed or aligned with the needs of HRM to meet decision making needs for water resource management at the local level.
A3	5.5.2	Policy Overview	HRM needs to define a broad social policy statement that integrates and subsumes existing environmental policies to achieve a sustaining socio-economic objective for the community.	HRM Council should consider adopting an overarching policy toward development within the region that addresses broad social policy objectives where one measurement of accountability of the HRM Council will be the effective implementation and reporting of the achievements of development agreement environmental monitoring plans. This broad policy document will need to integrate all of the individual policies adopted for development agreements and provide a comprehensive statement for all of the individual policies such that Council and residents can clearly understand the objective(s) and know that these actions are contributing to the socio-economic sustainability of the community as a whole.

Ref #	TOC Item #	Topic	Summary of Observation	Recommendation
A4	9.1	Collaboration	Partnerships and collaborations should be maximized for the delivery of an effective lake monitoring program	Creation of an HRM lake stewardship community committee to be led by HRM, to unite lake stewardship and community groups and HRM and to serve as a forum for communicating and sharing information relating to the management and protection of water resources. Establish an ongoing grant program with sustained funding for lake stewardship groups to apply for, for funding associated with projects/equipment/training deemed important and relevant by HRM. Establish an ongoing annual budget to be set-aside for leveraging funding opportunities associated with academic researchers for the purpose of lake-specific investigations, and/or investigations associated with key water concerns relevant on a region-wide basis. Continue to participate and support provincial and federal government initiatives.
B Recommendations Related to Monitoring Associated with Development Agreements				
B1	5.5.1	Developers Concerns	The success of a monitoring program for development agreements depends on a clear objective and consistency to the extent possible so that all developers are treated openly and that developers have full, advanced awareness of expectations.	Adopt a standardized process to create consistency for developers and for HRM staff that effectively considers the variations in development, the nature of the land to be developed and the differences among the receiving water bodies.
B2	5.5.1	Stormwater Management	Storm water management should not take an "end of pipe" approach. HRM and developers pay for stormwater discharges released off-site. Rather, storm water management is most cost-effective and beneficial to the natural environment by managing stormwater on-site both for the short term and the long term through the integration of BMPs and LID practices into the developments.	Full implementation of the ISMPF (Halifax, 2017) requirement that "a new property must retain the first inch of rainfall on site, as well as remove 80% TSS, using green stormwater infrastructure. These standards will be backed by a new by-law and will be triggered with development permits". Monitoring programs implemented under development permits need to confirm the achievement of these requirements and provide documentation of the best practices as they apply to the Halifax area. Implementation of the approved HRWC stormwater service charge exemptions and the stormwater credit program to encourage stormwater users including HRM to pursue BMPs to reduce their loading to the stormwater system by managing stormwater to the extent possible on their own sites, including roadways. The approved credits result in a reduction to the stormwater service charges Consideration should be given to expanding the current approved credit program against stormwater service charges to include "credit banking" such that developers who exceed minimum targets in one area can apply them in others or sell them to a municipally operated credit bank as a means of encouraging developers to go beyond the minimum standards. Credit banking could move stormwater management to another level with promising results from other jurisdictions.

Ref #	TOC Item #	Topic	Summary of Observation	Recommendation
B3	5.5.1	Objective of Development Agreement Monitoring Programs	The objective of development agreement-based monitoring programs should be restricted to establishing existing conditions and effectively measuring impacts of the development and the benefits of the BMPs and LID practices incorporated into the development plan.	Any monitoring program designed to assess the impact of development or the effectiveness of mitigation measures including BMPs and LID should not be used as a replacement of well-planned and ongoing lake monitoring programs. Development agreement monitoring programs must be used to measure the effectiveness of these planning initiatives in order to demonstrate their benefits. Monitoring associated with developments could augment a core lake monitoring program but should not replace it.
B4	5.5.1	Monitoring a subset of small catchments for TP export and stormwater management	CWRS (2016) recommended monitoring a small set of sub-catchments for the Bedford West site.	The Phosphorus Net Loading Assessment (PNLA) approach for the River Lakes Planning District be adopted or adapted to other developments such that the developer must demonstrate in advance that there will be no significant change to water quality and quantity exports from the project through the application of BMPs and LID practices on-site and incorporate a monitoring program appropriate to measuring the benefits and confirming model predictions.
B5	5.5.1	Enhance HRM staff complement	AECOM's review of reporting activities for the Bedford West Planning Strategy identified a number of concerns with the contracted reporting that can be overcome by stronger and timely oversight by municipal staff.	Enhance the staff complement to ensure sufficient resources are available to provide the necessary input to the design of the monitoring program and either to provide the technical and plain language reporting or to provide effective oversight of this reporting by others as reporting is critical to obtaining the ongoing support from HRM Council, citizens and developers; If reporting is to be contracted out, HRM staff need to ensure that expectations are clearly specified and followed and that preceding reports are effectively considered, and analytical methodologies are consistent and relevant to the available data and the purpose of the monitoring.
B6	5.5.1	Reporting of results	Effective and comprehensive progress reporting is essential to reviewing the outcomes of development agreement monitoring programs and to ensure that lessons are learned and implemented in a timely manner.	The approach to presenting data and synthesizing the data to provide an ongoing evaluation of the success, limitations or gaps in the monitoring program needs to be established early and comprise an integral part of the development monitoring agreement from pre-development, construction and through post-development phases. Interpretive reports must effectively consider broader activities in the study area that could affect the water quality data, not just limit the scope of the report to the initial purpose of the monitoring program.
B7	5.5.1	Clearly defined roles	Definition of roles and responsibilities of the multiple pieces of government, the developer and the community in successfully implementing the development-based monitoring programs is required.	Clearly defined roles and responsibilities of all stakeholders are essential (e.g., each HRM staff department involved in the development process, the Regional Watershed Advisory Board, the Province, and the developers). A clear assignment of responsibility for monitoring should be made to the developer (not to general contractor or sub-contractors) with the added requirement that the developer must ensure trained and qualified personnel are undertaking the monitoring. In addition, it must be clear that the developer is clearly responsible for maintenance during the construction period of the development as well as being responsible for ensuring a mechanism for maintaining all mitigation measures incorporated into the design that are on private property.

Ref #	TOC Item #	Topic	Summary of Observation	Recommendation
B8	5.5.2	Policy Overview	HRM needs to define a broad social policy statement that integrates and subsumes existing environmental policies to achieve a sustaining socio-economic objective for the community.	HRM Council should consider adopting an overarching policy toward development within the region that addresses broad social policy objectives where one measurement of accountability of the HRM Council will be the effective implementation and reporting of the achievements of development agreement environmental monitoring plans. This broad policy document will need to integrate all of the individual policies adopted for development agreements and provide a comprehensive statement for all of the individual policies such that Council and residents can clearly understand the objective(s) and know that these actions are contributing to the socio-economic sustainability of the community as a whole.
C Recommendations Related to Municipal Led Lake Monitoring Program				
C1	7.4	Lake Specific Management Plans and Triggered Monitoring	More complex or different monitoring approaches are warranted to more thoroughly investigate water quality issues that go beyond a core water quality monitoring program. These approaches are best designed and implemented on a lake-by-lake basis. These types of focused lake monitoring approaches need to consider the specific issue at hand and the individual characteristics of the lake in question and are therefore best developed as part of a lake management plan specifically designed and costed to fulfill the objectives of the plan.	Additional monitoring based on specific lakes with known water quality issues may be required and this monitoring should be designed as a part of **Lake Specific Management Plans**. Future work should be completed to determine the lakes which require lake specific management plans, which should be developed based upon a review of data that may identify issues, public concerns or external development pressures. Lake management plans would be developed under the direction of HRM with input from the community lake associations if they exist, academics and professionals in the field. Monitoring specifics and costs and the sharing of the workload among HRM, the community, academia and others would be addressed in the plan and is beyond the scope of this report. **Triggered Monitoring** – a future core monitoring program may identify special needs that need to be investigated. This triggered monitoring is derived from management considerations for an individual lake and would be based on a set of management threshold criteria and the monitoring program would be designed to address these criteria. Future undertakings are required to determine the set of management threshold criteria for HRM's purposes.
C2	9.2.1	Staffing	Implementation of either comprehensive frameworks 1 or 3 requires HRM staffing	HRM establish a full-time position for a dedicated corporate lake water quality Program Manager. It is further recommended that the Program Manager be supported by a full-time program assistant and these full-time personnel would be supported by seasonal staff members who are responsible for field monitoring as may be necessary as well as working with the volunteer teams.
C3	9.2.3	Community involvement	Leveraging support from community volunteers and existing stewardship or lake associations	Frameworks 1 and 2 propose and AECOM recommends leveraging support from volunteers from the community and lake-base stewardship groups for those lakes where groups are already established. Both frameworks propose utilizing community-based volunteers to conduct the field activities including collecting the scheduled samples during each of the spring and summer sampling events, along with collection of associated field observations. These frameworks utilize and empower members of the community who have a strong interest, commitment and knowledge pertaining to the lakes in their area. It is also anticipated that community members will be helpful contributors for observational data collection such as incidental sightings of aquatic invasive species and algae blooms, ice-on and ice-off dates and other water quality observations.

Ref #	TOC Item #	Topic	Summary of Observation	Recommendation
C4	9.2.4	Involvement of Academics	Ongoing involvement and support of locally based academics in the monitoring program	Partnership opportunities should be explored to gain assistance from academia for monitoring activities (e.g., student participation) in exchange for data sharing. HRM should also consider partnerships with academia for research-related activities that may be applicable to the municipality, or applicable to lakes with similar vulnerability classifications. To effectively achieve this we recommend that funds should be set aside on an annual basis to plan for future undertakings whereby these collaborations are expected, and funds invested by the Municipality can be essentially doubled or tripled through project-specific collaboration with academics/student researchers through NSERC match funding opportunities.
C5	9.2.5	Contract expertise as required	Specialized technical support for the new HRM staff be contracted as necessary	All three (3) proposed program frameworks recommend program operation and management by HRM through the hiring of a full-time program manager. Additional resources are recommended, depending on the framework that is chosen. Depending on the education and experience of the future direct hires by HRM, additional support by way of paid service arrangements will likely be required. However, the type and scope of additional support that may be needed will be determined based on the skills and expertise of the future program manager and/or program assistant. Specific budget allotments should be provided for this support.
C6	9.2.6	Equipment needs	An allocation for key equipment is required for purchase, rental and maintenance	A list of essential standard equipment that HRM should acquire for the lake monitoring program and their cost is provided.
C7	9.3	Quality Assurance / Quality Control	Effective implementation of a lake monitoring program requires a QA/QC program	A quality assurance and quality control (QAQC) plan is essential to a successful monitoring program to ensure that data are of adequate quality to meet the project objectives and to avoid potential loss of data due to sampling errors, malfunctioning equipment, data transcription errors, loss or breakage of samples in transit to the laboratory, etc.
C8	9.4	Program evaluation and reporting	Periodic review of the monitoring program is required.	Periodic review and evaluation of the monitoring program should be undertaken to determine if the program met or will continue to meet decision needs for HRM, to correct issues or challenges faced during implementation, and to incorporate changes that reflect improved understanding of the system or new or enhanced monitoring techniques and additional water quality variables. This review should consider all aspects of the program.
C9	9.4	Program evaluation	Receive input and maintain records	To inform the program evaluation, it is recommended that HRM obtain input from other municipal departments and agencies (i.e., Halifax Water), as well as from partners or collaborators. This can be achieved by a questionnaire, tailored to obtain feedback on specific elements of the program. It is also recommended that the Program Manager maintain a log of monitoring program successes and challenges, and comments or feedback obtained over the course of the program that can be brought forward into the evaluation
C10	9.4	Reporting	Evaluation undertaken with detailed reporting and plain language reporting	The program should be evaluated two years following program start-up. It is recommended that the evaluation be completed as a component of the detailed monitoring program report so that findings from the monitoring can be used in the evaluation and recommendations made in that report. These will be carried through into the plain language and administrative reports. After the initial two-year period following program start-up, reporting and program evaluation frequencies should be re-assessed to determine optimum frequencies.

Ref #	TOC Item #	Topic	Summary of Observation	Recommendation
				The success of the lake monitoring program will be judged based upon its ability to communicate effectively the outcomes of the program. Reporting, as noted above, must be technically competent, but without effective plain language reporting to Council and the community, it will not receive the sustained support that is required. This will be a primary responsibility of the HRM team.

11.2 Proposed Implementation Considerations

Although it was not a specific requirement of this project, AECOM wishes to offer some suggestions regarding the future implementation of a lake monitoring program within the boundaries of HRM. These thoughts come from our discussions with HRM staff, the academics and citizens that we consulted with over the course of the project as well as from our own experiences and internal discussions regarding this project. These considerations have been tempered by the current situation we are all facing with Covid-19. We do not pretend to be able to predict the future; but we are aware, that the way work and recreational activities are undertaken in the future will be different. It is within this context that we offer some observations with respect to the implementation of the lake monitoring program.

First, a lake monitoring program operated by HRM for the community is essential to the sustainable future of the Region and should be perceived as an investment in the community. Water resources and adjacent public lands need to be viewed and managed as assets, and not simply costs or expenses. Consequently, a multi-year objective is needed and should be executed as more or less outlined in Framework 1. Second, HRM should look at the implementation of a lake monitoring program as a continuing endeavour. Lake responses are not immediate. They need to be monitored over time to reveal trends and changes. That said, it is imperative that a future program is funded long-term. Implementation of any of the frameworks considered here, including Framework 2, directed community-based monitoring, is not feasible within 2020. In recognition of this step-wise approach we suggest that this year, 2020, be used by HRM to review the framework plans outlined here with their partners (community, academia, internally within HRM and provincially and federally) and refine their recommendations to Council during 2020-2021 with a time-line for the full implementation of the agreed to program framework. This provides an opportunity to gain feedback from the proposed partners and obtain the necessary support from the community and council to move forward with an effective and community supported lake monitoring program.

This report is highly technical in nature and includes suggestions for implementation. The report is founded on one key recommendation which includes the recommendation for HRM to establish a Water Quality Program Office, and to fund and establish a full time Water Program Manager position. Regardless of the water quality monitoring program framework that is chosen, each one will require ongoing leadership and management on HRM's behalf. We recommend this approach, based on the opinions and experience of our team members, but also as a result of our jurisdictional review, as this approach is adopted in other Canadian municipalities as well as Minneapolis – St. Paul as an effective way to manage water resources at the municipal level. Through management from a centralized resource, targeted partnerships and collaborations can be made, communication of information can be streamlined, and efficiencies can be realized. A summary of key recommendations of a future Halifax-led lake monitoring program is included as **Figure 15.**

A separate undertaking discussed in this report includes the review and recommendations for future monitoring associated with development agreements. While in the past, monitoring programs associated with developments have generally involved sampling of tributaries and inlets of waterbodies in proximity to the developments, we recommend that a future monitoring program be focused on monitoring the effectiveness of the proposed best management practices or low impact development controls that are put in place for the development itself. These monitoring programs need to be designed to effectively measure hydrologically related changes in a fluvial system. Monitoring associated with developments could augment a core lake monitoring program, but not replace it. We have shared a number of recommendations and considerations for future monitoring associated with development agreements. However, it cannot be understated that these recommendations should be discussed amongst HRM internal departments, as these undertakings involve multiple HRM departmental practice areas, that all have a role to play in this process. A summary of the key recommendations for monitoring associated with future developments is summarized as **Figure 16**.

Figure 15 – Summary of Recommendations for a Lake Water Quality Monitoring Program

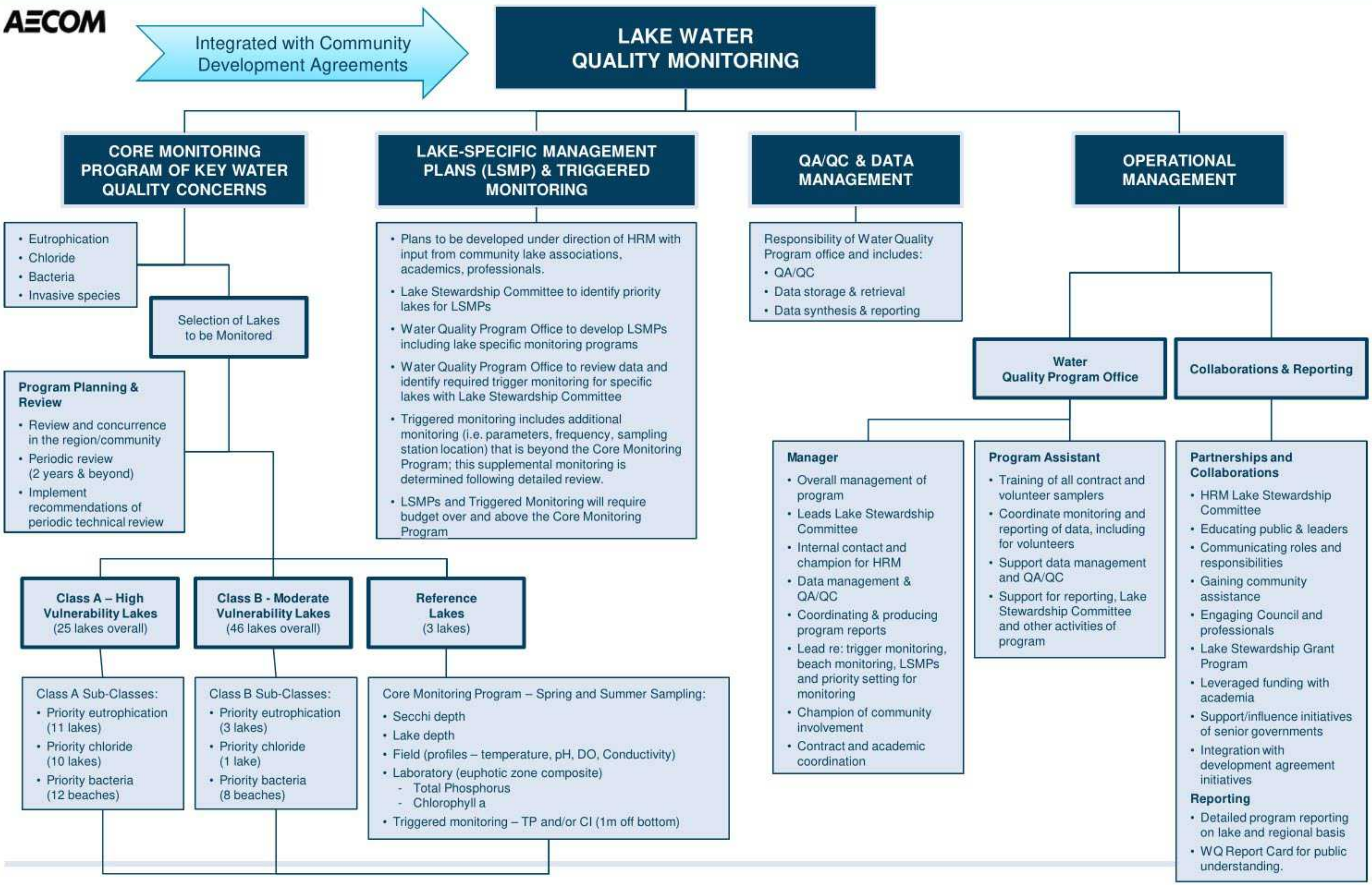
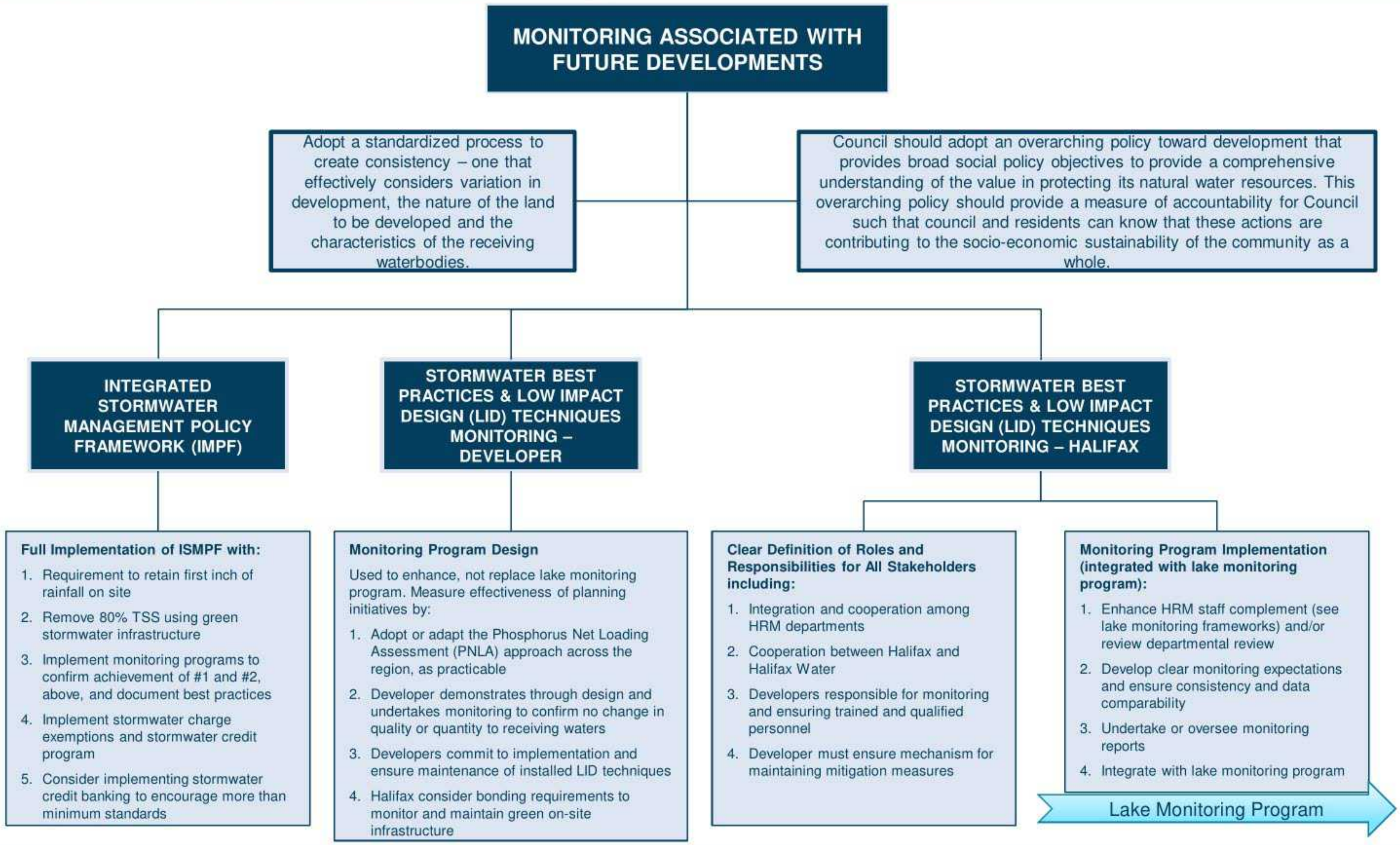


Figure 16 – Summary of Recommendations for Monitoring Associated with Future Development



In closing, this report includes a number of recommendations for a future lake water quality program. As discussed, it needs long-term funding and support. Its objectives need to be widely understood by both internal HRM departments, councillors and the community. Communication and reporting of the results is critical in gaining support for a long-term program, and to help inform the community, staff and council on the status of water resources within Halifax. This will help staff and council better manage the resource, in partnership and collaboration with other levels of government, and with academics and the community. **Figure 17** presents a graphic representing implementation considerations.

This is a complex report that contains a plan for moving forward. Successful implementation requires an implementation plan that we have only touched on in this report. The ellipse within Figure 19 containing "Manage Data and Report" and "Monitor', outlines what this report has focused on; the remaining graphics cover the other elements of a future program, that will need to developed.

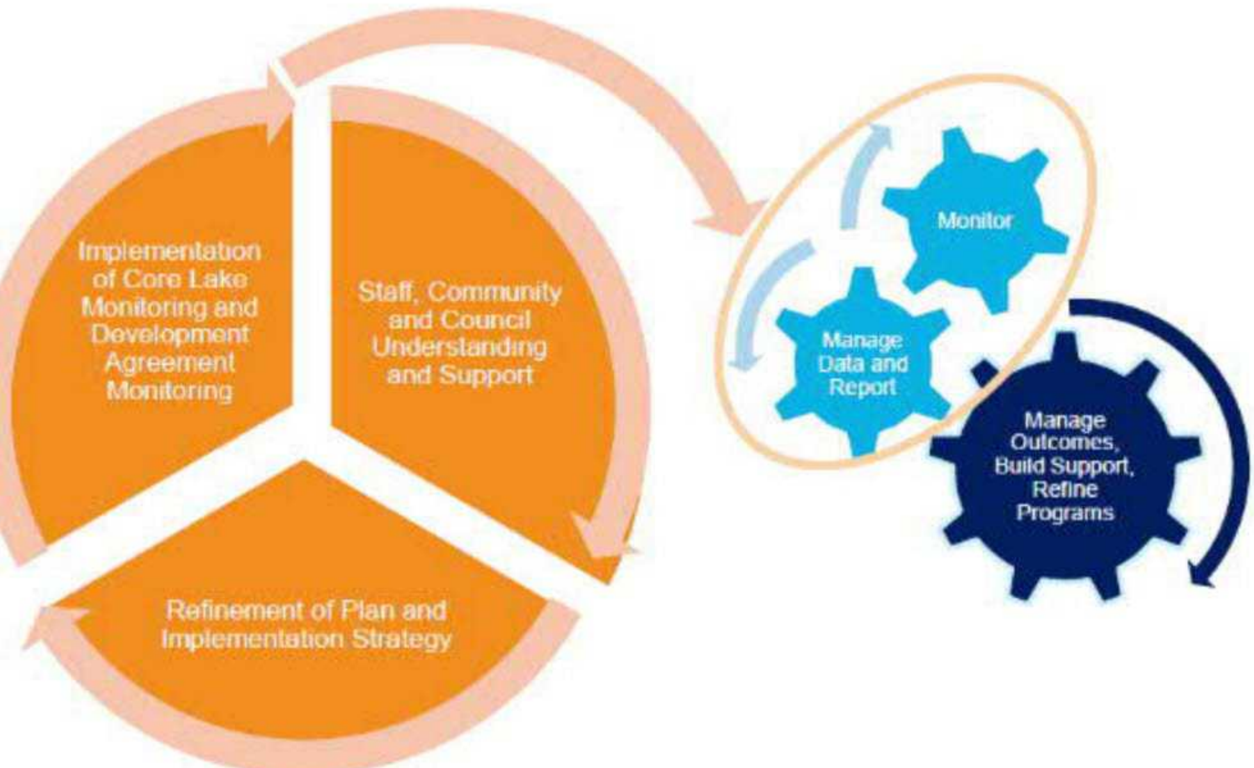


Figure 17 – Implementation Considerations Graphic

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Appendix A

Summary of Jurisdictional Review of Municipal-Led Water Quality Monitoring Programs

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Appendix A.1

Jurisdictional Review Summary Tables

- District of Muskoka, Ontario
- City of Greater Sudbury, Ontario
- King's County, Nova Scotia
- Carleton River Watershed, Nova Scotia
- Minneapolis – St. Paul, Minnesota

Table A-1

District Municipality of Muskoka - Lake System Health Program

Policy and Planning Grounds	Policy Reference	Monitoring Program Type	Monitoring Objectives	Program Duration	Sites	Parameters	Frequency	Costs
Recreational lake water quality monitoring is included as a Key Program Activity in the District's Official Plan (OP) under the the Lake System Health Program (LSHP). The LSHP aims to "guide and minimize the impact of human development on water resources, to preserve the environmental health and quality of life in Muskoka and also to protect the future of Muskoka as a premier recreational region" Monitoring data are required to inform implementation of "Development Policies" (site plan control, planning permits and "Causation Study Policies" under the LSHP that are based on water quality indicators, including: - presence of an increasing trend in phosphorus concentrations - phosphorus concentration that exceeds the provincial water quality objective for 3 consecutive years - occurence of a blue-green algal (cyanobacteria) bloom (not monitored under the program, but confirmed and documented by by the Province or Health Unit). Causation studies are required for waterbodies that have confirmed water quality indicators. They are undertaken to determine whether development is the primary cause of the water quality indicators. If development is the primary cause, then enhanced policies (e.g., water quality impact assessments, ongoing monitoring, lot creation limits, upstream development restrictions, increased setbacks) would apply to protect water quality. Monitoring data can also inform other key LSHP activities related to water quality including commitments to: - explore development of phosphorus offsetting program, - lead, support and participate in stewardship programs involving area stakeholders (lake associations, shoreline property owners, etc.) to engage and empower local community involvement in the care and remediation of water resources, -collaborate with stakeholders in remedial action programs and plans for waterbodies, -collaborate with stakeholders to conduct constraints analyses to identify development limits, inform lake plans, establish specific policies and evaluate cumulative impacts for specific water bodies of interest.	OPA 47, Schedule I, C2.6 Lake System Health	Water Quality	To establish a long-term record of key water quality parameters so that trends in water quality and phosphorus concentrations can be identified.	30+ years	164 lakes 193 sites	Routine: -phosphorus -Secchi depth -dissolved oxygen and temperature profiles Special: -pH -conductivity -alkalinity -calcium -nitrogen	In spring before stratification, rotating basis depending on development pressures and specific lake characteristics.	
		Shoreline Land Use Surveys	To obtain data on shoreline conditions that my contribute to water quality issues.	18 years	variable (~4-5 lakes per year)	Surveys: -count/location/type of manmade structures -condition of shoreline -general shoreline landuse -shoreline vegetation		
		Biological	To develop a network of monitoring partners to collect a broad range of chemical and biological data, physical lake attributes and shoreline development data that are in a useful form and can be made accessible to individuals, associations, businesses and government agencies.	17 years	variable	Plants Frogs Forest Health Benthic invertebrates	variable	

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Table A-1

District Municipality of Muskoka - Lake System Health Program

Policy and Planning Grounds	Policy Reference	Monitoring Program Type	Data Management and Analysis	Municipal Roles	Collaborations
Recreational lake water quality monitoring is included as a Key Program Activity in the District's Official Plan (OP) under the the Lake System Health Program (LSHP). The LSHP aims to "guide and minimize the impact of human development on water resources, to preserve the environmental health and quality of life in Muskoka and also to protect the future of Muskoka as a premier recreational region" Monitoring data are required to inform implementation of "Development Policies" (site plan control, planning permits and "Causation Study Policies" under the LSHP that are based on water quality indicators, including: - presence of an increasing trend in phosphorus concentrations - phosphorus concentration that exceeds the provincial water quality objective for 3 consecutive years - occurence of a blue-green algal (cyanobacteria) bloom (not monitored under the program, but confirmed and documented by by the Province or Health Unit). Causation studies are required for waterbodies that have confirmed water quality indicators. They are undertaken to determine whether development is the primary cause of the water quality indicators. If development is the primary cause, then enhanced policies (e.g., water quality impact assessments, ongoing monitoring, lot creation limits, upstream development restrictions, increased setbacks) would apply to protect water quality. Monitoring data can also inform other key LSHP activities related to water quality including commitments to: - explore development of phosphorus offsetting program, - lead, support and participate in stewardship programs involving area stakeholders (lake associations, shoreline property owners, etc.) to engage and empower local community involvement in the care and remediation of water resources, -collaborate with stakeholders in remedial action programs and plans for waterbodies, -collaborate with stakeholders to conduct constraints analyses to identify development limits, inform lake plans, establish specific policies and evaluate cumulative impacts for specific water bodies of interest.	OPA 47, Schedule I, C2.6 Lake System Health	Water Quality	Data are managed by the District and are made publically available online through the District's Water Web. http://www.muskokawaterweb.ca/ Water quality data are analyzed annually by District staff and presented online as Lake Data Sheets. Analyses include: -dissolved oxygen and temperature profiles, -average (10-year) phosphorus and Secchi depth, -phosphorus trends	-conduct monitoring -manage and analyze data -report annually on results -perform regular program reviews and monitoring results to inform policies/programs on shoreline development	Province (Dorset Environmental Science Centre), Lake Partner Program - perform chemical analyses on samples collected by the DMM program -contribute scientific and research support (e.g., special lake-specific studies to investigate issues of algal blooms)
		Shoreline Land Use Surveys	District staff collect the data and produce Shoreline Land Use Maps, available online through the Water Web.	-train lake residents on monitoring protocols -provide ongoing support to residents/lake associations -manage and analyze data -report annually on results	Lake Associations -provide volunteers to conduct the surveys
		Biological	Data are managed by the District and are made publically available online through the District's Water Web. http://www.muskokawaterweb.ca/ Data analysis includes calculation of general summary indices that can be interpreted using Information Sheets prepared by the District.	-train lake residents on monitoring protocols -provide ongoing support to residents/lake associations	Province (Dorset Environmental Science Centre) -provides scientific support Ecological Monitoring and Assessment Network (EMAN) -develops protocols Lake Associations -provide volunteers to conduct the surveys

Table A-1

District Municipality of Muskoka - Lake System Health Program

Policy and Planning Grounds	Policy Reference	Monitoring Program Type	Other Activities for Monitoring Support	Challenges and Lessons Learned
Recreational lake water quality monitoring is included as a Key Program Activity in the District's Official Plan (OP) under the the Lake System Health Program (LSHP). The LSHP aims to "guide and minimize the impact of human development on water resources, to preserve the environmental health and quality of life in Muskoka and also to protect the future of Muskoka as a premier recreational region" Monitoring data are required to inform implementation of "Development Policies" (site plan control, planning permits and "Causation Study Policies" under the LSHP that are based on water quality indicators, including: - presence of an increasing trend in phosphorus concentrations - phosphorus concentration that exceeds the provincial water quality objective for 3 consecutive years - occurence of a blue-green algal (cyanobacteria) bloom (not monitored under the program, but confirmed and documented by by the Province or Health Unit). Causation studies are required for waterbodies that have confirmed water quality indicators. They are undertaken to determine whether development is the primary cause of the water quality indicators. If development is the primary cause, then enhanced policies (e.g., water quality impact assessments, ongoing monitoring, lot creation limits, upstream development restrictions, increased setbacks) would apply to protect water quality. Monitoring data can also inform other key LSHP activities related to water quality including commitments to: - explore development of phosphorus offsetting program, - lead, support and participate in stewardship programs involving area stakeholders (lake associations, shoreline property owners, etc.) to engage and empower local community involvement in the care and remediation of water resources, -collaborate with stakeholders in remedial action programs and plans for waterbodies, -collaborate with stakeholders to conduct constraints analyses to identify development limits, inform lake plans, establish specific policies and evaluate cumulative impacts for specific water bodies of interest.	OPA 47, Schedule I, C2.6 Lake System Health	Water Quality	The District actively supports the Muskoka Watershed Council, a volunteer agency. The Coucil provides information to decision-makers, managers and the general public on ways to protect and restore the watershed resources. The Council develops and implements monitoring programs, advocates for healthy watersheds, educates and communicates information to the public, and seeks external funding to support partner collaborations.	not available
		Shoreline Land Use Surveys		not available
		Biological		not available

Table A-2

City of Greater Sudbury, Ontario - Lake Water Quality Program

Policy and Planning Grounds	Policy Reference	Component	Monitoring Objectives	Program Duration	Sites	Parameters	Frequency	Costs	Data Management and Analysis	Municipal Roles
The City is committed to maintaining and reviewing a lake water quality model and monitoring program under its Official Plan. Water quality monitoring activities are conducted under the Lake Water Quality Program. Monitoring focusses on phosphorus enrichment of lakes and the data are required to inform implementation of polices for shoreline development (lot creation, site-plan control, site alteration), which differ for lakes based on measured average total phosphorus and increasing trends in phosphorus. In addition to the above, monitoring results provide useful information to the City to support their OP commitments to protect water resources in the City, including the development of: -subwatershed plans that focus on flooding and water quality due to stormwater, and -Lake Plans that focus on recreational and natural heritage issues. These plans must follow specific policies in their development to identify and assess sensitive environmental features and functions critical to water systems. Agencies and stakeholders involved with water regulation and stewardship may be cooperatively involved in the development of the plans. While the focus of monitoring is on phosphorus, other program components have been added over the years to address emerging concerns due to aquatic invasive plants, cyanobacteria blooms and shoreline restoration needs.	OP (May 2019) Part III, Section 8.4 SURFACE WATER RESOURCES – LAKES, RIVERS AND STREAMS	Water Quality - Ramsey Lake Aquatic Monitoring System (RAMS)	To collect water quality and meteorology data to help investigate and gain a better understanding of algae blooms in Ramsey Lake, an urban lake of recreational significance and a drinking water source.	not available	1 (Ramsey Lake)	-algal pigments -dissolved organic matter -conductivity -turbidity -pH -dissolved oxygen -meteorological parameters	Continuous monitoring over the ice-free period	not available	Data generated are broadcast in realtime to a publically available website for viewing.	Provides funding for a full-time Program Co-ordinator and a seasonal Lake Water Quality Field Intern. These positions are responsible for monitoring as well as other activities such as the shoreline home visit program, providing technical assistance to lake stewardship groups and the Lakes Advisory Panel, organizing the annual Water Gathering, website content and report writing.
		Native Aquatic Vegetation Survey (aquatic invasive plants)	To map and identify native aquatic vegetation (macrophytes) and Eurasian watermilfoil (EWM) beds as follow up to a program aimed at controlling the invasive plant, Eurasian Watermilfoil using locally cultured weevils. Also aims to track recovery of aquatic vegetation from impacts of acid rain.	2014, 2017, 2018	5 lakes (2014) 2 lakes (2017) 1 lake (2018)	-visual survey of native aquatic plants on the surface of the lake and just below the water line, -type and percentage of native aquatic plant species and Eurasion Watermilfoil growing under water (rake tosses).	single event	not available	Data collected were used to prepare technical reports made availabe to the public on the City's website.	
		Water Quality		19 years	Routine: 64 lakes (selected based on historical phosphorus levels, waterfront development pressures, and requests from lake stewardship groups) Detailed: 15 lakes (selected as priority lakes exhibiting possible nutrient-related issues)	Routine (spring): -total phosphorus -Secchi depth -temperature Detailed (August): -dissolved oxygen and temperature profiles -total phosphorus (surface and bottom water) Other parameters of interest on occasion: -conductivity -chloride -sodium -dissolved organic carbon	single event	not available	Data are managed by the City and are made publically available online through reports posted on the City's website. Water quality data are analyzed annually by City staff Analyses include: -data summary tables -dissolved oxygen and temperature profiles, -average phosphorus and Secchi depth, -phosphorus trends -evaluation of the occurence of phosphorus loading from sediments	
		Cyanobacteria	To identify signs of cyanobacteria blooms on Ramsey Lake to provide an early warning system for residents and water treatment plant operators.	5 years	1 lake	-visual survey for bloom activity in beaches, main basins and small bays -cyanobacteria pigments (by fluorometry)	weekly	not available	Data are managed by the City and made publically available online through reports posted on the City's website.	not available
		Shoreline Surveys	To identify shoreline areas that could benefit from restoration and best management practices for the protection of water quality.	6 years	variable	visual surveys	single event	not available	Data are managed by the City, and results used to develop individualized, confidential recommendations for shoreline residents over an entire lake to improve the health of their lake.	Manages and conducts all aspects of the monitoring and reporting

Table A-2

City of Greater Sudbury, Ontario - Lake Water Quality Program

Policy and Planning Grounds	Policy Reference	Component	Collaborations	Other Activities for Monitoring Support	Challenges and Lessons Learned
The City is committed to maintaining and reviewing a lake water quality model and monitoring program under its Official Plan. Water quality monitoring activities are conducted under the Lake Water Quality Program. Monitoring focusses on phosphorus enrichment of lakes and the data are required to inform implementation of polices for shoreline development (lot creation, site-plan control, site alteration), which differ for lakes based on measured average total phosphorus and increasing trends in phosphorus. In addition to the above, monitoring results provide useful information to the City to support their OP commitments to protect water resources in the City, including the development of: -subwatershed plans that focus on flooding and water quality due to stormwater, and -Lake Plans that focus on recreational and natural heritage issues. These plans must follow specific policies in their development to identify and assess sensitive environmental features and functions critical to water systems. Agencies and stakeholders involved with water regulation and stewardship may be cooperatively involved in the development of the plans. While the focus of monitoring is on phosphorus, other program components have been added over the years to address emerging concerns due to aquatic invasive plants, cyanobacteria blooms and shoreline restoration needs.	OP (May 2019) Part III, Section 8.4 SURFACE WATER RESOURCES – LAKES, RIVERS AND STREAMS	Water Quality - Ramsey Lake Aquatic Monitoring System (RAMS)	not available	A Lakes Advisory Panel is appointed by City Council to provide advice and recommendations to the municipality on lake water quality matters including monitoring needs. The City funds the Lake Stewardship Grant Program to assist lake stewardship groups in carrying out projects on water quality and the natural environment of lakes. The numer of grants issued each year varies, and the total amount granted is ~$3000/yr.	not available
		Native Aquatic Vegetation Survey (aquatic invasive plants)	not available	not available	not available
		Water Quality	not available	not available	not available
		Cyanobacteria	not available	not available	not available
		Shoreline Surveys	Canadian Wildlife Federation and Watersheds Canada developed the program (Love Your Lake Program). They offer shoreline surveys and stewardship education to individual shoreline residents. This program can be leveraged for shorelines not covered by the City.	not available	not available

Table A-3

Municipality of the County of Kings, Nova Scotia - Lake Monitoring Program

Policy and Planning Grounds	Policy Reference	Component	Monitoring Objectives	Program Duration	Sites	Parameters	Frequency
The Kings County Lake Monitoring Program is an initiative begun by the Municipality of the County of Kings in 1997. It was started based on input from a multi-stakeholder group composed of members of all three levels of government and community groups. This group was assembled to address concerns on the impact of development of lake shorelines in Kings County. The model is used to estimate the carry-capacity of each lake using these objectives. - **<u>Volunteer Water Quality Monitoring Program</u>** The water quality monitoring program established for Kings County is designed to gather empirical data which can be used to check the accuracy of the Kings County Lakeshore Capacity model predictions. The program is also used to track levels of other constituents such as pH, alkalinity, conductivity and turbidity which can be used to assess the effects of anthropogenic influences (acid precipitation, road de-icing, construction) and colour and dissolved organic carbon which play a role in the biological response of a water body to nutrient loading. The program was initiated in 1997.	The current policy framework combines a number of watershed management tools to assist in the management of water quality. These tools range in nature, from site specific tools such as management of vegetation and watercourse setbacks, to broader land management tools such as identifying a maximum number of units in close proximity to the shore and managing the number of subdivisions occurring on a yearly basis. To support the application of these land management tools, the Kings County Lakeshore Capacity Model was also developed to assist in understanding the capacity of key receiving waters to assimilate future and existing development.	Volunteer Lake Monitoring Program	Purpose: To monitor lake water quality through ongoing community stewardship and engagement in order to encourage safe use for residents and users of these spaces for generations to come through the application of land use controls There are five overall goals for the program, including the following: 1) to address citizen's concerns regarding lakeshore development impacts to Kings County lakes by working with lake associations and municipal, provincial and federal departments 2) to put a planning tool in place to aid decision making 3) to develop a phosphorus loading model capable of predicting changes in water quality as a result of shoreline residential development 4) to consider municipal planning and approval activities in the context of predetermined water quality objectives for Kings County lakes 5) to implement a volunteer lake monitoring program to provide feedback to validate the model and facilitate awareness and stewardship initiatives in Kings County	Since 1997 = 23 years	Currently 13 lakes are sampled regularly as part of the Kings County Lake Monitoring Program.	Samples are analyzed for chl.a, total phosphorus (TP), total nitrogen (TN), dissolved organic carbon (DOC), alkalinity, pH, colour, turbidity, conductivity and orthophosphorus (Phosphate). Secchi depth, water temperature. Water quality index was also calculated. From May to October dedicated volunteers set out once a month to collect water samples, record water temperatures and take water transparency readings using a Secchi Disk. A total of 13 lakes are monitored.	Water sampling and field measurements occurs once a month for each lake from May to October and is conducted by volunteers.
<u>The Kings County Lakeshore Capacity Model</u> In 1995, Horner and Associates Limited in collaboration with Michael Michalski Associates and Raymond, Walton, Hunter developed the Kings County Lakeshore Capacity Model based on formulations and assumptions of Ontario's Lakeshore Capacity Model. The model, hereafter known as the Kings County Lakeshore Capacity Model (KCLCM), was applied to a chain of lakes in the Gaspereau River drainage basin with the expectation of it being used as a planning tool with the capability of reliably predicting the amount of sustainable development around individual lakes without exceeding target water quality objectives. In 1997, water quality objectives based on chlorophylla were established for the 18 lakes and ponds in the chain of lakes and the model used to estimate the carry-capacity of each lake using these objectives. In 2009, the Centre for Water Resources Studies at Dalhousie University and Stantec Consulting Ltd. undertook a review of the KCLCM model, volunteer monitoring program, the monitoring framework and related land us planning policies. (CWRS and Stantec, 2009).		Kings County Lakeshore Capacity Model	The group's objective was to implement a tool which could be used to determine the extent of development that could exist around a given Kings County lake while maintaining its water quality at acceptable levels. This tool was to be used by the Municipality in a planning context.	Developed in 1997. Model review by Centre for Water Resources Studies and Stantec in 2009.			

Table A-3

Municipality of the County of Kings, Nova Scotia - Lake Monitoring Program

Policy and Planning Grounds	Costs	Data Management and Analysis	Municipal Roles	Collaborations	Other Activities for Monitoring Support
The Kings County Lake Monitoring Program is an initiative begun by the Municipality of the County of Kings in 1997. It was started based on input from a multi-stakeholder group composed of members of all three levels of government and community groups. This group was assembled to address concerns on the impact of development of lake shorelines in Kings County. The model is used to estimate the carry-capacity of each lake using these objectives. - **<u>Volunteer Water Quality Monitoring Program</u>** The water quality monitoring program established for Kings County is designed to gather empirical data which can be used to check the accuracy of the Kings County Lakeshore Capacity model predictions. The program is also used to track levels of other constituents such as pH, alkalinity, conductivity and turbidity which can be used to assess the effects of anthropogenic influences (acid precipitation, road de-icing, construction) and colour and dissolved organic carbon which play a role in the biological response of a water body to nutrient loading. The program was initiated in 1997.	not available	A <u>report card</u> is generated for each lake sampled summarizing the data as well as an interpretation and recommendation for lakes showing a poor rating in water quality. The report card included a discussion on the WQI, figures and tables showing the paramteres measured/analyzed, and a discussion on long term trends. Volunteers and Municipal staff have collected lake water samples since 1997, <u>and have compiled an extensive database on lake water quality</u>	Council implemented the Volunteer Water Quality Monitoring Program to validate and calibrate the phosphorus loading model, as well as to facilitate awareness and stewardship initiatives in the county. The Kings County Wildlife Federation and The Acadia Center for Estuarine Research (notably Dr. M. Brylinsky) have provided local involvement in developing and coordinating this volunteer monitoring effort. The Municipality is encouraged to <u>continue to link</u> this lake monitoring program with land use planning activities and to consider supporting watershed management approaches to help maintaining and promote the health of the lakes. Kings County has a community participation platform, PlaceSpeak, where community residents can share informaiton. https://www.placespeak.com/en/topic/5756-lake-monitoring-program/fbclid=IwAR34yD5mlpLxIjY4vSm7WZ4BsNMTBdGwZ8p8U0nxLtf80JWLZ9wFFpZfrTA#/overview Municipal planners and elected officials use the monitoring and model information to help guide land-use decisions for the lakes and their watersheds. The program enjoys widespread support with both the community and elected councillors.	The Nova Scotia Department of the Environment has contributed funding and technical support for all aspects of this initiative since its inception, including the monitoring efforts. Similar support has been provided to other community groups involved in volunteer monitoring activities; e.g. Bluenose Atlantic Coastal Action Program, Soil & Water Conservation Society of Metro Halifax, Shubenacadie Watershed Environmental Protection Society, and Shubenacadie Grand Lake Watershed Advisory Board. Our Volunteers Acadia Centre for Estuarine Research, in particular Mike Brylinsky, for conducting training workshops for volunteer monitors and data analysis The Province of Nova Scotia and Environment Canada's Canadian Wildlife Service, for ongoing technical support for the monitoring effort Community groups: Lake George Property Owners Society, Black River Lake Association, Kings County Wildlife Federation, Bluenose Atlantic Coastal Action Program, Shubenacadie Watershed Environmental Protection Society, SGLWAB	There is a community information networking page, PlaceSpeak, for the Lake Monitoring Program. It contains resources for community residents as it relates to the Lake Monitoring Program and provides a communication mechanism for the community for lake stewardship initiatives. https://www.placespeak.com/en/topic/5756-lake-monitoring-program/?fbclid=IwAR34yD5mlpLxIjY4vSm7WZ4BsNMTBdGwZ8p8U0nxLtf80JWLZ9wFFpZfrTA#/overview
<u>The Kings County Lakeshore Capacity Model</u> In 1995, Horner and Associates Limited in collaboration with Michael Michalski Associates and Raymond, Walton, Hunter developed the Kings County Lakeshore Capacity Model based on formulations and assumptions of Ontario's Lakeshore Capacity Model. The model, hereafter known as the Kings County Lakeshore Capacity Model (KCLCM), was applied to a chain of lakes in the Gaspereau River drainage basin with the expectation of it being used as a planning tool with the capability of reliably predicting the amount of sustainable development around individual lakes without exceeding target water quality objectives. In 1997, water quality objectives based on chlorophylla were established for the 18 lakes and ponds in the chain of lakes and the model used to estimate the carry-capacity of each lake using these objectives. In 2009, the Centre for Water Resources Studies at Dalhousie University and Stantec Consulting Ltd. undertook a review of the KCLCM model, volunteer monitoring program, the monitoring framework and related land us planning policies. (CWRS and Stantec, 2009).			Municipal Council adopted a phosphorus loading model in 1997 which predicts changes in water quality as a function of shoreline residential development, watershed geology, and individual lake dynamics. Municipal staff are now in a position to consider development proposals within the context of pre-determined water quality objectives set for county lakes in the Municipal Planning Strategy.		

Table A-3

Municipality of the County of Kings, Nova Scotia - Lake Monitoring Program

Policy and Planning Grounds	**Challenges and Lessons Learned**
The Kings County Lake Monitoring Program is an initiative begun by the Municipality of the County of Kings in 1997. It was started based on input from a multi-stakeholder group composed of members of all three levels of government and community groups. This group was assembled to address concerns on the impact of development of lake shorelines in Kings County. The model is used to estimate the carry-capacity of each lake using these objectives. - **<u>Volunteer Water Quality Monitoring Program</u>** The water quality monitoring program established for Kings County is designed to gather empirical data which can be used to check the accuracy of the Kings County Lakeshore Capacity model predictions. The program is also used to track levels of other constituents such as pH, alkalinity, conductivity and turbidity which can be used to assess the effects of anthropogenic influences (acid precipitation, road de-icing, construction) and colour and dissolved organic carbon which play a role in the biological response of a water body to nutrient loading. The program was initiated in 1997.	Recommendations were made which included: 1) Continue with volunteer monitoring programming for all lakes. Ensure consistency of monthly data collection events to allow detection of seasonal trends. 2) Ask the residents about their main concerns and observations: do they observe an increase in plants in the water? 3) The accuracy of the year to year comparison is only possible if the data is collected and analysed in a consistent manner. 4) The frequency of sampling events should be increased to capture a minimum of 10 samples per season (biweekly collections) for each monitored lake for improved analysis of sampled parameters if feasible, and pending suitable budgetary support. 5) Communities in the watersheds of study lakes are encouraged to continue to use best practices and reduce/limit nutrient releases from all sources to protect lake water quality. 6) The Municipality is encouraged to continue to link this lake monitoring program with land use planning activities and to consider supporting watershed management approaches to help maintaining and promote the health of the lakes.
<u>The Kings County Lakeshore Capacity Model</u> In 1995, Horner and Associates Limited in collaboration with Michael Michalski Associates and Raymond, Walton, Hunter developed the Kings County Lakeshore Capacity Model based on formulations and assumptions of Ontario's Lakeshore Capacity Model. The model, hereafter known as the Kings County Lakeshore Capacity Model (KCLCM), was applied to a chain of lakes in the Gaspereau River drainage basin with the expectation of it being used as a planning tool with the capability of reliably predicting the amount of sustainable development around individual lakes without exceeding target water quality objectives. In 1997, water quality objectives based on chlorophylla were established for the 18 lakes and ponds in the chain of lakes and the model used to estimate the carry-capacity of each lake using these objectives. In 2009, the Centre for Water Resources Studies at Dalhousie University and Stantec Consulting Ltd. undertook a review of the KCLCM model, volunteer monitoring program, the monitoring framework and related land us planning policies. (CWRS and Stantec, 2009).	

Table A-4

Carleton River Watershed - Water Quality Program

Policy and Planning Grounds	Policy Reference	Component	Monitoring Objectives	Program Duration	Sites	Parameters
Monitoring began in response to a prevalence of potentially toxic blue-green algal blooms by Nova Scotia Environment, implemented by University of Acadia. Multiple nutrient sources were identified (i.e., agricultural, aquaculture, and residential) but the primary contributor of nutrients came from mink farming operations. Subsequently, in 2003 Nova Scotia Department of Agriculture enacted the Fur Industry Act to minimize the impact of fur farming on water quality.	No applicable policies referenced.	Lake Quality Monitoring Program	To collect water quality data and identify potential nutrient sources to the affected waterbodies	2008-2017	Carleton River Watershed - Hourglass Lake (5 sites), Placides Lake (3 sites), Porcupine Lake (3 sites), Wentworth Lake (6 sites), Parr Lake (5 sites), Ogden Lake (3 sites), Lake Fanning (5 sites), Sloans Lake (3 sites), Lake Vaughan (5 Sites). Meteghan River Watershed - Nowlans Lake (3 sites). Sissiboo River Watershed - Provost Lake (2 sites). Supplementary sampling included Raynards, Salmon and Kegshook.	At inlet/outlet: flow monitoring, pH, DO, specific conductance and temperature, single grab samples. At mid-lake sites: pH, DO, specific conductance, temperature, Secchi depth, depth, composite and bottom grab samples. Grab samples were analyzed for chlorophyll a, total phosphorus, ortho-phosphorus, total nitrogen, nitrate + nitrite, total ammonia, colour, pH and turbidity. Cyanobacteria and microcystin were measured at nearshore and shoreline stations.

Table A-4

Carleton River Watershed - Water Quality Program

Policy and Planning Grounds	Policy Reference	Frequency	Costs	Data Management and Analysis	Municipal Roles	Collaborations
Monitoring began in response to a prevalence of potentially toxic blue-green algal blooms by Nova Scotia Environment, implemented by University of Acadia. Multiple nutrient sources were identified (i.e., agricultural, aquaculture, and residential) but the primary contributor of nutrients came from mink farming operations. Subsequently, in 2003 Nova Scotia Department of Agriculture enacted the Fur Industry Act to minimize the impact of fur farming on water quality.	No applicable policies referenced.	Annual	n/a	2017 data entries were added to a historical database, which consisted of an Excel spreadsheet file.	In 2015, Carleton River Watershed Area Water Quality Monitoring Steering Committee through the Municipality of the District of Yarmouth was developed to oversee and organize water quality monitoring within the Carleton, Meteghan and Sissiboo watersheds.	From 2008 to 2013 Acadia University ran the monitoring program for Nova Scotia Environment. From 2013 to 2016 it became increasingly volunteer-based, until 2016 when it was completely volunteer-led. In 2017, Stantec (on behalf of Carleton River Watershed Area Water Quality Monitoring Steering Committee of the Municipality of the District of Yarmouth) and volunteers ran the program under a Water Resources Program Grant provided by Nova Scotia Federation of Agriculture. The Carleton River Watershed Area Water Quality Monitoring Steering Committee consists of representatives of concerned government departments, concerned municipalities, Nova Scotia Power, the mink farming industry and concerned NGO's and affected citizens under the auspices of the Municipality of the District of Yarmouth. Financial assistance to run the volunteer program has come from Nova Scotia Department of Environment, Salmon Association's Adopt-a-Stream Program, Mersey-Tobeatic Research Institute, Municipality of the DIstrict of Yarmouth, Municipality of Argyle, and in-kind support from the Nova Scotia Department of Fisheries and Aquaculture.

Table A-4

Carleton River Watershed - Water Quality Program

Policy and Planning Grounds	**Policy Reference**	**Other Activities for Monitoring Support**	**Challenges and Lessons Learned**
Monitoring began in response to a prevalence of potentially toxic blue-green algal blooms by Nova Scotia Environment, implemented by University of Acadia. Multiple nutrient sources were identified (i.e., agricultural, aquaculture, and residential) but the primary contributor of nutrients came from mink farming operations. Subsequently, in 2003 Nova Scotia Department of Agriculture enacted the Fur Industry Act to minimize the impact of fur farming on water quality.	No applicable policies referenced.	Flow monitoring and loading calculations at lake inlets and outlets Determination of the influence of benthic sediments in TP recharge to the water column	Microcystin and cyanobacteria measurement is expensive and may only be of value for particular lakes. It would be valuable to assess the contribution of other sources of nutrient but cost and practicalities interfere. Water quality at inlets and outlets is practicable if sufficient funding allows, but flow measurements are more challenging due to volunteer-based monitoring and overland flow, seepage, and point sources are not included. Stationary gauges are difficult to install, operate and would take a lot of time and money.

Table A-5

The Twin Cities of Minneapolis and St. Paul Metropolitan Council - Lake Water Monitoring

Policy and Planning Grounds	Policy Reference	Monitoring Program Type	Monitoring Objectives	Program Duration	Sites
The Metropolitan Council was charged with creating a comprehensive regional development guide that minimizes the adverse impacts of growth, including adverse impacts on the environment. At the outset, the Statute required the Metrolitan Council to conduct an assessment of the waters (lakes, streams, and rivers) in the metro area that have been polluted or that have potential for water pollution caused by non-point sources. The monitoring data collected by the Council, its partners, and citizen volunteers are used to identify pollution problems, support regional planning efforts, and meet federal and state regulations. Most of the lake monitoring efforts focus on the assessment of eutrophication, which is the process of nutrient enrichment. Eutrophication increases the biological productivity of a lake by enhancing the growth of algae and other plants. Human activities in the watersheds of lakes (e.g. non-point sources) increase the delivery of nutrients to lakes beyond what occurs naturally. The broad "outcomes" in a policy plan titled "2040 Water Resources Policy Plan" are: stewardship, prosperity, equity, livability, and sustainability. These outcomes provide policy direction for this Policy Plan. **Stewardship.** Stewardship advances the Council's longstanding mission of orderly and economical development by responsibly managing the region's natural and financial resources, and making strategic investments in our region's future. **Prosperity.** Prosperity is fostered by investing in infrastructure and amenities that make our region competitive in attracting and retaining successful businesses, a talented workforce, and strong economic opportunities. **Equity.** Equity means connecting all residents to opportunity and creates viable housing, transportation, and recreation options for people of all races, ethnicities, incomes, and abilities so that all communities share the opportunities and challenges of growth and change. **Livability.** Livability focuses on the quality of our residents' lives and experiences in the region, and how places and infrastructure create and enhance the quality of life that makes our region a great place to live. **Sustainability**. Sustainability seeks to protect our regional vitality for generations to come by preserving our capacity to maintain and support our region's well-being and productivity over the long term.	The Minnesota Legislature state law (Minn. Stat. 473.145) directed Council to prepare a metropolitan development guide that included a plan for the region's wastewater collection and treatment system, along with supporting poliies, goals, standards and maps. The Policy Plan was also prepared in response to Minn. Stat. 473.157 requiring the Council to adopt a water resources plan and federal requirements (33 U.S. Code §1288) for a regional management plan to address pollution from point sources (such as treatment plant discharges) and nonpoint sources (such as stormwater runoff). This Policy Plan replaced previous plans adopted in May 2005 and amended in 2006 and 2010. The Council is responsible for ensuring that waste treatment management policies, programs, and facilities are implemented in the metro area to provide wastewater treatment and urban stormwater management to protect water quality in the region. In addition, the Council in cooperation and consultation with our many partners fills gaps in monitoring and assessment of the water quality of area lakes, rivers and streams. The Council works closely with communities and watershed organizations as they prepare their local water plans and watershed management plans, providing technical assistance related to surface water management and water quality issues and conditions in the region.	Lake Water Quality - based on 6 lake grades that are defined by trophic state indicators (TP, chlorophyll a abd Secchi depth)	The quality and quantity of water in the region's lakes, rivers and streams sustain the health of wildlife habitat and ecosystems while enhancing the quality of life for the region's residents. Individual lakes and streams are important to their host communities, providing opportunities for swimming, boating and fishing and enhancing the livability of the community. In addition, the region's lakes, streams, and wetlands together form a system that discharges into the region's major rivers which provide drinking water for the urban core, recreational uses, and barge transportation that support the region's economy and quality of life. Plentiful, high-quality water is essential to achieving regional outcomes of stewardship, prosperity, equity, livability, and sustainability. The Council is committed to working with partners to protect, conserve, and utilize the surface and groundwater resources in the region. Achieving this goal requires that we consider how our activities in the individual areas of water supply, surface water management, and wastewater management and operations can support or reinforce each other. For example, the Council will promote treating stormwater on-site to support surface water needs while also allowing it to infiltrate into the groundwater. Thrive MSP 2040 includes accountability as its third principle to measure success in implementing our policies and strategies. Accountability requires a commitment to monitoring and evaluating the effectiveness of our programs and policies. In partnership with others in the region, we will assess and evaluate the quality of the region's water resources and work to maintain and improve these resources.	**Program Duration:** 1980 to present - has expanded ove that time.	**Sampling Sites:** In the metro area, the Council plays an important role in collecting water quality and flow The Council works closely with state agencies, communities, counties, watershed organizations, and others involved with monitoring water resources in the metro area to strategically design our program to fill gaps in needed monitoring and assessments related to the condition of our area lakes, rivers and streams. In partnership with many others the Council monitors and assesses the condition of around 200 lakes a year and 21 stream sites. We work closely with state agencies on coordinating and filling gaps in monitoring and assessment activities for the major rivers which includes and additional 22 river sites each year.

Table A-5

The Twin Cities of Minneapolis and St. Paul Metropolitan Council - Lake Water Monitoring

Policy and Planning Grounds	Parameters	Frequency	Costs	Data Management and Analysis	Municipal Roles
The Metropolitan Council was charged with creating a comprehensive regional development guide that minimizes the adverse impacts of growth, including adverse impacts on the environment. At the outset, the Statute required the Metrolitan Council to conduct an assessment of the waters (lakes, streams, and rivers) in the metro area that have been polluted or that have potential for water pollution caused by non-point sources. The monitoring data collected by the Council, its partners, and citizen volunteers are used to identify pollution problems, support regional planning efforts, and meet federal and state regulations. Most of the lake monitoring efforts focus on the assessment of eutrophication, which is the process of nutrient enrichment. Eutrophication increases the biological productivity of a lake by enhancing the growth of algae and other plants. Human activities in the watersheds of lakes (e.g. non-point sources) increase the delivery of nutrients to lakes beyond what occurs naturally. The broad "outcomes" in a policy plan titled "2040 Water Resources Policy Plan" are: stewardship, prosperity, equity, livability, and sustainability. These outcomes provide policy direction for this Policy Plan. **Stewardship.** Stewardship advances the Council's longstanding mission of orderly and economical development by responsibly managing the region's natural and financial resources, and making strategic investments in our region's future. **Prosperity.** Prosperity is fostered by investing in infrastructure and amenities that make our region competitive in attracting and retaining successful businesses, a talented workforce, and strong economic opportunities. **Equity.** Equity means connecting all residents to opportunity and creates viable housing, transportation, and recreation options for people of all races, ethnicities, incomes, and abilities so that all communities share the opportunities and challenges of growth and change. **Livability.** Livability focuses on the quality of our residents' lives and experiences in the region, and how places and infrastructure create and enhance the quality of life that makes our region a great place to live. **Sustainability**. Sustainability seeks to protect our regional vitality for generations to come by preserving our capacity to maintain and support our region's well-being and productivity over the long term.	**Parameters:** Field measurements taken during each monitoring event typically include temperature and water clarity (measured with a Secchi disk). In addition, surface water samples are collected for lab analyses, which include total phosphorus (TP), total Kjeldahl nitrogen (TKN), and chlorophyll-a (Chl-a). The routine chemical analyses are performed at the Metropolitan Council Environmental Services laboratory following U.S. EPA approved methods.	**Frequency:** Lakes monitored by Council staff and volunteers are typically sampled at two-week intervals from mid-April through mid-October. Most lakes are sampled at one station located over the deepest spot in the lake.	Not Available	Each lake is assigned a lake grade using an A through F grading system as originally developed by Council staff in 1989. The objective of the lake grade system is to provide a tool for assessing lakes on a regional basis. The grading system allows comparisons of lake water quality across the metro area, yet is understandable to the public and non-technical audiences. The grading system uses percentile ranges of the summer-time (May-September) average values for three water quality indicators: total phosphorus, chlorophyll-a, and Secchi depth. Total phosphorus is a key nutrient measure; chlorophyll-a is a measure of algal abundance; and Secchi depth is a measure of water clarity. The lake's water quality grade is calculated as the average grade for the three individual parameter grades. Only lakes with a sufficient quantity of data are assigned a lake grade. A more detailed description of CAMP methods and the lake grade system can be found in the Annual Lake Report at: http://es.metc.state.mn.us/eims/related_documents/view_documents.asp All of the Council's lake monitoring data can be accessed online using the Council's Environmental Information Management System, at: http://es.metc.state.mn.us/eims.	The Metropolitan Council has roles and responsibilities that provide a unique regional perspective for planning and management, all aimed at protecting the region's valuable water resources. n the metro area, the Council plays an important role in collecting water quality and flow data needed to assess the condition of these valued resources in order to measure success in meeting our goal of water sustainability. The Council works closely with state agencies, communities, counties, watershed organizations, and others involved with monitoring water resources in the metro area to strategically design our program to fill gaps in needed monitoring and assessments related to the condition of our area lakes, rivers and streams. For example, in partnership with many others the Council monitors and assesses the condition of around 200 lakes a year and 21 stream sites. We work closely with state agencies on coordinating and filling gaps in monitoring and assessment activities for the major rivers. For that program, the Council monitors 22 river sites a year.

Table A-5

The Twin Cities of Minneapolis and St. Paul Metropolitan Council - Lake Water Monitoring

Policy and Planning Grounds	Collaborations	Other Activities for Monitoring Support	Challenges and Lessons Learned
The Metropolitan Council was charged with creating a comprehensive regional development guide that minimizes the adverse impacts of growth, including adverse impacts on the environment. At the outset, the Statute required the Metrolitan Council to conduct an assessment of the waters (lakes, streams, and rivers) in the metro area that have been polluted or that have potential for water pollution caused by non-point sources. The monitoring data collected by the Council, its partners, and citizen volunteers are used to identify pollution problems, support regional planning efforts, and meet federal and state regulations. Most of the lake monitoring efforts focus on the assessment of eutrophication, which is the process of nutrient enrichment. Eutrophication increases the biological productivity of a lake by enhancing the growth of algae and other plants. Human activities in the watersheds of lakes (e.g. non-point sources) increase the delivery of nutrients to lakes beyond what occurs naturally. The broad "outcomes" in a policy plan titled "2040 Water Resources Policy Plan" are: stewardship, prosperity, equity, livability, and sustainability. These outcomes provide policy direction for this Policy Plan. **Stewardship.** Stewardship advances the Council's longstanding mission of orderly and economical development by responsibly managing the region's natural and financial resources, and making strategic investments in our region's future. **Prosperity.** Prosperity is fostered by investing in infrastructure and amenities that make our region competitive in attracting and retaining successful businesses, a talented workforce, and strong economic opportunities. **Equity.** Equity means connecting all residents to opportunity and creates viable housing, transportation, and recreation options for people of all races, ethnicities, incomes, and abilities so that all communities share the opportunities and challenges of growth and change. **Livability.** Livability focuses on the quality of our residents' lives and experiences in the region, and how places and infrastructure create and enhance the quality of life that makes our region a great place to live. **Sustainability**. Sustainability seeks to protect our regional vitality for generations to come by preserving our capacity to maintain and support our region's well-being and productivity over the long term.	In 1993, the Council initiated the Citizen-Assisted Monitoring Program (CAMP) to help expand coverage of lake monitoring in the metro area and to provide information to support local water management efforts. This highly successful program collects data on the lakes each year through the efforts of trained, dedicated volunteers and their local sponsors. 2013 was the 21st year of the Council's volunteer program, with 118 citizen volunteers participating in the CAMP. The volunteers were sponsored by local partners, including 11 cities, 9 watershed management organizations and watershed districts, 2 counties, 1 basin planning team, and 1 conservation district. Through the dedicated efforts of the volunteers and local partners a total of 175 lake-sites on 159 lakes were monitored in 2013 through the CAMP. Three of the lakes monitored by the CAMP also were monitored by Metropolitan Council staff (but for different parameters), so the total number of lakes monitored by the Metropolitan Council's lake monitoring program was 162 in 2013.	1. Invest in nonpoint-source pollution control when the cost and long-term benefits are favorable compared to further upgrading wastewater treatment. 2. Consider pollutant trading or off-set opportunities with nonpoint-sources of pollution when cost-effective and environmentally beneficial. 3. Invest in wastewater reuse when justified, as sources of nonpotable water to support regional growth, and by the benefits for maintaining water quality. 4. Potentially invest strategically to further the effectiveness of the region's nonpoint-source pollution prevention and control program and to ensure efficient investment to achieve regional water quality objectives.	1. Given that there are 950 lakes in the Twin Cities metro area the Council deveoped a priority list in 2003 to focus limited resources to managing the sustainability of the region's lakes. 2. Volunteer Program has run for 21 years with 118 citizen volunteers participating. Volunteers are trained and in 2013 implemented the Rgion's program across the area at a total of 175 sites on 159 lakes. 3. Volunteer monitoring has played a key role in the use of satellite images to assess lake water clarity by providing ground truthing to calibrate mathematical models used to interpret satellite images.

Appendix A.2

Sample Water Quality Monitoring Reports

- Muskoka Watershed Report Card – 2018[1]
- Lake Muskoka Data Sheet[2]
- City of Sudbury Lake Water Quality Program – 2018 Annual Report[3]
- King's County Lake Monitoring Program, 2017 Season[4]
- Carleton River Watershed Monitoring Program, 2017 Season – 2 reports[5][6]
- Minneapolis – St. Paul, Lake Water Quality Summary, 2013[7]

[1] https://www.muskokawatershed.org/wp-content/uploads/2018-MWC-ReportCard.pdf

[2] http://www.muskokawaterweb.ca/images/lds/MuskokaBay.pdf

[3] https://www.greatersudbury.ca/live/environment-and-sustainability1/lake-health/pdf-documents/2018-annual-report-lake-water-quality-program/

[4] https://www.countyofkings.ca/upload/All_Uploads/Living/services/planning/LakeMonitoring/Data/KINGS%20COUNTY%202017%20report%20final.pdf

[5] https://www.district.yarmouth.ns.ca/images/PDF/Carleton%20River%20Watershed/Supplemental%20Results%20of%20the%202017%20Water%20Quality%20Survey%20of%20Fourteen%20Lakes%20in%20Yarmouth%20and%20Digby%20Counties.pdf

[6] https://www.district.yarmouth.ns.ca/images/PDF/Carleton%20River%20Watershed/Results%20of%20the%202017%20Water%20Quality%20Survey.pdf

[7] https://metrocouncil.org/Wastewater-Water/Publications-And-Resources/WATER-QUALITY-MONITOR-ASSESS/Lake-Water-Quality-Summary,-2013.aspx

Muskoka Watershed Report Card 2018

The Muskoka Watershed Report Card is a science-based evaluation of the health of Muskoka's watersheds. It is produced by Muskoka Watershed Council every four years, with 2018 being the fifth Report Card.

The Report Card provides a snapshot of watershed health by evaluating 8 indicators, 4 of which measure the health of the watershed, and 4 that consider potential threats.

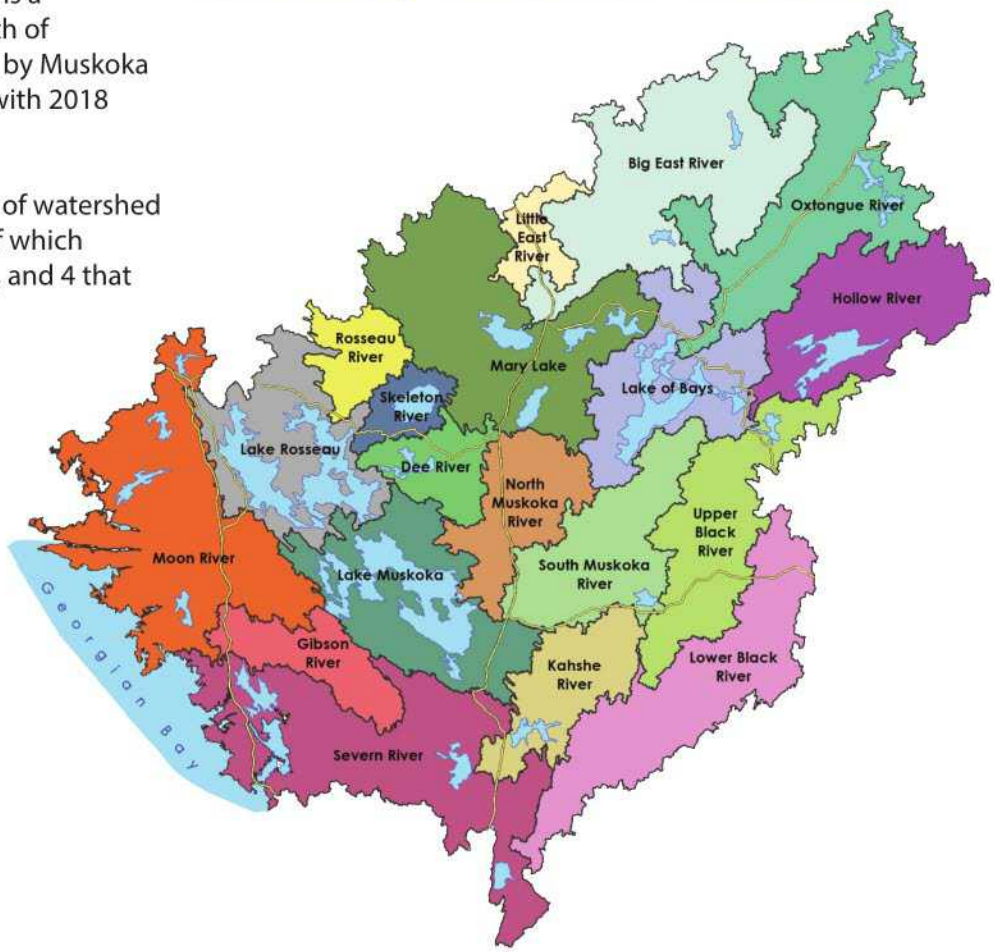
Health Indicators

- Total Phosphorus
- Calcium
- Benthic Macroinvertebrates
- Interior Forest

Threat Indicators

- Climate Change
- Species at Risk
- Invasive Species
- Fragmentation

Quaternary Watersheds of Muskoka



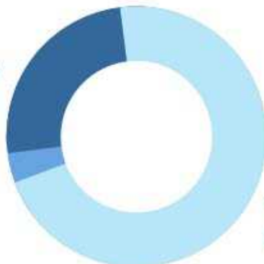
A watershed is an area of land that drains to a river, lake or stream. The Muskoka Watershed refers to all watersheds lying totally or partially within the District Municipality of Muskoka and includes areas in Algonquin Park, the Township of Seguin and the Township of Algonquin Highlands. All water in the Muskoka Watershed eventually flows into Georgian Bay.

The map above shows the nineteen subwatersheds within the Muskoka Watershed. A healthy watershed not only benefits our lakes, forests, and wildlife, but also supports our health, our communities, and the economy.

Muskoka Watershed Council (MWC) is a volunteer-based non-profit organization with the mandate to champion watershed health. MWC is comprised of representatives from a wide range of stakeholders and has been providing a coordinated and science-based voice on issues affecting the environmental quality of our watersheds since 2001.

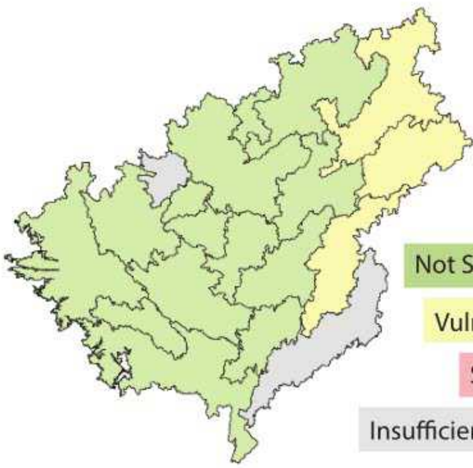
Phosphorus Concentrations in Lakes

Trophic Status of Sampled Lakes (2001-2017)



Phosphorus is a nutrient in limited supply in most Precambrian Shield lakes & generally controls the growth of algae. In general, lakes in Muskoka have had stabilized phosphous levels in recent years.

Calcium Concentrations in Lakes



Calcium is the **5th** most abundant natural element

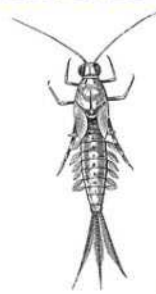
Did You Know?
187 lakes across Muskoka were assessed for the calcium indicator.

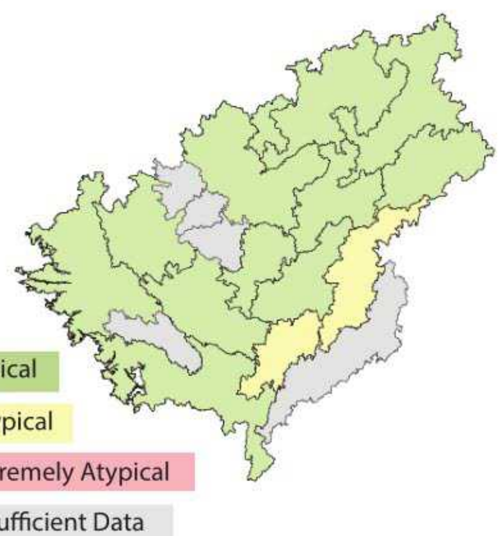
56% of lakes sampled for the Report Card, have calcium concentrations below the threshold of 2.5 milligrams of calcium per Litre, the amount when Daphnia become stressed. Daphnia are keystone herbivores in lake food webs.

Benthic Macroinvertebrates

Did You Know?
These creatures are small but large enough to see with the naked eye (macro), have no backbone (invertebrate) and live on the bottom of lakes & rivers (benthic).

The District Municipality of Muskoka has continuously sampled **45** lakes across the watershed to monitor benthos through the Biological Monitoring Program with lake associations.





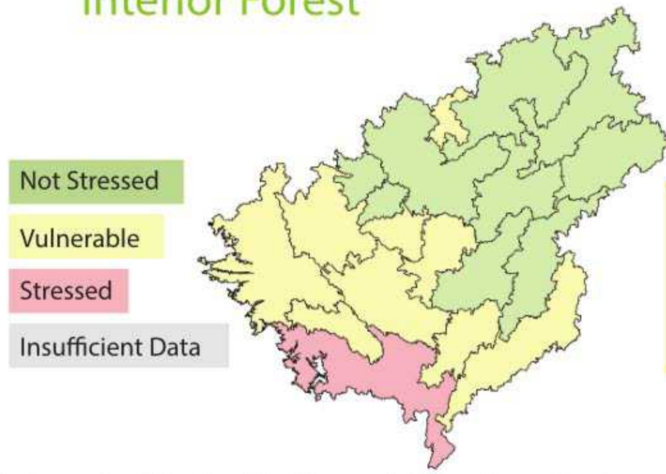
Benthos are used as a biological indicator of water quality & habitat condition. Healthy lakes support high species richness & abundance.

Interior Forest

Interior forest is habitat

DEEP

in the forest which is secluded from development and open areas.

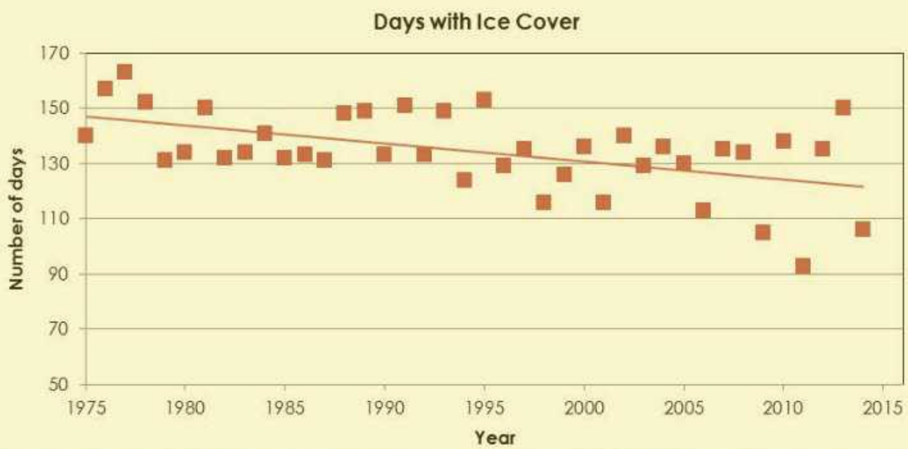


Did You Know?

46% of the Muskoka Watershed is interior forest.

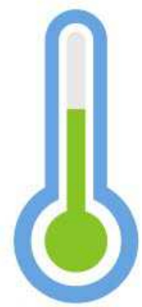
Interior forest is important for the filtering and absorption of water, sequestration of carbon dioxide, and provides essential habitat to wildlife.

Climate Change in Muskoka



The number of days with ice coverage on lakes from 1975 to 2016. In 1975, there was an average of 140 days with ice on the lakes. By 2016, an average of 121 days of ice coverage was observed.

In Muskoka, trends include an increase in surface water temperature & declining ice coverage days.



The typical year by mid-century is likely to be 3-4°C warmer and 10% wetter than present.

Species at Risk in Muskoka

There are **46** species at risk in the watershed

Did You Know?

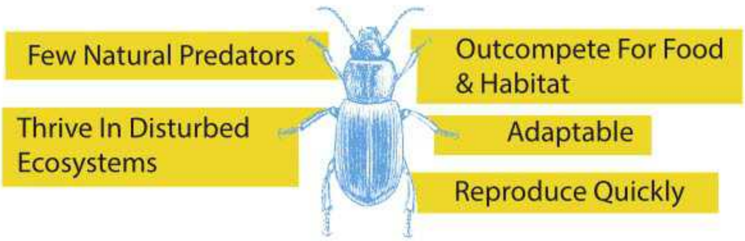
Species at risk are classified as special concern, threatened, endangered or extirpated

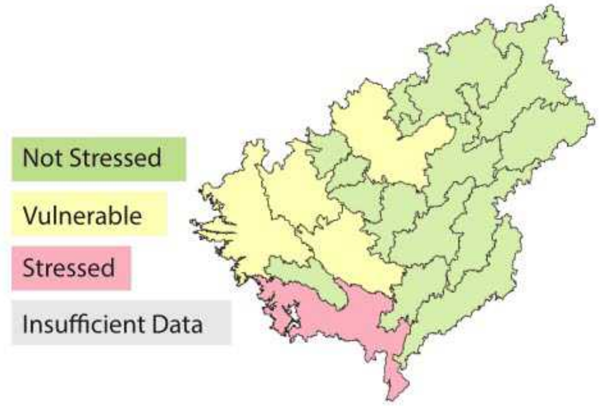
Being at the southern edge of the Canadian Shield in Ontario, Muskoka is the northern limit for many southern species, and the southern limit for many northern species. This has resulted in biologically diverse ecosystems that support many species that are at risk.

Dive deeper into the story map at www.muskokawatershed.org/reportcard-story-map

Invasive Species

Main characteristics of invasive species





The Ministry of Natural Resources and Forestry (MNRF) has identified

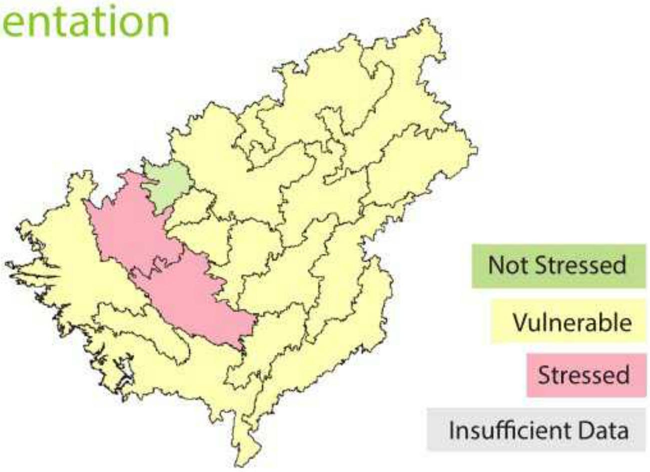
24 Invasive Species of concern in Ontario

7 of which are found in Muskoka

Fragmentation

Did You Know?

82% of the Muskoka Watershed is natural area. This includes lakes, wetlands, forests, rock barrens, and other natural ecological communities.



Development such as roads, urban areas, and railways disrupt large natural areas like interior forest and contribute to habitat loss, decreased biodiversity, and a fragmented landscape.

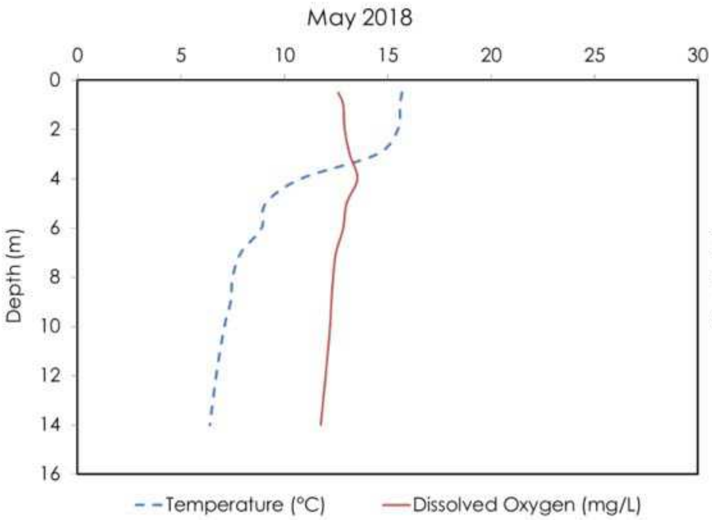
It's Your Turn! Top 5 Actions You Can Take

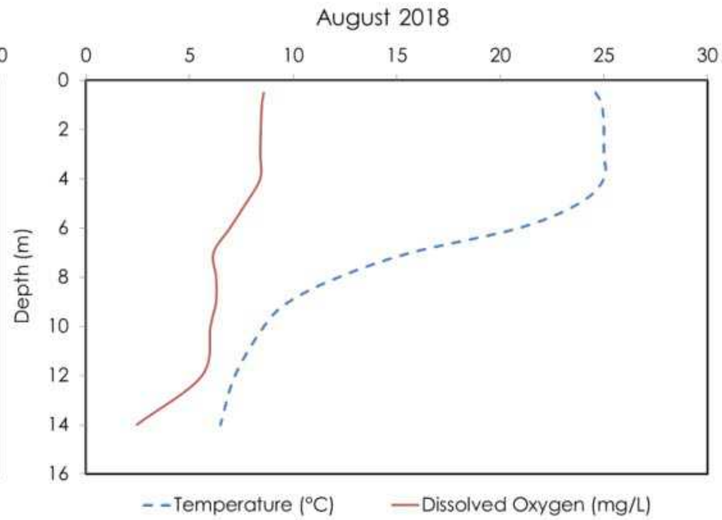
1. Get involved in citizen science programs! Key ones include:
    - Lake Partner Program (calcium and phosphorus)
    - EDDMapS (invasive species)
    - iNaturalist (Species at Risk reporting)
2. Prevent the spread of invasive species
3. Reduce your carbon footprint
4. Volunteer for your local lake association or environmental organization
5. Support your municipality's green initiatives such as decreasing energy consumption and greenhouse gas emissions

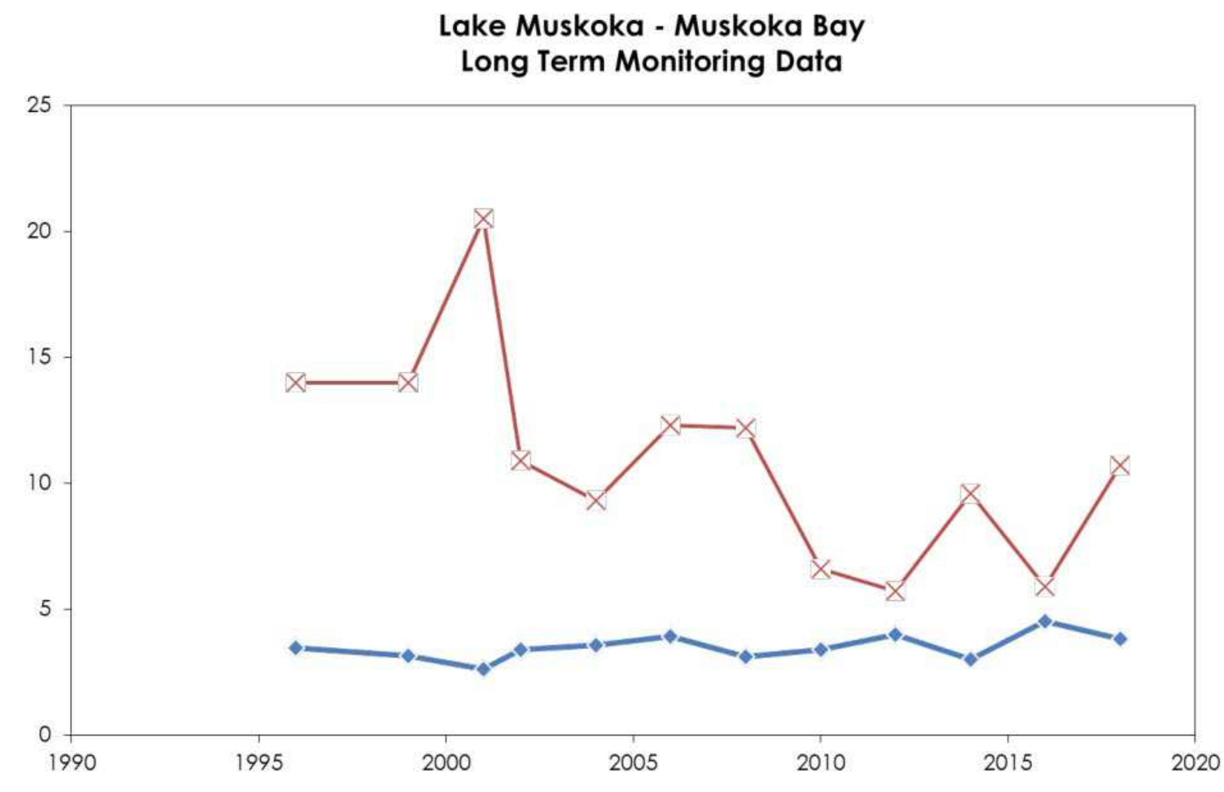
Lake Muskoka – Muskoka Bay

Sample Point: 44.9259 -79.3979

Municipality:	**Gravenhurst**	Quaternary Watershed:	**Lake Muskoka**
Surface Area:	**4.03 km²**	Watershed Area (excluding lake):	**20.0 km²**
Maximum Depth:	**14 m**	Lake Trout Lake?	**Yes**
Wetland Area:	**13 %**	Secchi Depth (10-year average):	**3.7 m**
Phosphorus (10-year average):	**7.7 µg/L**	Sensitivity:	**Moderate (OT)**







Lake Water Quality Program

Environmental Planning Initiatives

City of Lakes Ville de lacs

2018 Annual Report

Greater | Grand Sudbury
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City Of Lakes

The City of Greater Sudbury is recognised as the 'City of Lakes'. With over 330 lakes, it contains more lakes than any other municipality in Canada. These lakes are prized by our citizens who have a vested interest in their health and quality.

Lake Water Quality Program

The Lake Water Quality Program helps ensure that Greater Sudbury is positively recognised as a City of Lakes. The Lake Water Quality Program advocates for the ecological health of the lakes, provides lake water quality monitoring and education, offers technical support to lake stewardship groups and the community, and provides research into various issues related to lake water quality.

Staffing

The City of Greater Sudbury provides funding for the full-time position of the Program Co-ordinator and a seasonal Lake Water Quality Field Intern. These positions are responsible for the day-to-day program and activities including water quality monitoring, shoreline home visit program, technical assistance to lake stewardship groups and the Watershed Advisory Panel. Additional duties include website content management and report writing.

Summary of Activities

In collaboration with its partners, the Lake Water Quality Program carried out annual spring phosphorus sampling, the Love Your Lake shoreline assessment program, aquatic vegetation mapping, weekly cyanobacteria watch on Ramsey lake, the Lake Stewardship Grant Program and co-ordinated the Shoreline Home Visit Program. In summary:

- 44 total sites sampled on 37 lakes sampled for spring phosphorus, sodium and chloride
- 232 properties on Long Lake were surveyed through the Love Your Lake shoreline assessment program
- Richard Lake was selected to be a part of the aquatic vegetation mapping project undertaken by the Lake Water Quality program. Mapping of all 260 points on Richard Lake was completed during the 2018 season.
- Weekly cyanobacterial bloom (blue-green algae) watch conducted on Lake Ramsey during the summer months including the use of the Lake Water Quality Programs fluorometer to test reflectance values of water samples to help detect potential cyanobacterial blooms
- 6 lake stewardship grants awarded for a total of $3000 in funding to local lake stewardship groups
- 7 Watershed Advisory Panel meetings held in 2018
- 30 active lake stewardship groups

Lake Water Quality Program Components

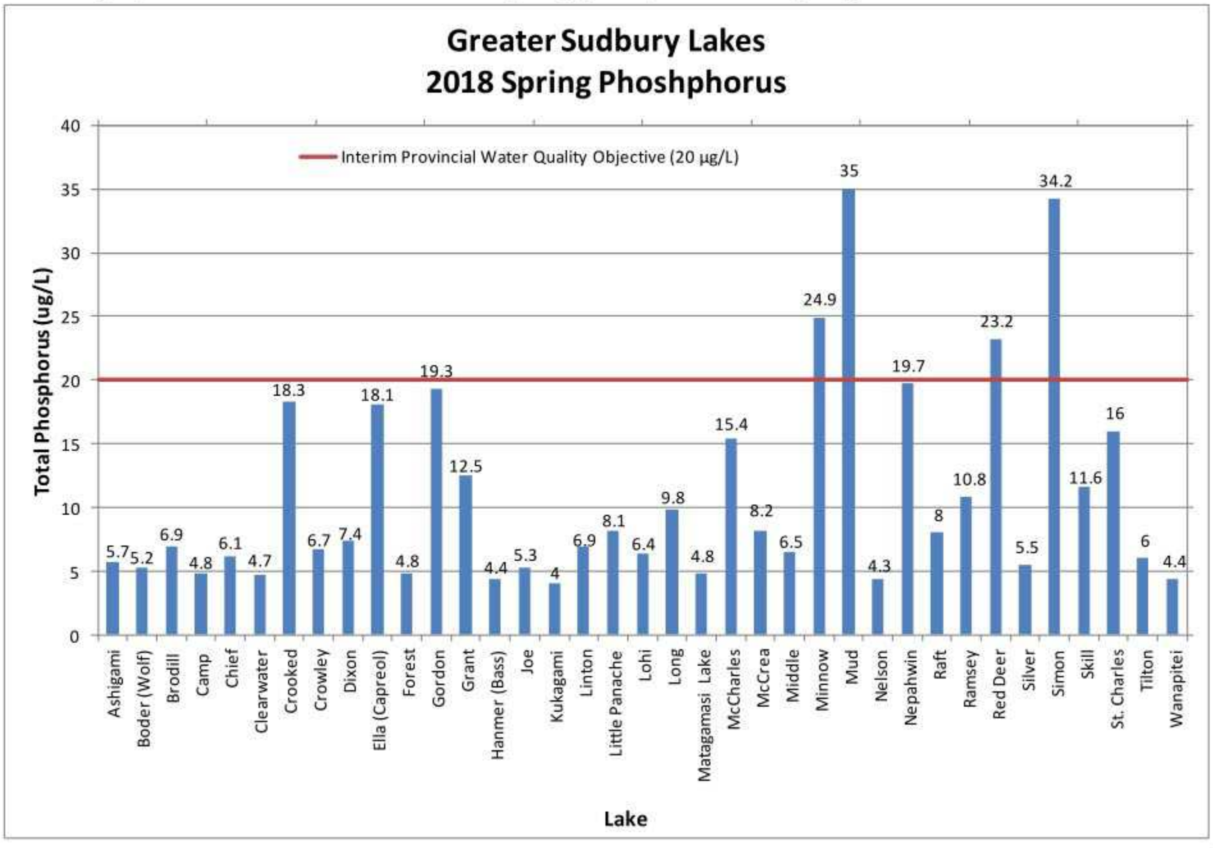
Spring Phosphorus Sampling Program

The City of Greater Sudbury has been sampling a group of approximately 67 local lakes for spring phosphorus since 2001 on a rotating basis. These lakes were chosen based on their historical phosphorus levels, waterfront development pressures, and requests from lake stewardship groups. Phosphorus is the main contributing nutrient that controls the growth and development of algae. Spring phosphorus samples are taken during a natural phenomenon called "spring turnover". This event occurs shortly after 'ice off' in the early spring when the water on the surface warms up and becomes the same temperature as the bottom of the lake. Through wind action the surface water mixes with the bottom layers creating equilibrium in the water column. This is the optimal time for phosphorus samples in the Canadian Shield as recommended by the Ontario Ministry of the Environment, Conservation and Parks. Phosphorus can enter a lake through natural sources, such as aerial deposition, wildlife, vegetation cover, and soil. Phosphorus can also enter our local lakes through human activity, including fertilization of lawns and gardens, agricultural practices, detergents and cleaners, and private, industrial and municipal wastewater.

Spring Phosphorus Results

The spring phosphorus sampling was conducted in May on 37 lakes, at 44 total sites. Sampling results are shown in the graph below. Individual spring phosphorus graphs for lakes sampled this year are found at the end of this report. Of the lakes sampled, eight lakes had phosphorus concentrations greater than the Interim Provincial Water Quality Objective of 20 µg/L (micrograms per litre). Phosphorus concentrations that are at or above this level indicate that the lake is likely eutrophic and nutrient rich.

The bar graph below indicates the 2018 spring phosphorus sampling results for 34 local lakes.



Weekly Cyanobacteria (Blue-green Algae) Watch

Lake Water Quality Program staff checked for signs of cyanobacterial blooms on Lake Ramsey once a week throughout the summer. This was the third year that the City undertook this initiative which aims to provide early warning of developing cyanobacterial blooms for residents and operators of the David Street water treatment plant. The initiative involved a weekly visual check of the entire lake, including beaches, main basins and small bays by way of a motor boat. The 2018 season also included the use of an Aquafluor Fluorometer which helps detect trace levels of cyanobacteria in the water during the weekly surveys. The 2018 visual check confirmed three (3) cyanbacterial blooms on Ramsey Lake during the season. Blooms were found: August 9th in Moonlight Bay near Camp Sudaca, August 14th in Moonlight Bay along the northern portion of the beach area, August 16th near Amphitheatre beach.

Aquatic Vegetation Mapping – Richard Lake

Between August 1, 2018 and August 20, 2018 members of the Lake Water Quality program at the City of Greater Sudbury performed a vegetation survey of Richard Lake to identify all species present within the lake at the time of the survey. The goal of the project was to create a database of locations in which aquatic vegetation species are present including invasive Eurasian Watermilfoil. Lakes will be revisited in future years to determine whether various species populations are growing or shrinking which will help the city create invasive species management strategies.

The sampling procedures done by the City of Greater Sudbury were based on procedures outlined in the Recommended Baseline Monitoring of Aquatic Plant in Wisconsin: Sampling Design Field and Laboratory Procedures, Data Entry and Analysis, and Applications by the Wisconsin Department of Natural Resources. Using calculations outlined in the Wisconsin Department of Natural Resources document as well as a journal article (Mikulyuk et al 2010), 260 sampling points were created based on lake surface area, depth and the shoreline development factor. Each point was sampled by boat using a double sided rake and three rake tosses at each location as per the outlined procedure. Aquatic vegetation was identified and recorded. Maps were then created to show the distribution of each species within the lake and the relationship between the various species found within the lake.

The mapping project identified fourteen (14) different aquatic vegetation species across the lake, see Table 1 below. The mapping also identified the relative density of vegetation at the site and the dominate vegetation found at each site. A complete report will be available under a separate cover.

Table 1. Aquatic plant species composition and percentage of sampling locations in descending order for species is present for Richard Lake vegetation sampling conducted in 2018.

Common Name	Scientific Name	Locations Present	% of Sampling Locations
Muskgrass/Stonewort	***Chara spp.***	**77**	**29.6%**
Flat-Stem Pondweed	***Potamogeton Compressus***	**73**	**28.1%**
Eurasian water-milfoil	***Myriophyllum spicatum***	**64**	**24.6%**
Northern water-milfoil	***Myriophyllum sibiricum***	**56**	**21.5%**
Richardson's pondweed	***Potamogeton richardsonii***	**39**	**15.0%**
Nitella spp	*Nitella spp.*	19	7.3%
Largeleaf pondweed	*Potamogeton amplifolius*	18	6.9%
Spiny-spored quillwort	*Isoetes echinospora*	16	6.2%
Slender Naiad	*Najas flexilis*	12	4.6%
White water-lily	*Nymphaea odorata*	7	2.7%
Slender pondweed	*Potamogeton pusillus*	5	1.9%
Canada Waterweed	*Elodea canadensis*	3	1.2%
Tapegrass	*Vallisneria americana*	3	1.2%
Illinois pondweed	*Potamogeton illinoensis*	1	0.4%

Community Outreach

Love Your Lake Program

Love Your Lake, a program of the Canadian Wildlife Federation and Watersheds Canada, offers comprehensive shoreline surveys and stewardship education to individual shoreline residents. In Greater Sudbury, the field work and administration of this program is undertaken by Lake Water Quality staff. Underway locally since 2014, Love Your Lake yields individualized, confidential recommendations to shoreline residents over an entire lake. Residents are encouraged to become stewards of their lake by acting on the recommendations to improve the health of their lake.

In 2018 the Lake Water Quality program continued the Love Your Lake shoreline assessments on Long Lake that was started in 2017. All remaining shoreline properties on Long Lake were assessed during the 2018 field season. In 2018, a total of 232 properties and their shorelines were assessed and completed. Final reports for each property are to be sent to property owners in spring 2019.

Sudbury Children's Water Festival

This was the 14th year that the Lake Water Quality Program participated in the water festival, which was attended by over 800 grade 3 students. The Lake Water Quality Program staff present taught students the need for diversity in shorelines and the impacts and causes of erosion. The Children's Water Festival in Greater Sudbury is organized by the City's Earthcare Program with the support of many community organizations.

Natural Shoreline Demonstration Site

The City of Greater Sudbury's Lake Water Quality Program in partnership with Science North and the Nickel District Conservation Authority's Source Water Protection Program established a Natural Shoreline Demonstration site on Ramsey Lake. Funding for this educational project was received from the Ministry of Environment's Source Water Protection Program, the City of Greater Sudbury and Science North. Natural shoreline planting workshops and tours of the demonstration site are available to the community and shoreline homeowners to learn how they can improve the health of shorelines on their property.

Watershed Advisory Panel

The Watershed Advisory Panel is appointed by City Council to provide advice and recommendations to the municipality on matters relating to watershed and lake water quality in Greater Sudbury. The current Panel members were appointed in 2015 for a three -year term, ending with the term of Council in 2018. A total of 7 meetings were held in 2018.

Members

The Lakes Advisory Panel is made up of one City Councillor, eight community volunteers, six technical experts and two City staff.

Community Volunteers

- Lin Gibson - Chair
- Mary Henderson – Vice Chair
- Jeffery Huska
- Margaret McLaughlin
- Lily Noble
- Paul Truskoski
- Wendy Wisniewski
- Sarah Woods

Technical Experts

Burgess Hawkins – Sudbury & District Health Unit
Derrick Luetchford - MNRF
Dr. John Gunn – Vale Living With Lakes Centre
Ed Snucins – Ontario Ministry of Environment
Anoop Naik –Conservation Sudbury
Dr. Charles Ramcharan – Laurentian University

City Councillors

Mark Signoretti

Lake Stewardship Grant Assistance Program

Introduction

Established as a pilot project in 2005, Lake Stewardship Grant Program assists lake stewardship groups in carrying out projects that protect and improve the water quality and natural environment of the lakes. The Grant Program is funded by the City of Greater Sudbury through its Lake Water Quality Program. The Lakes Advisory Panel awards individual grants to stewardship groups in Greater Sudbury.

Grant applicants were required to demonstrate how their proposed project would improve or protect the water quality of the lake and/or watershed and increase support from the lake community. In total, 6 applications for funding were received with all applicants receiving the full $500 grant. The following is a list of the successful applicants.

Funding recipients for 2018

Clearwater Lake Stewardship Group
Project Name: On Water Educational/Information/Fun Paddle
Amount Received: $500

Four Lakes Community Association
Project Name: Four Lakes Waterfront Garden Tour
Amount Received: $500

Lake Panache Camper's Association
Project Name: Association Communication & Hazardous Waste Day
Amount Received: $500

Richard Lake Stewardship
Project Name: Richard Lake Stewardship - Newsletter
Amount Received: $500

Long Lake Stewardship
Project Name: Long Lake: Ours to Protect
Amount Received: $500

Lake Wahnapitae Home And Campers Association
Project Name: Shoal Markers
Amount Received: $500

Stewardship Groups

Currently, there are 30 lake stewardship groups throughout the Greater Sudbury area, acting as important agents for positive change in shoreline living practices.

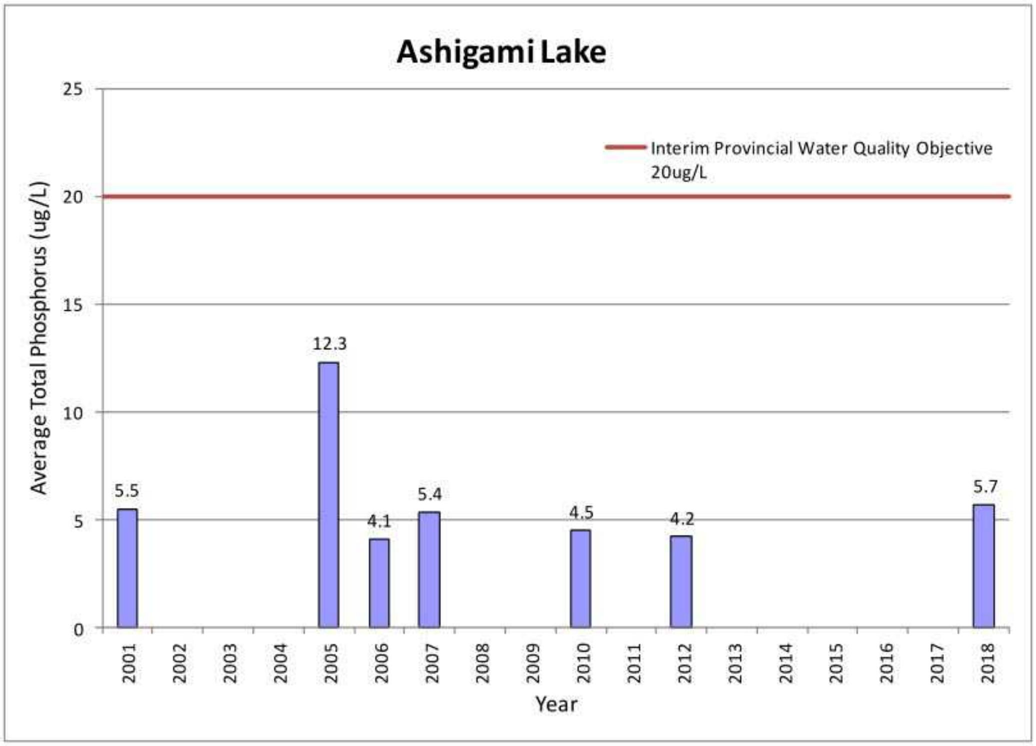
The following is a list of the active lake stewardship groups in Greater Sudbury.

Stewardship Group	Lake(s)
Friends of Bennett Lake	Bennett Lake
Black Lake	Black Lake
Broder 23	Broder 23 Lake
Crooked Lake	Crooked Lake
Fairbank Lake Cottagers Association	Fairbank Lake
Friends of McFarlane Lake	McFarlane Lake
Grassy Lake	Grassy Lake
Forest Lake Stewardship Commmittee	Forest Lake
Four Lakes Association	Joe, Hanmer, Frenchman and Dixon Lakes
Ironside Lake	Ironside Lake
Kukagami Lake Campers Association	Kukagami Lake
Kusk (Rat) Lake	Kusk (Rat) Lake
Lake Nepahwin Stewardship Group	Nepahwin Lake
Lake Panache Campers Association	Panache Lake
Lake Robinson Stewardship	Robinson Lake
Lohi Lake	Lohi Lake
Long Lake Stewardship	Long Lake
McCrea Lake Stewardship Group	McCrea Lake
Minnow Lake Restoration Group	Minnow Lake
Richard Lake Stewardship	Richard Lake
St. Charles Lake	St. Charles Lake
Silver Lake	Silver Lake
Simon Lake	Simon Lake
Vermilion Lake	Vermilion Lake
Windy Lake Stewardship	Windy Lake
Onwatin Lake Stewardship	Onwatin Lake
Ramsey Lake Stewardship Committee	Ramsey Lake
Vermillion River Stewardship	Vermillion River
Whitewater Lake	Whitewater Lake
Lake Wanapitei Lake Stewardship	Wanapitei Lake

Appendix A
Phosphorus Graphs for Lakes Sampled in 2018

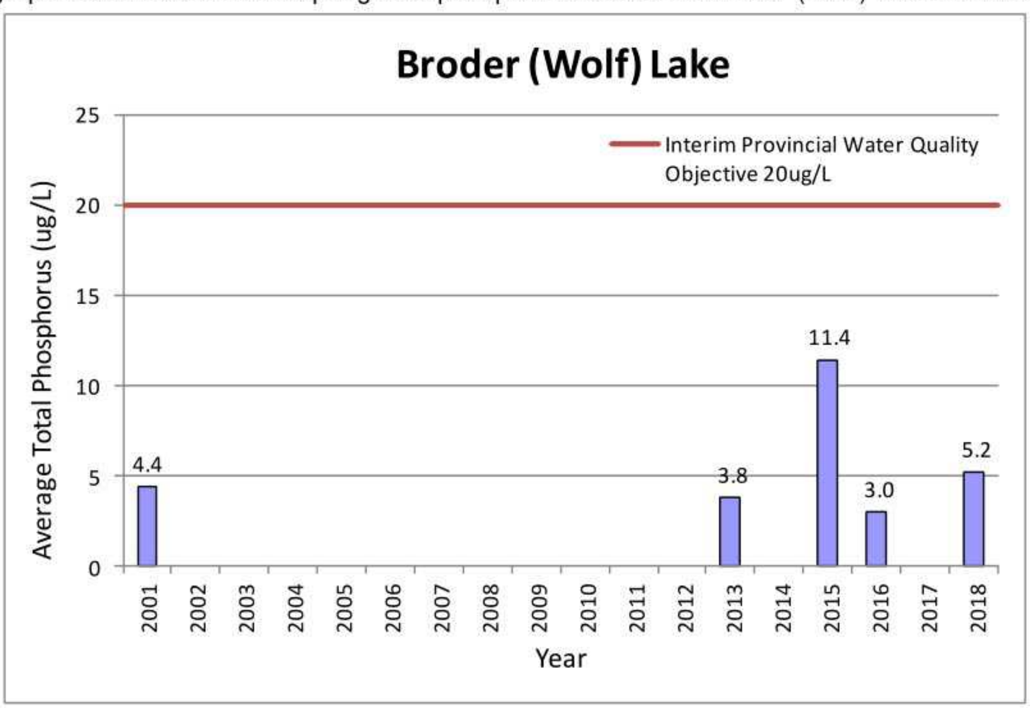
Ashigami Lake

The bar graph below indicates the spring total phosphorus results for Ashigami Lake from 2001-2018.



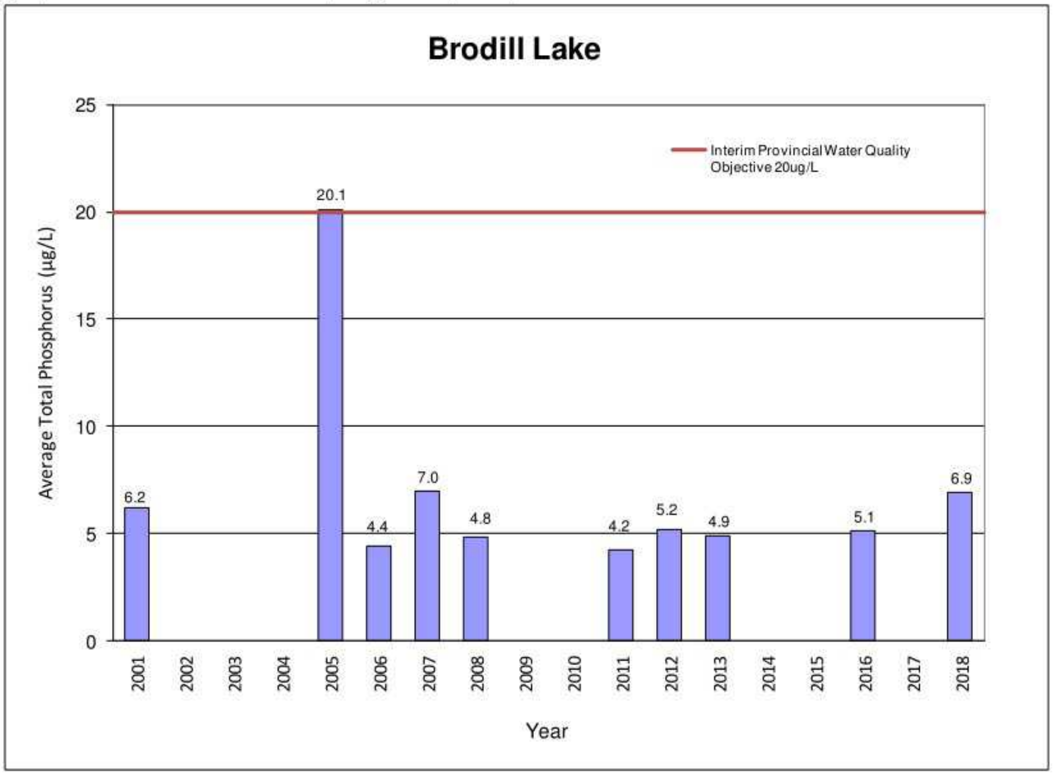
Broder (Wolf) Lake

The bar graph below indicates the spring total phosphorus results for Broder (Wolf) Lake from 2001-2018.



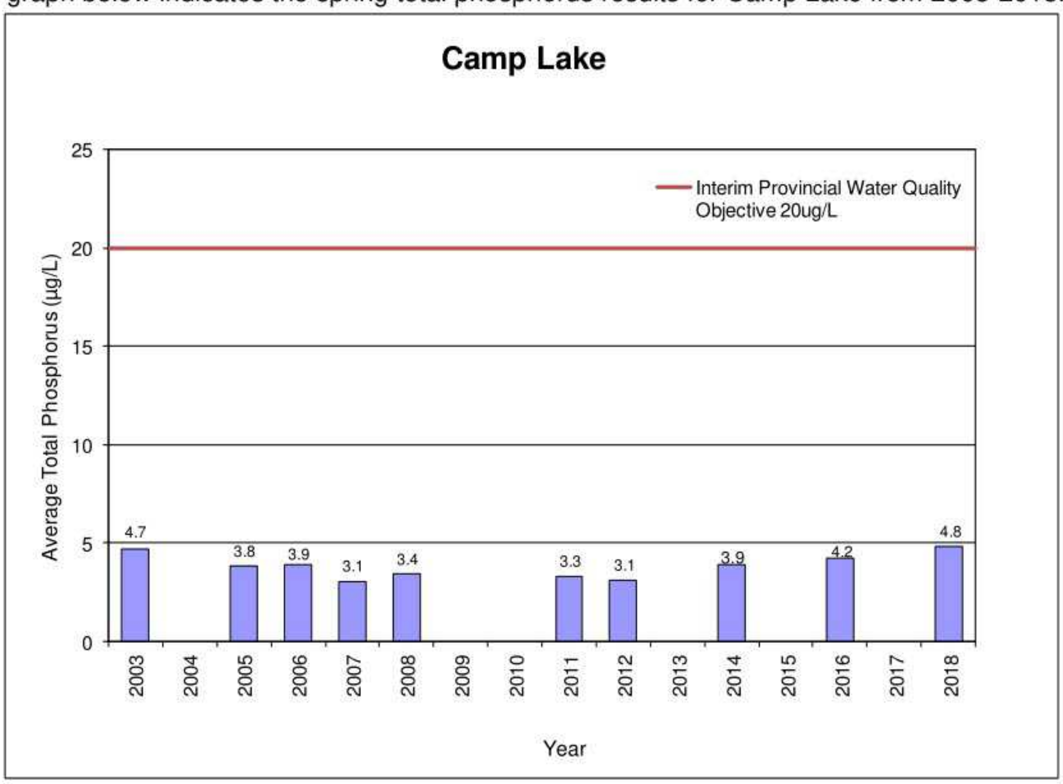
Brodill Lake

The bar graph below indicated the spring total phosphorus results for Brodill Lake from 2001-2018.



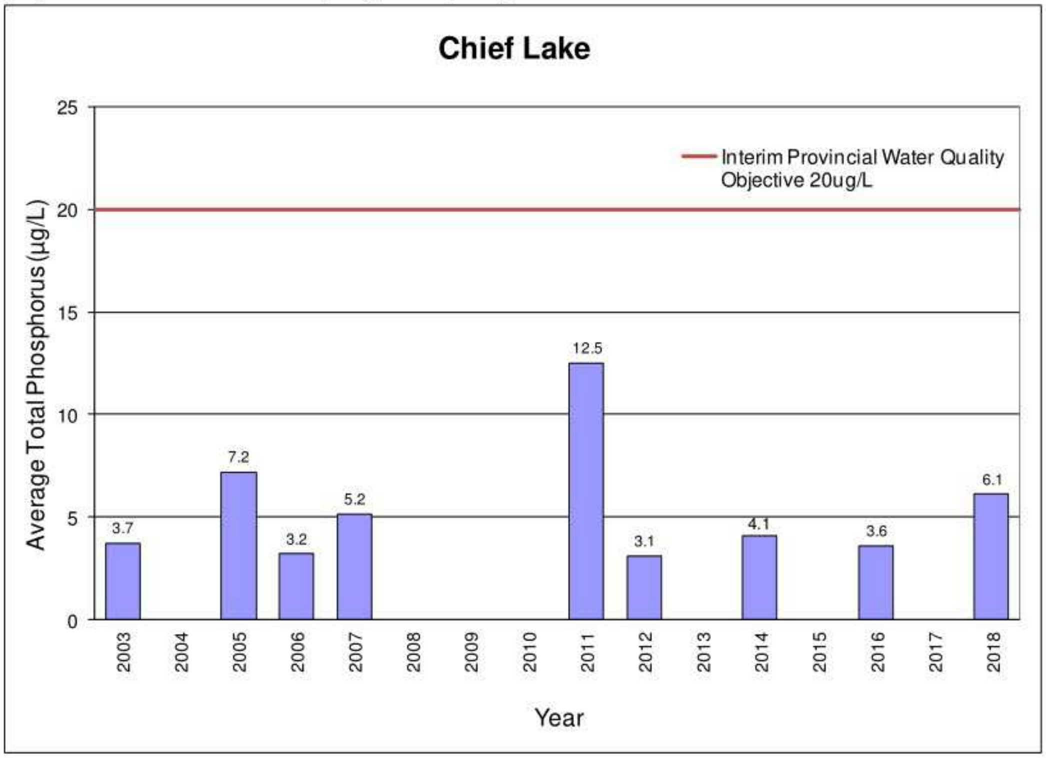
Camp Lake

The bar graph below indicates the spring total phosphorus results for Camp Lake from 2003-2018.



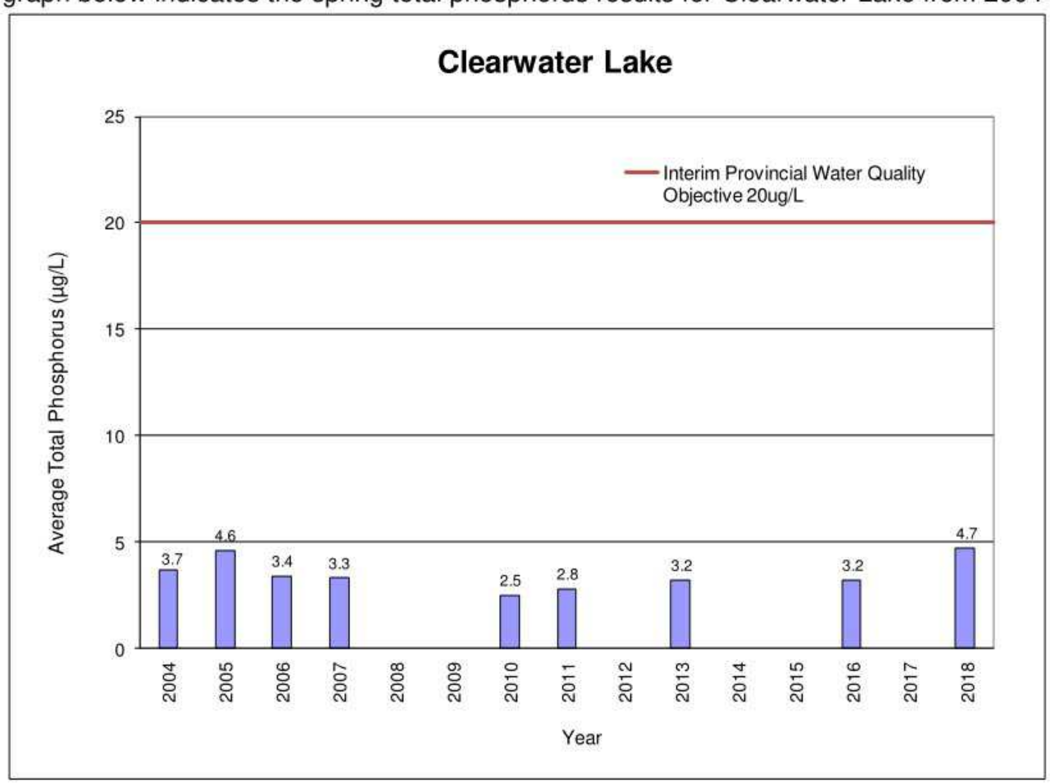
Chief Lake

The bar graph below indicates the spring total phosphorus results for Chief Lake from 2003-2018.



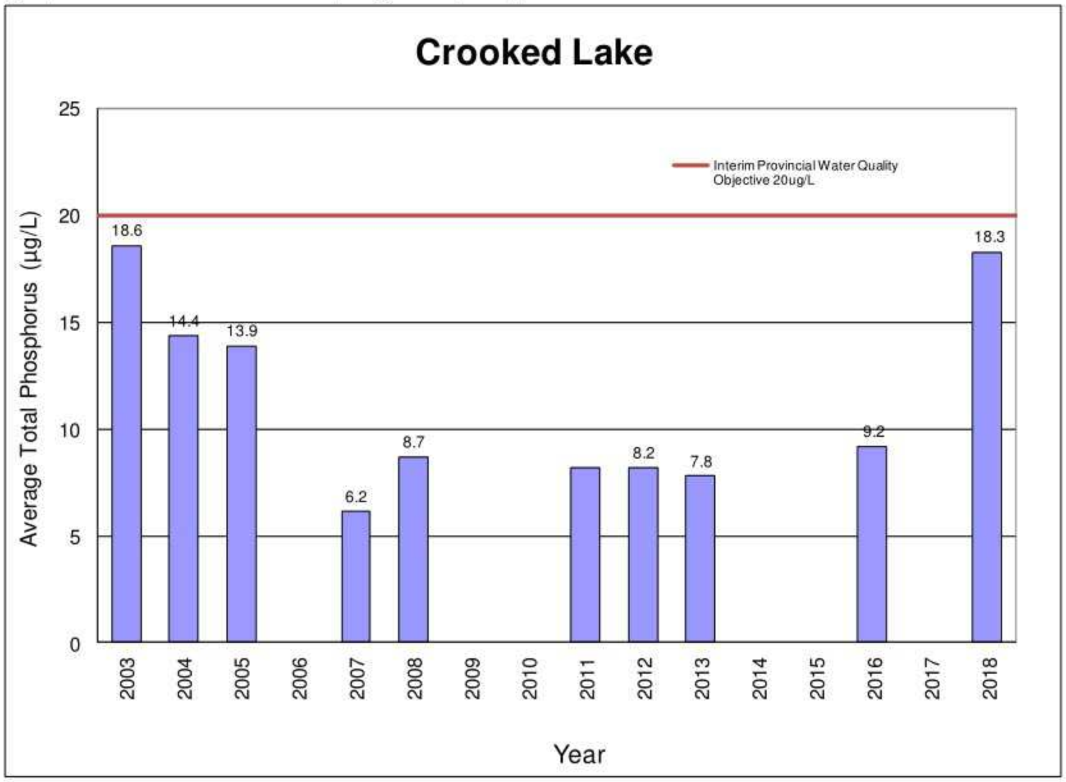
Clearwater Lake

The bar graph below indicates the spring total phosphorus results for Clearwater Lake from 2004-2018.



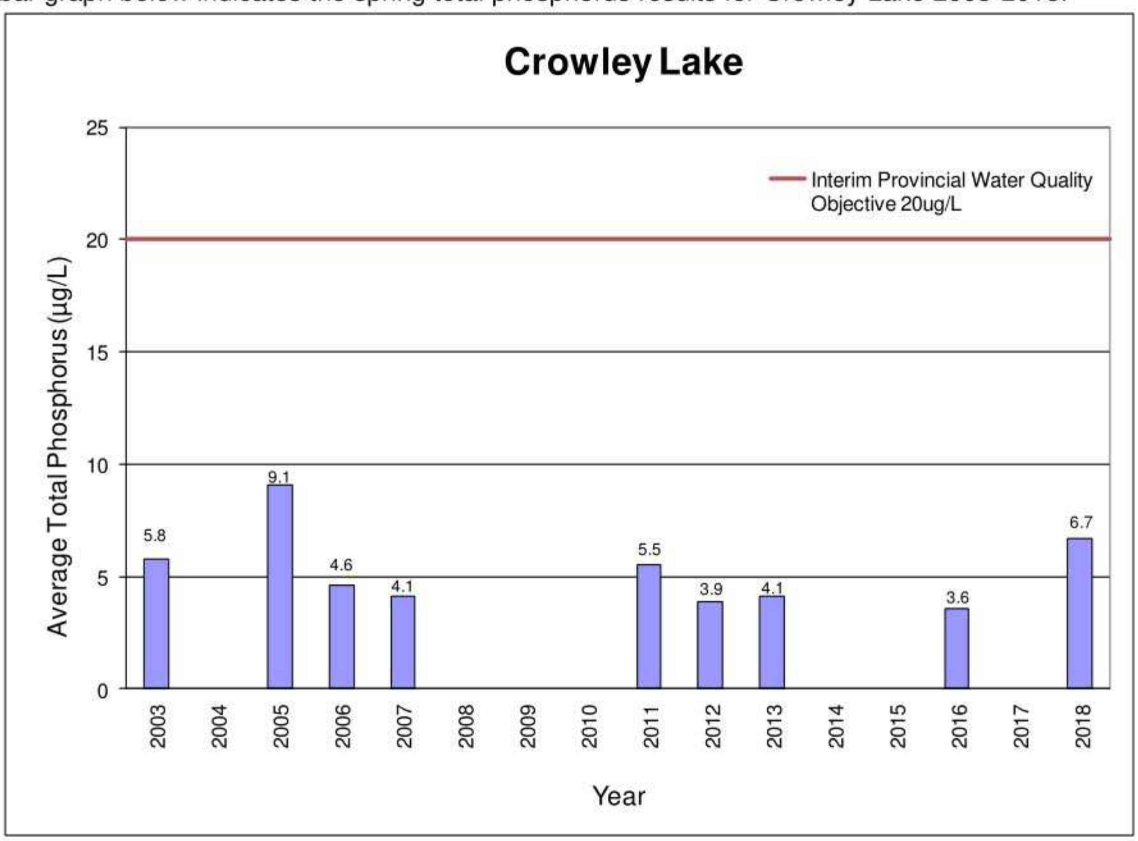
Crooked Lake

The bar graph below indicates the spring total phosphorus results for Crooked Lake from 2003-2018.



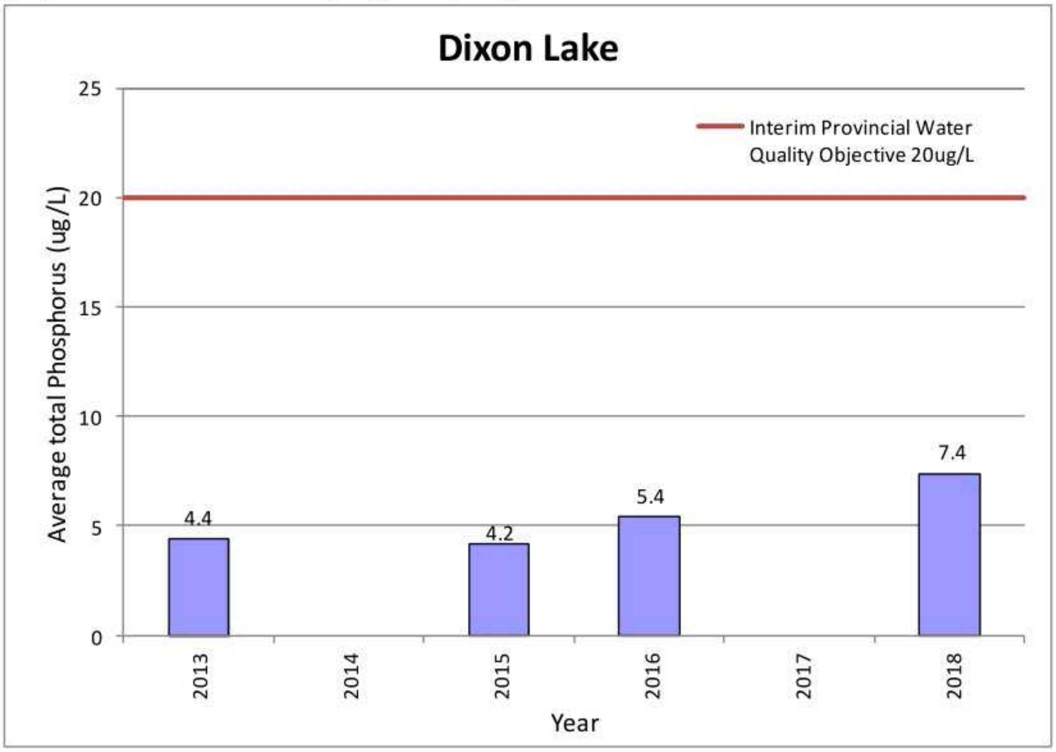
Crowley Lake

The bar graph below indicates the spring total phosphorus results for Crowley Lake 2003-2018.



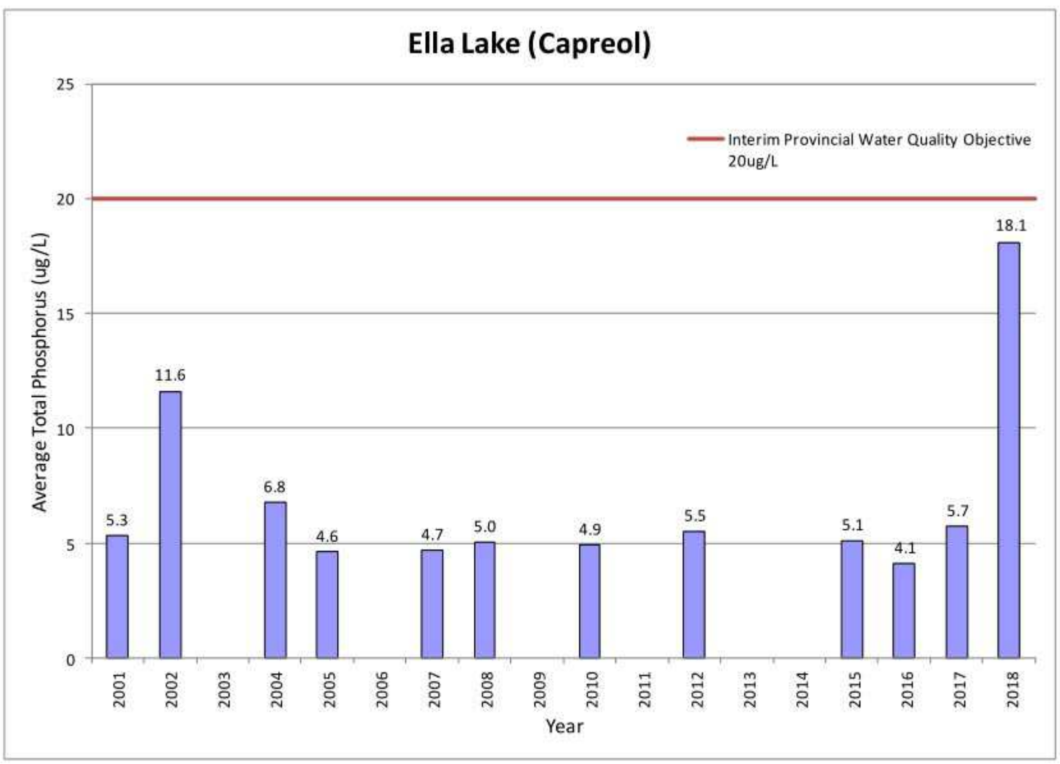
Dixon Lake

The bar graph below indicates the spring total phosphorus results for Dixon Lake from 2013-2018.



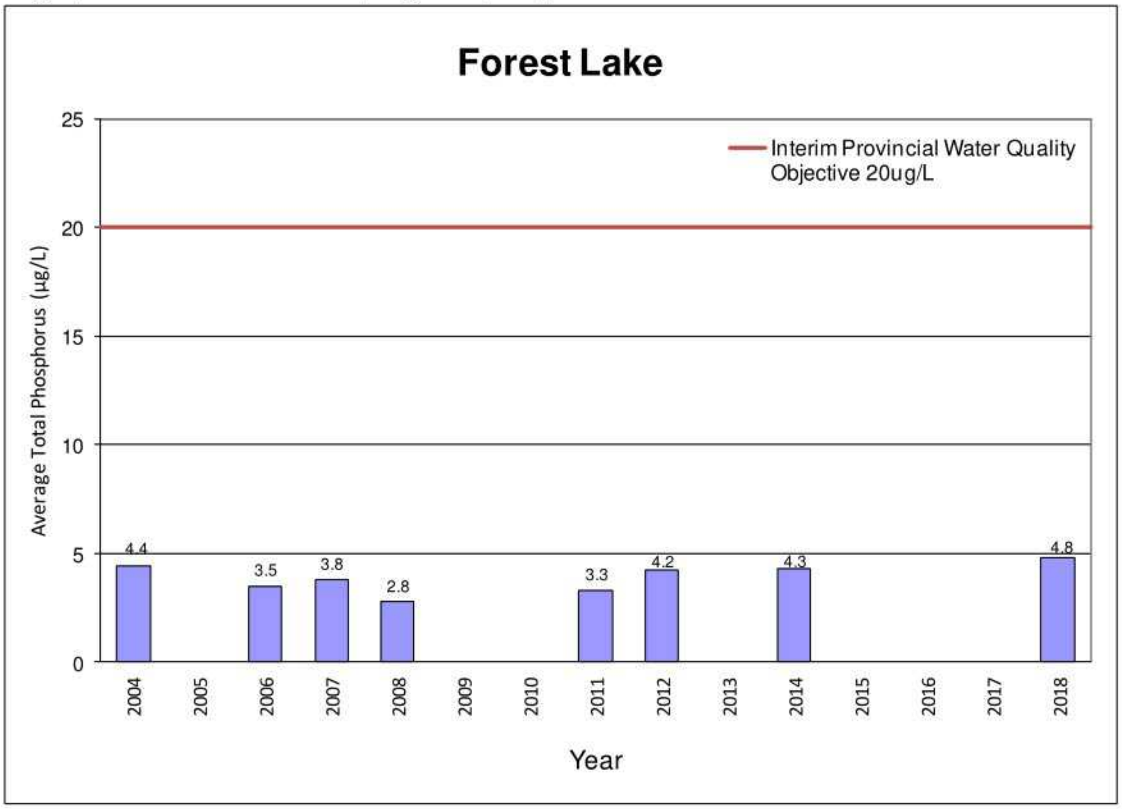
Ella (Capreol) Lake

The bar graph below indicates the spring total phosphorus results for Ella Lake (Capreol) from 2001-2018.



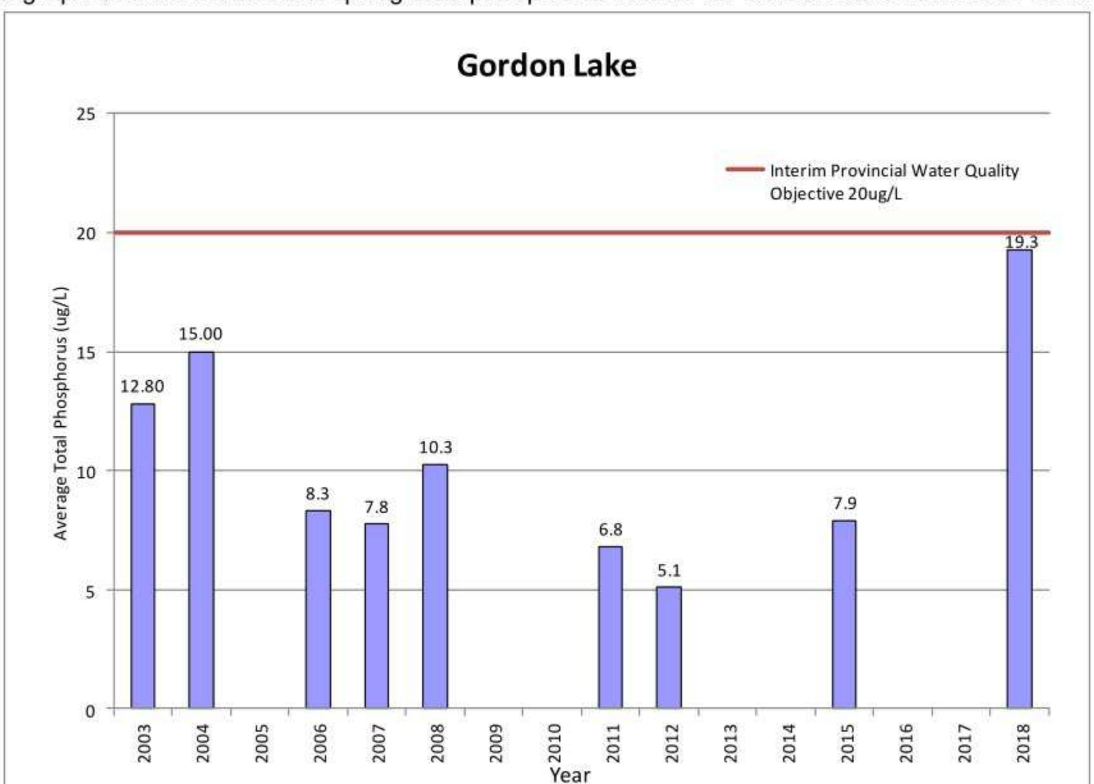
Forest Lake

The bar graph below indicates the spring total phosphorus results for Forest Lake from 2004-2018.



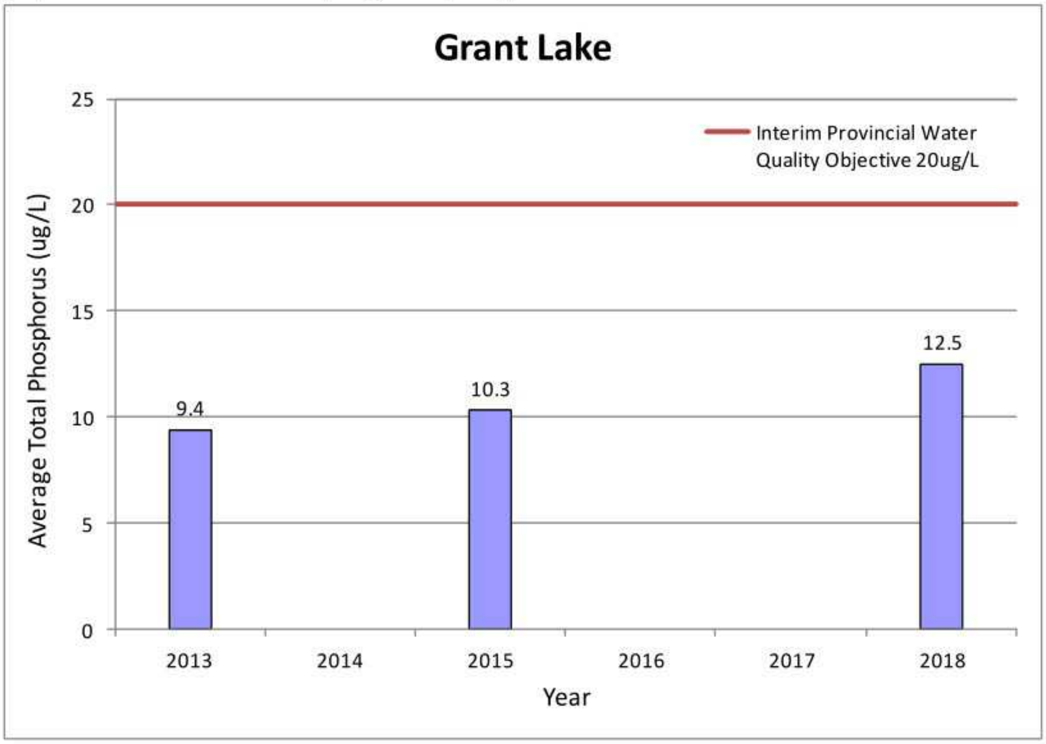
Gordon Lake

The bar graph below indicates the spring total phosphorus results for Gordon Lake from 2003-2018



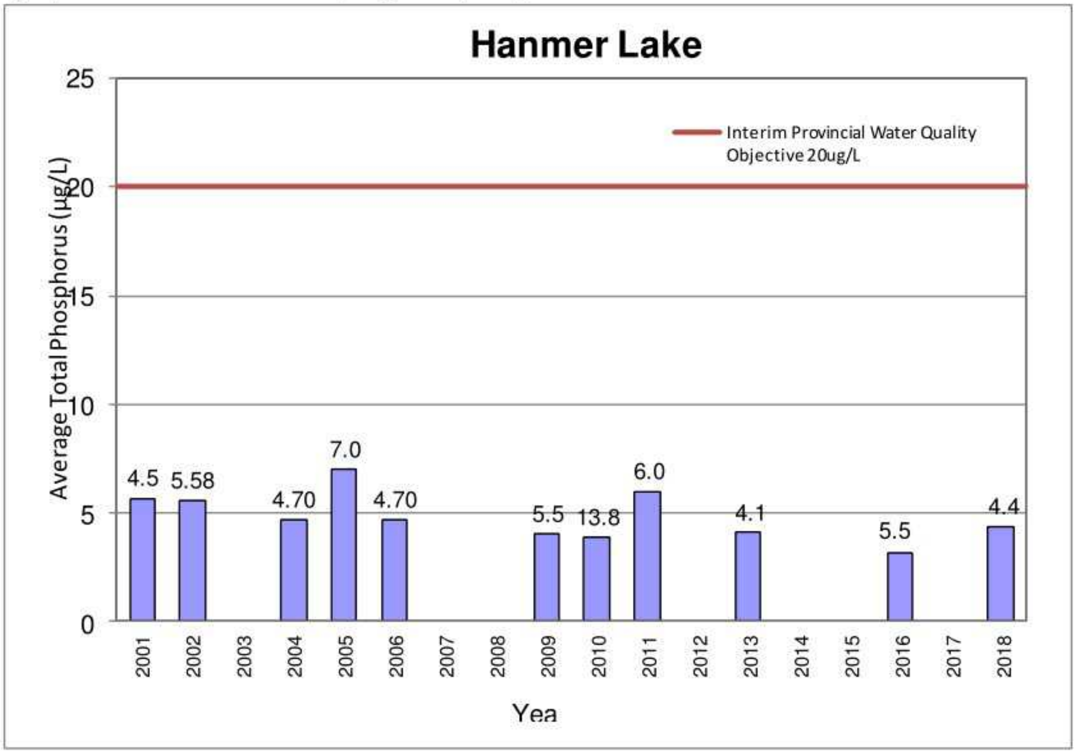
Grant Lake

The bar graph below indicates the spring total phosphorus results Grant Lake from 2013-2018.



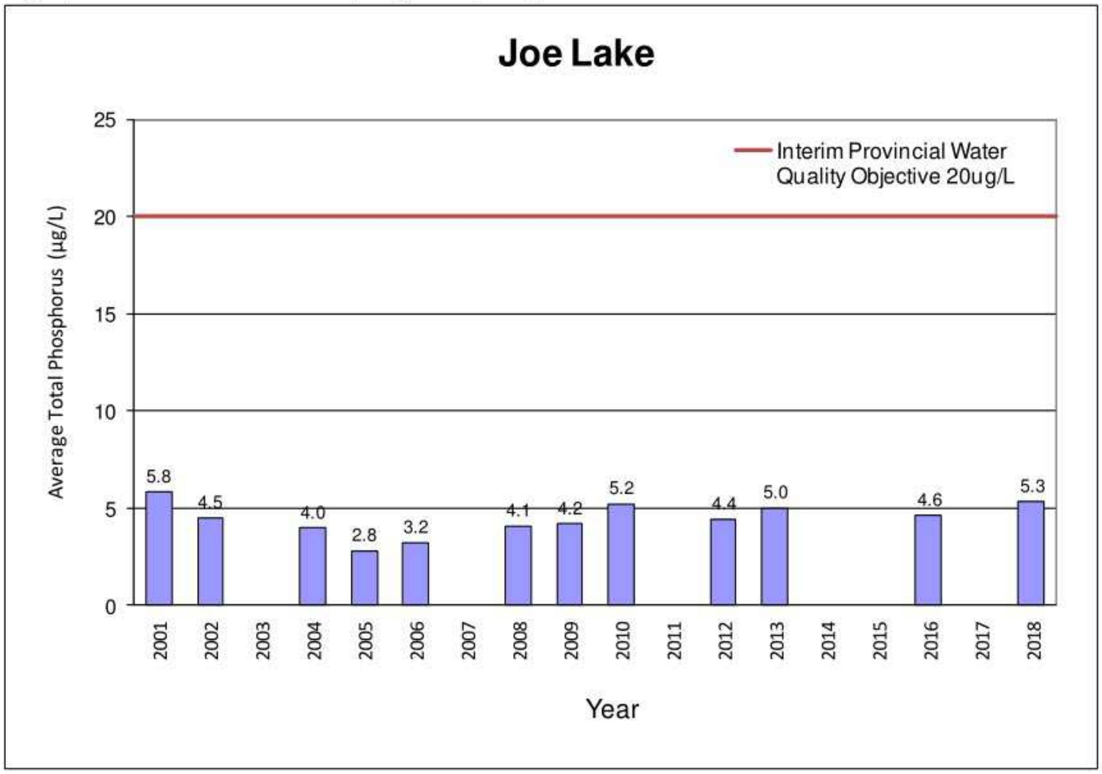
Hanmer (Bass) Lake

The bar graph below indicates the spring total phosphorus results for Hanmer Lake from 2001-2018.



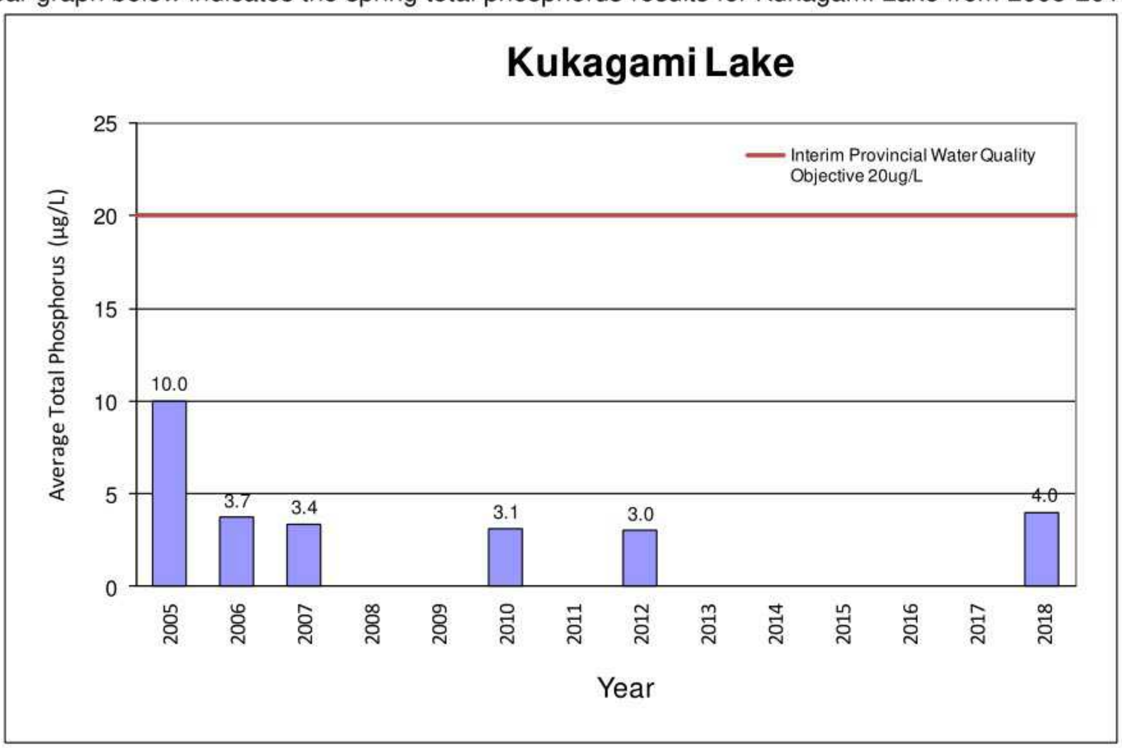
Joe Lake

The bar graph below indicates the spring total phosphorus results for Joe Lake from 2001-2018.



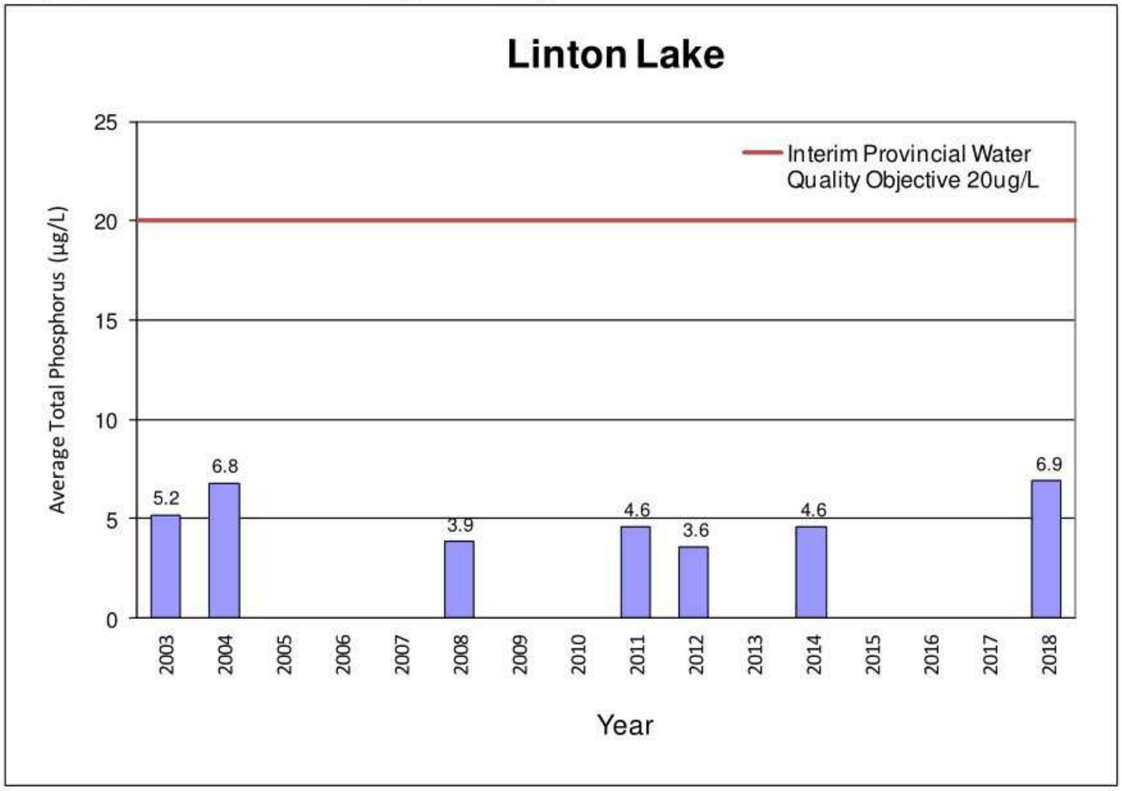
Kukagami Lake

The bar graph below indicates the spring total phosphorus results for Kukagami Lake from 2005-2018.



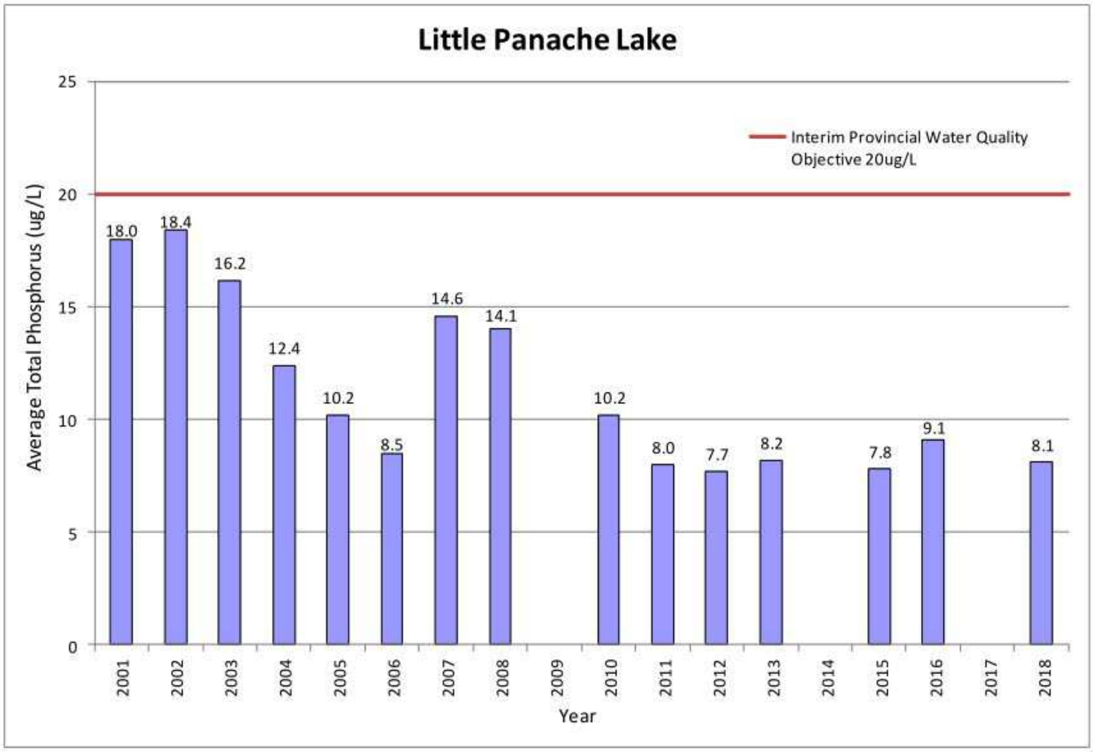
Linton Lake

The bar graph below indicates the spring total phosphorus results for Linton Lake from 2003-2018.



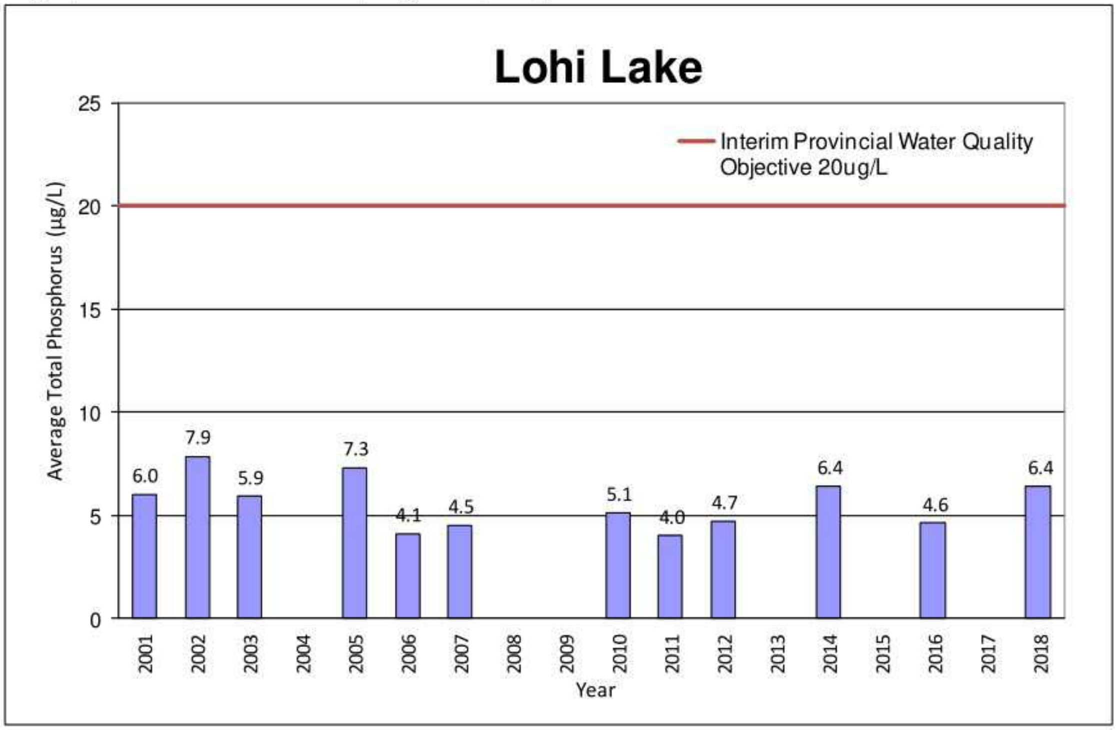
Little Panache Lake

The bar graph below indicates the spring total phosphorus results for Little Panache Lake from 2001-2018.



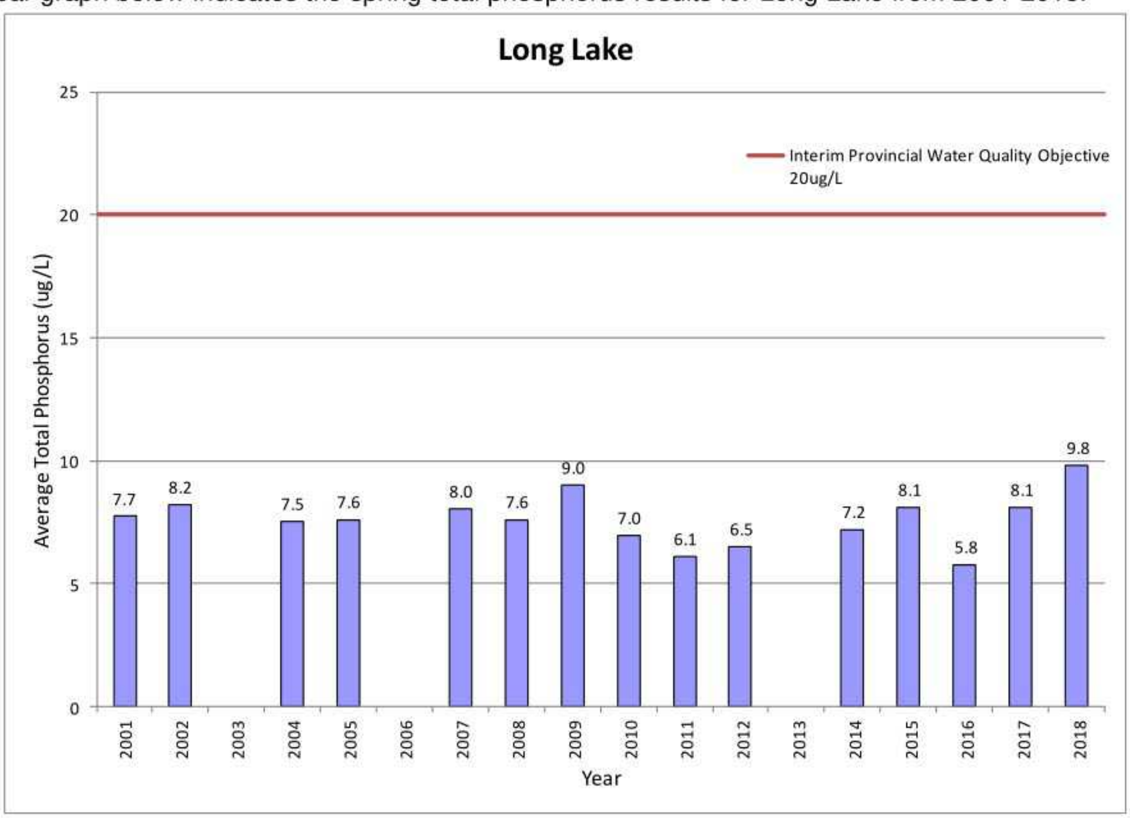
Lohi Lake

The bar graph below indicates the spring total phosphorus results for Lohi Lake from 2001-2018.



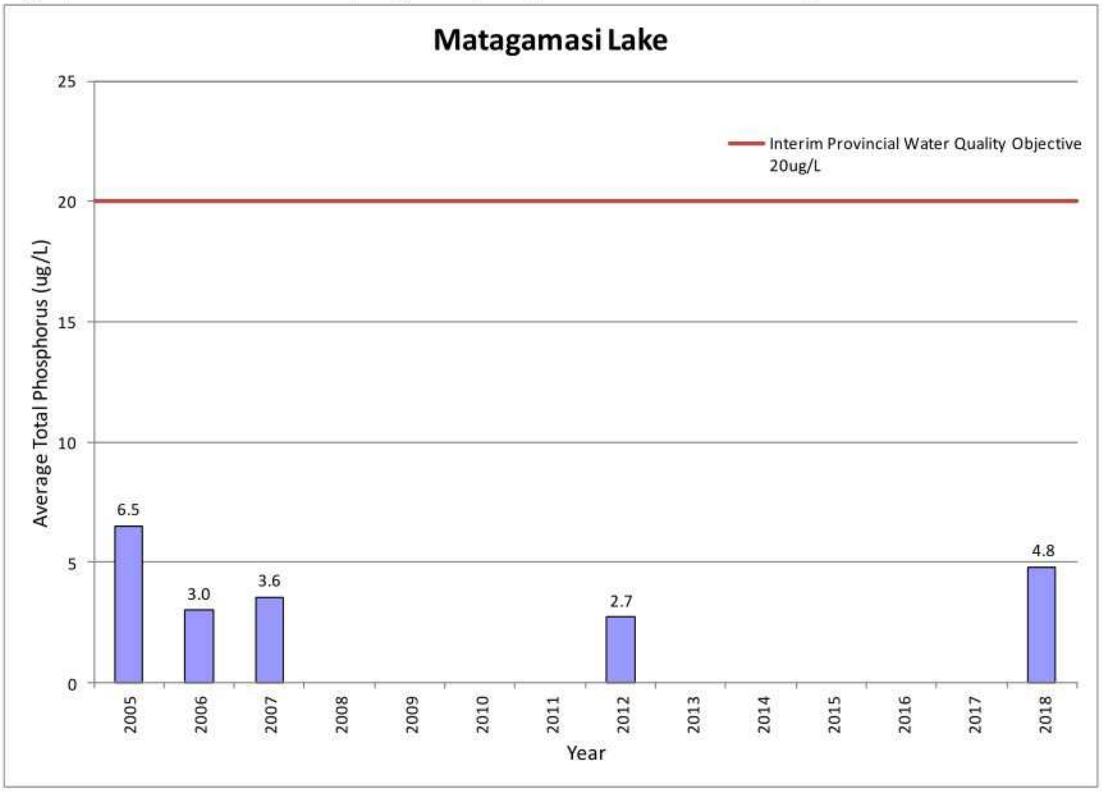
Long Lake

The bar graph below indicates the spring total phosphorus results for Long Lake from 2001-2018.



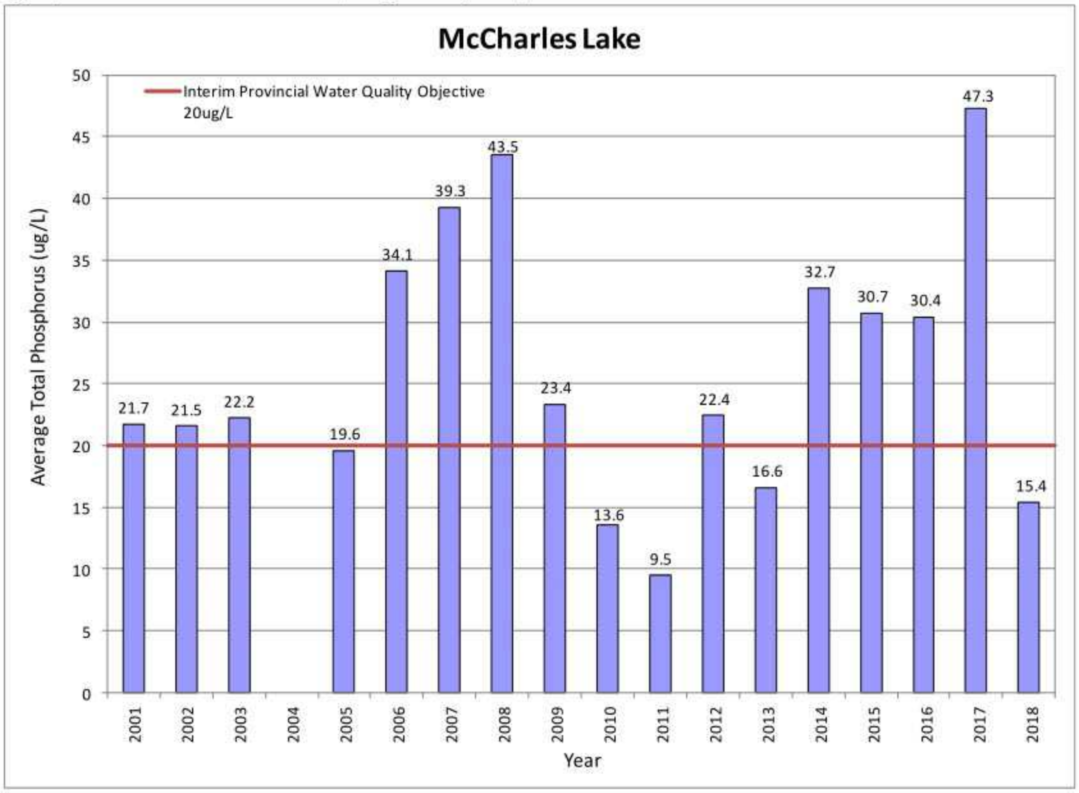
Matagamasi Lake

The bar graph below indicates the spring total phosphorus results for Matagamasi Lake from 2005-2018.



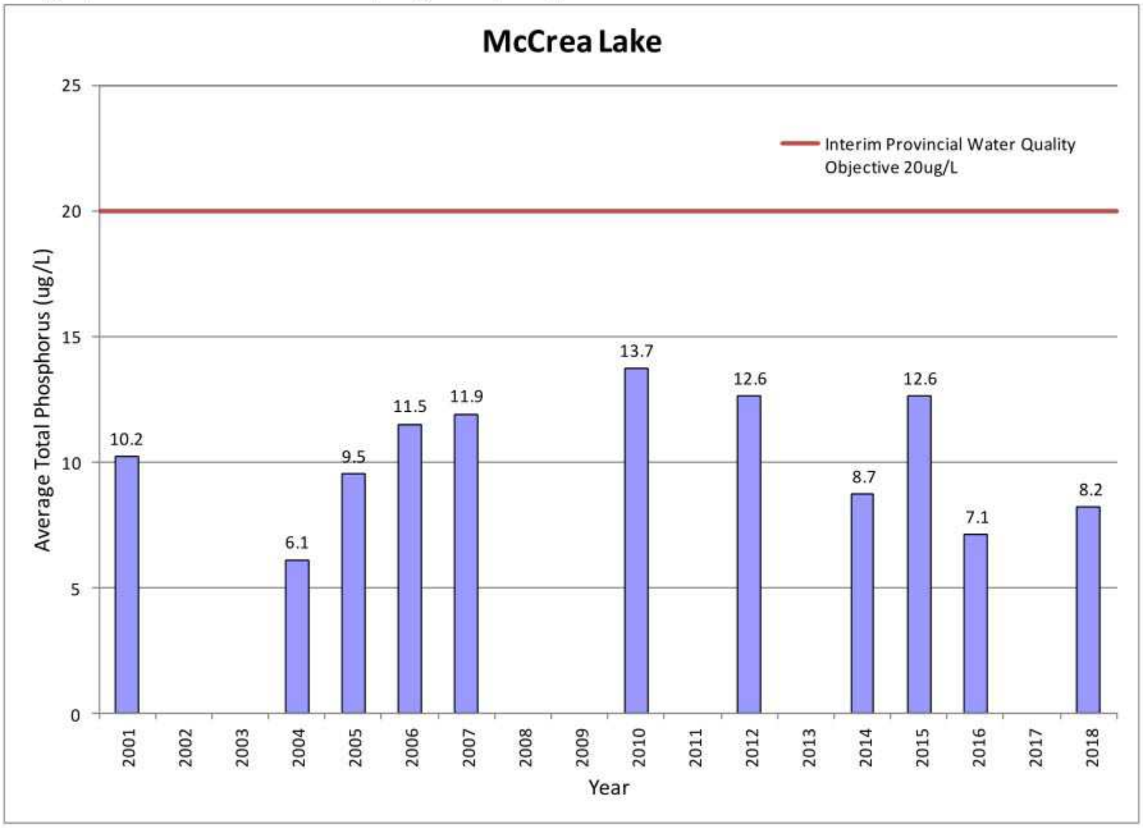
McCharles Lake

The bar graph below indicates the spring total phosphorus results for McCharles Lake from 2001-2018.



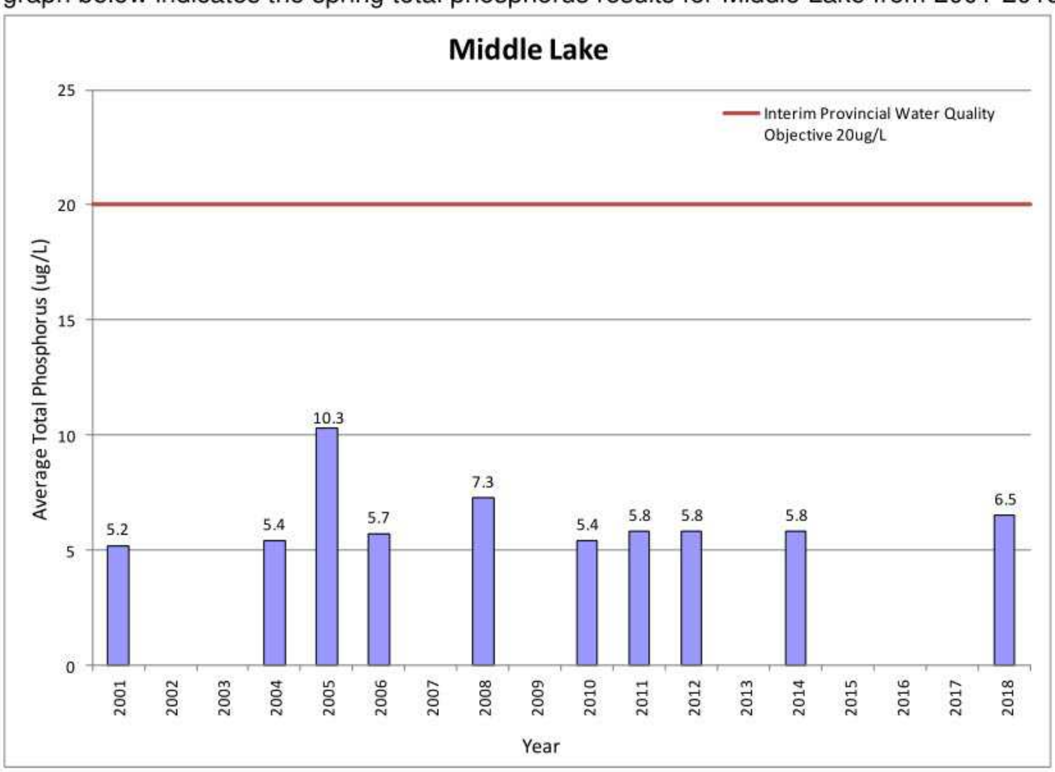
McCrea Lake

The bar graph below indicates the spring total phosphorus results for McCrea Lake from 2001-2018.



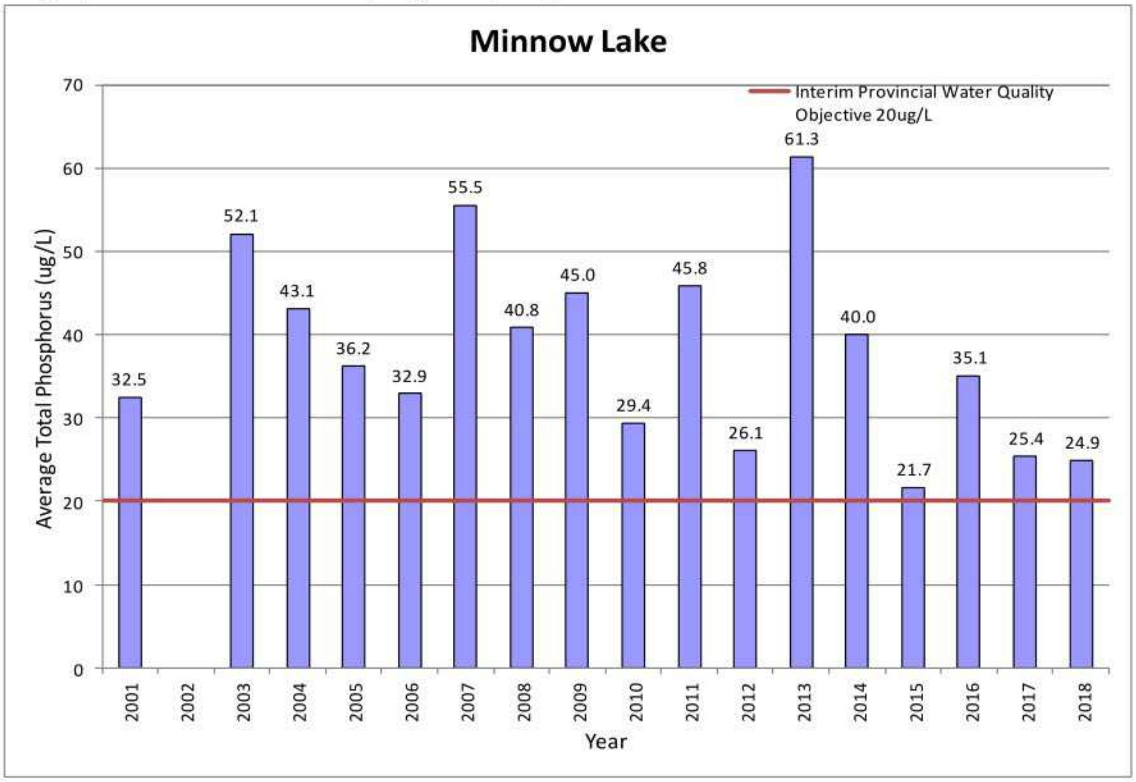
Middle Lake

The bar graph below indicates the spring total phosphorus results for Middle Lake from 2001-2018.



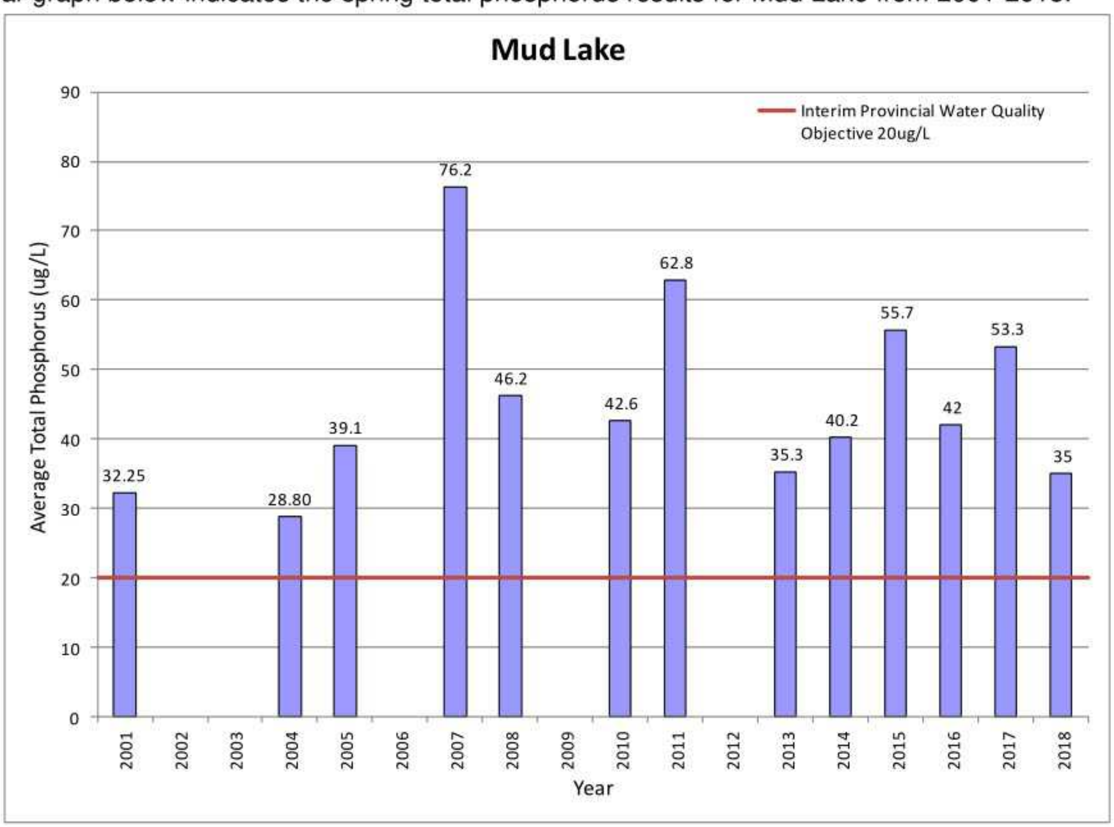
Minnow Lake

The bar graph below indicates the spring total phosphorus results for Minnow Lake from 2001-2018.



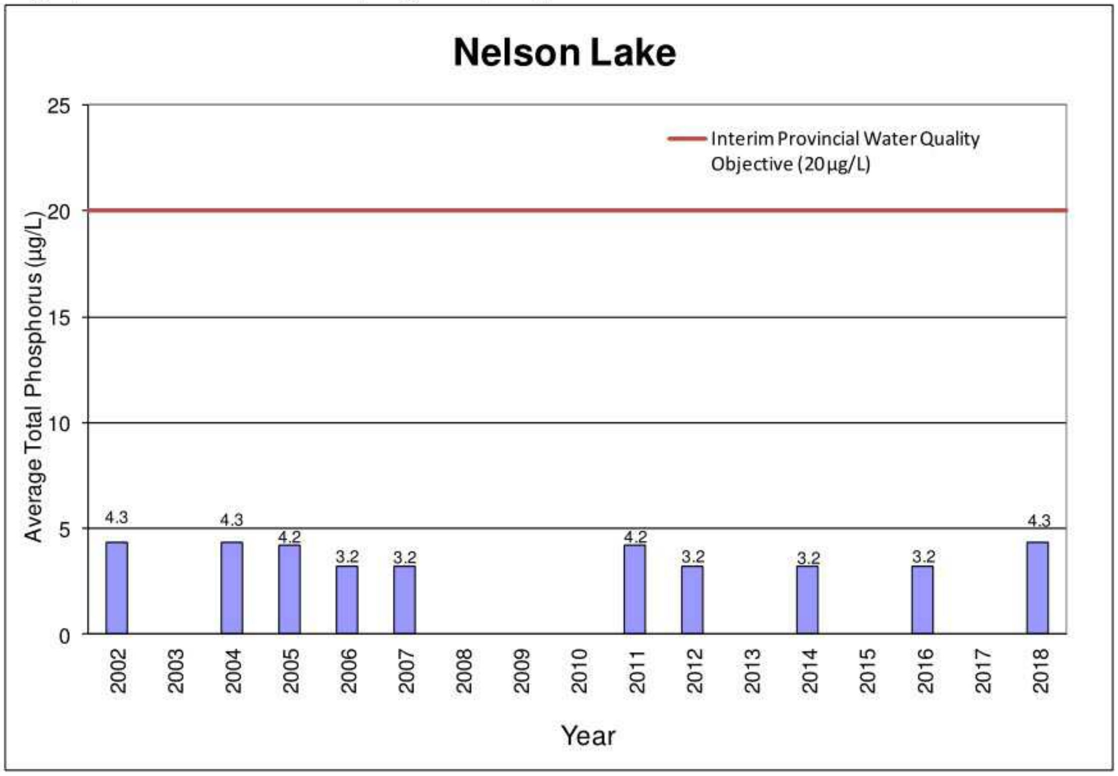
Mud Lake

The bar graph below indicates the spring total phosphorus results for Mud Lake from 2001-2018.



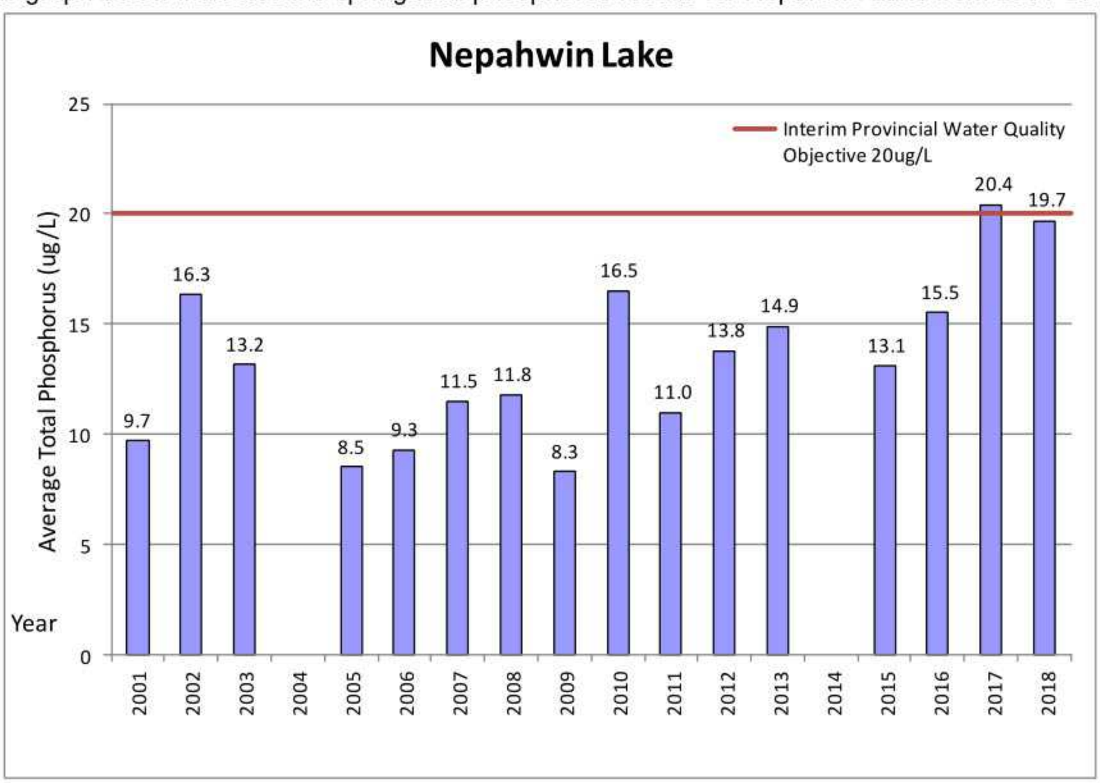
Nelson Lake

The bar graph below indicates the spring total phosphorus results for Nelson Lake from 2002-2018.



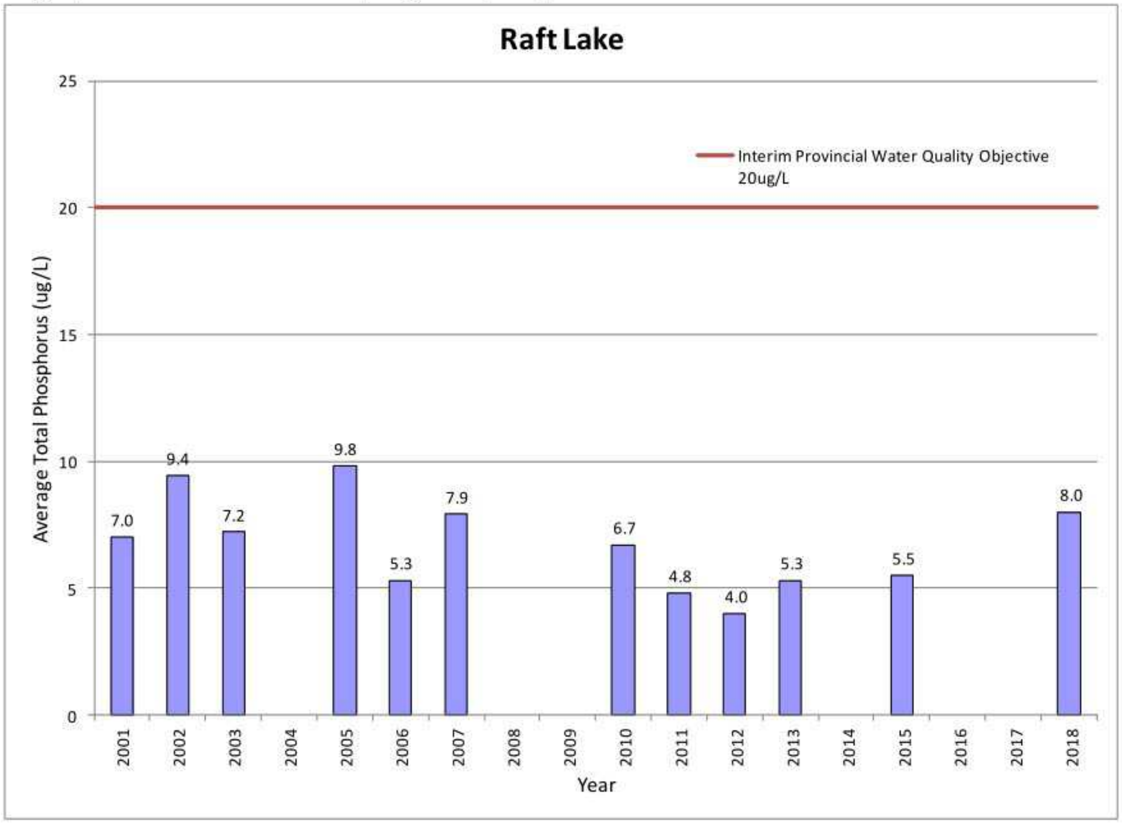
Nepahwin Lake

The bar graph below indicates the spring total phosphorus results for Nepahwin Lake from 2001-2018.



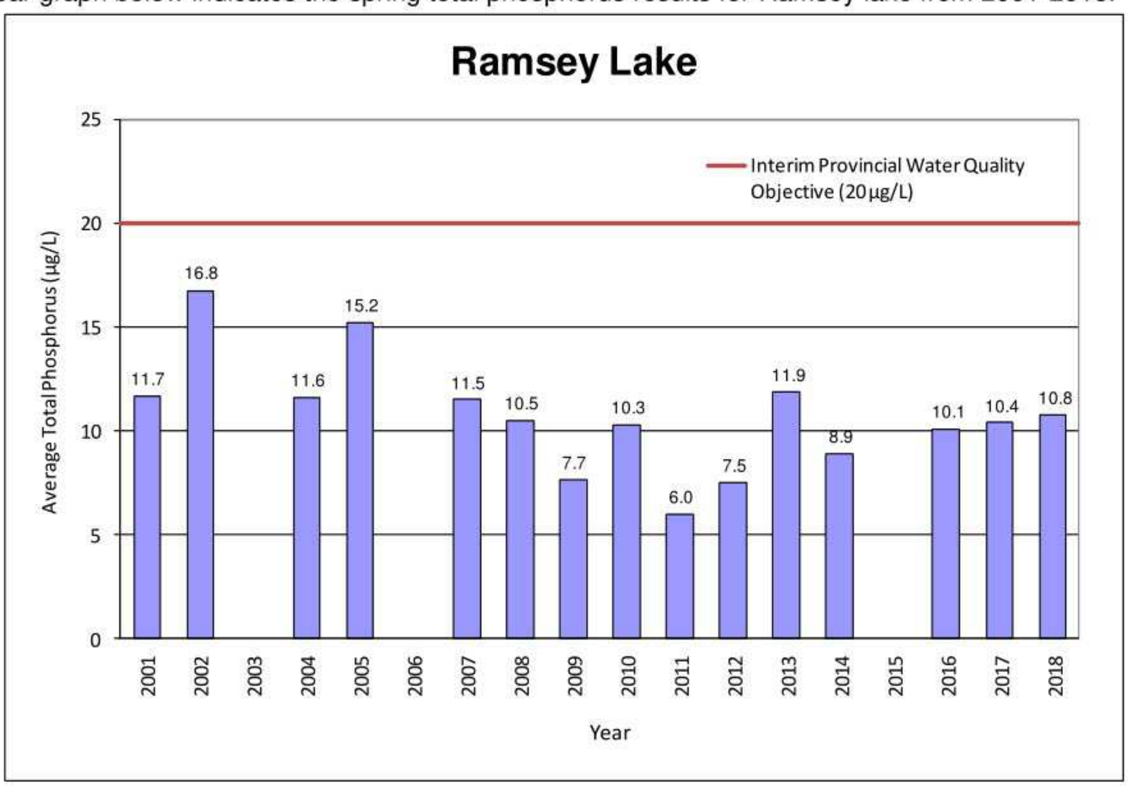
Raft Lake

The bar graph below indicates the spring total phosphorus results for Raft Lake from 2001-2018.



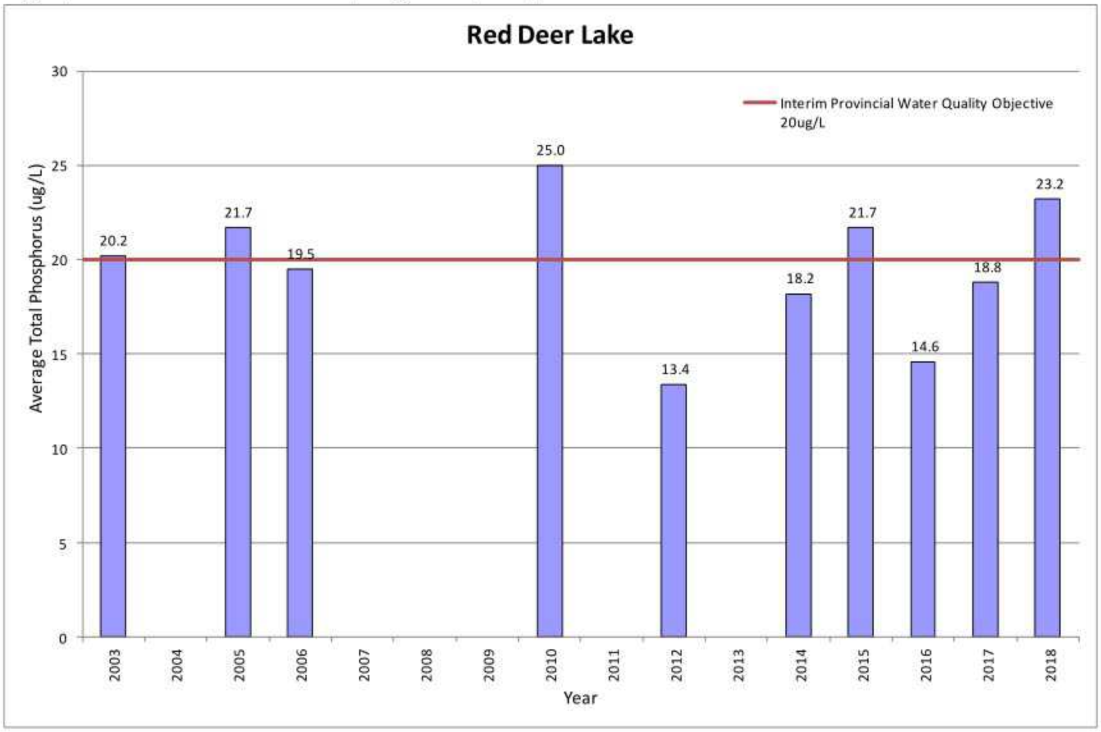
Ramsey Lake

The bar graph below indicates the spring total phosphorus results for Ramsey lake from 2001-2018.



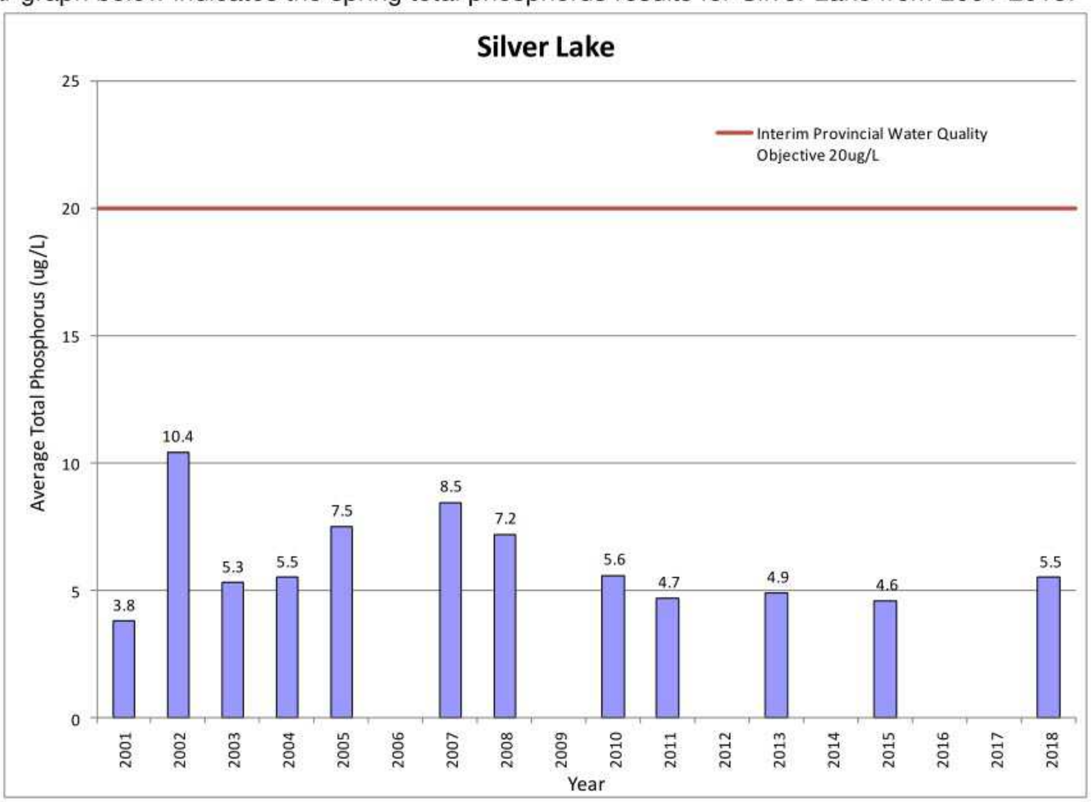
Red Deer Lake

The bar graph below indicates the spring total phosphorus results for Red Deer Lake from 2003-2018.



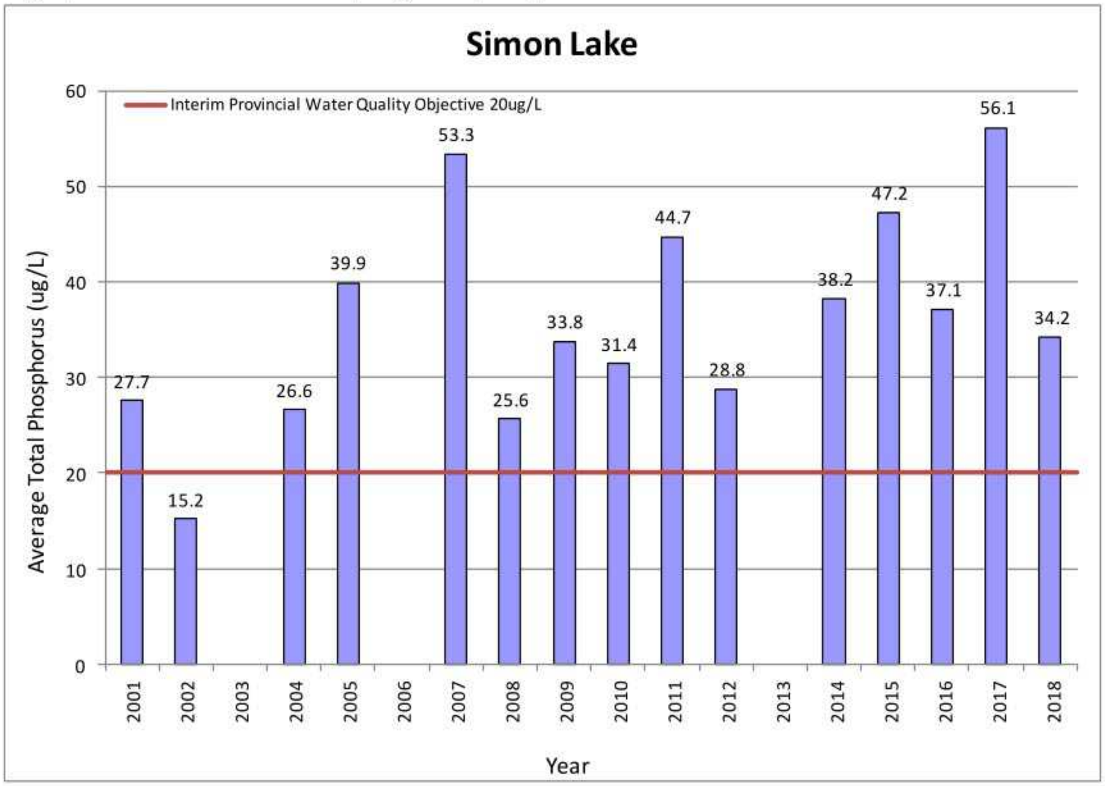
Silver Lake

The bar graph below indicates the spring total phosphorus results for Silver Lake from 2001-2018.



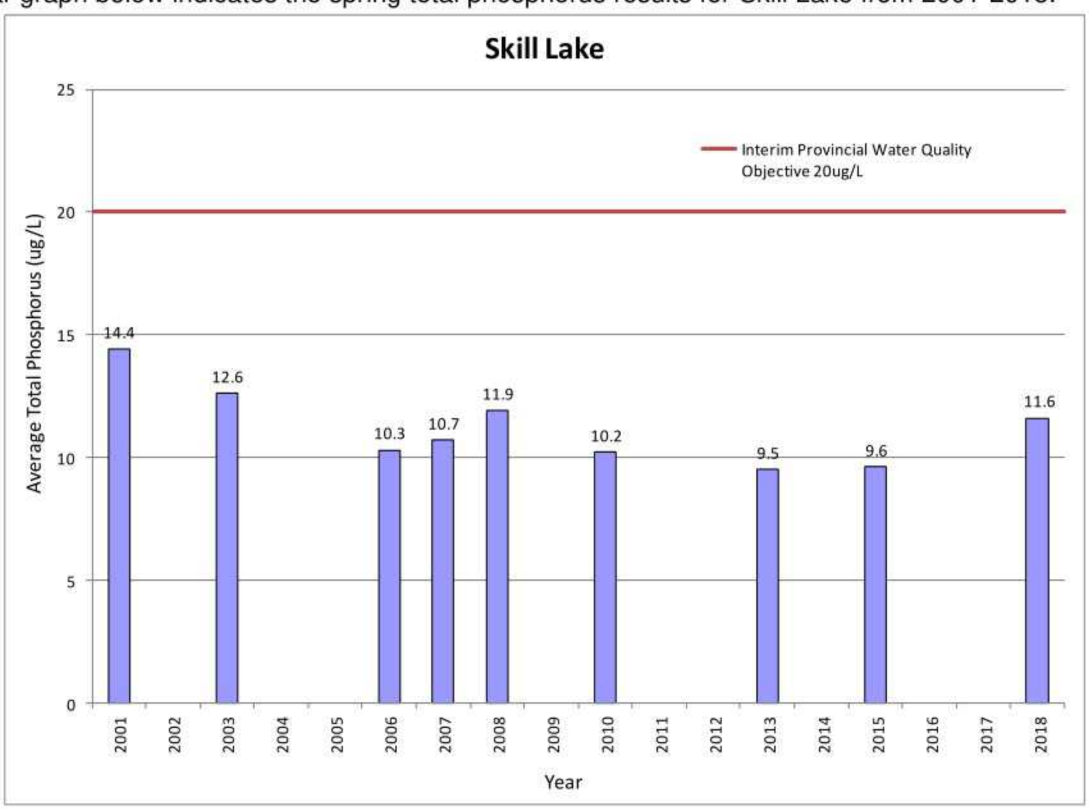
Simon Lake

The bar graph below indicates the spring total phosphorus results for Simon Lake from 2001-2018.



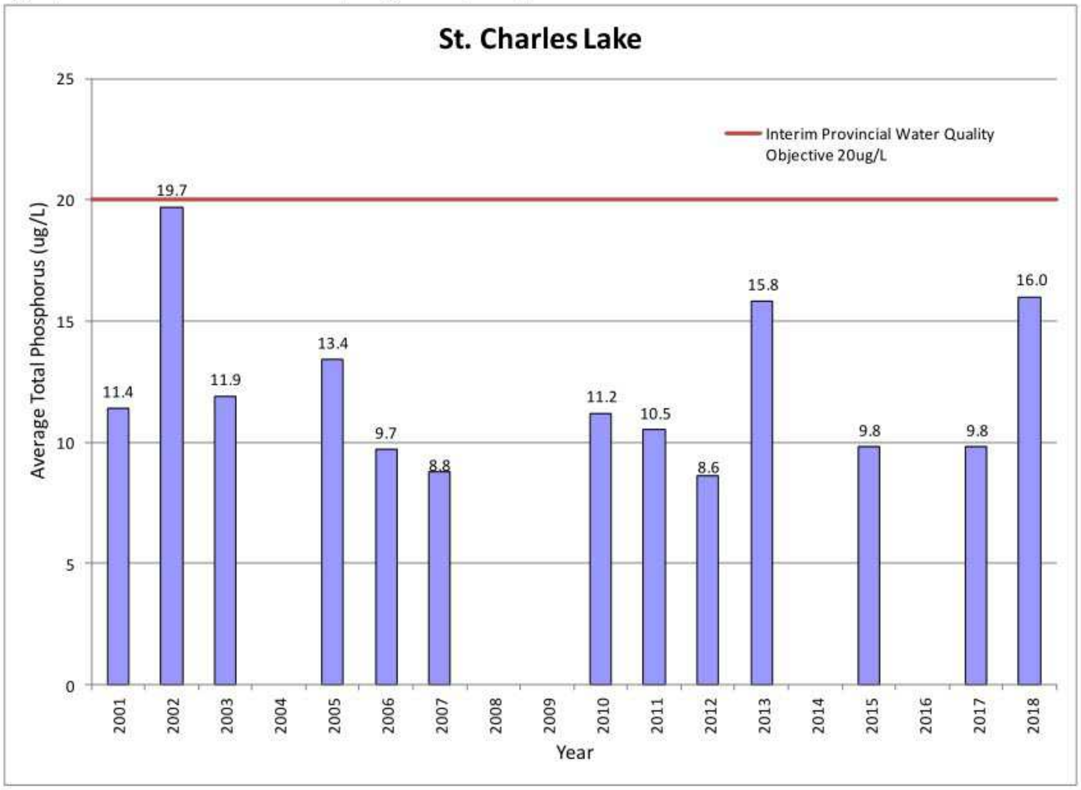
Skill Lake

The bar graph below indicates the spring total phosphorus results for Skill Lake from 2001-2018.



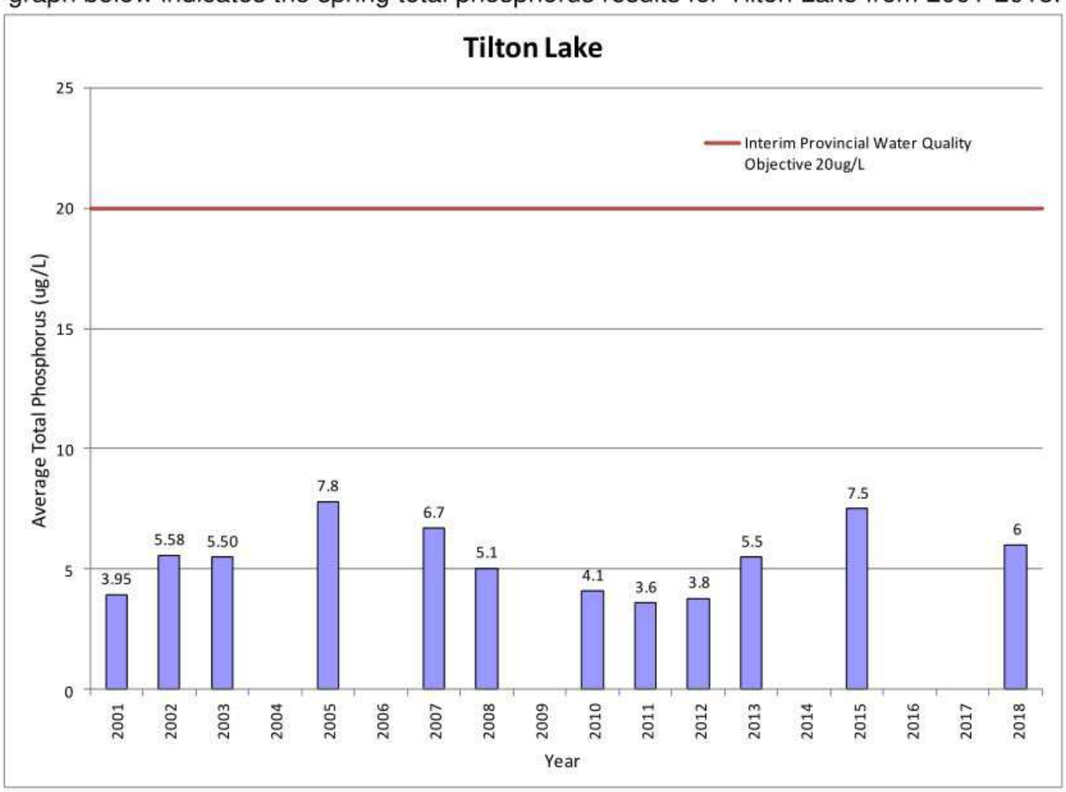
St. Charles Lake

The bar graph below indicates the spring total phosphorus results for St. Charles Lake from 2001-2018.



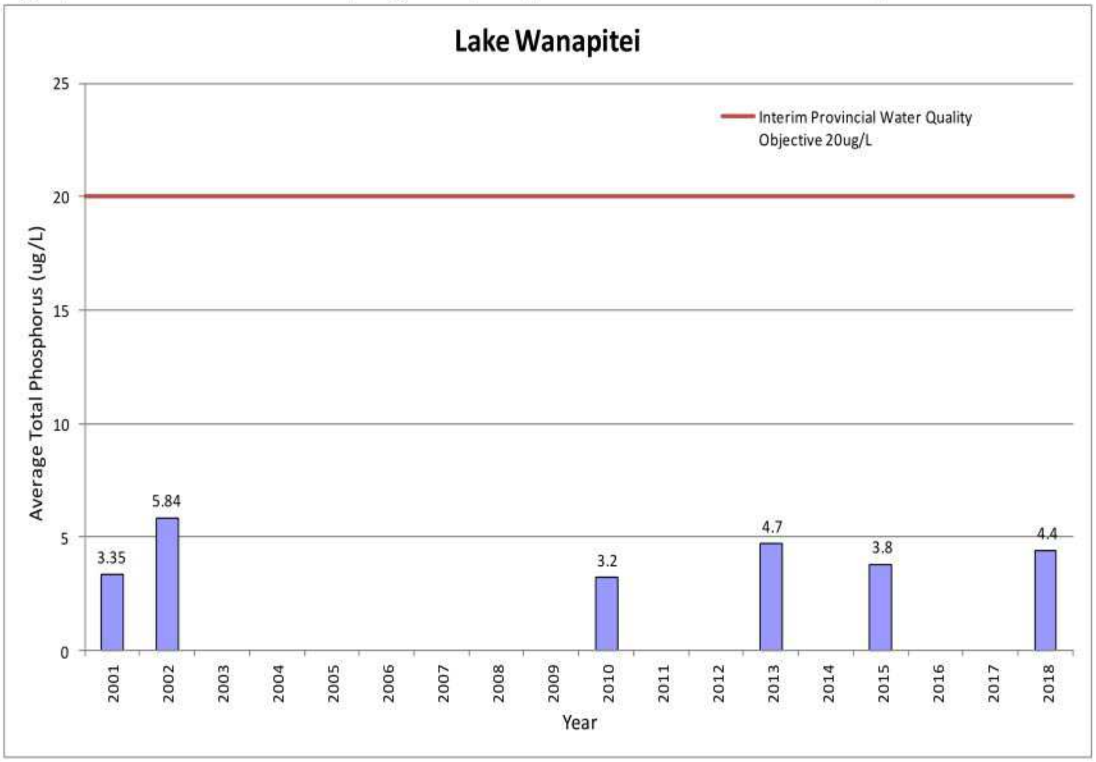
Tilton Lake

The bar graph below indicates the spring total phosphorus results for Tilton Lake from 2001-2018.



Wanapitei Lake

The bar graph below indicates the spring total phosphorus results for Lake Wanapitei from 2001-2018.



For further information, contact

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KINGS COUNTY

LAKE MONITORING PROGRAM

2017 SEASON

Municipality of the County of Kings

Results presented to TAC in November 2018.

PREPARED AND PRESENTED TO THE TAC BY

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Freshwater ecologist.

[redacted] ________

EXCECUTIVE SUMMARY

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

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

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

The colour values and dissolved organic carbon (DOC) concentrations in the KCVLMP lakes are naturally very high with the exception of Sunken and Tupper lakes where the water is clear. These values reflect the input of terrestrial organic matter that enters the lakes via run-off. The low nutrient levels recorded in the lakes indicate that the organic matter loading is nutrient poor, as observed in most boreal shield lakes. In the Atlantic regions, high DOC and colour in lake water are associated to the presence of *Sphagnum* bogs in the watershed. Because of the strong connection between the land and the water, this report would benefit from a better understanding of the importance of wetlands in the watershed of each lakes, coupled with an assessment of annual and seasonal precipitations.

Although nutrient levels are low in most of the KCVLMP lakes, the influence of the watershed on colour or DOC indicates that local residents should continue and maintain programs aiming at reducing nutrient loading to the lakes. Although most of the WQI rating was good in 2017, it does not mean that the lakes will remain in good health if nutrient loading was to increase in the future or climate change effects to lake biological, physical and chemical processes.

Table of Contents

Acronyms

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

Acknowledgements

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

- Emily Lutz– Councillor for District 7
- Kyle Hicks – Nova Scotia Power
- Stephanie Walsh – Nova Scotia Power
- Darrell Taylor – Nova Scotia Environment
- Andrew Sinclair – Nova Scotia Environment
- Wesley White – Saint Mary's University
- Anne Muecke – Griffiths Muecke Associates, Citizen Member
- Joe Kerekes – Scientist Emeritus, Environment Canada
- Reg Newell – Nova Scotia Department of Natural Resources
- Drew Peck – Citizen Member

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

Mike Armstrong
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Kelly Sheehan
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Gloria Armstrong

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Michael Lowe
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Mike Ryan
Mark Raymond
Gary Weisner
Wendy Weisner
Ray Cote
Gary Henderson
Bob Pearce
Carl Kent
Vivian Kent

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

1 Introduction

The Kings County Lake Monitoring Program is an initiative begun by the Municipality of the County of Kings in 1997. It was started based on input from a multi-stakeholder group composed of members of all three levels of government and community groups. This group was assembled to address concerns on the impact of development of lake shorelines in Kings County. The data collected by the volunteered group informs on long-term changes in Kings County Lakes. Based on this long-term monitoring, trends are valuable to detect and understand changes that may not be detected using a limited number of sampling years. The Volunteer Water Quality Monitoring program was initiated to help calibrate this model and foster environmental awareness within the community.

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

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

- To document long-term changes in water quality in the lakes and provide an assessment of the health of the lakes, which in turn can inform on their use.

Water sampling occurs once a month for each lake from May to October and is conducted by volunteers. The monitoring has been conducted every year since 1997 and currently thirteen lakes are sampled regularly as part of the Kings County Lake Monitoring Program. Quality Assurance and Quality Control (QA/QC) sampling was added to the protocols in 2011. Duplicate samples were collected from ten of the lakes in September 2017 and submitted for laboratory analysis. Two new lakes, Lake Torment and Armstrong Lake, were added to the lake monitoring program in July of 2014. The list of lakes sampled in 2017 is presented in Table 1-1 and Figure 1-1.

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

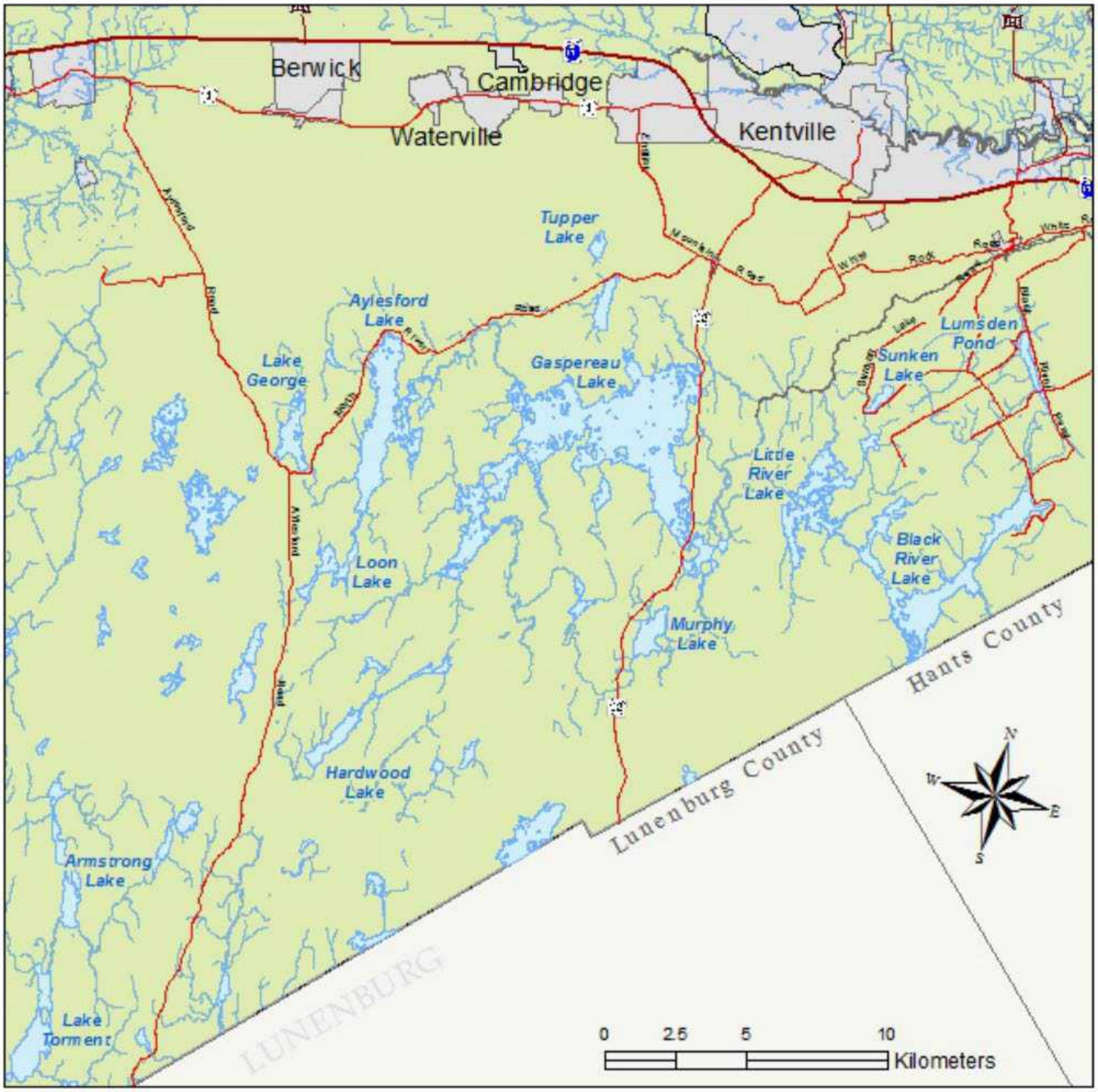


FIGURE 1-1 LAKES OF THE KINGS COUNTY LAKE MONITORING PROGRAM (SOURCE: MUNICIPALITY OF THE COUNTY OF KINGS)

All of the lakes are located on the South Mountain, south of the Annapolis and Gaspereau valleys.

Eight of the thirteen lakes are directly connected via surface flow and eventually drain into the Gaspereau River. Hardwood, Torment, Armstrong, Tupper and Sunken lakes are not part of this system; Hardwood, Torment and Armstrong Lakes are in the LaHave River watershed, Tupper Lake is part of the Cornwallis River watershed and Sunken Lake drains directly into the Gaspereau River without being connected to any of the other lakes (See Figure 1-2).

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

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

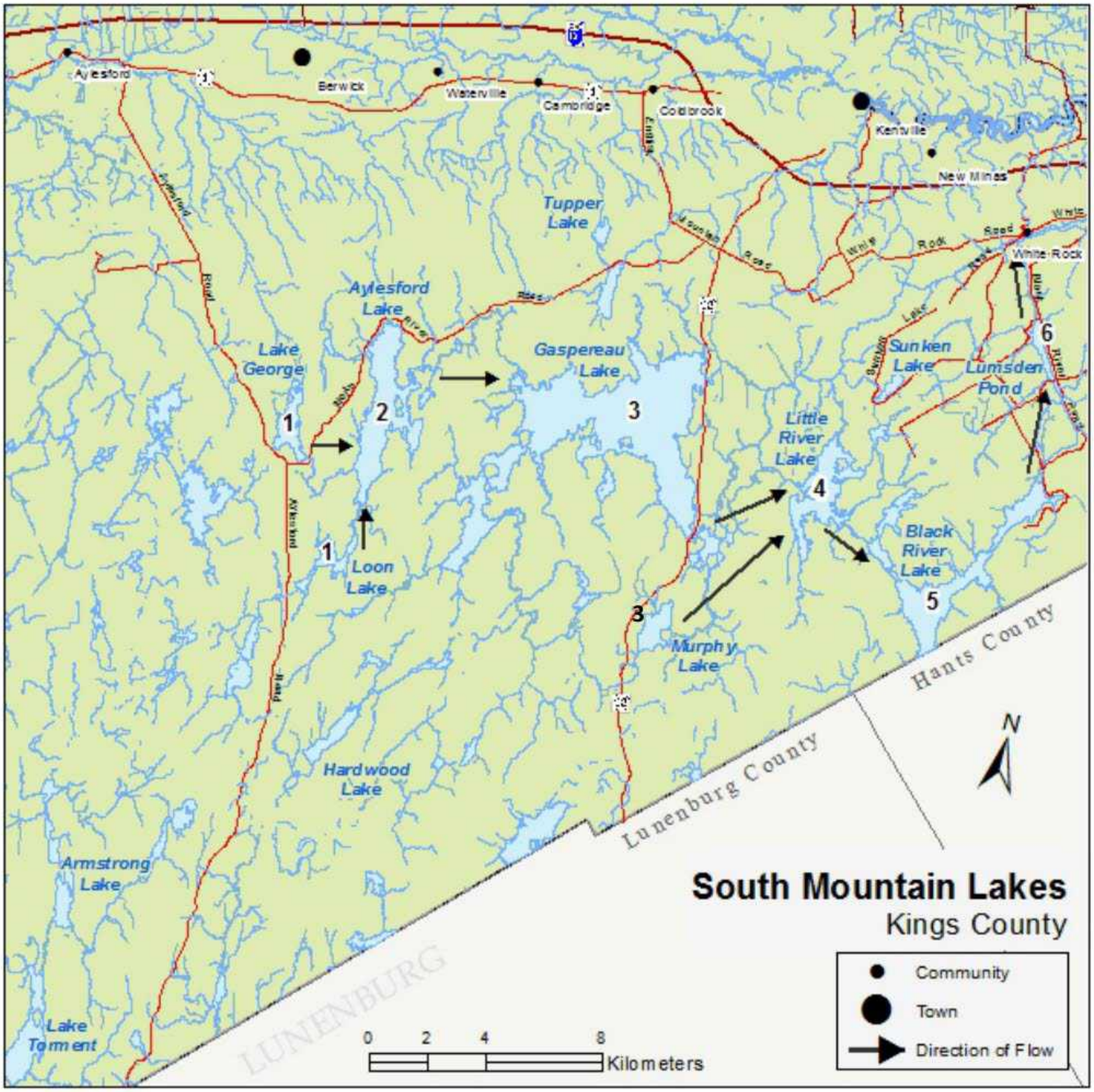


FIGURE 1-2 DRAINAGE MAP OF THE AYLESFORD LAKES

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

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

*Coordinates were estimated using Google Earth.

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

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

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

2 Methodology

The following description of methodology is similar to that described in previous recent years and was updated for 2017 following yearly review comments from the Technical Advisory Committee (TAC).

Thirteen lakes were sampled during the 2017 field season. Sample collection and field measurements were undertaken by volunteers once per month beginning in May and ending in October.

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

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

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

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

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

FIGURE 2-1 A SECCHI DISK USED TO TAKE A SECCHI DEPTH READING AT MONITORED LAKES

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

Quality control/quality assurance sampling was conducted in 2017 through the collection of duplicate samples from ten of the thirteen regularly sampled lakes.

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

2.1 Parameters Measured

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

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

2.1.2 Dissolved Organic Carbon

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

2.1.3 pH and Alkalinity

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

2.1.4 Turbidity and Colour

Turbidity is a way of expressing the suspended sediment load of a water body. It is a measurement of the extent to which light will penetrate the water column. Turbidity gives an indication of the amount of suspended sediments in the water because light is less likely to penetrate as far in cloudy (i.e. ‘turbid’) waters. It is measured by passing a beam of light through the water column and measuring the amount of light that is scattered and absorbed. Elevated sediment levels can block light from getting to aquatic plants, impair the functioning of fish gills and interfere with feeding mechanisms of zooplankton. It is measured in nephelometric turbidity units (NTU). Lake colour is a parameter that can indicate the types of particulate matter present in the water column (Mackie, 2004). For instance, lakes with a blue colour tend to be clearer, with low amounts of sediments; lakes with a greenish colour likely contain considerable amounts of blue-green algae and if lakes display a reddish-brown colour, this indicates high levels of organic material (Mackie, 2004). Colour is measured in true colour units (TCU).

2.1.5 Conductivity

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

2.1.6 Water Temperature

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

2.2 Establishing Water Quality Objectives

Thirteen lakes are monitored as part of the Kings County Lake Monitoring program. Each lake has unique properties and varying levels of shoreline development; thus, each lake is examined separately. The 2017 averages for each parameter were compared against the historical average from 1997 to 2016 (including data from 2004 which was omitted in previous years). Water quality guidelines have been developed for many parameters (i.e. total phosphorus, Secchi depth, and pH) by organizations such as Parks Canada, the British Columbia Ministry of Environment and the Canadian Council of Ministers of the Environment (CCME). These guidelines generally refer to clear water lakes, although Parks Canada has determined guidelines for coloured lakes in Kejimkujik National Park (Parks Canada, 2010). For some parameters within the monitoring program (TP, Secchi depth, pH, colour and dissolved organic carbon), the objectives are determined by deviations from historic values due to lack of specific guidelines for these parameters in coloured lakes.

2.2.1 Phosphorus

As per the recommendations of the Centre for Water Resources Studies and Stantec (2009), averages for the values of total phosphorus from 1993, and 1997 to 2017 for each lake were calculated. Although the Kings County Lake Monitoring Program has not yet formally adopted this phosphorus objective, it was used here as an interim measure as no other relevant phosphorus guidelines could be found for dystrophic lakes. The most common provincial guideline for total phosphorus limit is 20 µg/L. In order to capture potential deviation to baseline levels, the total phosphorus water quality objective for each lake was calculated as 150% of the baseline (average) level, not exceeding 20 µg/L. The calculated thresholds for total phosphorus are presented in Table 2-1.

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

LAKE	TOTAL PHOSPHORUS AVERAGE (UP TO 2017) (µG/L)	TOTAL PHOSPHORUS OBJECTIVE (µG/L)
George	10	13.9
Loon	12	18.1
Aylesford	10	15.6
Gaspereau	12	17.8
Murphy	12	17.4
Little River	14	**20 (21.6)**
Black River	11	16.4
Lumsden	12.5	18.9
Hardwood	13	19.1
Sunken	9.4	18.9
Tupper	11.4	16.8
Torment	17	**20 (25.4)**
Armstrong	18	**20 (27)**

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

2.2.2 Chl.a

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

2.2.3 Secchi Depth, pH and Colour

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

2.2.4 Total Nitrogen

There is not a definitive water quality guideline for total nitrogen in surface water in Nova Scotia. Kejimkujik National Park is located in central southern Nova Scotia and contains a number of coloured lakes. Eighteen lakes have been monitored for many years and a guideline of 350 µg/L established for oligotrophic, brown-water lakes (Parks Canada, 2010). This guideline was used in the analysis of the Lake Monitoring Program data as Kejimkujik lakes are more similar to lakes in Kings County than surface water used to establish other guidelines.

2.2.5 Dissolved Organic Carbon

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

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

2.2.6 Turbidity

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

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

2.3 Water Quality Index

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

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

2.4 Quality Assurance / Quality Control

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

3 Results

The following section present for each lake, a report card summarizing the 2017 data as well as an interpretation and recommendation for lakes showing a poor rating in water quality.

The Water Quality index (WQI) for 2017 developed by the CCME was calculated using the following variables: chl.a concentrations, Total Phosphorus, Total Nitrogen, pH and turbidity. As indicated earlier, other variables were considered in the past but were removed from the calculations because of the limitations of the WQI in coloured waters. For example, the WQI is designed to use colour or DOC as a parameter defining water quality. Although high DOC values may be observed for high trophic status lakes, it is generally not DOC associated with a humic content. Therefore, variables such as colour and DOC, which are naturally high in humic, coloured lakes were not considered in the WQI, but are still presented in the lake summary table, and compared to guidelines values.

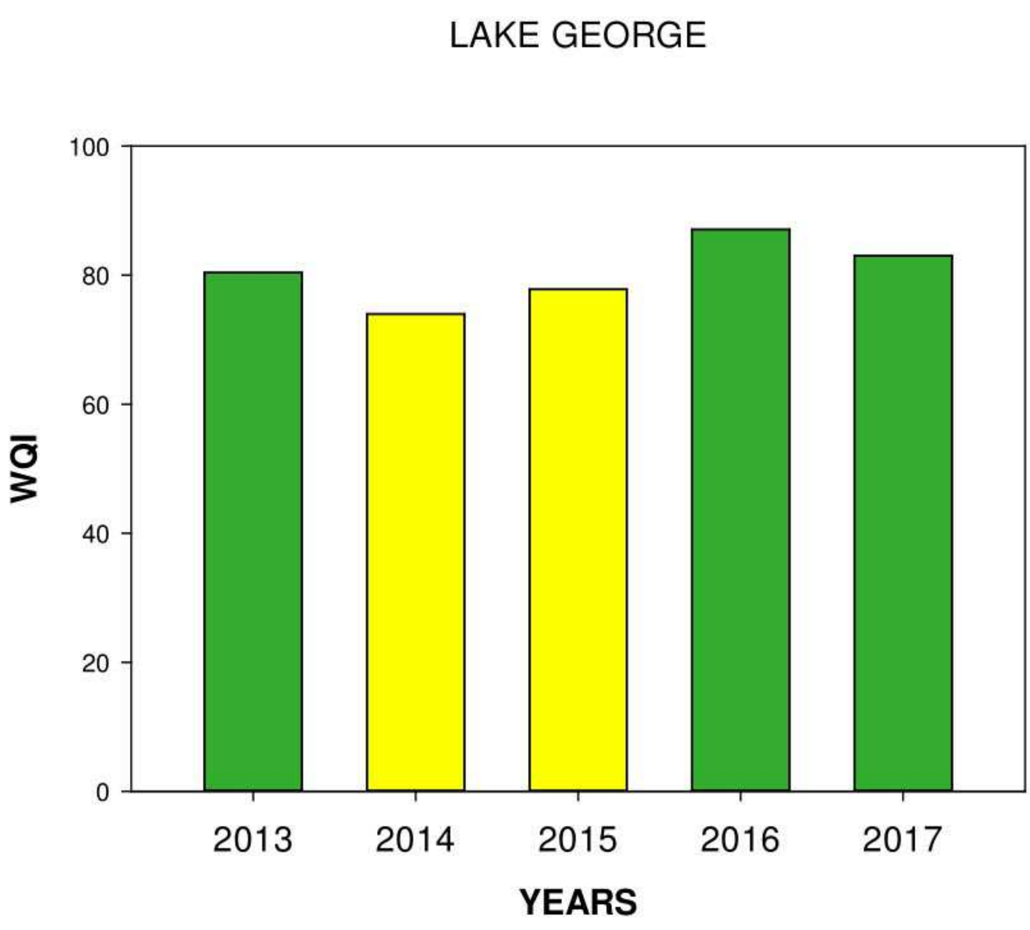
The following section provides includes an interpretation of the data collected for each lake sampled as part of this study including and illustrated with a summary table of all water quality parameters, histograms of the trends in WQI between 2013 to 2017, histograms of the concentration in chl.a, TP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

3.1 Lake George

Among the Kings County lakes, Lake George is the first lake in term of drainage. It is a fairly small lake (Lake surface area about 153 ha) and fairly shallow, with a maximum depth of 9 meters. This lake has been sampled as early as 1993, which is one of the longest time series for the Kings County lakes monitoring program.

Water Quality Index (WQI):

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



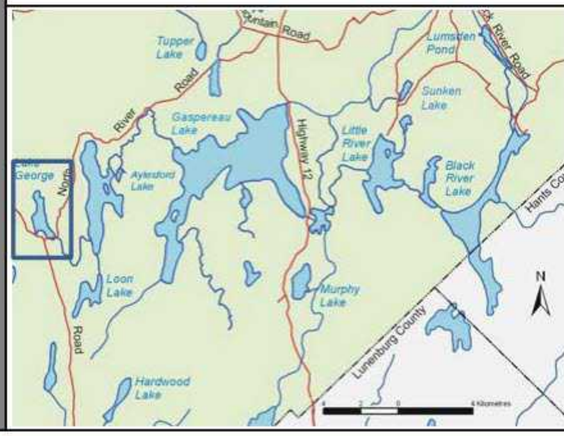
Summary report card:

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

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

LAKE GEORGE

83



Drainage Order = 1

Elevation = 231 m

Lake Area = 153 ha

Max Depth = 9.5 m

1997-2017 Trends:

Chl.a = 0.1 µg/L/yr
TP= n.s.
TN =22 µg/L/yr
WQI % Change = -5%*

	Parameter							
	TP (µg/L)	**Chl A (mg/m^3)**	**DOC (mg/L)**	**pH**	**Secchi Depth (m)**	**Colour (TCU)**	**TN (µg/L)**	**Turbidity (NTU)**
Guideline	13,9	2,5	3.5-5.3	6.2-6.7	2.9-4.1	17-31	350	1,3
2017 average	6,7	2,2	4,2	6,6	**3**	20,9	185	0,8
2017 (min - max)	(6 - 10)	(1.4-**3.1**)	(4-4.4)	(6.6-6.7)	(2.4-3.5)	(17-25.7)	(150-230)	(0.5-1.3)
1997-2016 average	9,61	2,42	4,39	6,51	3,56	24,52	164	0,71

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

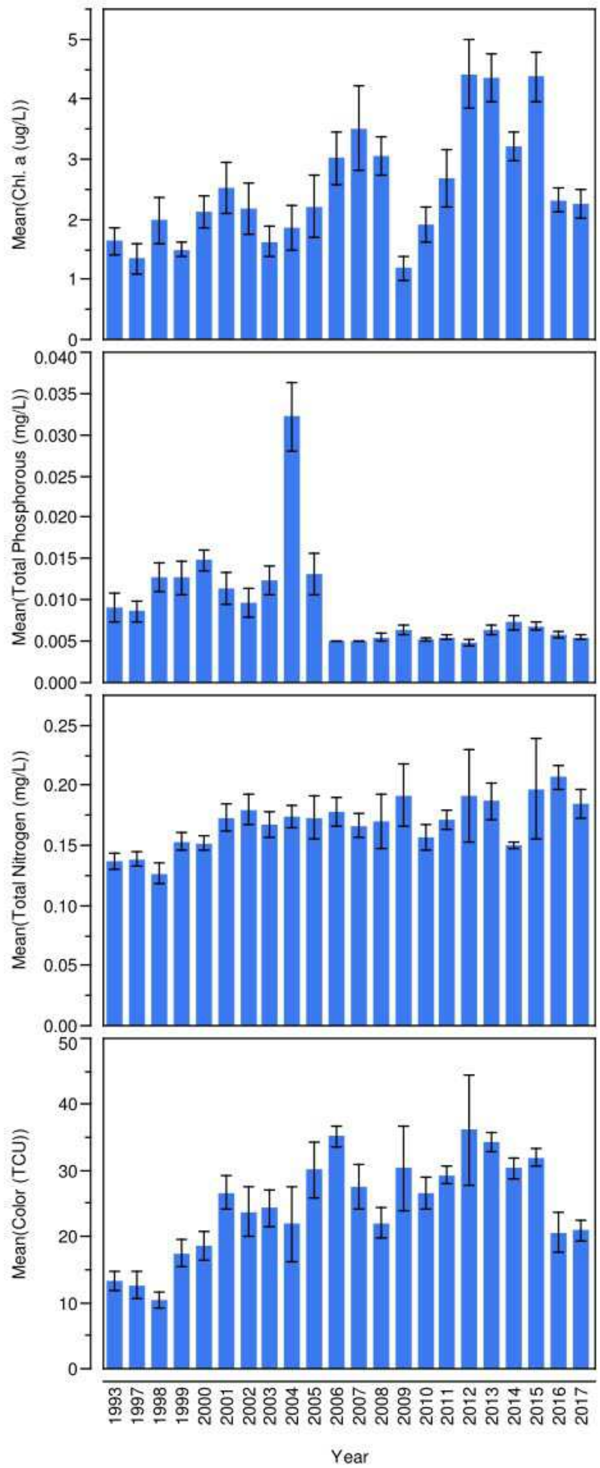
Numbers in red indicate exceedances of the criteria. n.s. indicates non significant result.

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

Long-term trends:

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

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

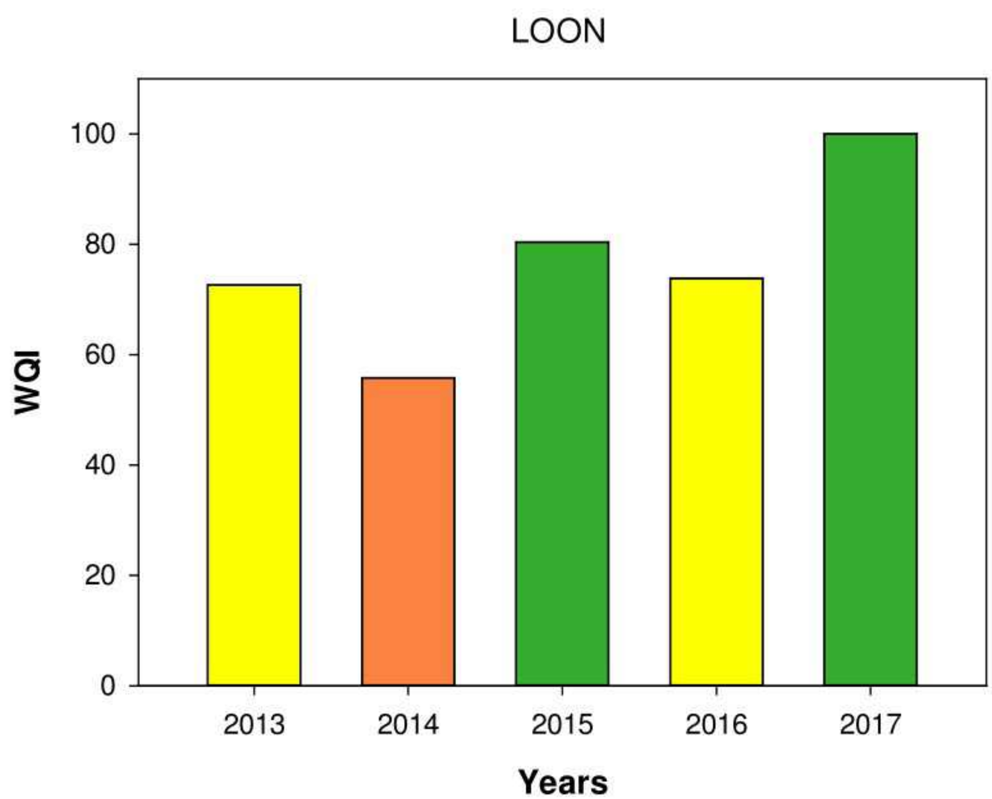


3.2 Loon Lake

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

Water Quality Index (WQI):

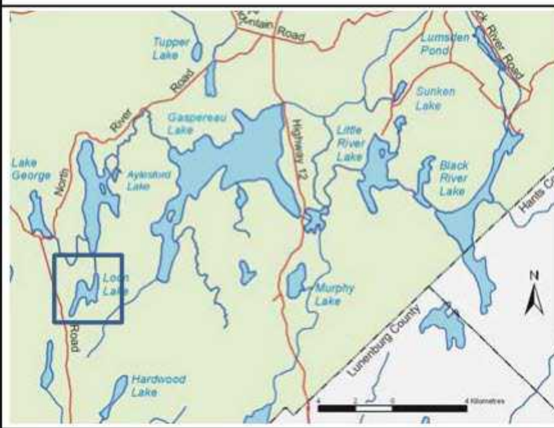
The Water Quality Index value for Lake Loon in 2017 reached 100, an excellent water quality rating. This value is the result of no data exceeding guideline values. In 2017, there was a significant increase in WQI compared to 2016 (from 74 to 100).



Summary report card:

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

LOON LAKE



100

Drainage Order = 1

Elevation = ~206 m

Lake Area = ~90 ha

Max Depth = 8.1 m

1997-2017 Trends:

Chl.a = 0.1 µg/L/yr
TP= n.s.
TN = 2.4 µg/L/yr
WQI % Change = 36% *

	Parameter							
	TP (µg/L)	Chl A (mg/m^3)	DOC (mg/L)	pH	Secchi Depth (m)	Colour (TCU)	TN (µg/L)	Turbidity (NTU)
Guideline	18,1	2,5	4.4-6.5	6-6.4	2.1-2.8	25-44	350	1,3
2017 average	10	1,7	5,3	6,3	2,7	35,3	196	0,9
2017 (min - max)	(10 - 10)	(1.2-2.4)	(5-5.7)	(6.2-6.4)	(2.5-**2.9**)	(26.2-40.4)	(190-200)	(0.6-1.2)
1997-2016 average	12,20	**3,40**	5,50	6,20	2,50	35,50	191	1,03

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

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

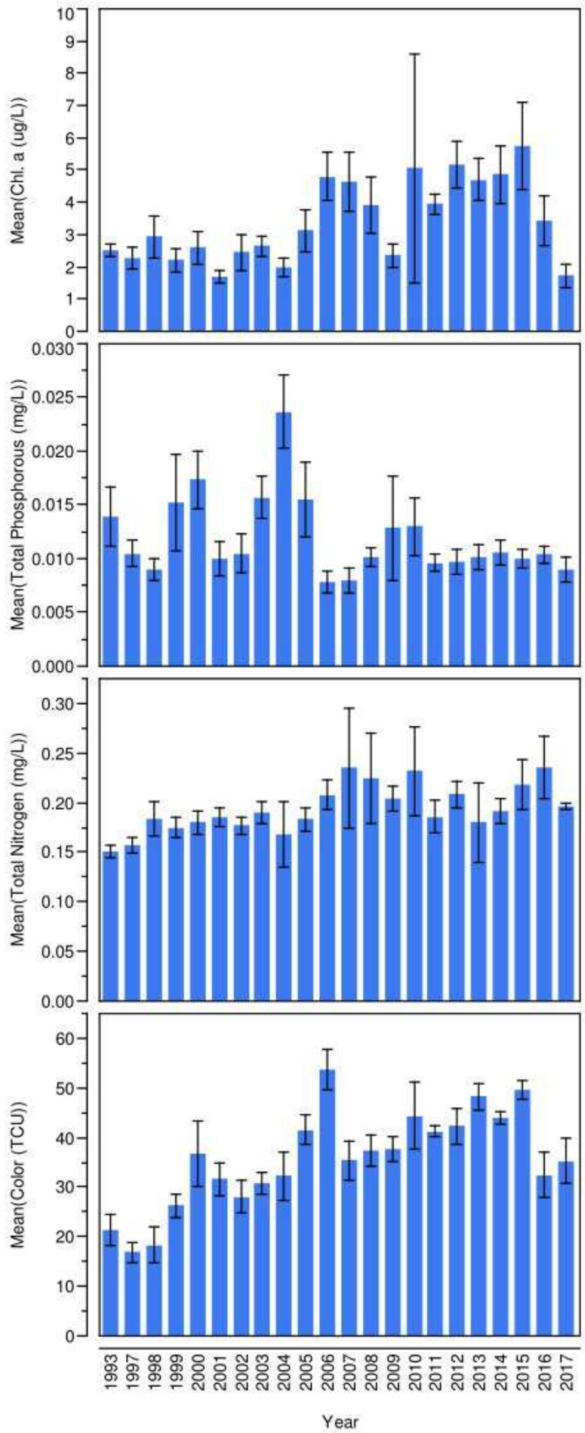
0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Long-term trends:

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

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

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

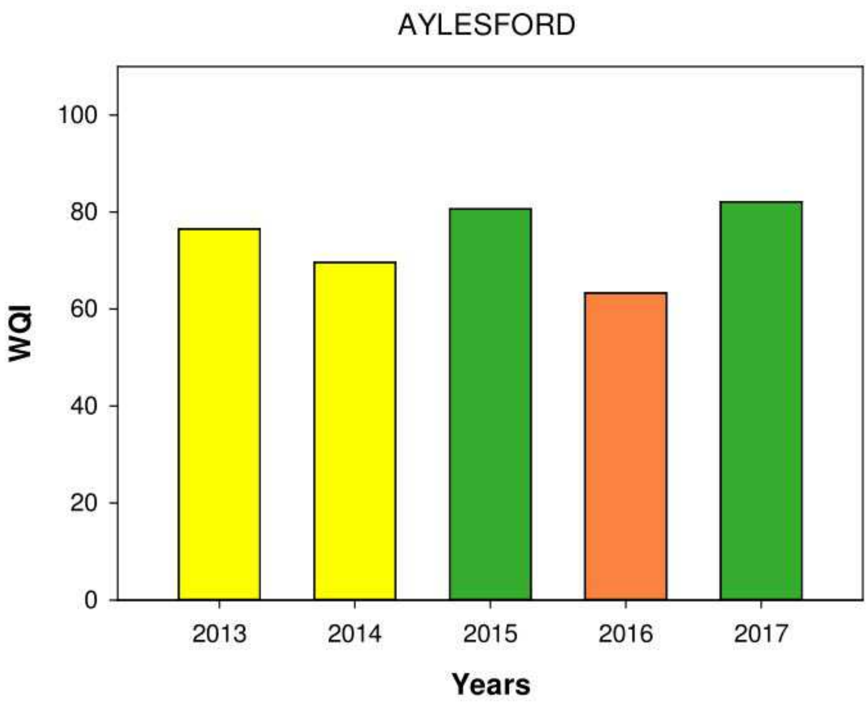


3.3 Aylesford Lake

Aylesford Lake is the third largest lake in this study with a surface area of 532 ha. It is a fairly shallow lake (given its size) with maximum depth of 12m. The lake is part of chain of several lakes, and is positioned as second order in drainage. The water of Aylesford Lake flows into the largest lake, Gaspereau. As for the other lakes in the area, Lake Aylesford is surrounded by forested areas and has some residential development mostly situated at north and south ends.

Water Quality Index (WQI):

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



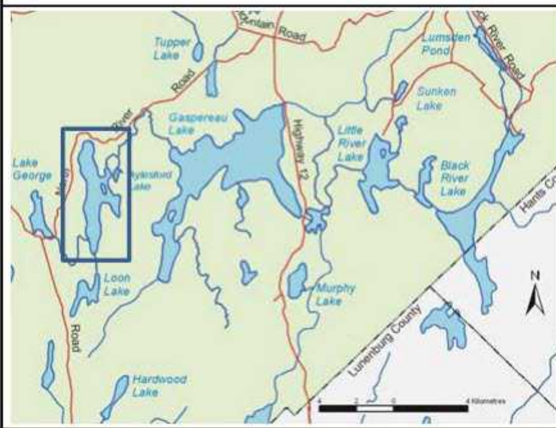
Summary report card:

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

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

AYLESFORD LAKE

82,1



Drainage Order = 2

Elevation = 216 m

Lake Area = 532 ha

Max Depth = 12 m

1997-2017 Trends:

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

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

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

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

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

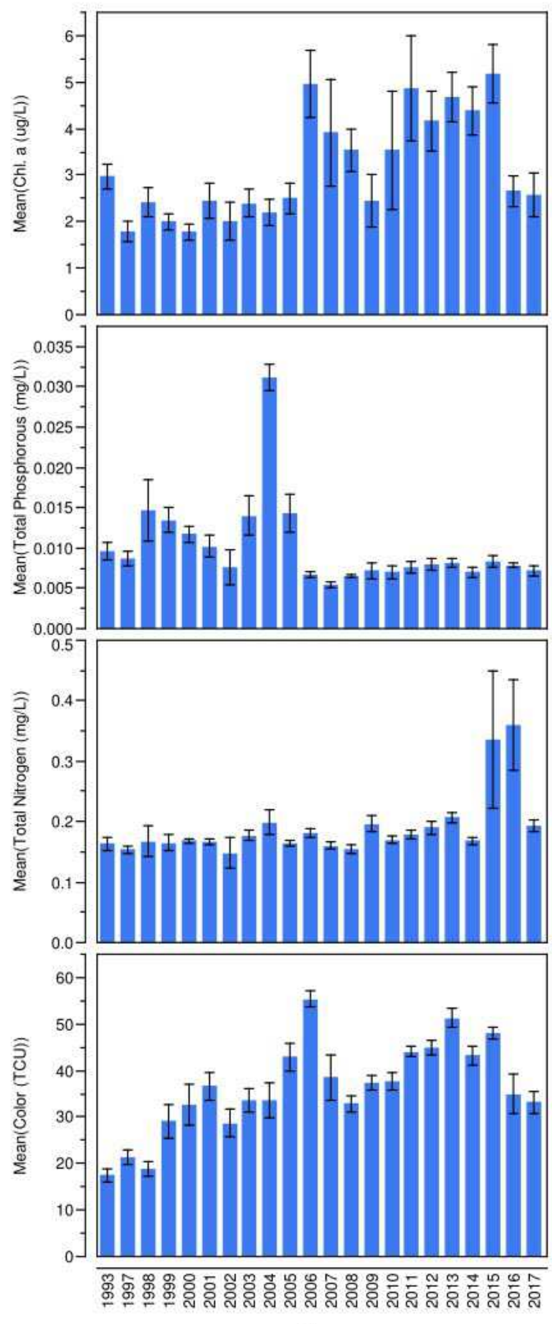
Long-term trends:

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

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

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

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

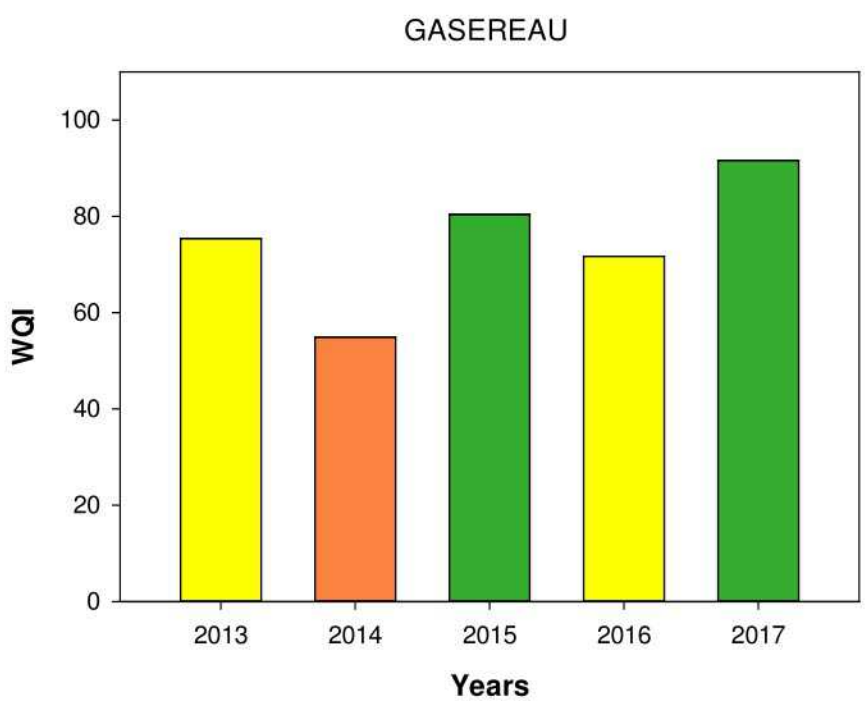


3.4 Gaspereau Lake

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

Water Quality Index (WQI):

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

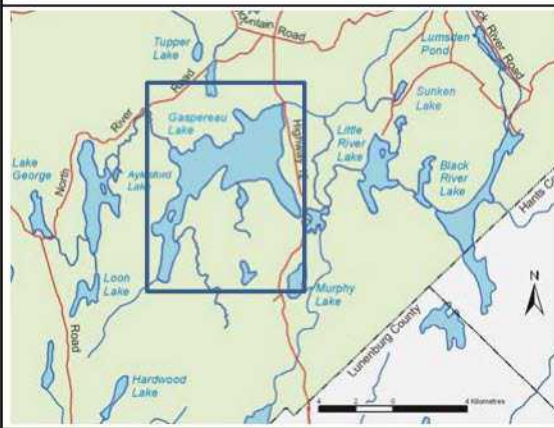


Summary report card:

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

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

GASPEREAU LAKE



91,6

Drainage Order = 3

Elevation = 175 m

Lake Area = 2200 ha

Max Depth = 10.9 m

1997-2017 Trends:

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

	Parameter							
	TP (µg/L)	Chl A (mg/m^3)	DOC (mg/L)	pH	Secchi Depth (m)	Colour (TCU)	TN (µg/L)	Turbidity (NTU)
Guideline	17,8	2,5	4.6-6.9	6.1-6.4	1.7-2.2	35-48	350	1,3
2017 average	10,00	1,60	4,90	6,30	2,60	30,80	208	0,83
2017 (min - max)	(10 - 10)	(0.9-2.8)	(4.4-5.2)	(6.2 - 6.4)	(2.2-2.9)	(24.5-43.4)	(180-220)	(0.75-1.0)
1997-2016 average	12,00	3,60	5,80	6,30	1,96	41,50	228	0,98

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

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

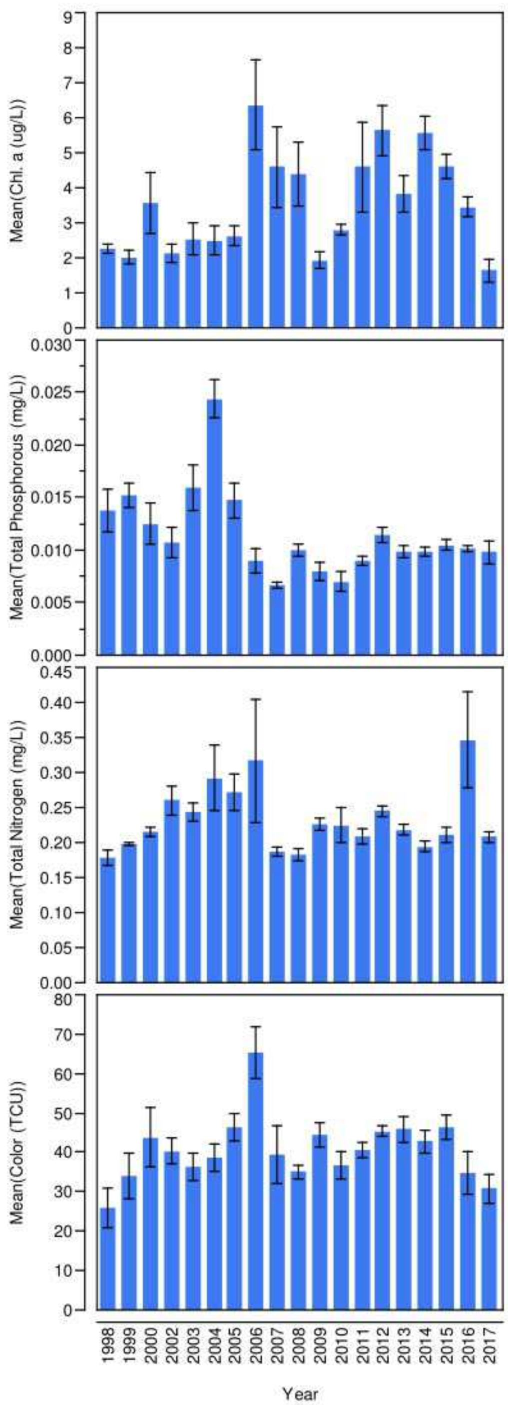
0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Long-term trends:

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

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

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

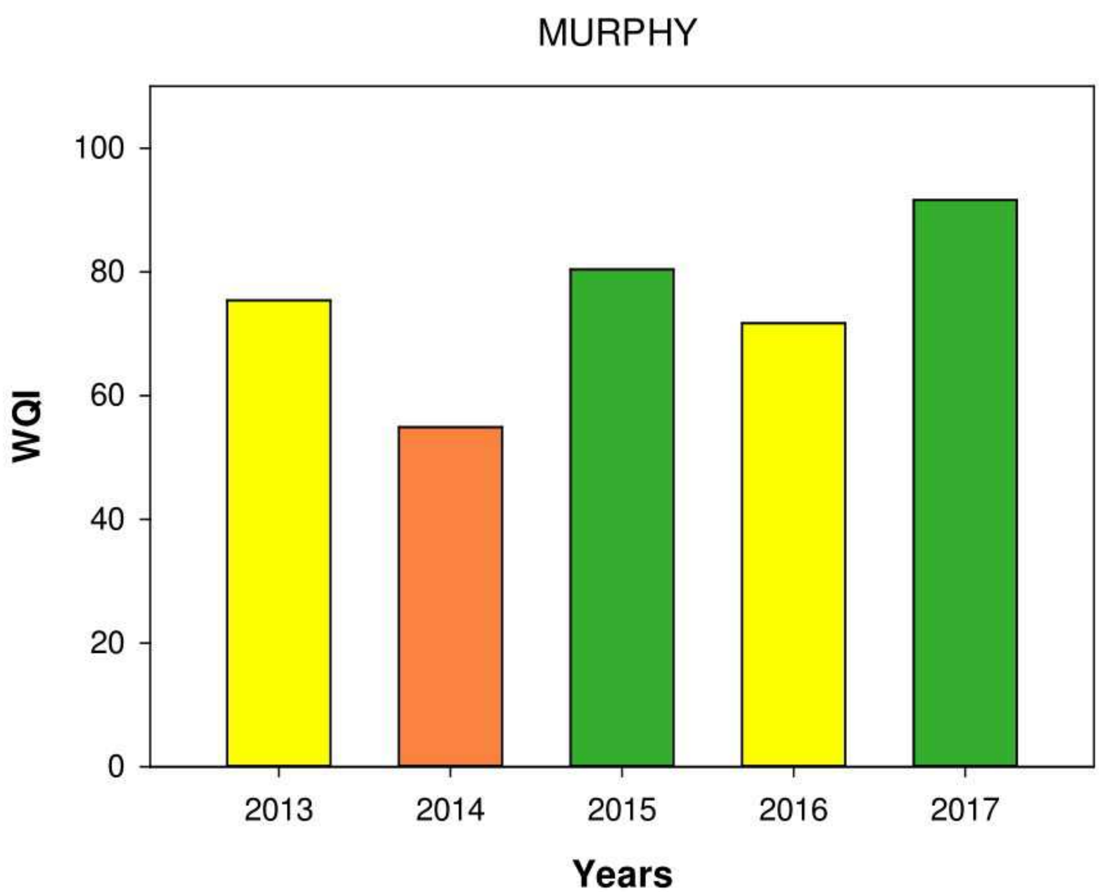


3.5 Murphy Lake

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

Water Quality Index (WQI):

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

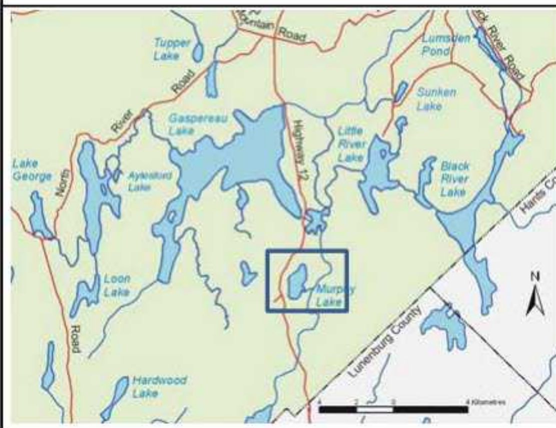


Summary report card:

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

MURPHY LAKE

82,5



Drainage Order = 3

Elevation = 207 m

Lake Area = 121 ha

Max Depth = 6.8 m

1997-2017 Trends:

Chl.a = 0.1 µg/L/yr
TP= n.s.
TN = 3.2 µg/L/yr
WQI % Change= 33 %*

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

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

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

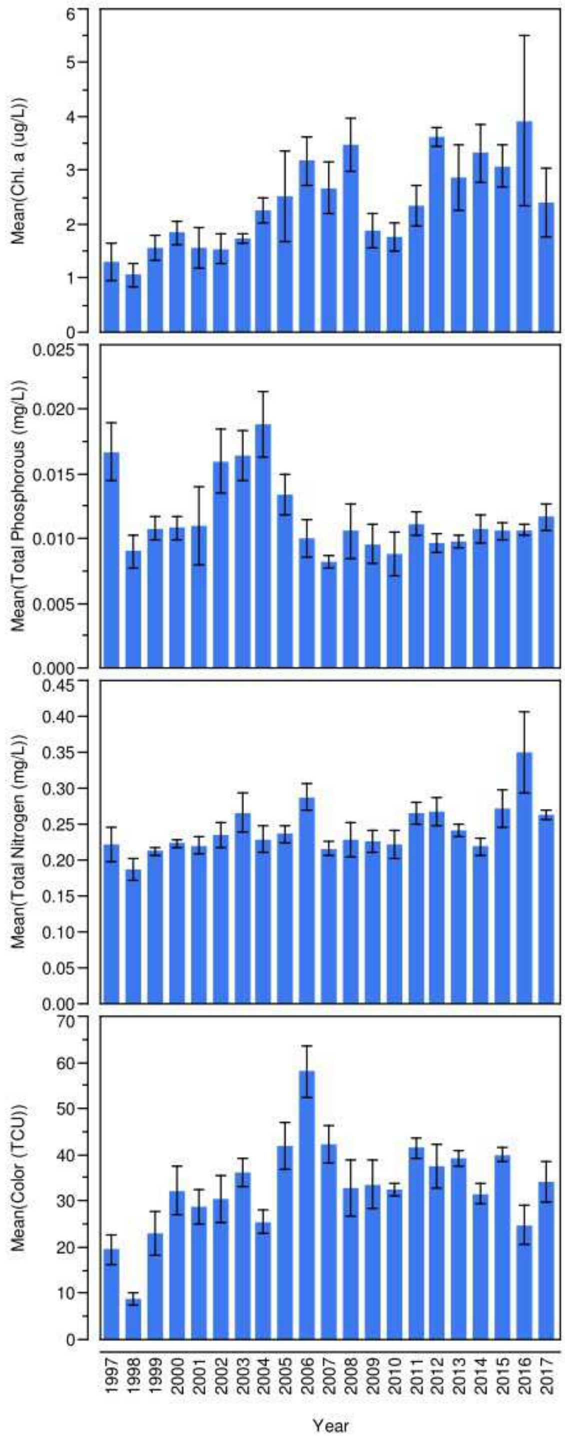
0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Long-term trends:

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

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

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

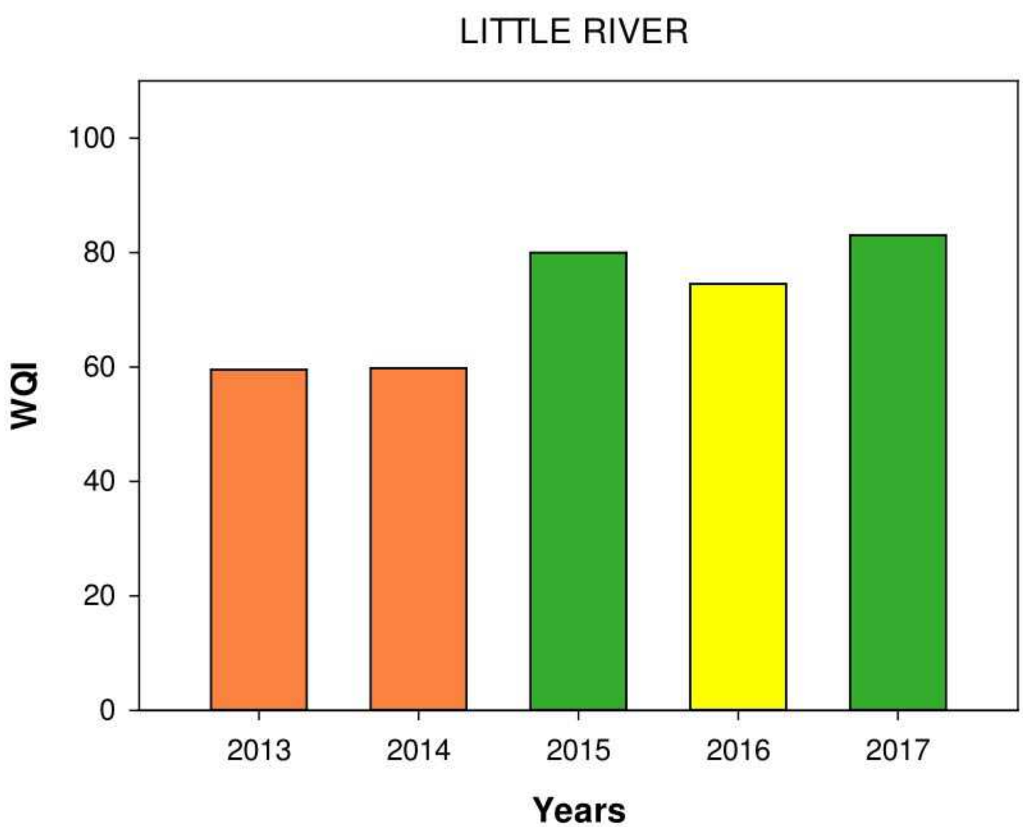


3.6 Little River Lake

Little River Lake is a medium size lake (surface: 520 ha) and has a maximum depth of 6.6m. Little River Lake is located between 2 much larger lakes: Lake Gaspereau upstream and Black River Lake downstream.

Water Quality Index (WQI):

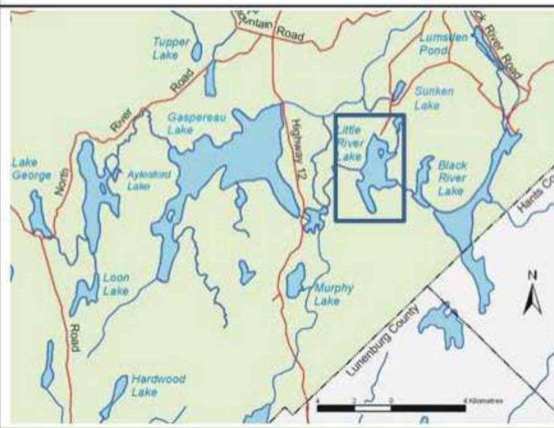
The Water Quality Index for Little River Lake was 83, indicative of a good water quality. This value is slightly higher than that observed in 2016 (2016:74; 2017:83). Little River Lake water quality is similar to that observed in 2015. Similar to Murphy Lake, exceedances were observed only for 2 variables,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



Summary report card:

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

LITTLE RIVER LAKE



83

Drainage Order = 4

Elevation = 189 m

Lake Area = 520 ha

Max Depth = 6.6 m

1997-2017 Trends:

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

	Parameter							
	TP (µg/L)	**Chl A (mg/m^3)**	**DOC (mg/L)**	**pH**	**Secchi Depth (m)**	**Colour (TCU)**	**TN (µg/L)**	**Turbidity (NTU)**
Guideline	20	2,5	5.2-7.8	6.1-6.5	1.8-2.4	43-55	350	1,3
2017 average	11,60	2,30	6,70	6,50	2,00	55,20	315	0,97
2017 (min - max)	(10 - 20)	(1.4-**3.6**)	(6.3-7.3)	(6.4 - **6.7**)	(1.7 - 2.3)	(44.3-**62.4**)	(260-**370**)	(0.7-1.3)
1997-2016 average	14,40	**3,20**	6,50	6,40	2,12	49,60	261	1,01

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

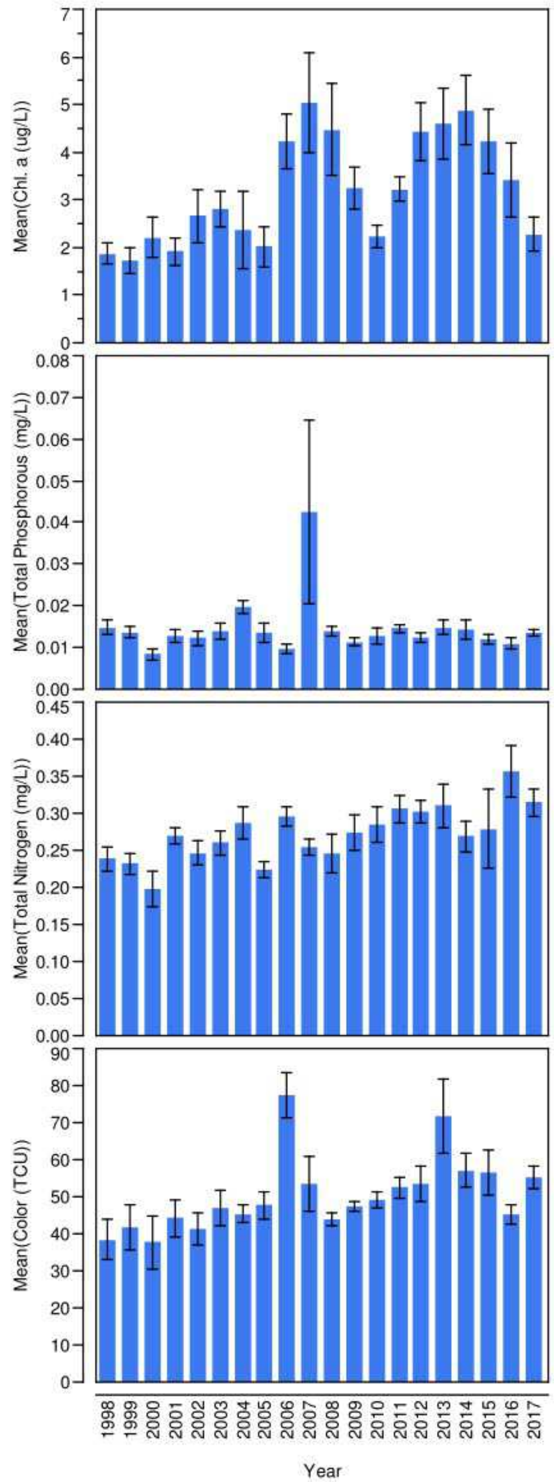
Numbers in red indicate exceedances of the criteria. n.s. indicates non significant result.

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

Long-term trends:

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

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

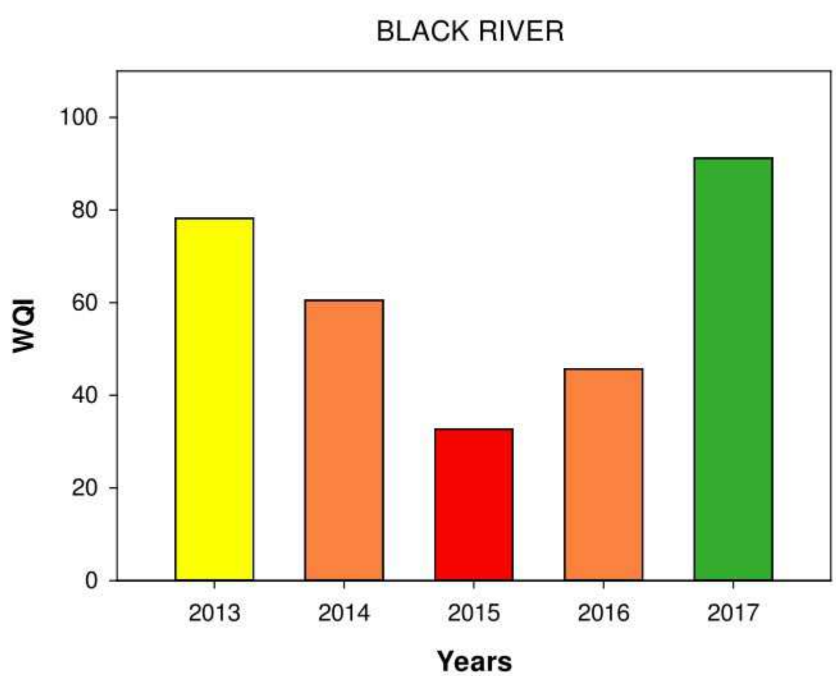


3.7 Black River Lake

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

Water Quality Index (WQI):

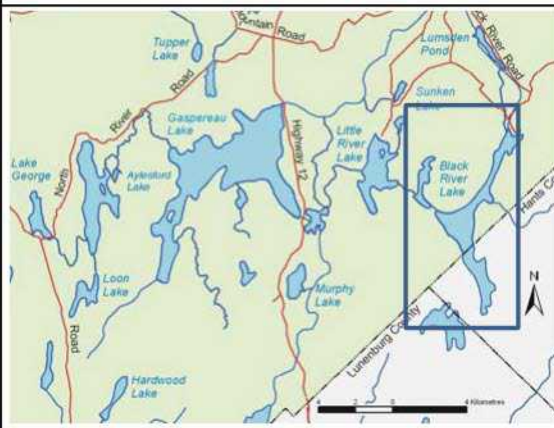
The Water Quality Index value for Black River Lake in 2017 was 91 which is indicative of a good water quality. This value has doubled from 45 in 2016 to 91 in 2017.Overall, an improvement of the water quality has been observed in this lake for the last 3 years. One variable exceeded guideline values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



Summary report card:

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

BLACK RIVER LAKE



91,2

Drainage Order = 5

Elevation = 170 m

Lake Area = 668 ha

Max Depth = 15 m

1997-2017 Trends:

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

	Parameter							
	TP (μg/L)	Chl A (mg/m^3)	DOC (mg/L)	pH	Secchi Depth (m)	Colour (TCU)	TN (μg/L)	Turbidity (NTU)
Guideline	16,4	2,5	5.3-8.0	6.1-6.5	1.6-2.3	44-57	350	1,3
2017 average	13,30	2,70	6,20	6,40	1,70	53,10	242	1,00
2017 (min - max)	(10-10)	(1.1-5.4)	(5.7-6.7)	(6.2-6.5)	(1.3-1.8)	(48.1-57)	(200-300)	(0.9-1.1)
1997-2016 average	10,80	3,10	6,60	6,27	2,00	52,90	251	1,00

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

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

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

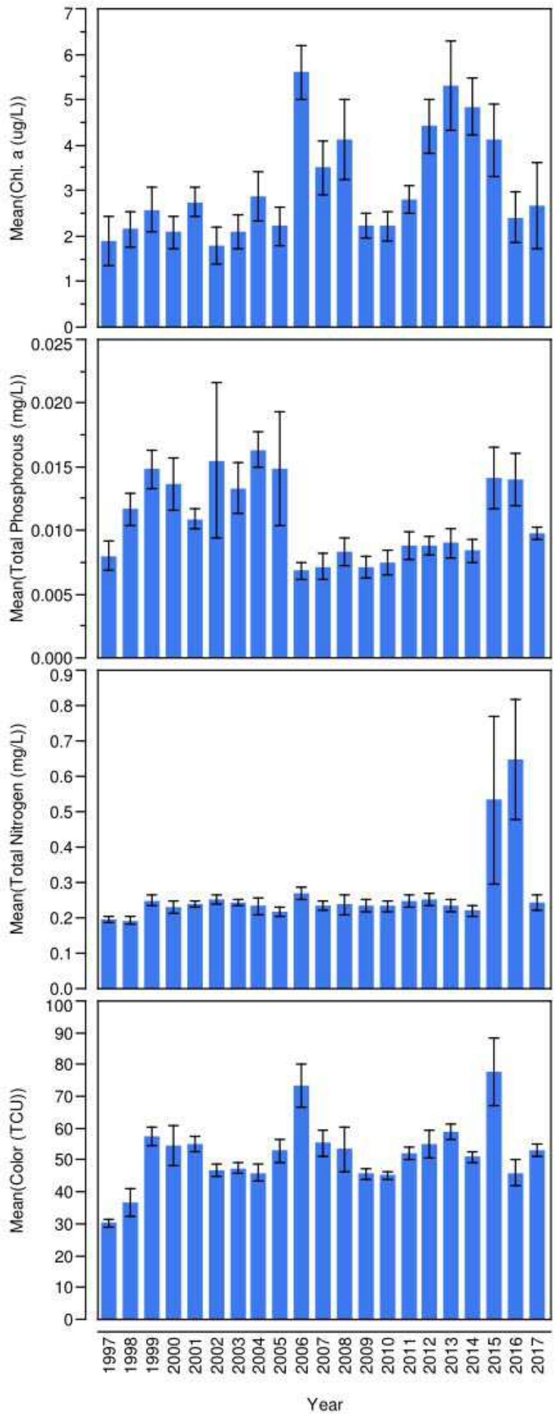
Long-term trends:

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

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

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

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

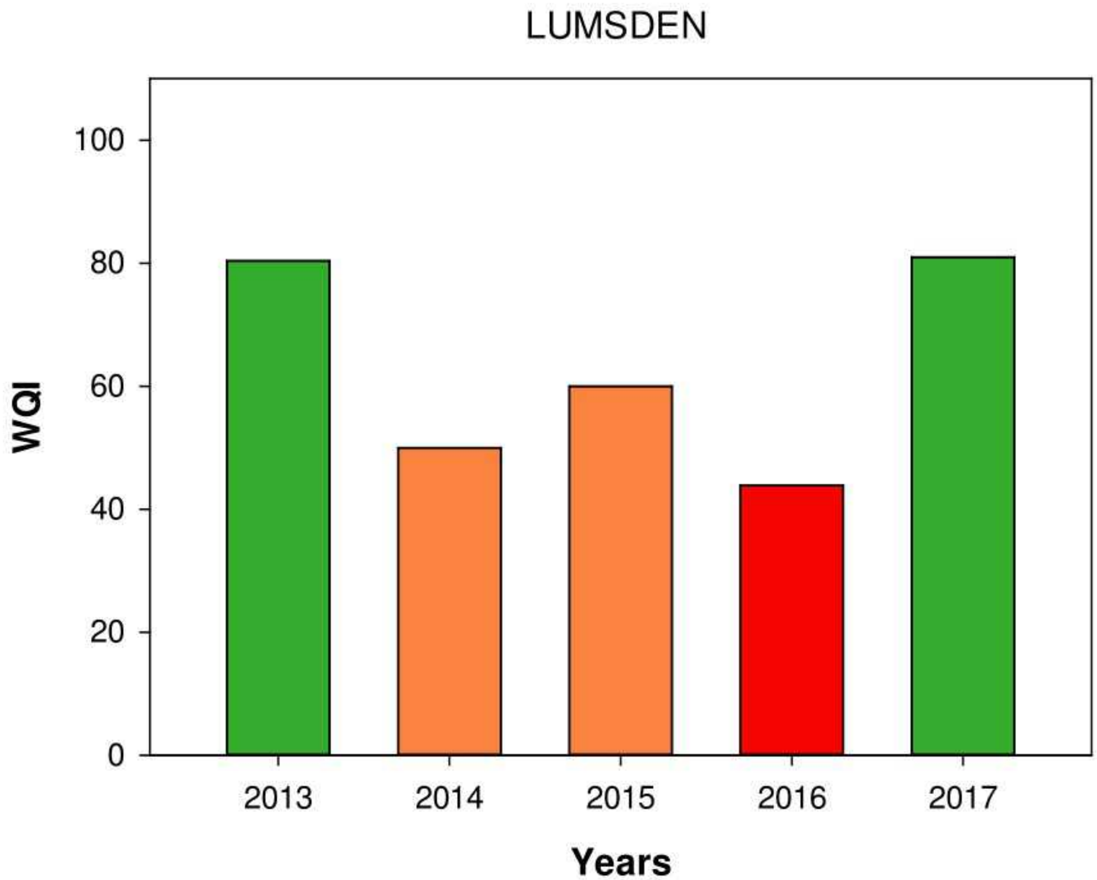


3.8 Lumsden Pond

Lumsden pond is an enlargement of a river system. This body of water is small (88 ha) and has a reported maximum depth of 19 m (which is unexpected given the surface and the fact that this is a pond). The pond is receiving water from Black River Lake and is the last system in the chain of lakes in this study. The pond has some residential development and also some agriculture development in its watershed.

Water Quality Index (WQI):

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



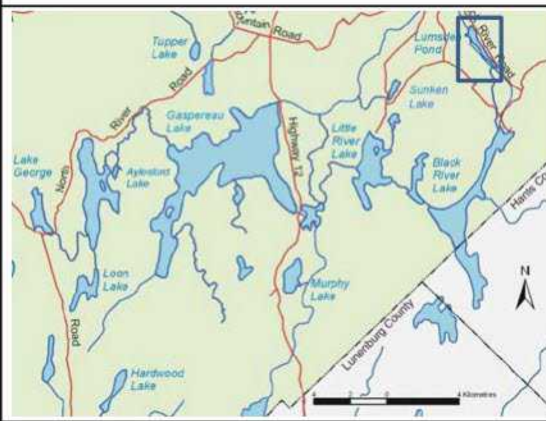
Summary report card:

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

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

LUMSDEN POND

81



Drainage Order = 6

Elevation = 126 m

Lake Area = 88 ha

Max Depth = 19 m

1997-2017 Trends:

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

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

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

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

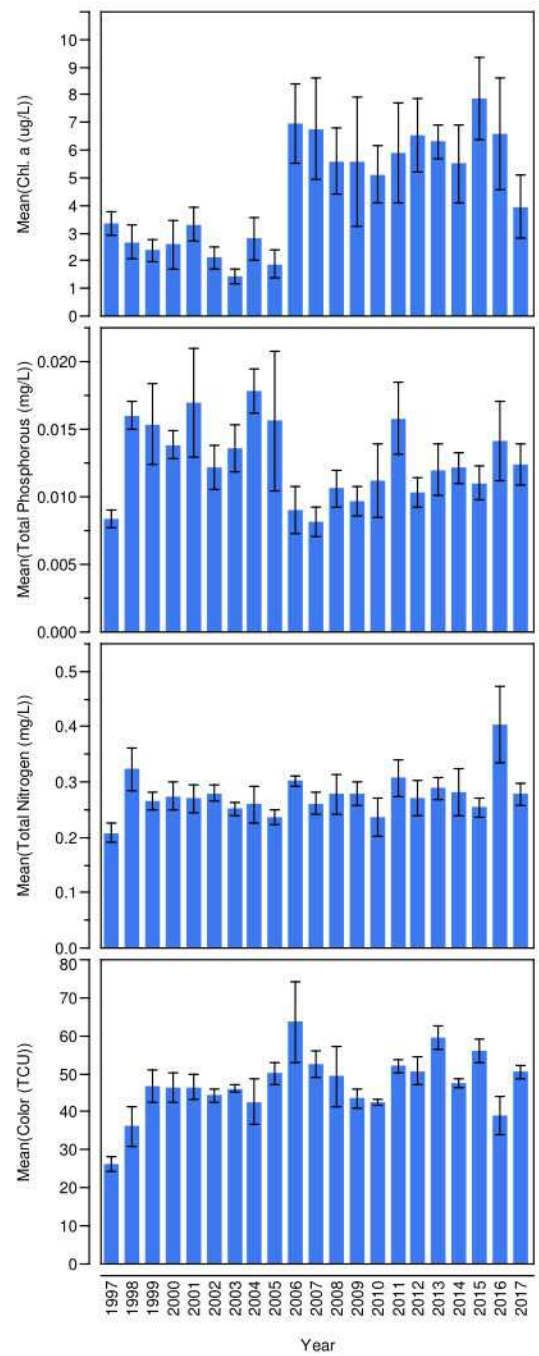
0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Long-term trends:

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

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

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

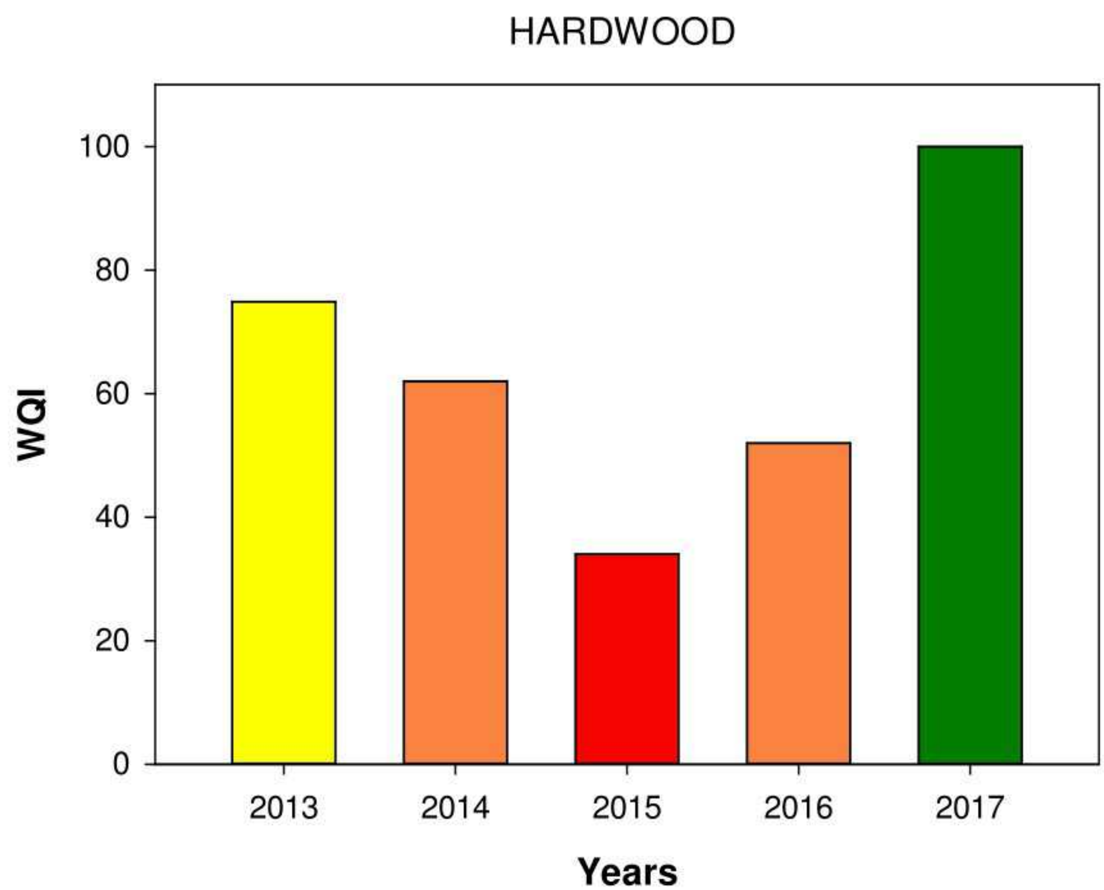


3.9 Hardwood Lake

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

Water Quality Index (WQI)

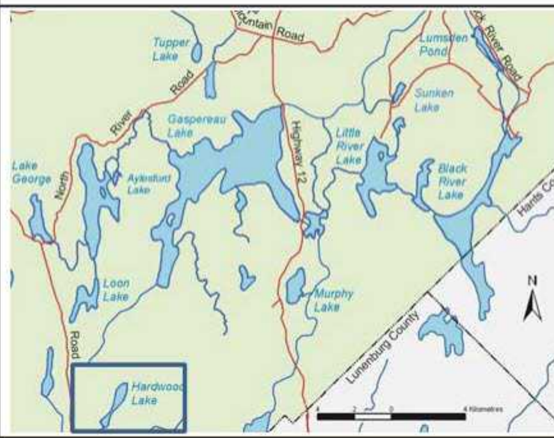
In Hardwood Lake, The Water Quality index (WQI) for 2017 reached the value of 100 (Excellent) because none of the values used in the calculation exceeded guidelines values. The trends in WQI are showing an improvement over the last 3 years, with a value that as doubled from 52 to 100 between 2016 and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



Summary report card:

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

HARDWOOD LAKE



100

Drainage Order = n/a

Elevation = 208 m

Lake Area = 120 ha

Max Depth = 7.0 m

1997-2017 Trends:

Chl.a = n.s.

TP=n.s.

TN = 3.1 µg/l/yr

WQI % Change =92% *

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

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

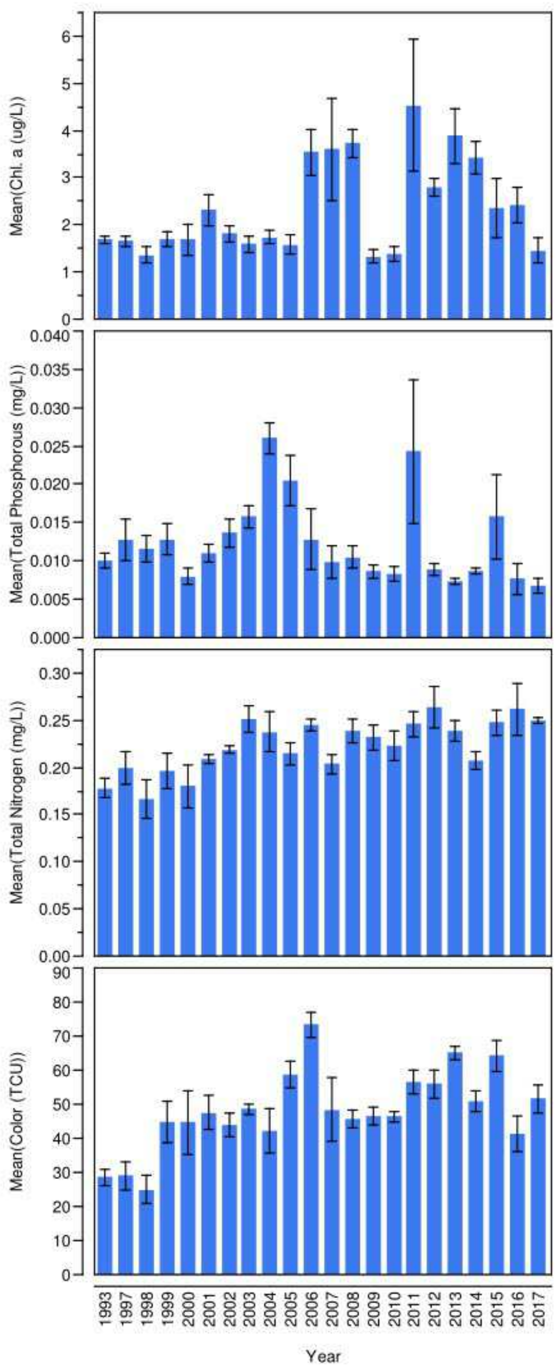
Numbers in red indicate exceedances of the criteria. n.s. indicates non significant result.

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

Long-term trends:

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

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

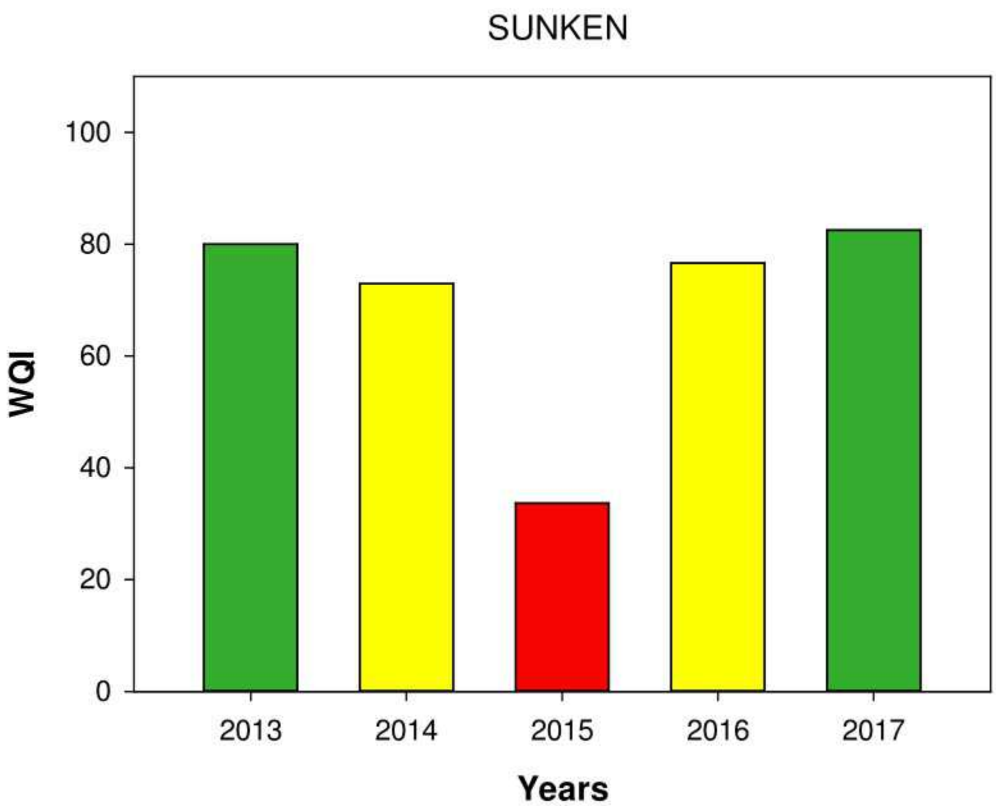


3.10 Sunken Lake

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

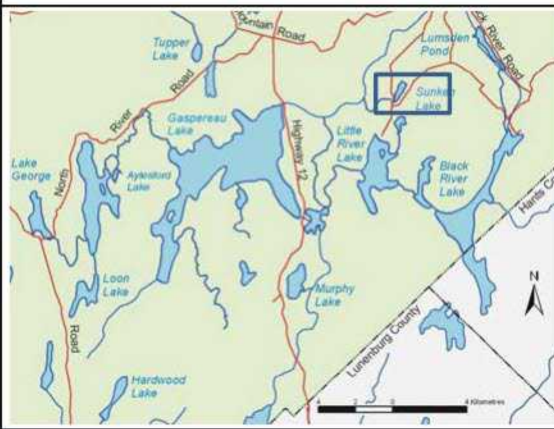
Water Quality Index (WQI):

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



Summary report card:

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



SUNKEN LAKE

82,5

Drainage Order = n/a

Elevation = ~209 m

Lake Area = ~22.2 ha

Max Depth = 6.9 m

1997-2017 Trends:

Chl.a = n.s.
TP= n.s.
TN = n.s.
WQI % Change = 8 % *

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

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

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

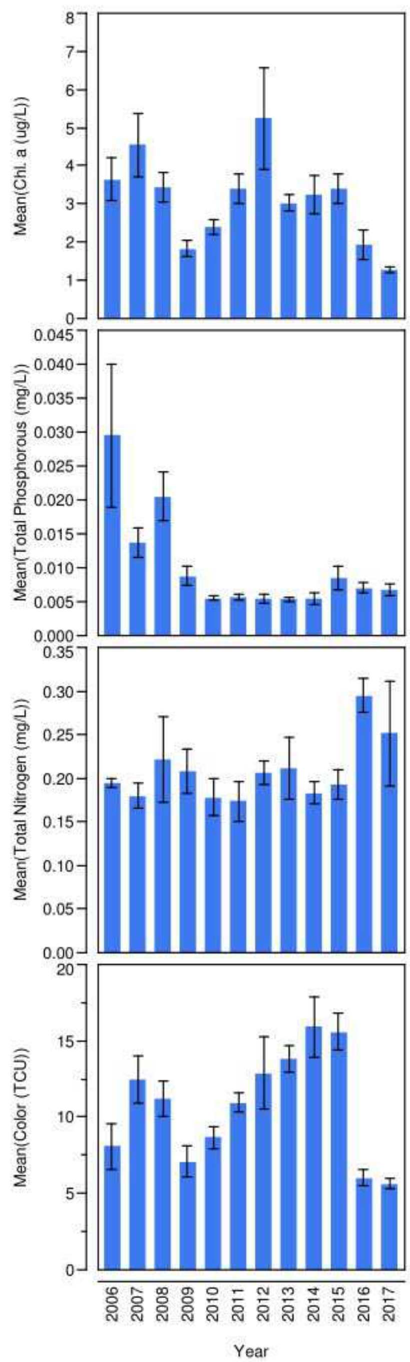
0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Long-term trends:

Temporal trends for nutrient (TP and TN) as well as for chl.a a are not showing any statistical trends over time. The concentrations in chl.a were lower in 2017 compared to the last 6 years (explaining the increase in WQI values) and declining over the last 3 years. The mean concentration in chl.a measured in 2017 was the lowest in over a decade. The concentrations in TP remained low (below 10 mg/L) and constant over the last 8 years. These findings are consistent with oligotrophic conditions for Lake Sunken. The mean concentrations in TN have increased (from close to 200 to 300 µg/L) in 2016 and 2017 and further analyses would be needed to confirm if this trend is maintained over the longer-term.

Interestingly, water colour has declined to a mean value of 5.6 TCU over the last 2 years. This result is unclear because Secchi depth or DOC concentrations did not follow a similar trend.

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

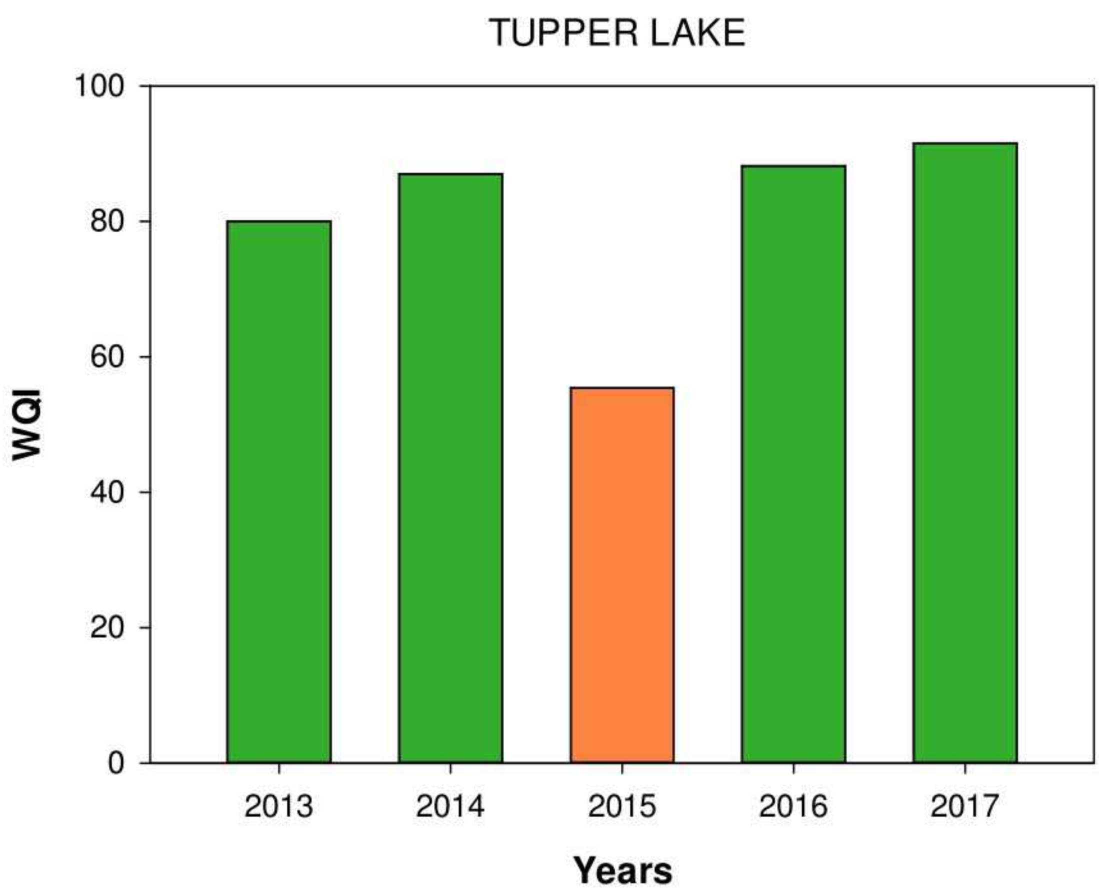


3.11 Tupper Lake

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

Water Quality Index (WQI):

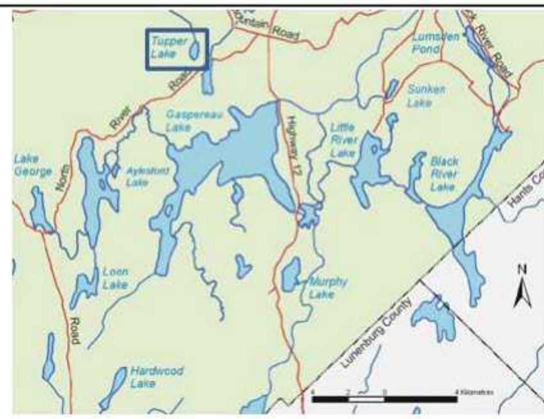
In 2017, the Water Quality Index for Lake Tupper was 91.5, which indicates an excellent water quality rating. The value increased slightly between 2016 and 2017 (2016:88; 2017: 91). This WQI rating has been consistent for this lake, with 4 'excellent' rating over the last 5 years.



Summary report card:

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

TUPPER LAKE



91,5

Drainage Order = n/a

Elevation = 201 m

Lake Area = 36 ha

Max Depth = 3.0 m

1997-2017 Trends:

Chl.a = n.s.
TP= -0.7 μg/L/yr
TN = n.s.

WQI % Change =4% *

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

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

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

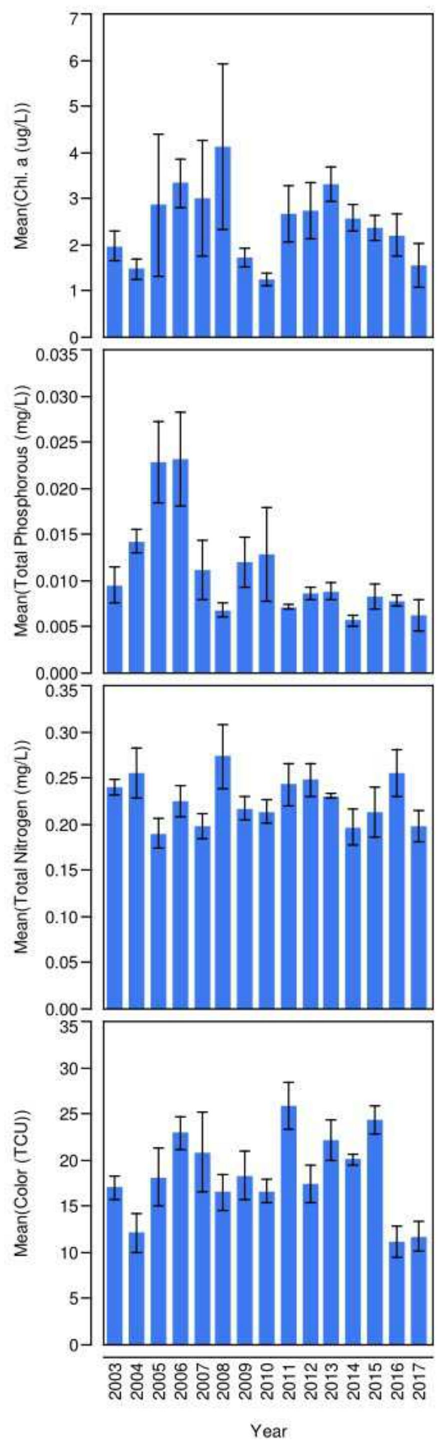
0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Long-term trends:

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

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

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

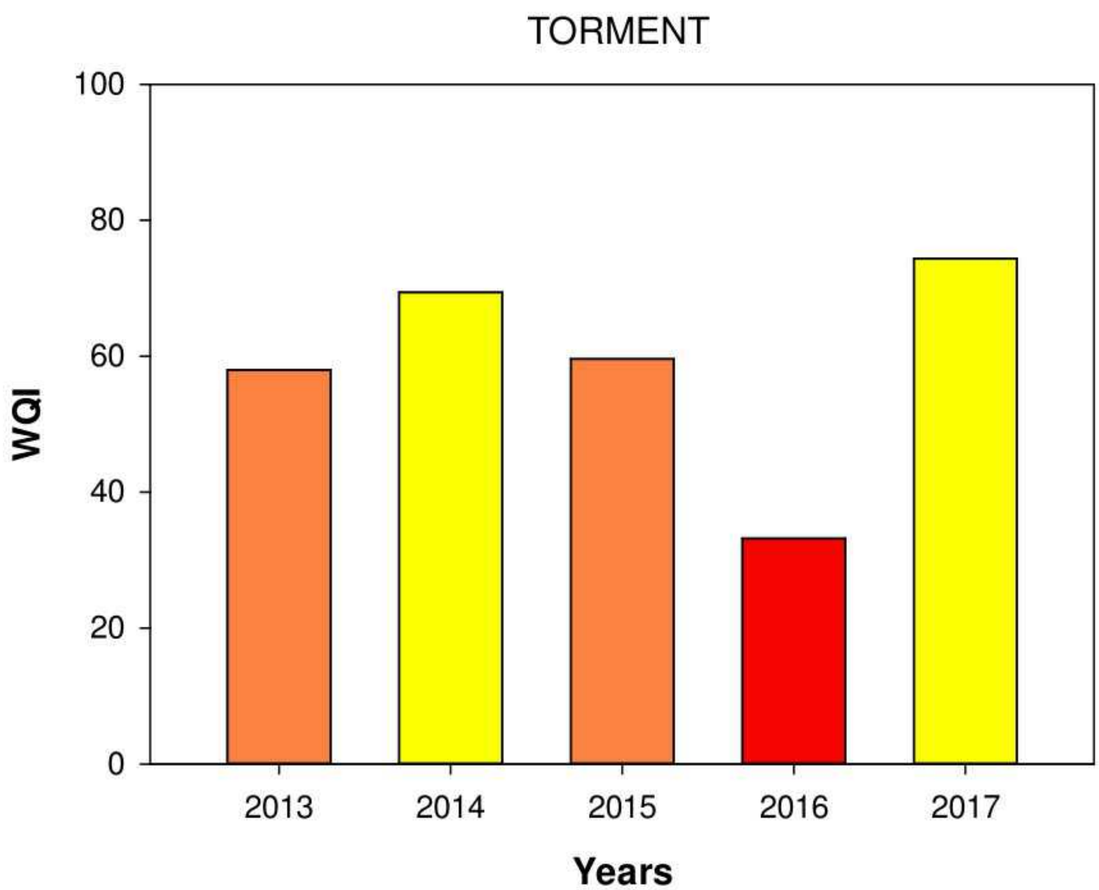


3.12 Lake Torment

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

Water Quality Index (WQI):

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



Summary report card:

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

Lake Torment

74,4

Drainage Order = n/a

Elevation = 174 m

Lake Area = 261 ha

Max Depth = 3.4 m

1997-2017 Trends:

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

WQI % Change = 124% *

	Parameter							
	TP (µg/L)	**Chl A (mg/m^3)**	**DOC (mg/L)**	**pH**	**Secchi Depth (m)**	**Colour (TCU)**	**TN (µg/L)**	**Turbidity (NTU)**
Guideline	20	2,5	8.0-12	6.3-6.5	1.1-1.6	53-98	350	1,3
2017 average	14,00	2,30	10,80	6,30	1,30	96,00	**372**	0,96
2017 (min - max)	(10 - 20)	(1.8-**2.8**)	(9.0-**13.8**)	(**6.2** - 6.4)	(1.2-1.4)	(85.8-**118**)	(280-**520**)	(0.52-**1.42**)
1997-2016 average	16,89	**5,02**	9,57	**6,51**	1,53	79,57	304,44	1,03

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

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

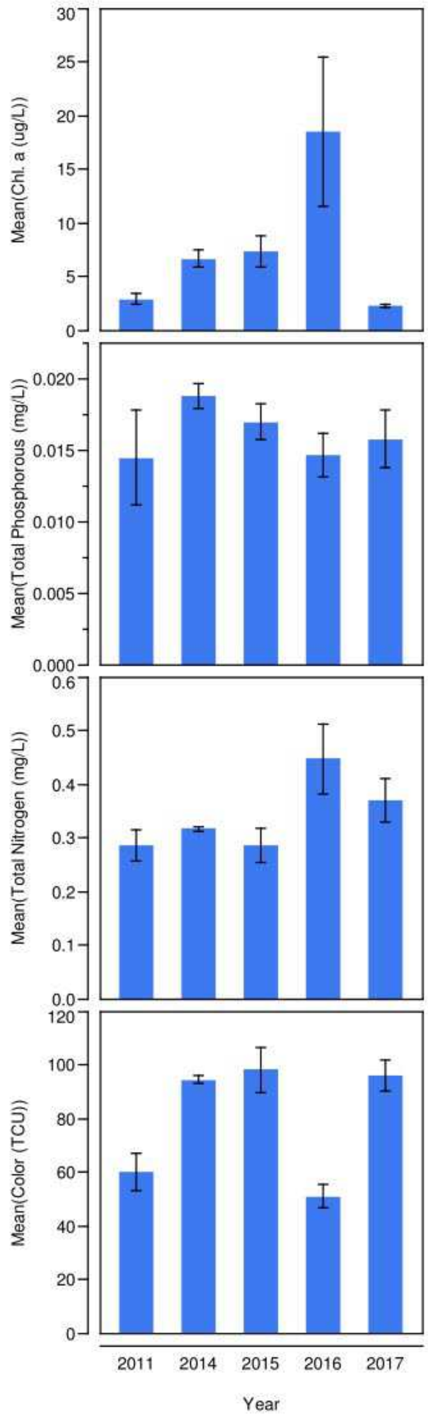
0-44	45-64	65-79	80-94	95-100
Poor	Marginal	Fair	Good	Excellent

Long-term trends:

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

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

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

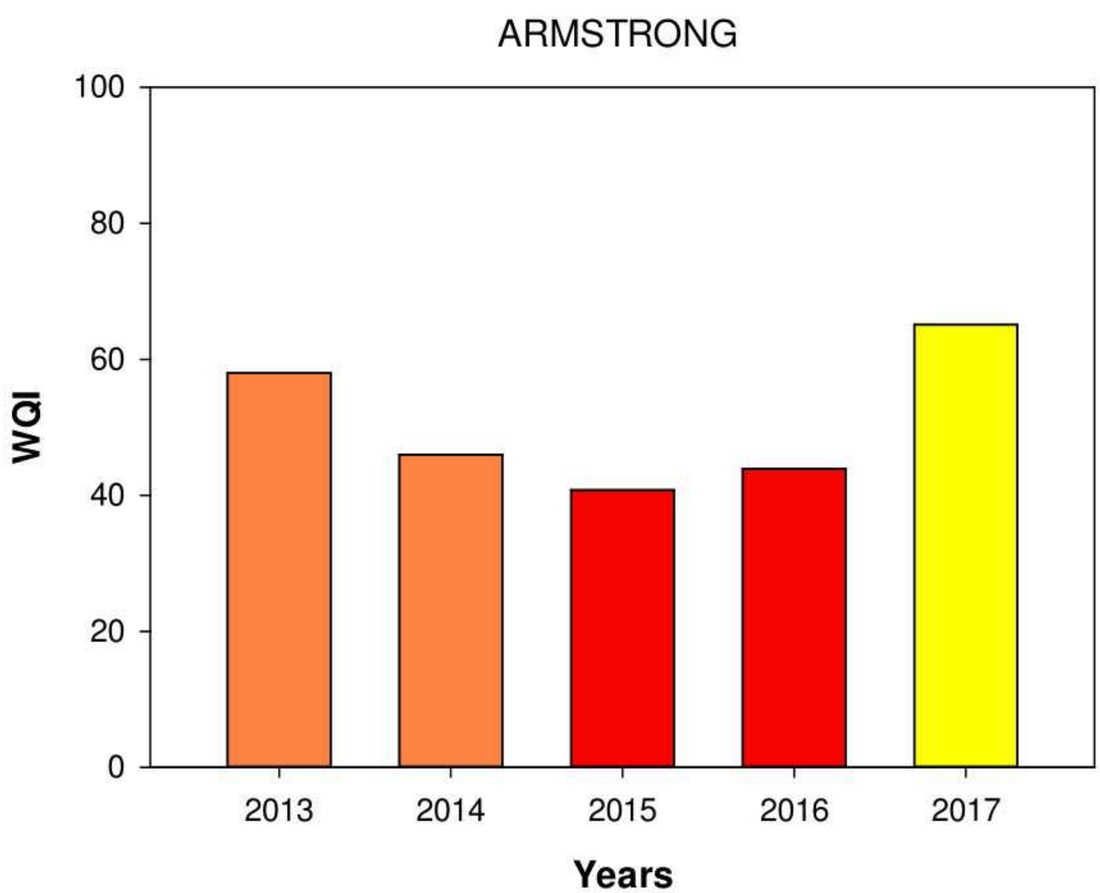


3.13 Armstrong Lake

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

Water Quality Index (WQI):

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



Summary report card:

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

Armstrong Lake

65,1

Drainage Order = n/a

Elevation = 178 m

Lake Area = 89 ha

Max Depth = 21 m

1997-2017 Trends:

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

	Parameter							
	TP (µg/L)	Chl A (mg/m^3)	DOC (mg/L)	pH	Secchi Depth (m)	Colour (TCU)	TN (µg/L)	Turbidity (NTU)
Guideline	20	2,5	8.6-12.9	6.2-6.4	1.1-1.7	57-104	350	1,3
2017 average	16,67	**2,7**	10,8	6,2	1,1	100,7	355	1
2017 (min - max)	(10 - 20)	(1.1-**5.4**)	(8.8-**13.1**)	(6-6.3)	(**1**-1.3)	(88.1-112)	(280-**430**)	(0.6-**1.6**)
1997-2016 average	19,6	**3,34**	11,22	6,36	**1,63**	94,5	**362**	0,91

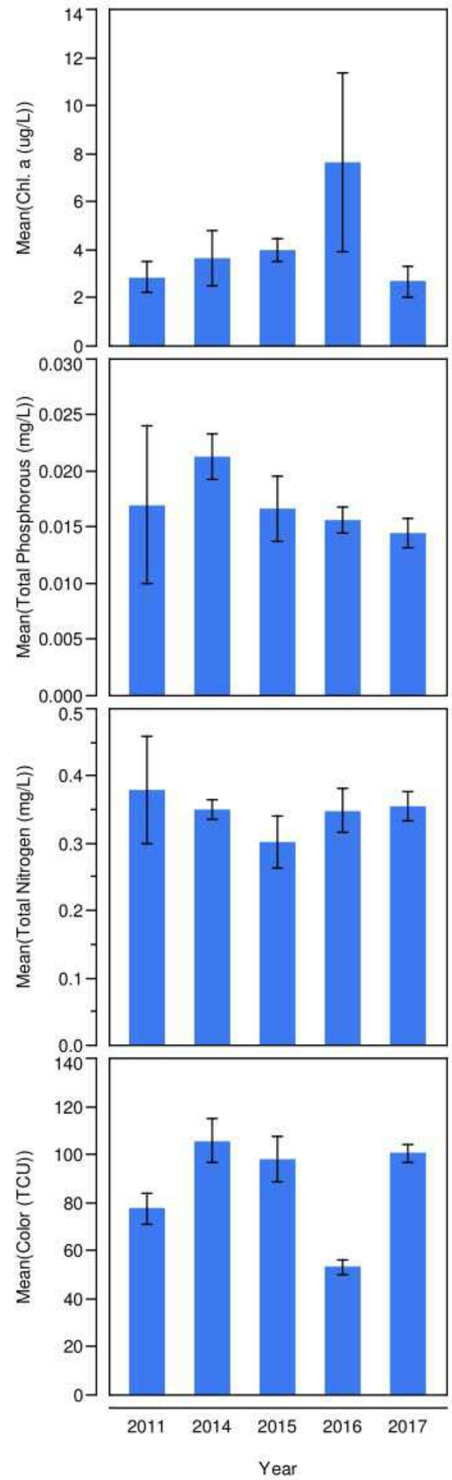
*** Trends for WQI are relative to 2016 only.**
Numbers in red indicate exceedances of the criteria. n.s. indicates non significant result.

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

Long-term trends:

The long-term trends for Lake Armstrong are similar to those reported for Lake Torment. The concentration in chl.a declined from close to 8 µg/L in 2016 to less than 4 µg/L in 2017. The concentrations in both TP and TN remained fairly similar since 2011. The value for colour increased in 2017, back to values comparable to 2014 and 2015.

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



4 Conclusions and Recommendations

The following recommendations are suggested for the Kings County Lake Monitoring Program and have been carried forward from previous reports with changes based on the 2017 data:

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

The colour values and dissolved organic carbon (DOC) concentrations in the KCVLMP lakes are naturally very high with the exception of Sunken and Tupper lakes where the water is clear. These values reflect the input of terrestrial organic matter that enters the lakes via run-off. The low nutrient levels recorded in the lakes indicate that the organic matter loading is nutrient poor, as observed in most boreal shield lakes. In the Atlantic regions, high DOC and colour in lake water are associated to the presence of *Sphagnum* bogs in the watershed. Because of the strong connection between the land and the water, this report would benefit from a better understanding of the importance of wetlands in the watershed of each lakes, coupled with an assessment of annual and seasonal precipitations.

Although nutrient levels are low in most of the KCVLMP lakes, the influence of the watershed on colour or DOC indicates that local residents should continue and maintain programs aiming at reducing nutrient loading to the lakes. Although most of the WQI rating was good in 2017, it does not mean that the lakes will remain in good health if nutrient loading was to increase in the future or climate change effects to lake biological, physical and chemical processes.

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

1) Continue with volunteer monitoring programming for all lakes. Ensure consistency of monthly data collection events to allow detection of seasonal trends. Two new lakes were added in 2014 and additional data would be required to understand their characteristics (and year to year variations). Most of the lake WQI increased this year: although this is good news for 2017, it also indicates that the value varies greatly from year to year. Some lakes were rated with a poor WQI last year, showing improvement this year, which calls for continued monitoring. Although the cause of such variability is not well understood, the analysis would benefit from considering weather related variables, as well as potential long-term changes in the climate.

2) As per the recommendation from TAC in 2016, the report card includes a temporal trend of colour that was not part of previous report. In 2016, colour declined in most lakes and this finding could explain why more algal biomass was observed in the lakes, as they become clearer (allowing for additional algal production). In 2017, the trends in colour was not as clear as in 2016. In some lakes, colour came back at level

comparable to before 2016. It is recommended that variables such as colour, turbidity and Secchi depth continue to be monitored as part of this study to better understand their effects on other variables (such as chl.a).

3) As noted in previous years, with this long-term data set, the opportunity to relate long-term changes to watershed characteristics is evident. The analysis will benefit greatly from the following estimates:

   a. Lake surface area and volumes for all lakes;

   b. Watershed area;

   c. Land use (residential, resource forest, wetland cover);

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

   e. Number of residences along the shores of the lakes;

   f. The presence of beaver dams;

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

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

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

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

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

   An alternative approach would consist in recording algal observations (see template shared in 2016 report).

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

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

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

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

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

9) Despite a weak relationship between nutrients and chl.a reported in this study, , significant increase in lake productivity and chl.a levels would be expected if additional

nutrients were added to the watershed. Therefore, nutrient control and reduction strategies are recommended to maintain good water quality and protection of desired water uses. Communities in the watersheds of study lakes are encouraged to continue to use best practices and reduce/ limit nutrient releases from all sources to protect lake water quality.

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

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Supplemental Results of the 2017 Water Quality Survey of Fourteen Lakes in Yarmouth and Digby Counties

Prepared for

Carleton River Watershed Area Water Quality Steering Committee

By

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Hebron, N.S.

April, 2018.

SUMMARY

Water quality surveys carried out by or for Nova Scotia Environment (NSE) between 2008 and 2015 within the Carleton, Meteghan, and Sissiboo watersheds have shown a number of lakes within these watersheds to be seriously degraded with respect to high nutrient enrichment, leading to high algal concentrations. These studies have also shown this degradation to be primarily due to high phosphorus inputs. While multiple nutrient sources have been identified including agricultural, aquaculture, and likely residential sources, previous studies have indicated releases associated with a number of mink farming operations in the area as likely the largest single source of the nutrients. As a result, the Nova Scotia Department of Agriculture developed and enacted the Fur Industry Act, and associated Regulations, which were enacted in 2013. These include a number of measures designed to minimize the impact of fur farming operations on water quality.

In order to assess water quality trends in the survey lakes, NSE has encouraged and supported efforts to establish a long-term water quality monitoring program that could be executed with the aid of a community-based volunteer organization. Such a program could serve to identify changes in water quality, including potential problem areas. This work can help identify the need for additional studies and mitigation measures. It can also help evaluate the effectiveness of mitigation measures implemented to reduce the impact of fur farming operations on water quality. This work, involving volunteer monitoring, began in 2013, and has continued in subsequent years, with the financial assistance of the Nova Scotia Department of Environment, Salmon Association's Adopt-a-Stream program, Mersey-Tobeatic Research Institute, Municipality of the District of Yarmouth, Municipality of Argyle, and in-kind support from the Nova Scotia Department of Fisheries and Aquaculture.

Beginning in 2015, the monitoring program has been under the oversight of the Carleton River Watershed Area Water Quality Monitoring Steering Committee, which consists of representatives of concerned government departments, concerned municipalities, Nova Scotia Power, the mink farming industry, concerned NGO's and affected citizens. The Committee works under the auspices of the Municipality of the District of Yarmouth, and is chaired by the Municipality's Chief Planning Officer.

In 2016, for the first time, local volunteers took the lead in monitoring in all lakes.

In 2017, Stantec was engaged to do a case study on the system in order to develop a complementary data base, clarify environmental stressors in the system, and develop related recommendations related to management, education, and future research. Their work and subsequent report focused on spring runoff in headwater lakes and the summer situation in all lakes but Raynards, Salmon, and Kegeshook.

This report will complement the work by Stantec and focus on data from the spring and autumn of 2017, as well as the summer data from Raynards, Salmon, and Kegeshook, and as appropriate, consider trends for the entire system.

The results from the 2017 sampling program continued to show that total phosphorus levels decreased along the main Carleton, from upstream to downstream, with low levels observed in the

tributary lakes of Porcupine and Sloans. The year-to-year decrease in total phosphorus levels, first noted in the summer of 2015 on the mainstream Carleton, continued in 2017, in Digby County lakes, but there were slight upticks in Raynards and Vaughan, on the lowermost Carleton. Total nitrogen and colour levels were uniformly up from 2016. These upticks are probably a result of increased precipitation in 2017.

It is possible that the continued drop in phosphorus and orthophosphate in the upper Carleton, combined with an unprecedented increase in these parameters in the lower lakes along the Carelton mainstream reflect the start of a return to more normal conditions, where downstream levels tend to be higher than those upstream.

Nutrient and chlorophyll levels in Nowlans were down from the previous year for the first time since data have been collected. The microcystin level was also below measurable limits for the first time since 2013.

Trends in Hourglass remain a concern. To date, no blooms have been recorded, but given the right conditions, they can be anticipated, if trends in nutrient levels continue.

Kegeshook remained borderline low-mesotrophic, but a heavy bloom observed near the boat launch site in late June, combined with high transparency and a high level of cottage development generate concern about the future condition of the lake. Education about the importance of minimum shoreline development targeted at land owners in the catchment, combined with municipal by-laws limiting such development, are advisable.

Salmon River Lake showed no alarming trends, but continued monitoring is advised.

To the extent that funds permit, cyanobacterial monitoring is desirable both shortly after the summer solstice, when blooms tend to peak, and late August, when stratification tends to be maximal. The merits of continuing expensive testing for microcystins in lakes other than Nowlans are questionable.

Assessing the contribution of nutrients from other sources besides the upstream Carleton certainly has merit, but costs and other practicalities intrude. Water chemistry monitoring at the mouths of inlets and outlets of selected lakes is practicable, given sufficient funding, but flow measurements are considerably more challenging. Further discussion is needed.

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Supplemental Results of the 2017 Water Quality Survey of Fourteen Lakes in Yarmouth and Digby Counties

1. Background

Since 2008,nine water quality studies have been carried out on a number of lakes located within the Carleton, Meteghan and Sissiboo River watersheds, under the auspices of, or on behalf of the Nova Scotia Department of Environment (NSE), with significant supplementary support from the Nova Scotia Salmon Association's Adopt-a-Stream program, Mersey-Tobeatic Research Institute, and Yarmouth County municipalities. According to Brylinsky and Sollows (2014), the studies done annually from 2008 to 2011 showed many of the lakes to be seriously degraded as a result of high phosphorus inputs. While nutrients come from many sources, the predominant spatial pattern of nutrient distribution reported in these studies, particularly Brylinsky (2012), presented strong evidence that these high phosphorus levels resulted primarily from releases emanating from mink farming operations. In some instances the high algal concentrations associated with these nutrients contained species of cyanobacteria (blue-green algae) known to produce microcystins, a toxin that, under certain conditions, may be harmful to humans, livestock and wildlife.

The Department of Agriculture has various measures in place to mitigate potential impacts from agricultural activities on water quality, including the Nova Scotia Fur Industry Act and Regulations, which were enacted in 2013.

The Department of Environment has supported efforts to establish a long-term water quality monitoring program that captures the annual changes in water quality – providing an indication of the efficacy of mitigation programs and controls implemented to reduce nutrient related impacts. Accordingly, in 2013 a water quality study was designed and implemented that could form the basis of a routine annual survey to meet this need, and one that could in the future be carried out primarily by a community volunteer based organization. In 2013, the Tusket River Environmental Protection Association (TREPA) carried out this survey with the assistance of the Acadia Center for Estuarine Research (ACER) of Acadia University. TREPA took the lead in carrying out similar studies in subsequent years, with help from the Nova Scotia Department of Fisheries and Aquaculture.

Beginning in 2015, the monitoring program has been under the oversight of the Carleton River Watershed Area Water Quality Monitoring Steering Committee, which consists of representatives of concerned government departments, concerned municipalities, Nova Scotia Power, the mink farming industry, concerned NGO's and affected citizens. The Committee works under the auspices of the Municipality of the District of Yarmouth, and is chaired by the Municipality's Chief Planning Officer.

In 2017, Stantec was engaged to do a case study on the system in order to develop a complementary data base, clarify environmental stressors in the system, and develop related recommendations related to management, education, and future research. Their work and subsequent report focused on spring runoff in headwater lakes and the summer situation in all lakes but Raynards, Salmon, and Kegeshook.

This report will focus on data from the spring and autumn of 2017, as well as the summer data from Raynards, Salmon, and Kegeshook, and as appropriate, consider spatial and temporal trends for the entire system.

2. Approach and Methods

The basic approach and water sampling methodologies followed those of Brylinsky and Sollows (2014). In addition to the work done by Stantec, additonal samplings were done by Nova Scotia Department of Fisheries and Aquaculture staff in Provost, Nowlans, Placides, and Porcupine. Otherwise, volunteers living on or near each lake took the lead in sampling in the spring, and autumn, and on Raynards, Salmon River, and Kegeshook Lakes. All lakes were sampled in late August, and seven Yarmouth County lakes (Parr, Fanning, Sloans, Raynards, Vaughan, Salmon River, and Kegeshook) were also sampled in early May and late October in order to assess seasonal trends.

Nine annual water quality surveys have been carried out between 2008 and 2017, but not all were carried out at the same time of year. Six (2008, 2011 and 2013 to 2016) were carried out in August, one (2009) in late September, and another (2010) was carried out in late October. No surveys were carried out in 2012. In 2013 and subsequent years, all lakes of interest were sampled in August and when possible, in May and October, as well. In practice, however, this was possible for all lakes only in 2013, and spring and fall sampling other years was limited to the above seven Yarmouth County lakes.

In assessing annual variations in water quality, comparisons need to be made between data for the same season. In the spring and autumn, lower temperatures and stronger winds lead to mixing of deeper and surface water, and this affects surface water quality. The long, warm days of summer, combined with stratification of the water column, tend to lead to worst case scenarios, in terms of algal blooms and maximal stratification. As a result, more attention has historically been paid to the situation in late summer, so analyses of annual changes in water quality in this report were limited to surveys carried out in August and September (i.e. late summer).

With lake stratification in mind, every surface sample collected by volunteers was composite, with half collected at the surface and half at twice Secchi depth. In August, an additional sample was collected 1 meter above bottom at the same time. Nova Scotia Department of Fisheries and Aquaculture staff working in Provost, Nowlans, Placides, and Porcupine sampled separately at 25 cm. and at twice Sechhi depth, as well as 1 meter off bottom. The surface data from these lakes represents an average of results from the two upper depths.

In previous years, these samples had been collected with a Van Dorn sampler. Beginning in 2016, the volunteers used home-made samplers, each consisting of a sturdy, weighted, 500-ml. plastic bottle with a stopper and a measured line. To collect a sample the stopper was pulled with another line, once the bottle reached the desired depth. At depths over 7 m., bottles tended to deform under pressure; in this case, samples collected from near bottom needed to be collected twice, in order to get a full volume for shipment to the lab.

Water chemistry parameters were analysed at the Environmental Services Laboratory of the Nova Scotia Health Authority, with chlorophyll-a analyses outsourced to ALS in Winnipeg. Up to and including the spring of 2016, chlorophyll-a samples were analysed in New Brunswick. The analytical method used in

New Brunswick was Standard Method 10200 H Spectrophotometric Determination of Chlorophyll; that used in Winnipeg was based on the Fluorescence Standard Method 10200H, which used frozen, filtered samples. This change in labs may affect year-to-year comparability.

Until 2015, a YSI Professional Series multimeter was used to collect various data at the sampling site, including dissolved oxygen, temperature, pH, and conductivity. Since 2016, when sampling was done by volunteers, the meter in question has not been available, so these data, particularly oxygen and temperature profiles, are not available. pH was assessed as part of the water chemistry analyses, but this change in method does affect comparability between 2016-17 and previous years.

In addition to water quality, shoreline sampling for cyanobacteria and microcystin was carried out in historically targeted lakes in August. Selected sites were on the windward side of lakes and/or at locations where there were visible blooms, when possible. All bottles were opened about 25 cm. below the surface. Lugol's solution was added as a fixative for the cyanobacterial samples at 10 drops per 100 ml. All bottles were capped immediately after collection and kept cold by application of freezer packs. Samples were kept cold and in the dark to prevent degradation until they could be analysed at the ALS laboratory in Winnipeg.

For the first time this year, additional samples for cyanobacterial speciation and abundance were also collected in later June to /early July, in order to catch the blooms at peak abundance.

3. Results

The complete database for all NSE-supported surveys carried out to date is available as an Excel database held by the Tusket River Environmental Protection Association and the Municipality of the District of Yarmouth. Appendix 1 contains the database used in the current analyses, and Appendix 2 contains a series of bar graphs for each lake illustrating the results of all late summer surface water surveys carried out between 2008 and 2017. Appendices 3 and 4 show the data bases used to assess seasonal trends, and surface and bottom contrasts, respectively.

Summer 2017 water chemistry results from Parr and Ogden are not included because of sampling issues.

Comparisons with 2016 levels are based on Sollows (2017).

3.1 Annual and Spatial Variation in Lake Trophic Status

Stantec (2017) has covered the 2017 summer situation in most lakes. This report will focus on results from spring and fall, as well as those from Raynards, Salmon River, and Kegeshook Lakes, which were not part of that report, and consider the extent to which data from these three lakes add to the overall picture.

The duration of the cyanobacterial blooms in most of the Carleton system lakes was comparable with that in 2016, with a couple of exceptions. A resident on Ogden indicated that the duration was shorter than in 2016; by contrast, the bloom in Fanning lasted over a month longer, disappearing only in the early autumn (Cleveland, pers. comm.).

Spatial considerations focus on the lakes in the Carleton catchment.

Chlorophyll-a:

August chlorophyll-a levels were considerably down in Kegeshook and Salmon and slightly up in Raynards. Increases were also noted in Hourglass, Wentworth, and Vaughan.

By 2017, the tendency for chlorophyll levels to drop in mainstream lakes from upstream to downstream had more or less disappeared. Highest levels within the Carleton appeared to be in Hourglass and Vaughan.

Total Phosphorus:

Overall, along the Carleton, levels appeared to be down from 2016 in the upper river, and up from 2016 further downstream. Hence, surface August total phosphorus level was barely down from 2016 in Fanning and up in Raynards and Vaughan.

Levels were down slightly in Kegeshook and considerably down in Salmon. No records were set.

The tendency for total phosphorus levels along the main Carleton to drop from upstream to downstream remained consistent in 2017, as in previous years, as were the relatively low levels in the tributary lakes, Porcupine and Sloans. Phosphorus levels in Hourglass, another tributary lake in the upper catchment, while high, were still well below those seen in Placides, and Wentworth on the Carleton mainstream.

Orthophosphate levels were unchanged in Raynards, and up in Fanning and Vaughan where a record was set.

They were unchanged in Kegeshook, and up slightly in Salmon.

Orthophosphate: total phosphorus ratio

Dissolved inorganic phosphate (orthophosphate) is the form of phosphorus immediately available to living things, but other forms of phosphorus can be converted into orthophosphate under certain conditions, such as anoxia. High orthophosphate: total phosphorus ratios, combined with high phosphorus levels are causes for concern. Arbitrarily, a ratio of greater than .5 or higher at a total phosphorus level of 0.02 mg/l has been taken as a threshold. On this basis, Placides, Wentworth, and Nowlans would be flagged in 2017.

Compared with 2016, the orthophosphate : total phosphorus ratio was up in most lakes, with drops noted only in Porcupine, Raynards, and Nowlans.

Colour:

Except for Sloans, surface August colour was up in all lakes from 2016, markedly so in most cases. Increases of around 100% were noted in Fanning, Salmon, and Provost.

The spatial pattern in the Carleton system is similar to that in other years. Hourglass and Placides show similar, high colour levels. Colour peaks in Wentworth, then drops consistently downstream. Again, the very low colour level in Sloans indicates a vulnerability to algal blooms, should nutrient levels become sufficient. It is also worth contrasting the high colour levels in Placides and Hourglass, where blooms were not noted despite high phosphorus levels, with the much lower colour levels in Nowlans and

Porcupine. Like Sloans, the low colour levels in Porcupine make it vulnerable to blooms, should nutrient levels be sufficient.

Secchi Depth Transparency:

Secchi depth tends to be inversely related to colour, turbidity, and level of suspended particles in the water.

Given the consistent increase in colour from 2016 to 2017, Secchi depth transparency measurements would be expected be uniformly down. Actually, half the lakes (Hourglass, Porcupine, Ogden, Raynards, Vaughan, Provost, and Nowlans) showed Secchi depths higher than those in 2016.

Total Nitrogen

August surface total nitrogen levels was up slightly from 2015 on all lakes for which data were available, except for Wentworth, which showed a slight drop.

The historically decreasing trend in total nitrogen levels from upstream lakes to downstream lakes is still present, but has weakened from earlier years. The overall spatial pattern is very similar to that in 2016.

Surface August nitrate levels were below detectable limits in 2016 in every lake except Nowlans. Since 2013, this has been more the rule than the exception.

pH

August surface pH levels showed little change in most lakes from 2016. Wentworth showed the most appreciable rise, and Kegeshook and Salmon the most notable drops.

3.2 Seasonal Variation in Trophic Parameters

Water quality data were collected in May August, and October in seven selected lakes in Yarmouth County, as well as in July for certain lakes in 2013 and 2014. Bar graphs summarizing these seasonal variations are given in Appendix 3, and are considered briefly here.

Except for oligotrophic Sloans, chlorophyll-a levels tend to drop sharply between August and October. In 2017, October levels in Fanning were also similar to those in August. Peaks were common in summer, but not universal. Levels were down from 2017 in all cases, except for the summer levels in Raynards and Vaughan.

High autumn levels for total phosphorus have been the norm most years, except in Sloans, and probably reflect turnover of more nutrient-rich bottom water and less absorption by plants and phytoplankton, in light of lower temperatures and shorter photoperiods. Seasonal levels and patterns were similar to those in 2016, with a few exceptions: October levels were decidedly up in the Carleton system from Fanning on downstream, and August levels were higher in Raynards and Vaughan. By contrast, in both Kegeshook and Salmon, spring levels were slightly up over 2016 while August and October levels were down. The declining trend in phosphorus noticed from 2014 to 2016 in the lower Carleton did not continue.

Spring and fall orthophosphates levels were up in most lakes. There were exceptions for May and August in Kegeshook, May in Fanning and August in Raynards, where levels were essentially unchanged from

2016. Spring and summer levels in Sloans were down from 2016. The annual pattern in Vaughan showed a drop in from August to October, in contrast to the other lakes. Year-to-year trends in orthophosphate levels have not returned to earlier high levels but bear further monitoring.

Spring orthophosphate: total phosphorus ratios were down in all cases but Fanning (unchanged) and Salmon (up). Later levels were up or unchanged in all cases except for August in Raynards and October in Sloans and Vaughan.

Colour levels in May were down from 2016, and up in August and October, in all cases except the August level in Sloans.

Except for a decrease for Parr in May, total nitrogen levels were up from 2016, for all cases. Levels were highest in October except in Salmon (slightly down from August) and Sloans (where levels dropped from May to October). Vaughan showed an August minimum. There were insufficient data to detect any seasonal patterns with regard to nitrate because most levels were too low to be measurable.

pH was seasonally low in May in all lakes but Kegeshook, and spatially, tended to climb downstream from Parr to Fanning to Raynards, which receives the inflow from Sloans. Otherwise, Salmon showed a slight drop in pH from 2016, which was consistent for all seasons. More generally, there was a continued tendency for seasonal pH lows in May, and a possible tendency for pH to rise from year to year bears further monitoring.

3.3 Surface and Bottom Comparisons of Trophic Parameters

Surface and bottom sampling was done only in August when stratification is normally observed. This section will focus on the data from Raynards, Kegeshook, and Salmon, since Stantec (2017) covered this issue for the other lakes. Appendix 4 provides the pertinent graphical comparisons. Total phosphorus is given the most attention since it is likely the chemical parameter most strongly linked to trophic level.

Like most other lakes, bottom phosphorus levels were considerably higher than surface levels in Raynards and Kegeshook, and set record highs in both lakes. By contrast, bottom phosphorus in Salmon was similar to the surface level in Salmon and at a record low 2016.

Orthophosphate patterns were similar, except in Salmon, where the bottom level was unusually much lower than the surface level.

Orthophosphate: total phosphate ratios in bottom waters were higher than the ratios in surface waters for Raynards and Kegeshook, but considerably lower in Salmon.

Surface and bottom total nitrogen levels were not remarkable, except in Salmon, where surface total nitrogen was higher than on the bottom. Changes from 2016 were up in all of Raynards, Salmon, and Kegeshook.

Colour levels tended to be considerably more homogeneous than in 2016, although bottom levels were clearly higher in Raynards and Vaughan.

Bottom colour was up over 2016 in all three lakes and similar to surface colour. Bottom colour in Raynards was noticeably higher than surface colour.

Surface and bottom pH were similar to levels in 2016.

3.4 Cyanobacterial Abundance, Composition and Presence of Toxins

Appendix 6 gives cyanobacterial counts, percent species composition, and microcystin levels by lake and year. This year, for the first time, sampling was also done in late June-early July, when blooms tended to be maximal.

In general, patterns did not differ much from those reported in Sollows for 2016 (2017). Given the method of sample collection, the raw cell counts cannot be compared with much rigour. In 2017, high levels (over 2,000 cells/ml) were recorded from Nowlans (20,320/ml), Hourglass (3,468/ml), Placides in July (4,314), Ogden in July (2,630), Fanning in July (2,410), Raynards in July (6,170), Vaughan in July (5,492), and Kegeshook June 28 (19,296). August counts were up in Provost, Porcupine, Ogden, Fanning and Vaughan, with no record highs set, and record August lows were reported from Nowlans, Parr, and Raynards.

Bloom patterns were similar to those in 2016, except that the bloom in Fanning lasted considerably longer (Cleveland, pers. comm.). Also, Keizer (pers. comm.) reported a heavy bloom at the Wentworth River inlet to Wentworth Lake, but this site had never been checked before. As with other years, no bloom was detected in the lower part of Wentworth lake, where deep station sampling is done.

Cyanobacterial levels dropped from July to August in all lakes sampled both months, except for Hourglass, Porcupine, and Wentworth.

Microcystin, if present, was below detectable levels in all lakes, including Nowlans, for the first time since 2013.

4. Discussion

4.1 Spatial and Temporal Considerations in the Carleton Catchment

As Stantec (2017) pointed out, the winter of 2016-17 and the spring and summer that followed were more typical in terms of precipitation than the previous year. The record-setting drought of 2016 was not repeated, and this would have affected water quality parameters.

This section attempts to explain the temporal and spatial variation in August surface chlorophyll-a readings, as a reflection of various environmental parameters, most notably nutrient and light availability. This year, there was no overall spatial trend in chlorophyll-a levels; the highest reading on the Carleton catchment came from Hourglass, the highest-lying tributary lake, and the second highest from Vaughan, just below the mouth of the Carleton

As in previous years, there was a consistent drop from upstream to downstream in terms of both total phosphorus and orthophosphate. The only notable exception to this was the rise in orthophosphate from Raynards to Vaughan. Total phosphorus levels were down from 2016 for all Digby lakes, but tended to show slight increases from Fanning downstream. Changes in orthophosphate levels along the Carleton mainstream showed a similar tendency

The pattern for surface total nitrogen was similar to that in 2016, showing a weak tendency to drop from upstream to downstream. Levels were up from 2016 in all lakes but Wentworth.

As in 2016, summer surface colour levels along the mainstream Carleton were higher in the Digby County lakes, peaked in Wentworth, and were lowest in Raynards, and colour was up from 2016 in all lakes except Sloans.

The higher precipitation in 2017 probably affected the increases in both colour and total nitrogen over 2016.

In general, high nutrient levels, particularly high phosphorus levels, tend to increase production, and hence have a positive effect on chlorophyll levels. High levels of colour interfere with light penetration and have the opposite effect. Hence, the drop in phosphorus, combined with rise in consistent colour would help explain the drop in chlorophyll levels in most of the Digby County lakes. By contrast, in Raynards and Vaughan, the uptick in chlorophyll-a may be directly due to phosphorus (and in Vaughan especially orthophosphate) increases. Colour levels in these lakes are lower than in the upstream lakes and therefore less likely to be limiting.

The high level of chlorophyll-a in Hourglass is anomalous: Colour was up and phosphorus slightly down from 2016, so chlorophyll should have dropped, not risen. Placides had much higher phosphorus and orthophoshate levels, and slightly higher colour and total nitrogen, but much lower chlorophyll-a. A colour threshold of some sort might be operating (Colour from Hourglass was 80.4 TCU's, while the figures from Placides were between 96 and 100 TCU's). Hourglass bears continued monitoring.

The four lakes outside the Carleton basin show a variety of conditions.

The level of chlorophyll-a in Nowlans has historically been the highest of any lake, by virtue of its very low colour and very high surface phosphorus level. This year, chlorophyll-a was sharply down, and probably reflects a considerable increase in colour, combined with a levelling-off in phosphorus. The anomalously high chlorophyll level in Hourglass was similar to Nowlan's, but no bloom was observed there; this may reflect the higher colour level in this lake.

The chlorophyll-a level in Provost was unremarkably down from 2016, reflecting a minor drop in phosphorus and considerable increase in colour.

The summer chlorophyll-a level in Salmon was down 77% from the level in 2016; phosphorus was down by 44% and colour was more than double the 2016 level. At 108 TCU's there is a good chance that colour was limiting production.

In Kegeshook, surface summer chlorophyll-a was down by 82% from 2016. A slight drop in phosphorus levels and a more substantial increase in colour would explain some of this, but given the low colour (56.5 TCU), other factors may also be operating..

4.2 Seasonal Variation and Surface and Bottom Comparisons of Trophic Parameters

These issues are interrelated and therefore are considered jointly.

The high bottom phosphorus levels noted in Raynards and Kegeshook are usual and may reflect in part mobilization of phosphorus from bottom sediments under low oxygen conditions.

Salmon, by contrast tends to be a well-mixed lake. That does not completely explain the **higher** surface levels of both orthophosphate and total nitrogen in Salmon, compared to the bottom, but the mixing would tend to mitigate the usual contrast between upper and lower levels.

Total nitrogen contrasts between surface and bottom were less consistent than in 2016. Like last year, most lakes showed higher levels near the bottom, but there was near homogeneity in a number of lakes, including Kegeshook. Also, surface total nitrogen was higher in Salmon. Higher precipitation in 2017 may explain the differences from 2016.

Colour levels tended to be considerably more homogeneous than in 2016, although bottom levels were clearly higher in Raynards and Vaughan, This was probably a result of the higher precipitation in 2017.

Spring and fall data are limited to seven lakes in Yarmouth County. Chlorophyll-a levels from those seasons were down in all seven lakes from 2016.

Spring phosphorus levels were similar to those in 2016 except for increases in Raynards and Kegeshook. Post-spring phosphorus levels were up to varying extents in all lakes except for drops in Kegeshook and Salmon. Changes in orthophosphate levels were less consistent, but the only decreases were spring readings in Sloans and Vaughan. The only year-to-year drops in total nitrogen were the spring readings from Parr and Kegeshook, and they were minor. So none of these account satisfactorily for the drop in chlorophyll-a. The year-to-year changes in colour, however, were much more consistent. Spring levels were uniformly slightly down from those in 2016 in all lakes, but, summer in Sloans aside, summer and autumn levels were consistently up. These increases in colour may not completely explain the drops in chlorophyll-a from 2016, but would play a role.

Summer chlorophyll maxima were the norm, although levels in Fanning did not change between August and October. This drop is normal and probably reflects drops in photoperiod and temperatures, notwithstanding the autumn increase in surface nutrients, which is due to turnover as temperatures drop and winds strengthen.

4.3 Cyanobacterial levels, species, and toxins

As earlier noted, comparisons of algal counts must be interpreted with caution because of the collection method. Given the increase in colour levels, counts would be expected to be down from 2016. Instead, levels were up in five lakes: Porcupine, Ogden, Fanning, Vaughan, and Provost. The 2016 sampling in Ogden and Fanning happened respectively during and just after a cyanobacterial crash. There is no convenient explanation for the increase in the other three lakes, but all are relatively low in colour; the increases in available phosphorus in Vaughan and Porcupine do not apply in Provost.

The high cyanobacterial count reported from the June 27 sample from Kegeshook contrasts with the August 28 water quality data. Spring total phosphorus and orthophosphate levels were higher than those in the summer, and spring colour levels were lower. Otherwise the cyanobacterial sampling was done from near the boat launch site, an area with more cottage and lawn than forest in the immediate vicinity.

Hence, the high count is likely a local phenomenon to some extent, but does speak to the vulnerability of Kegeshook to cyanobacterial blooms.

Zero counts were reported from July in Hourglass and Salmon and the July count in Wentworth (10/ml) was extremely low.

When funding permits, it is probably worth sampling both in early July (when blooms normally peak) and late August (when summer conditions of stratification tend to leak).

No measurable level of microcystin was detected in Nowlans Lake in 2017, for the first time since 2013. Total phosphorus and orthophosphate levels were also down for the first time since these data were collected. Continued monitoring is needed to determine if this is the start of a trend towards decreased eutrophication.

4.4 Calculated Carlson Trophic State Indices

Relevant data and histograms are given in Appendix 7.

The Carlson Trophic State Index is an imperfect, but convenient, way of estimating the trophic health of a lake. The index is based on levels of chlorophyll-a and total phosphorus, as well as Secchi depth; as chlorophyll-a and total phosphorus increase, so does TSI, and as Secchi depth increases, TSI drops, since it is based on the assumption that transparency is based primarily on plankton density. Hence, a high TSI implies a higher level of eutrophication.

No single number can adequately reflect the trophic health of a lake. The utility of the Carlson TSI in the lakes under study is further compromised by the high colour level in many of the lakes under study. Colour reduces both Secchi depth and productivity. Here, this has been addressed historically by dropping Secchi depth from the calculation in any lake where the colour was higher than 125TCU, because above this level, colour seems to have a significant negative effect on cyanobacterial abundance and chlorophyll-a levels. In 2017, summer levels in Wentworth and Salmon were over this threshold, so Secchi depths were ignored in their cases.

Carlson TSI's below 40 are considered to reflect oligotrophic situations; mesotrophic lakes have indices between 40 and 50; eutrophic lakes between 50 and 70, and hypereutrophic lakes have indices over 70.

On this basis, Sloans has been consistently oligotrophic, and Porcupine fell into the barely oligotrophic category for the first time this year. Kegeshook and Salmon have been consistently mesotrophic, Raynards has been mesotrophic for the last three years, Provost for two years, and Fanning for the first time since 2008. Vaughan's TSI crept up into the barely eutrophic category. Three other lakes (Hourglass, Placides, and Wentworth) were all eutrophic; this was the second year for formerly hypereutrophic Placides to fall into this category. Nowlans remained hypereutrophic.

Reliable summer data were missing for Parr and Ogden, but spring and autumn data for Parr indicated trophic levels higher than that of Fanning, and given spatial tendencies, both lakes likely remained in eutrophic territory in 2017.

August TSI levels were mostly down or virtually unchanged from 2016; significant increases were noted only in Sloans and Vaughan, with a barely perceptible increase in Raynards . August TSI indices have dropped consistently from 2013 in Provost, Placides, and Porcupine. Consistent drops since 2014 were noted for Wentworth and Fanning. The sharp drop since 2015 in Nowlans also deserves note.

Besides the increases in Sloans and Vaughan, future trends in Raynards and Hourglass bear monitoring. Raynards and Vaughan are low in colour and are the lowest-lying lakes in the Carleton catchment. The higher precipitation in 2017 and concomitant increases in nutrients in both lakes may explain the reversal to previous falling trends. Sloans and Hourglass have more limited catchments and had less consistent changes in nutrient levels. Sloans' low colour would make it more susceptible to effects of nutrient increase. And while the TSI in Hourglass dropped, the change (about 0.7%) was not significant.

5. Final Considerations

The very strong tendency for the high total phosphorus levels along the main Carleton to drop from upstream to downstream remained consistent in 2016, as was the contrast with the low levels in the tributary lakes Porcupine and Sloans. Summer phosphorus levels continued to drop from the previous year in mainstream Digby county lakes, but not in the lakes from Fanning down. An examination of seasonal trends from the Yarmouth county lakes indicates that with the exception of Parr, 2017 spring levels were similar to or lower than spring levels from 2016. By autumn, levels in 2017 were consistently higher than in 2016. This may reflect the higher precipitation in 2017.

This contrast in patterns between the upper and lower Carleton lakes may imply the start of a return to more typical watershed conditions, where levels of dissolved solids tends to increase from upstream to downstream, as running water accumulates dissolved solids. However, the present pattern of blooms is likely to continue into the foreseeable future, until nutrient levels drop below levels critical to bloom development.

Nowlans remained hypereutrophic in 2017, but for the first time, nutrient levels were down from the previous year, decidedly so in most cases. Chlorophyll was also down, and microcystin was below measurable levels. Given the low colour level and extremely high nutrient levels in this lake, visible blooms are likely to continue for years to come, but this year's changes give cause for optimism, for the first time.

Nutrient trends in Hourglass are less reassuring. This lake's high colour levels may have protected it from blooms so far, but given the right combination of parameters, blooms may well appear at any time.

In Kegeshook, bottom nutrient levels were all up from 2016, but changes in surface parameters were less consistent and minor, when they occurred. Nutrient levels remain low, compared to many of the lakes in this study, but low colour levels make this lake vulnerable to blooms. This year's late June bloom and the growing density of cottage development around this lake are cause for concern. Continued education focusing on landowners around Kegeshook and upstream lakes, combined with by-laws limiting shoreline development are desirable.

In Salmon, while total phosphorus was down from 2016, orthophoshate and summer and autumn total nitrogen were up. This may be a result of higher precipitation in 2017. Surface orthophosphate and total nitrogen were also unusually higher at surface than at bottom in this lake. The tends to be well-mixed, so differences tend to be small. That makes the contrast in orthophosphate particularly difficult to explain.

Monitoring of cyanobacterial blooms deserves less priority than water chemistry monitoring, but does help add to overall understanding. Should funding be available, it is desirable to monitor twice during the summer: a week or two after the summer solstice, when blooms tend to peak, and late in /august, when summer stratification tends to be maximal. The need to continue monitoring for microcystin at past levels is more questionable: The tests are very costly. Measurable levels have been found only in Nowlans, and overall patterns in nutrient and chlorophyll levels suggest a gradually improving scenario. The Steering Committee should consider suspending microcystin monitoring, except in Nowlans.

Nutrients come from many sources, and the desirability of monitoring nutrient inputs from various inlets into lakes in the system is recognized. Anomalous data suggesting significant phosphorus loading into Parr and Fanning from sources besides the upstream Carleton are of particular interest. Monitoring water quality at inlets and outlets, as well as at mid-lake stations, has merit and should be continued, if funds allow, in order to better understand lake conditions and nutrient dynamics.

In order to quantify the contributions from these inlets, though, flow volumes are needed. The practicability of achieving this with volunteer help is under discussion. Stationary gauges would appear to be the most practicable option, but getting them installed and operational is costly in terms of both money and time. The added cost and effort of doing this on all lakes would be considerable. Also, inputs from overland flow, seepage, and point sources would not be included. More discussion is needed on if and how to address this.

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Appendix 1. Data Base Used in Analyses

Lake_ID	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Orthophosphate (mg/l)	**OrthoP/ Total P ratio**	Total nitrate (mg/l)	Total Nitrogen (mg/l)	Colour (TCU)	pH
Hourglass	Aug. 13/2008	1.30	15	0.069	0.034	0.493	0.03	0.57	60	6.2
Hourglass	Sept. 25/2010	1.25	13	0.050	0.022	0.440	0.01	0.35	58	6.80
Hourglass	Aug. 13/2011	1.40	2.1	0.045	0.018	0.400	0.04	0.64	89	6.80
Hourglass	Aug. 12/2013	0.63	7	0.056	0.029	0.518	<.01	0.56	161.7	6.07
Hourglass	Aug. 18/2014	0.80	44	0.067	0.037	0.552	<.01	0.45	145.2	6.31
Hourglass	Aug. 17/2015	0.93	19	0.065	0.038	0.585	<.01	0.4	105	6.35
Hourglass	Aug. 21/2016	0.925	44.9	0.08	0.026	0.325	<.01	0.39	66.5	6.5
Hourglass	Aug. 24/2018	1	49.8	0.073	0.028	0.383562	<.02	0.41	80.4	6.7
Placides	Aug. 13/2008	1.30	20	0.740	0.58	0.784	0.35	1.69	68	6.50
Placides	Sept. 26/2010	0.70	15.5	0.820	0.705	0.860	0.47	1.23	90	6.90
Placides	Aug. 22/2011	ND	2.8	0.960	0.786	0.819	0.58	1.83	117	6.80
Placides	Aug. 6/2013	0.40	52	0.792	0.764	0.965	0.52	1.34	227.8	6.80
Placides	Aug. 25/2014	0.63	32	0.806	0.611	0.758	<.01	0.57	149.5	ND
Placides	Aug. 26/2015	0.95	22	0.698	0.592	0.848	<.01	0.5	126	ND
Placides	Aug. 30/2016	1.40	15.1	0.624	0.5725	0.917	<.01	0.38	66	6.90
Placides	Aug. 22/17	3.375	8.28	0.618	0.506	0.81877	<.01	0.46	98.6	6.2
Placides	Aug. 29/17	1	4.01	0.609	0.512	0.840722	<.01	0.48	96.8	6.8
Porcupine	Aug. 12/2008	2.50	7.8	0.012	0.005	0.417	0.01	0.22	25	6.60
Porcupine	Sept. 26/2010	1.95	2.8	0.021	0.005	0.238	0.01	0.25	39	6.80
Porcupine	Aug. 14/2011	0.90	3.4	0.014	0.005	0.357	0.01	0.3	46.6	6.90
Porcupine	Aug. 6/2013	0.59	7.0	0.032	0.014	0.438	0.02	0.42	105.3	6.90
Porcupine	Aug. 25/2014	1.63	6.9	0.016	0.005	0.313	<.01	0.28	73.2	ND

Lake_ID	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Orthophosphate (mg/l)	**OrthoP/ Total P ratio**	Total nitrate (mg/l)	Total Nitrogen (mg/l)	Colour (TCU)	pH
Porcupine	Aug. 26/2015	1.90	7.3	0.016	0.003	0.188	<.01	0.24	53.2	ND
Porcupine	Aug. 30/2016	2.30	3.2	0.018	0.0055	0.306	<.01	0.255	30.55	6.80
Porcupine	Aug. 22/17	0.875	2.41	0.017	0.013	0.764706	<.01	0.29	44.7	6.9
Porcupine	Aug. 29/17	2.5	1.13	0.013	0.004	0.307692	<.01	0.3	38.3	6.8
Wentworth	Aug. 12/2013	0.46	14	0.160	0.138	0.863	0.01	0.58	250.6	5.58
Wentworth	Aug. 18/2014	0.33	13	0.187	0.140	0.749	<0.01	0.54	304.1	5.64
Wentworth	Aug. 17/2015	0.6	11	0.130	0.111	0.854	<0.01	0.37	182	6.00
Wentworth	Aug. 21/2016	1.57	3.9	0.154	0.146	0.948	0.06	0.51	115	6.10
Wentworth	Aug. 21/17	0.625	4.63	0.084	0.082	0.97619	<.01	0.46	158	6.3
Parr	Aug. 14/2008	1.5	11	0.033	0.012	0.364	0.01	0.27	64	6.20
Parr	Aug. 24/2010	1	6.7	0.075	0.075	1.000	0.01	0.03	97.2	6.20
Parr	Sept. 26/2010	0.75	13	0.061	0.031	0.508	0.01	0.33	86	6.20
Parr	Aug. 12/2013	0.51	6.1	0.105	0.080	0.762	0.04	0.53	199.6	5.71
Parr	Aug. 25/2014	0.57	11	0.111	0.084	0.757	<0.01	0.49	193.9	5.86
Parr	Aug. 20/2015	1.8	7.8	0.075	0.047	0.627	<0.01	0.41	123	6.26
Parr	Aug. 21/2016	1.35	13.7	0.055	0.022	0.400	<0.01	0.38	67.7	6.30
Ogden	Aug. 14/2008	1.8	10	0.014	0.005	0.357	0.01	0.25	39	6.10
Ogden	Sept. 27/2010	0.95	18.8	0.029	0.008	0.276	0.05	0.35	58	6.30
Ogden	Aug. 24/2011	1.2	12.5	0.022	0.005	0.227	0.01	0.28	59.2	6.10
Ogden	Aug. 6/2013	0.6	9.4	0.052	0.035	0.673	0.02	0.41	145.3	6.40
Ogden	Aug. 25/2014	0.66	26	0.046	0.021	0.457	<0.01	0.44	126.5	6.20
Ogden	Aug. 20/2015	1.17	11	0.022	0.004	0.182	<0.01	0.32	83.2	6.53
Ogden	Aug. 21/2016	1.25	4.46	0.024	0.004	0.167	0.02	0.33	48.6	6.30
Fanning	Aug. 16/2008	2.3	5.8	0.011	0.005	0.455	0.01	0.21	31	6.40
Fanning	Sept. 12/2009	0.75	1.3	0.056	0.037	0.661	0.06	0.4	120	5.90

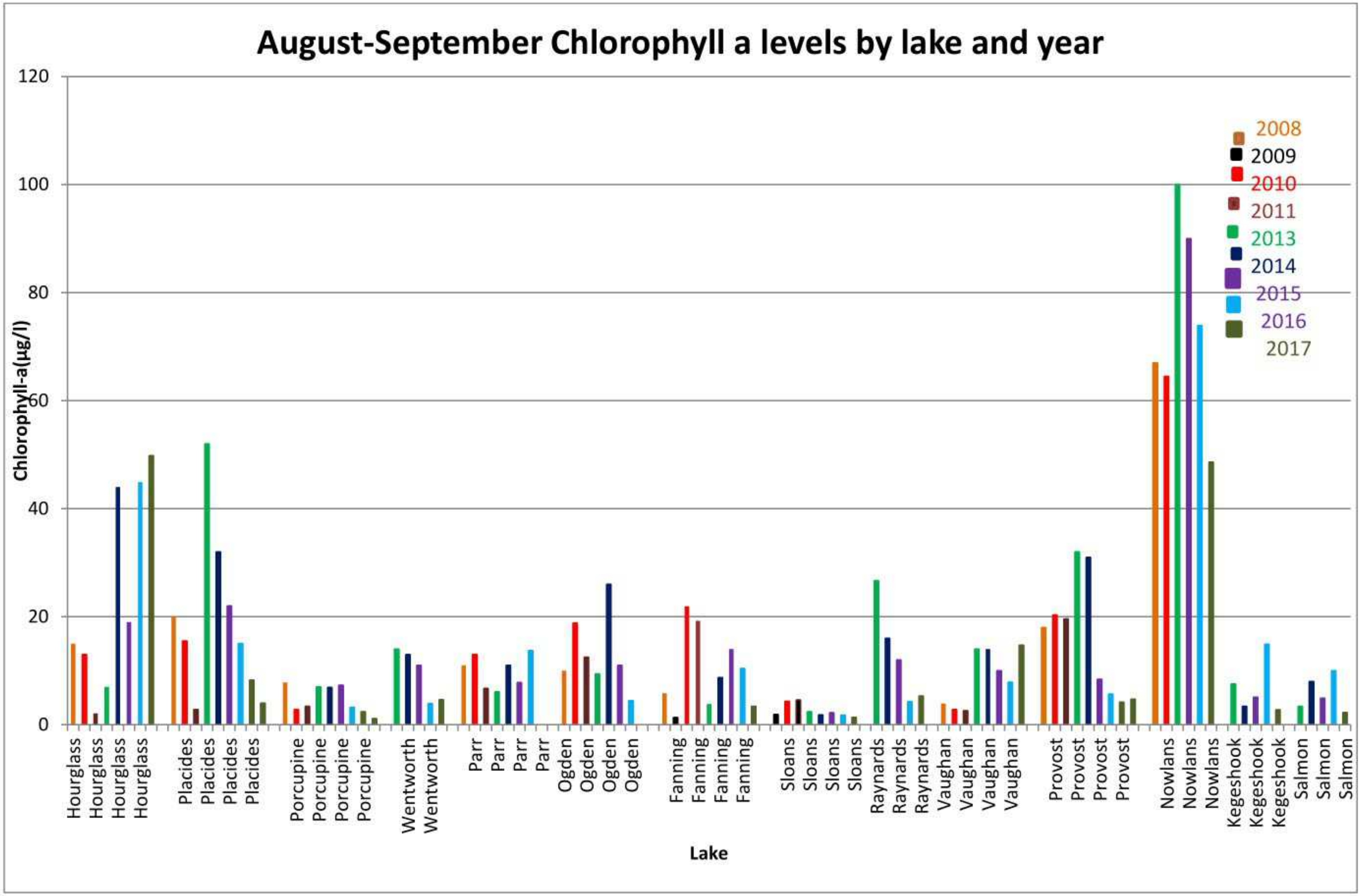
Lake_ID	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Orthophosphate (mg/l)	**OrthoP/ Total P ratio**	Total nitrate (mg/l)	Total Nitrogen (mg/l)	Colour (TCU)	pH
Fanning	Sept. 29/2010	1.15	21.9	0.021	0.005	0.238	0.06	0.35	55	6.40
Fanning	Aug. 17/2011	1.3	19.2	0.023	0.005	0.217	0.01	0.05	63.1	6.20
Fanning	Aug. 11/2013	1.01	3.8	0.045	0.023	0.511	0.01	0.4	131.4	5.93
Fanning	Aug. 24/2014	0.98	8.7	0.027	0.012	0.444	0.02	0.34	99	6.07
Fanning	Aug. 16/2015	1.4	14	0.019	0.006	0.316	<0.01	0.34	73.6	6.19
Fanning	Aug. 21/2016	1.55	10.4	0.023	0.003	0.130	0.03	0.32	43.8	6.40
Fanning	Aug. 23/2017	1.5	3.39	0.022	0.01	0.454545	<.01	0.33	82.2	6.4
Sloans	Sept. 12/2009	3.8	1.9	0.005	0.005	1.000	0.01	0.18	20	6.90
Sloans	Sept. 30/2010	4.3	4.3	0.009	0.005	0.556	0.01	0.12	12	7.00
Sloans	Aug. 15/2011	4.6	4.6	0.005	0.005	1.000	0.01	0.13	15.3	7.00
Sloans	Aug. 1/2013	3.11	2.4	0.004	0.003	0.625	<0.01	0.14	22.3	6.77
Sloans	Aug. 4/2014	4.65	1.8	0.004	0.001	0.25	<0.01	0.13	20.1	6.85
Sloans	Aug. 6/2015	5.375	2.2	0.004	0.004	1.000	0.02	0.16	21.2	6.50
Sloans	Aug. 8/2016	6.25	1.78	0.004	0.004	1.000	0.01	0.14	18.6	6.90
Sloans	Aug. 21/2017	4.35	1.35	0.004	0.004	1	<.01	0.15	14.6	7.0
Raynards	Aug. 1/2013	1.2	26.66	0.021	ND	ND	ND	ND	ND	6.20
Raynards	Aug. 4/2014	1.23	16	0.013	0.002	0.154	<0.01	0.27	54	6.19
Raynards	Aug. 9/2015	1.85	12	0.011	0.004	0.364	<0.01	0.27	47	6.44
Raynards	Aug. 4/2016	1.5	4.27	0.009	0.004	0.444	<0.01	0.2	32.3	6.50
Raynards	Aug. 17/2017	2.25	5.3	0.012	0.004	0.333333	<.01	0.25	43.9	6.5
Vaughan	Sept. 4/2008	3	3.9	0.012	0.005	0.417	0.01	0.17	22	7.20
Vaughan	Sept. 0/2010	1.2	2.8	0.019	0.005	0.263	0.04	0.34	69	6.20
Vaughan	Aug. 6/2011	1.9	2.6	0.01	0.005	0.500	0.01	0.22	63	6.20
Vaughan	Aug. 3/2013	1.17	14	0.02	0.0025	0.125	<0.01	0.29	81	6.24
Vaughan	Aug. 8/2014	1.43	14	0.012	0.003	0.250	<0.01	0.35	54.9	6.32

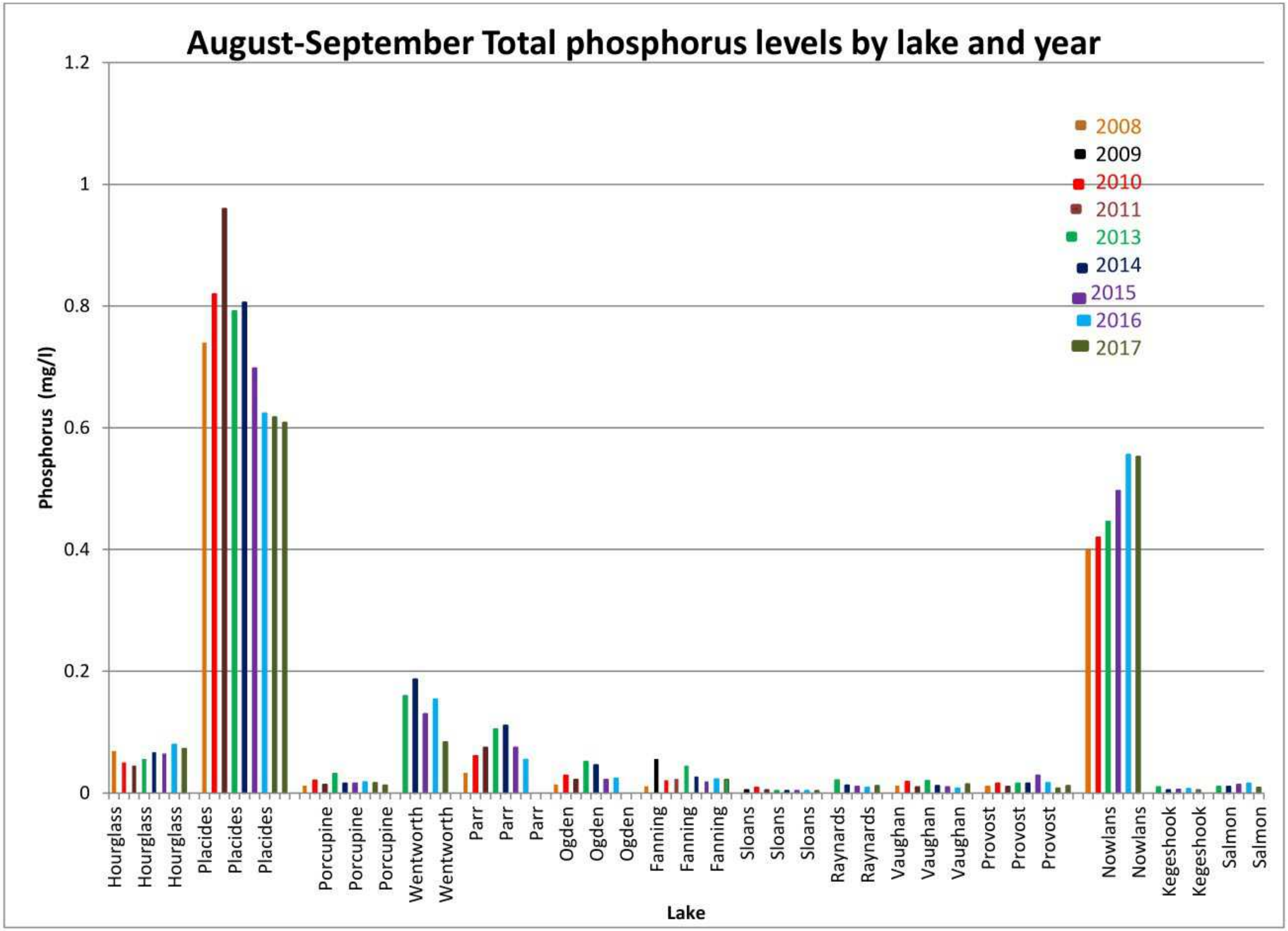
Lake_ID	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Orthophosphate (mg/l)	**OrthoP/ Total P ratio**	Total nitrate (mg/l)	Total Nitrogen (mg/l)	Colour (TCU)	pH
Vaughan	Aug. 8/2015	1.8	10	0.01	0.003	0.300	<0.01	0.24	57	6.52
Vaughan	Aug. 4/2016	1.3	7.87	0.008	0.003	0.375	<0.01	0.21	41.8	6.40
Vaughan	Aug. 24/2017	1.625	14.7	0.015	0.01	0.666667	<.01	0.28	51.2	6.5
Provost	Aug. 4/2008	1.7	18	0.011	0.005	0.455	0.01	0.45	32	6.10
Provost	Sept. 30/2010	1.7	20.3	0.016	0.005	0.313	0.04	0.29	36	6.00
Provost	Aug. 14/2011	0.6	19.6	0.011	0.005	0.455	0.01	0.03	43.8	6.00
Provost	Aug. 13/2013	0.99	32	0.016	0.0025	0.156	0.05	0.48	74.3	5.96
Provost	Aug. 24/2014	1.05	31	0.016	0.006	0.375	0.02	0.52	82.6	ND
Provost	Aug. 25/2015	2.65	8.4	0.029	0.007	0.241	<0.01	0.56	127.55	ND
Provost	Aug. 30/2016	2.4	5.68	0.017	0.005	0.2647	<0.01	0.27	19.7	6.30
Provost	Aug. 22/2017	2.2	4.15	0.008	0.004	0.5	<.01	0.29	34.3	6.4
Provost	Aug. 30/2017	3	4.7	0.012	<.002	0.083333	<.01	0.33	74	6.6
Nowlans	Aug. 14/2008	0.85	67	0.4	0.3	0.75	0.01	1.01	16	6.50
Nowlans	Sept. 26/2010	0.55	64.5	0.42	0.287	0.683	0.01	1.06	15	8.50
Nowlans	Aug. 6/2013	ND	100	0.446	0.39	0.874	0.005	0.73	57.4	ND
Nowlans	Aug. 26/2015	0.625	90	0.497	0.43	0.865	<0.01	0.77	58.9	ND
Nowlans	Aug. 31/2016	0.85	73.9	0.556	0.525	0.944	<0.01	n/a	15.3	7.40
Nowlans	Aug. 20/2017	1	48.6	0.553	0.437	0.790235	0.01	n/a	25.4	7.3
Kegeshook	Aug. 15/2013	0.98	7.55	0.010	ND	ND	ND	ND	ND	5.51
Kegeshook	Aug. 21/2014	1.97	3.4	0.005	<.002	0.200	<0.01	0.18	60.8	6.00
Kegeshook	Aug. 25/2015	2.125	5.1	0.006	0.004	0.167	<0.01	0.19	55.6	6.04
Kegeshook	Aug. 21/2016	1.87	14.9	0.007	0.003	0.143	<0.01	0.18	38.2	6.40
Kegeshook	Aug. 28/2017	1.25	2.75	0.005	0.003	0.6	<.01	0.21	56.5	6.3
Salmon	Aug. 20/2013	0.78	3.38	0.011	ND	ND	ND	ND	ND	5.84
Salmon	Aug. 19/2014	1.03	7.99	0.011	ND	ND	ND	ND	223.95	6.04

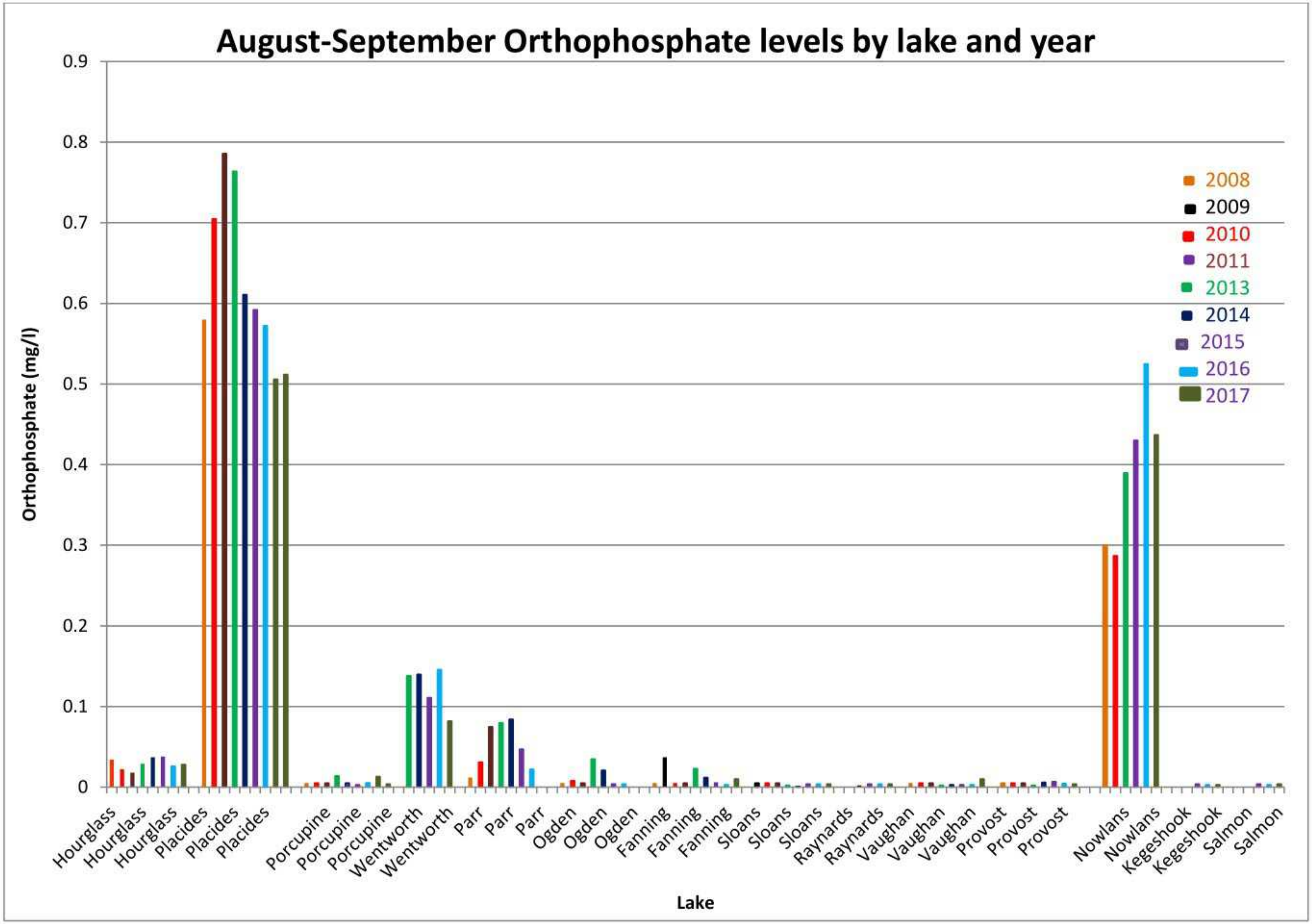
Lake_ID	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Orthophosphate (mg/l)	**OrthoP/ Total P ratio**	Total nitrate (mg/l)	Total Nitrogen (mg/l)	Colour (TCU)	pH
Salmon	Aug. 18/2015	1.55	4.9	0.014	0.004	0.071	<0.01	0.76	90.4	6.12
Salmon	Aug. 21/2016	2.25	9.99	0.016	0.003	0.063	<.0.01	0.28	53.3	6.40
Salmon	Aug. 17/2017	1.375	2.28	0.009	0.004	0.444444	<.01	0.48	108	6.2

ND=No Data

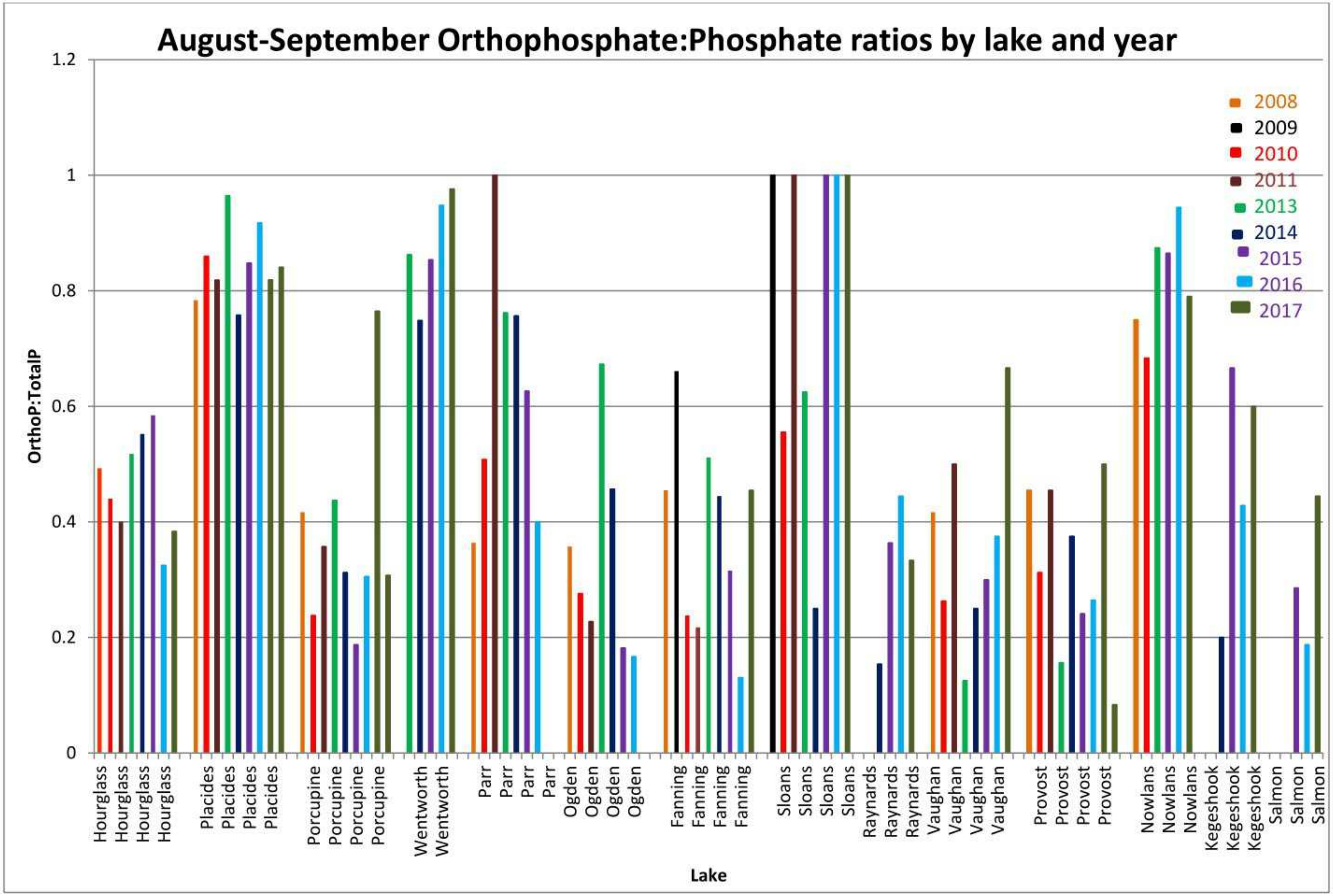
Appendix 2. Water Quality Parameters compared by lake, through Time and Space

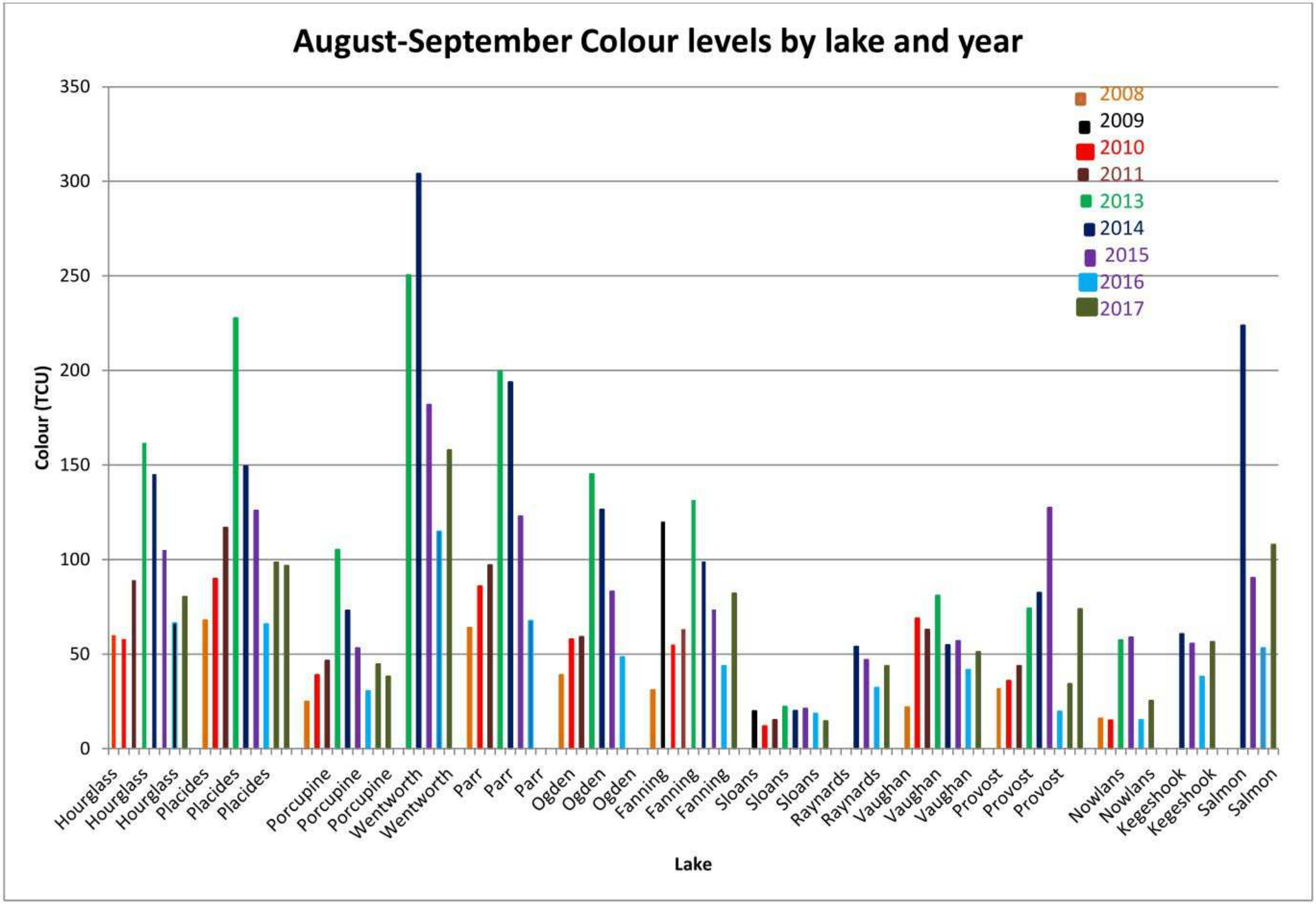


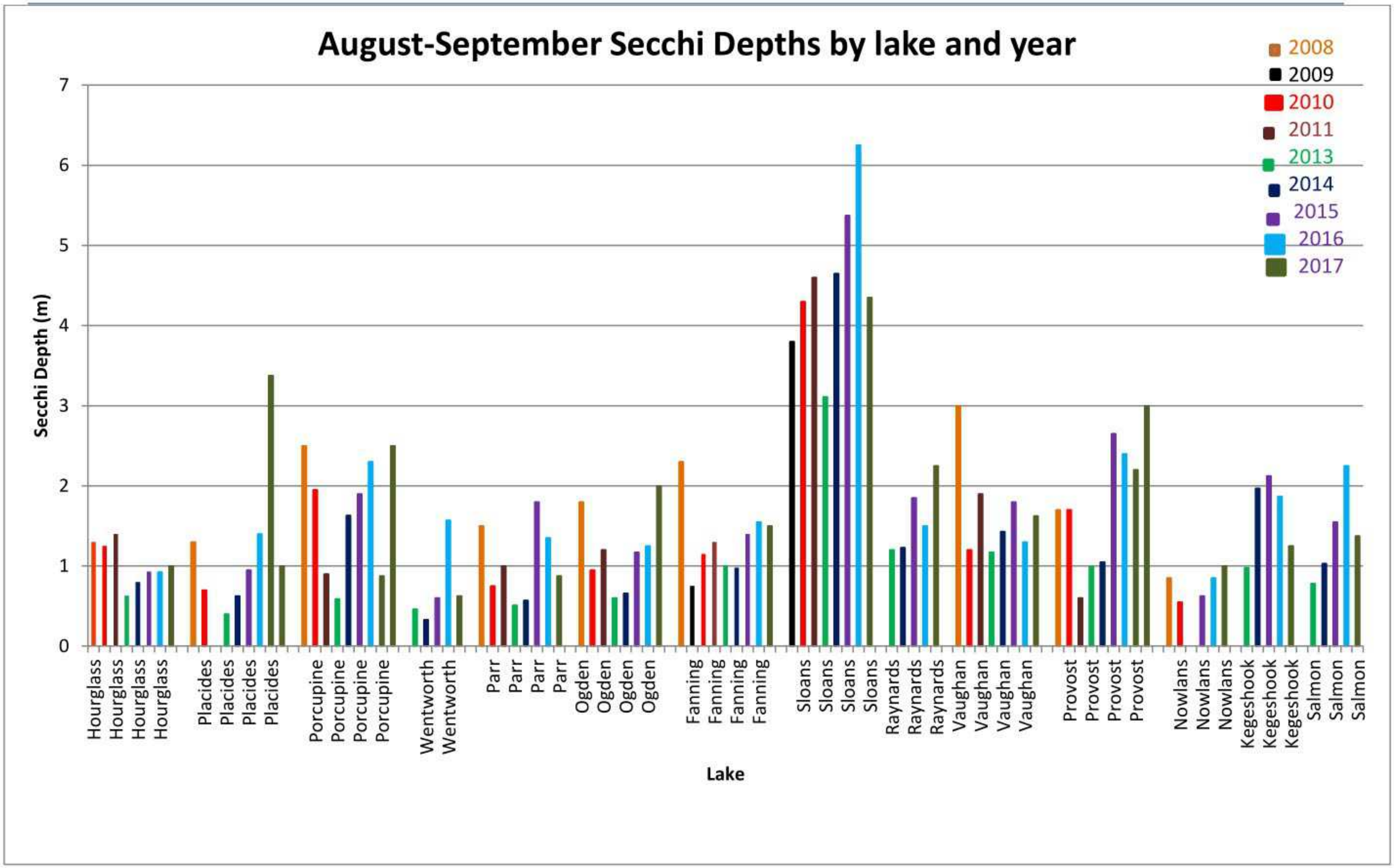

August-September Total phosphorus levels by lake and year
Phosphorus (mg/l)
1.2
1
0.8
0.6
0.4
0.2
0
2008
2009
2010
2011
2013
2014
2015
2016
2017
Hourglass
Hourglass
Hourglass
Placides
Placides
Placides
Porcupine
Porcupine
Porcupine
Wentworth
Wentworth
Parr
Parr
Parr
Ogden
Ogden
Ogden
Fanning
Fanning
Fanning
Sloans
Sloans
Sloans
Raynards
Raynards
Vaughan
Vaughan
Vaughan
Provost
Provost
Provost
Nowlans
Nowlans
Kegeshook
Kegeshook
Salmon
Salmon
Lake

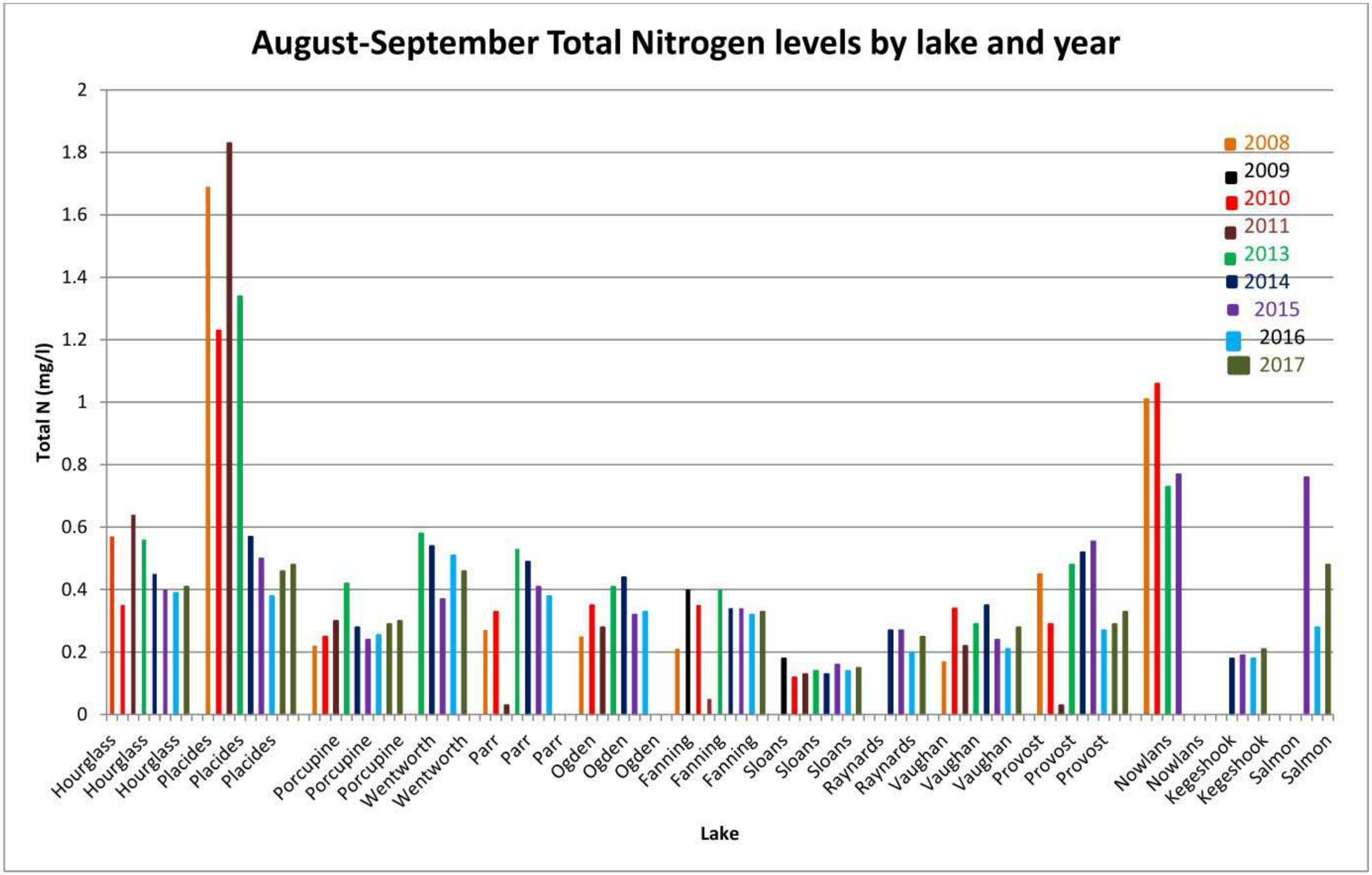


August-September Orthophosphate levels by lake and year
Orthophosphate (mg/l)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2008
2009
2010
2011
2013
2014
2015
2016
2017
Hourglass
Hourglass
Hourglass
Placides
Placides
Placides
Porcupine
Porcupine
Porcupine
Wentworth
Wentworth
Parr
Parr
Parr
Ogden
Ogden
Ogden
Fanning
Fanning
Fanning
Sloans
Sloans
Sloans
Raynards
Raynards
Vaughan
Vaughan
Vaughan
Provost
Provost
Provost
Nowlans
Nowlans
Kegeshook
Kegeshook
Salmon
Salmon
Lake

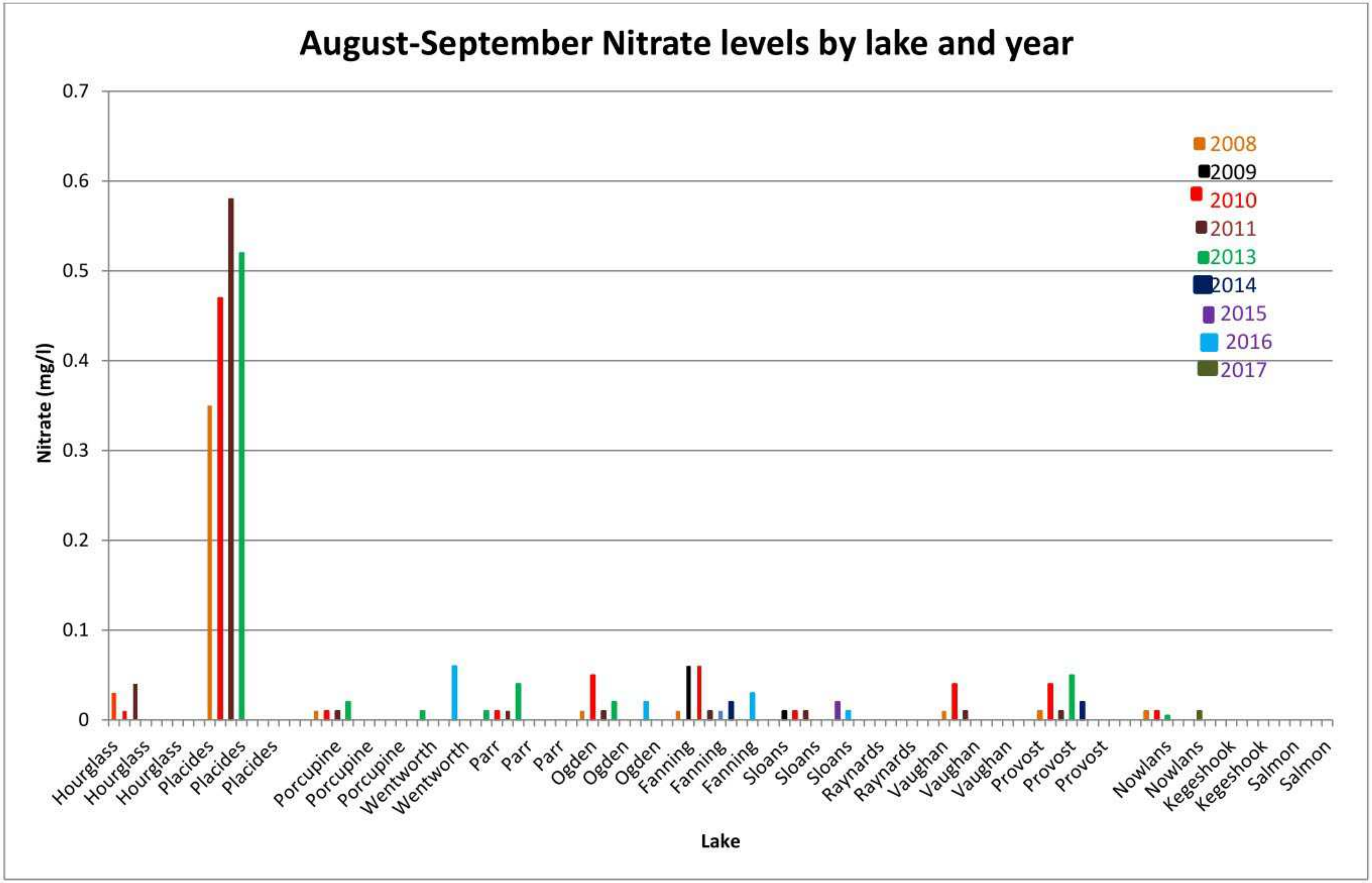

August-September Orthophosphate:Phosphate ratios by lake and year
OrthoP:TotalP
Lake
1.2
1
0.8
0.6
0.4
0.2
0
2008
2009
2010
2011
2013
2014
2015
2016
2017
Hourglass
Placides
Porcupine
Wentworth
Parr
Ogden
Fanning
Sloans
Raynards
Vaughan
Provost
Nowlans
Kegeshook
Salmon

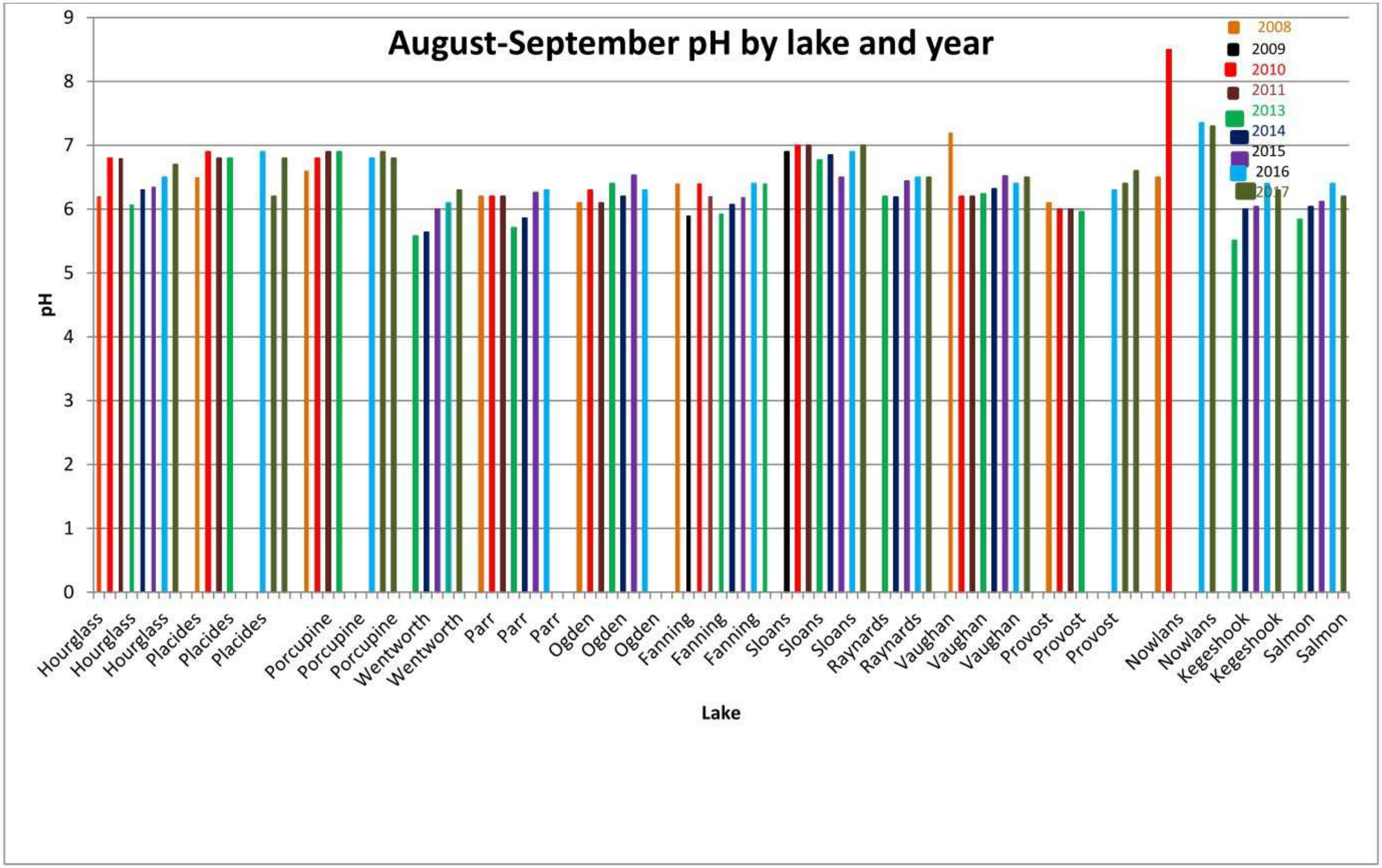

August-September Colour levels by lake and year
Colour (TCU)
350
300
250
200
150
100
50
0
2008
2009
2010
2011
2013
2014
2015
2016
2017
Hourglass
Hourglass
Hourglass
Placides
Placides
Placides
Porcupine
Porcupine
Porcupine
Wentworth
Wentworth
Parr
Parr
Parr
Ogden
Ogden
Ogden
Fanning
Fanning
Fanning
Sloans
Sloans
Sloans
Raynards
Raynards
Vaughan
Vaughan
Vaughan
Provost
Provost
Provost
Nowlans
Nowlans
Kegeshook
Kegeshook
Salmon
Salmon
Lake


August-September Secchi Depths by lake and year
Secchi Depth (m)
Lake
2008
2009
2010
2011
2013
2014
2015
2016
2017
Hourglass
Placides
Porcupine
Wentworth
Parr
Ogden
Fanning
Sloans
Raynards
Vaughan
Provost
Nowlans
Kegeshook
Salmon



August-September Total Nitrogen levels by lake and year
Total N (mg/l)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2008
2009
2010
2011
2013
2014
2015
2016
2017
Hourglass
Hourglass
Hourglass
Placides
Placides
Placides
Porcupine
Porcupine
Porcupine
Wentworth
Wentworth
Parr
Parr
Parr
Ogden
Ogden
Ogden
Fanning
Fanning
Fanning
Sloans
Sloans
Sloans
Raynards
Raynards
Vaughan
Vaughan
Vaughan
Provost
Provost
Provost
Nowlans
Nowlans
Kegeshook
Kegeshook
Salmon
Salmon
Lake


August-September Nitrate levels by lake and year
Nitrate (mg/l)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2008
2009
2010
2011
2013
2014
2015
2016
2017
Hourglass
Hourglass
Hourglass
Placides
Placides
Placides
Porcupine
Porcupine
Porcupine
Wentworth
Wentworth
Parr
Parr
Parr
Ogden
Ogden
Ogden
Fanning
Fanning
Fanning
Sloans
Sloans
Sloans
Raynards
Raynards
Vaughan
Vaughan
Vaughan
Provost
Provost
Provost
Nowlans
Nowlans
Kegeshook
Kegeshook
Salmon
Salmon
Lake



No pH data for Provost, Nowlans, Placides, nor Porcupine in 2014 and 2015.

Appendix 3. Seasonal Variation in Water Quality Parameters for Selected Lakes

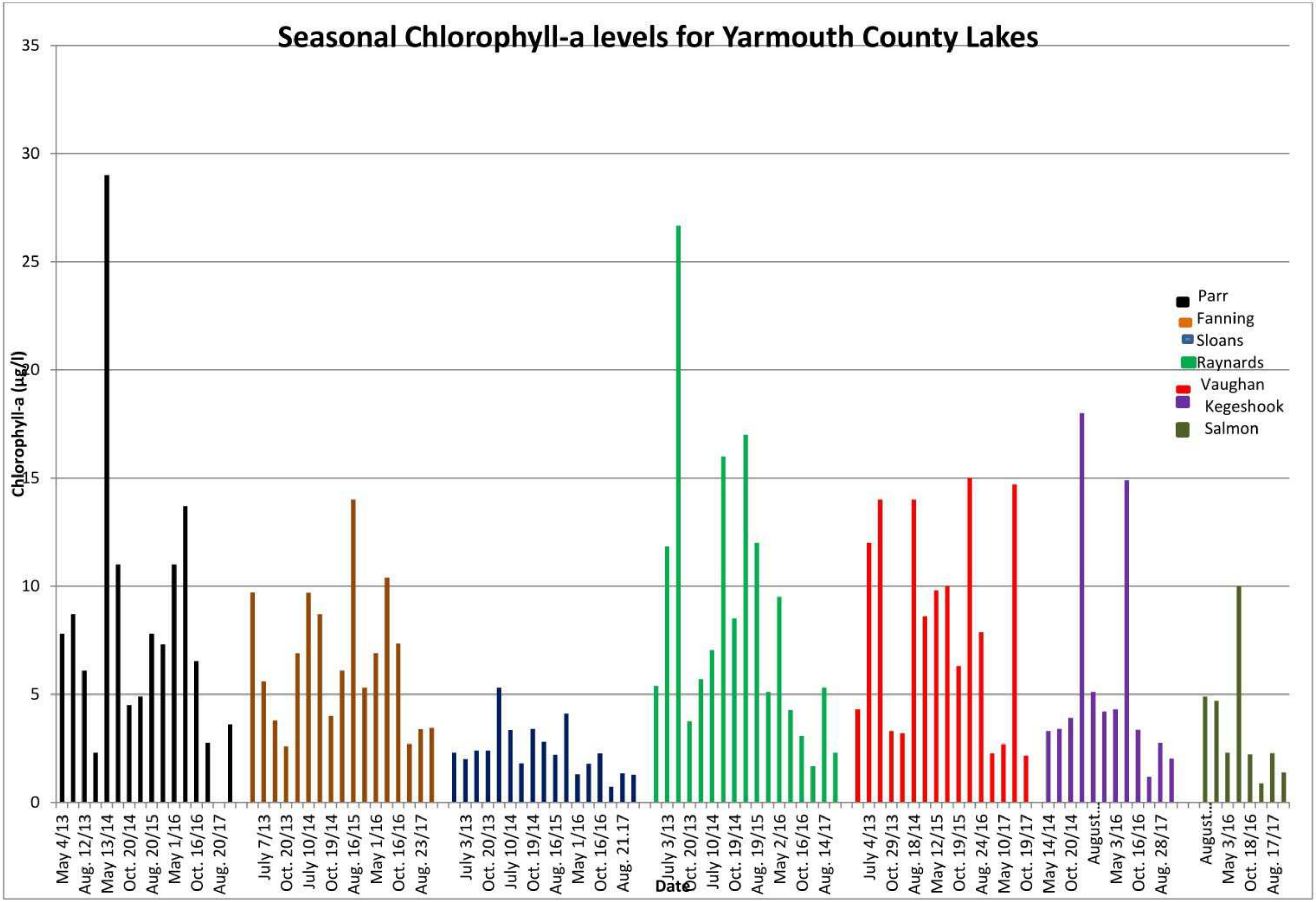
Data Base

Lake Name	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Orthophosphate (mg/l)	OrthoP/ TotalP ratio	Total nitrate (mg/l)	Total Nitrogen) (mg/l)	Colour (TCU)	pH
Parr	May 4/2013	0.96	7.80	0.025	0.012	0.480	<0.01	0.25	100.4	5.87
	July 8/2013	0.55	8.70	0.086	0.068	0.791	0.01	0.50	223.9	5.44
	Aug. 12/2013	0.51	6.10	0.105	0.080	0.762	0.04	0.53	199.6	5.71
	Oct. 28/2013	0.55	2.30	0.088	0.072	0.818	0.04	0.53	214.3	5.59
	May 13/2014	0.90	29.0	0.032	0.024	0.750	<0.01	0.21	92.1	5.67
	Aug. 25/2014	0.57	11.0	0.111	0.084	0.757	<0.01	0.49	193.9	5.86
	Oct. 20/2014	0.65	4.50	0.084	0.064	0.762	0.02	0.45	169.0	5.98
	May 11/2015	1.00	4.90	0.042	0.029	0.690	0.04	0.27	74.0	5.29
	Aug. 20/2015	1.80	7.80	0.075	0.047	0.627	<0.01	0.41	123.0	6.26
	Oct. 20/2015	0.80	7.30	0.087	0.062	0.713	0.01	0.40	156.0	5.83
	May 1/2016	1.00	11.0	0.032	0.011	0.344	<0.01	0.29	90.5	5.70
	Aug. 21/2016	1.35	13.7	0.055	0.022	0.400	<0.01	0.34	67.7	6.30
	Oct. 16/2016	1.00	6.50	0.052	0.026	0.500	<0.01	0.32	71.0	6.00
	May 7/17	1.175	2.75	0.032	0.018	0.5625	<.01	0.26	86.6	6.00
	Aug. 20/17	.875								
	Oct. 15/17	.85	3.61	0.055	0.029	0.527273	<.01	0.42	145	6.1
Fanning	May 5/2013	1.30	9.70	0.017	0.007	0.412	<0.01	0.22	72.4	6.11
	July 7/2013	0.90	5.60	0.037	0.022	0.595	<0.01	0.33	128.2	5.81
	Aug. 11/2013	1.01	3.80	0.045	0.023	0.511	0.01	0.40	131.4	5.93
	Oct. 20/2013	0.58	2.60	0.052	0.039	0.750	0.06	0.42	156.3	5.78
	May 11/2014	1.20	6.90	0.019	0.012	0.632	0.03	0.21	68.2	5.65
	July 10/2014	1.10	9.69	0.015						5.89
	Aug. 24/2014	0.98	8.70	0.027	0.012	0.444	0.02	0.34	99.0	6.07
	Oct. 19/2014	1.07	4.00	0.044	0.021	0.477	0.07	0.41	99.3	6.12
	May 10/2015	1.70	6.10	0.028	0.024	0.857	0.06	0.30	66.3	5.38
	Aug. 16/2015	1.40	14.0	0.019	0.006	0.316	<0.01	0.34	73.6	6.19

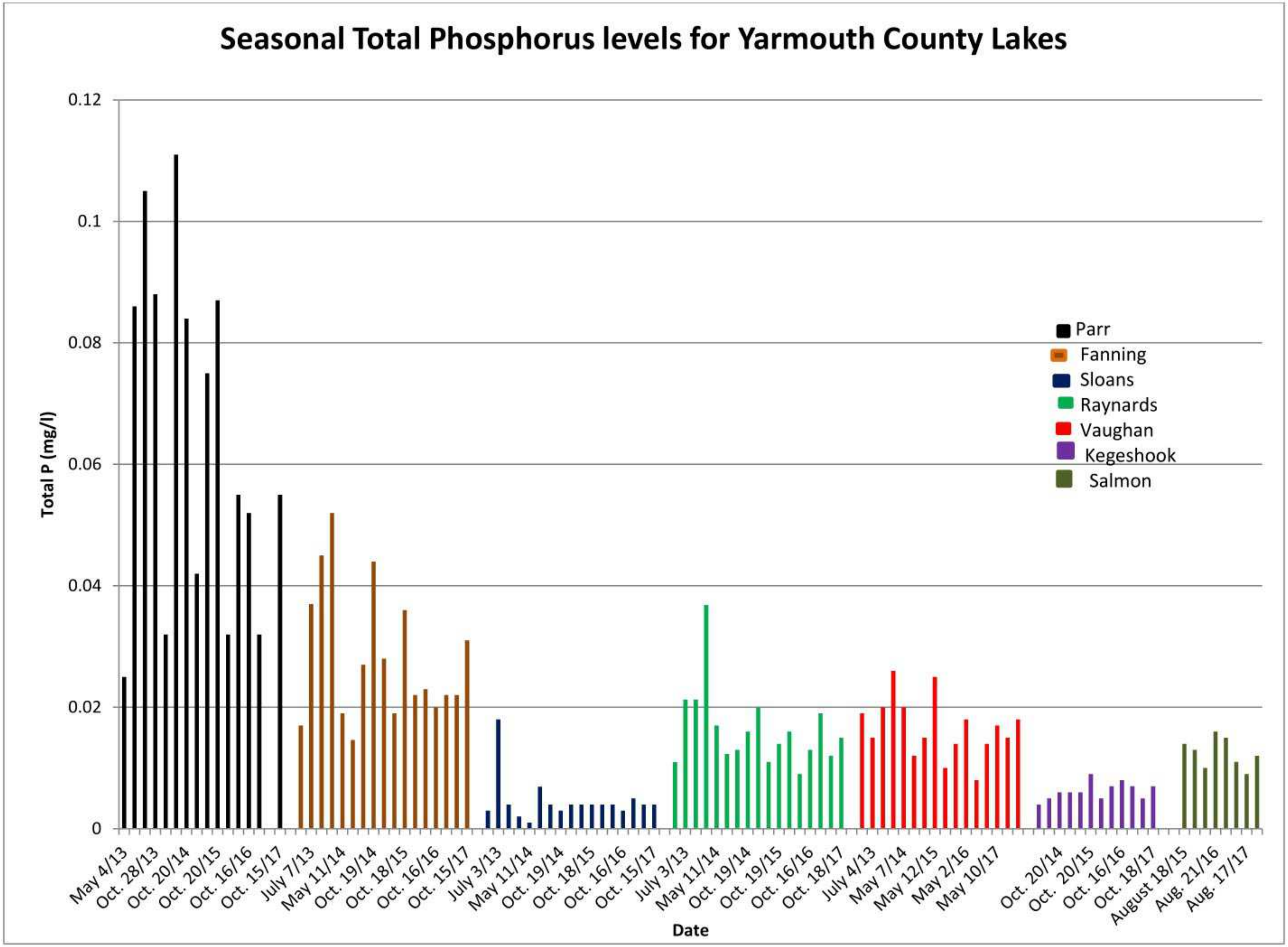
Lake Name	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Orthophosphate (mg/l)	OrthoP/ TotalP ratio	Total nitrate (mg/l)	Total Nitrogen) (mg/l)	Colour (TCU)	pH
	Oct. 18/2015	1.35	5.30	0.036	0.017	0.472	0.04	0.34	87.7	6.10
	May 1/2016	1.65	6.90	0.022	0.012	0.545	<0.01	0.22	72.7	5.80
Fanning	Aug. 21/2016	1.55	10.4	0.023	0.003	0.130	0.03	0.32	43.8	6.40
	Oct. 16/2016	1.75	7.34	0.020	0.005	0.250	<0.01	0.24	37.8	6.40
	May 7/17	1.6	2.7	0.022	0.012	0.545455	<.01	0.24	65.7	6.2
	Aug. 23/17	1.5	3.39	0.022	0.01	0.454545	<.01	0.33	82.2	6.4
	Oct. 15/17	1.55	3.45	0.031	0.012	0.387097	0.02	0.36	82.3	6.4
Sloans	May 6/2013	3.5	2.30	0.003	0.003	0.833	<0.01	0.14	22.0	6.64
	July 3/2013	2.65	2.00	0.018	0.006	0.333	<0.01	0.16	29.2	6.81
	Aug. 11/2013	3.11	2.40	0.004	0.003	0.625	<0.01	0.14	22.3	6.77
	Oct. 20/2013	3.30	2.40	0.002	0.002	1.000	<0.01	0.14	23.0	6.56
	May 11/2014	2.35	5.30	0.001	0.001	1.000	<0.01	0.13	29.0	6.63
	July 10/2014	2.94	3.35	0.007						6.8
	Aug. 24/2014	4.65	1.80	0.004	0.001	0.250	<0.01	0.13	20.1	6.85
	Oct. 19/2014	3.69	3.40	0.003	0.001	0.333	<0.01	0.13	14.3	6.75
	May 18/2015	4.04	2.80	0.004	0.004	1.000	<0.01	0.17	27.7	6.75
	Aug. 16/2015	5.38	2.20	0.004	0.004	1.000	0.02	0.16	21.2	6.60
	Oct. 18/2015	4.90	4.10	0.004	0.004	1.000	<0.01	0.13	20.5	6.60
	May 1/2016	4.75	1.30	0.004	0.003	0.750	<0.01	0.15	23.5	6.80
	Aug. 28/2016	6.25	1.78	0.004	0.004	1.000	0.01	0.14	18.6	6.90
	Oct. 16/2016	4.25	2.27	0.003	0.002	0.667	<0.01	0.13	11.4	7.00
	May 7/17	4.25	0.72	0.005	0.003	0.6	<.01	0.19	16.4	6.7
	Aug. 21.17	4.35	1.35	0.004	0.004	1	<.01	0.15	14.6	7.0
	Oct. 15/17	4.6	1.28	0.004	<.002	0.25	<.01	0.14	14.2	6.9
Raynards	May 6/2013	1.52	5.38	0.011						6.17

Lake Name	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Orthophosphate (mg/l)	OrthoP/ TotalP ratio	Total nitrate (mg/l)	Total Nitrogen) (mg/l)	Colour (TCU)	pH
Raynards	July 3/2013	1.25	11.83	0.021						6.28
	Aug. 11/2013	1.20	26.66	0.021						6.2
	Oct. 20/2013	1.08	3.76	0.037					96.369	6.01
	May 11/2014	1.41	5.70	0.017	0.010	0.588	0.05	0.23	65.5	5.75
	July 10/2014	1.43	7.05	0.0123						6.08
	Aug. 24/2014	1.23	16.0	0.0130	0.002	0.154	<0.01	0.27	54.0	6.19
	Oct. 19/2014	1.53	8.50	0.0160	0.003	0.188	0.07	0.35	52.0	6.17
	May 18/2015	0.96	17.0	0.0200	0.011	0.55	0.03	0.24	55.8	5.92
	Aug. 19/2015	1.85	12.0	0.0110	0.004	0.364	<0.01	0.27	47.0	6.44
	Oct. 19/2015	1.7	5.10	0.0140	0.004	0.286	0.03	0.24	50.4	6.34
	May 2/2016	1.5	9.50	0.0160	0.010	0.625	<0.01	0.24	67.7	6.00
	Aug. 24/2016	1.5	4.27	0.0090	0.004	0.444	<0.01	0.2	32.3	6.50
	Oct. 16/2016	3.3	3.07	0.0130	0.001	0.077	<0.01	0.2	25.9	6.60
	May 17/17	1.5	1.67	0.019	0.011	0.578947	0.01	0.25	59.1	6.4
	Aug. 14/17	2.25	5.3	0.012	0.004	0.333333	<.01	0.24	43.9	6.5
	Oct. 18/17	2.75	2.3	0.015	0.006	0.4	0.01	0.28	47.5	6.6
Vaughan	Apr. 30/2013	1.45	4.30	0.0190	0.007	0.368	0.05	0.32	82.4	5.95
	July 4/2013	1.5	12.0	0.0150	0.003	0.167	<0.01	0.26	74.1	6.05
	Aug. 13/2013	1.17	14.0	0.0200	0.003	0.125	<0.01	0.29	81.0	6.24
	Oct. 29/2013	1.2	3.30	0.0260	0.008	0.308	0.07	0.42	92.7	6.01
	May 7/2014	1.34	3.20	0.0200	0.014	0.700	0.07	0.25	62.6	5.79
	Aug. 18/2014	1.43	14.0	0.0120	0.003	0.250	<0.01	0.35	54.9	6.32
	Oct. 21/2014	1.59	8.60	0.0150	0.003	0.200	0.07	0.38	65.1	6.12
	May 12/2015	1.5	9.80	0.0250	0.018	0.720	0.09	0.32	58.6	5.68
	Aug. 18/2015	1.8	10.0	0.0100	0.003	0.300	<0.01	0.24	57.0	6.52
	Oct. 19/2015	1.9	6.30	0.0140	0.004	0.286	0.04	0.24	50.5	6.20
	May 2/2016	1.3	15.0	0.0180	0.009	0.500	<0.01	0.26	65.0	6.10
	Aug. 24/2016	1.3	7.87	0.0080	0.003	0.375	<0.01	0.21	41.8	6.40
	Oct. 16/2016	2.4	2.27	0.0140	0.006	0.429	0.02	0.22	35.9	6.40
	May 10/17	1.55	2.69	0.017	0.008	0.470588	<.01	0.26	59.7	6.4

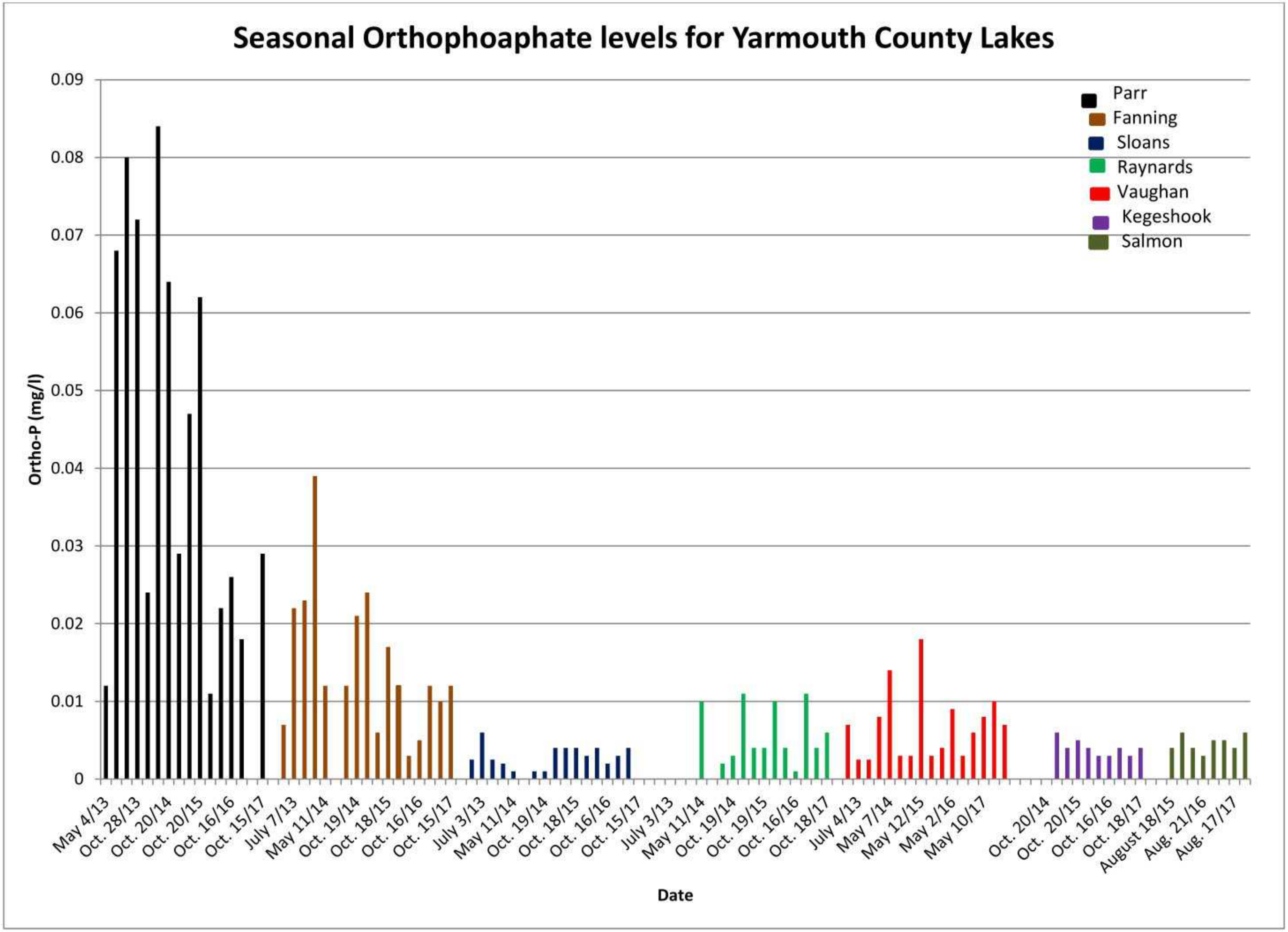
Lake Name	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Orthophosphate (mg/l)	OrthoP/ TotalP ratio	Total nitrate (mg/l)	Total Nitrogen) (mg/l)	Colour (TCU)	pH
Vaughan	Aug. 24/17	1.625	14.7	0.015	0.01	0.666667	<.01	0.28	51.2	6.5
	Oct. 19/17	1.8	2.16	0.018	0.007	0.388889	0.03	0.29	55	6.6
Kegeshook	Apr. 30/13	1.45	4.3	0.019	0.007	0.368421	0.05	0.32	82.4	5.95
	July 4/13	1.5	12	0.015	0.0025	0.166667	<.01	0.26	74.1	6.05
	Aug. 13/13	1.17	14	0.02	0.0025	0.125	<.01	0.29	81	6.24
	Oct. 29/13	1.2	3.3	0.026	0.008	0.307692	0.07	0.42	92.7	6.01
	May 7/14	1.34	3.2	0.02	0.014	0.7	0.07	0.25	62.6	5.79
	Aug. 18/14	1.43	14	0.012	0.003	0.25	<.01	0.35	54.9	6.32
	Oct. 21/14	1.59	8.6	0.015	0.003	0.2	0.07	0.38	65.1	6.12
	May 12/15	1.5	9.8	0.025	0.018	0.72	0.09	0.32	58.6	5.68
	Aug. 18/15	1.8	10.0	0.010	0.003	0.3	<.01	0.24	57	6.52
	Oct. 19/15	1.9	6.3	0.014	0.004	0.285714	0.04	0.24	50.5	6.2
	May 2/16	1.3	15	0.018	0.009	0.5	<.01	0.26	65	6.1
	Aug. 24/16	1.3	7.87	0.008	0.003	0.375	<.01	0.21	41.8	6.4
Salmon	May 19/15	0.7								
	August 18/15	1.55	4.9	0.014	0.004	0.285714	<.01	0.76	90.4	5.75
	Oct. 18/15	1.3	4.7	0.013	0.006	0.461538	0.02	0.34	103	6.16
	May 3/16	1.435	2.3	0.01	0.004	0.4	<.01	0.28	84.1	6.08
	Aug. 21/16	2.25	9.99	0.016	0.003	0.1875	<.01	0.28	53.3	
	Oct. 18/16	2.25	2.22	0.015	0.005	0.333333	<.01	0.25	36.3	6.4
	May 4/17	1.74	0.88	0.011	0.005	0.454545	<.01	0.26	72.4	6.4
	Aug. 17/17	1.38	2.28	0.009	0.004	0.444444	<.01	0.48	108	5.9
	Oct. 21/17	1.3	1.39	0.012	0.006	0.5	0.02	0.47	126	6.2

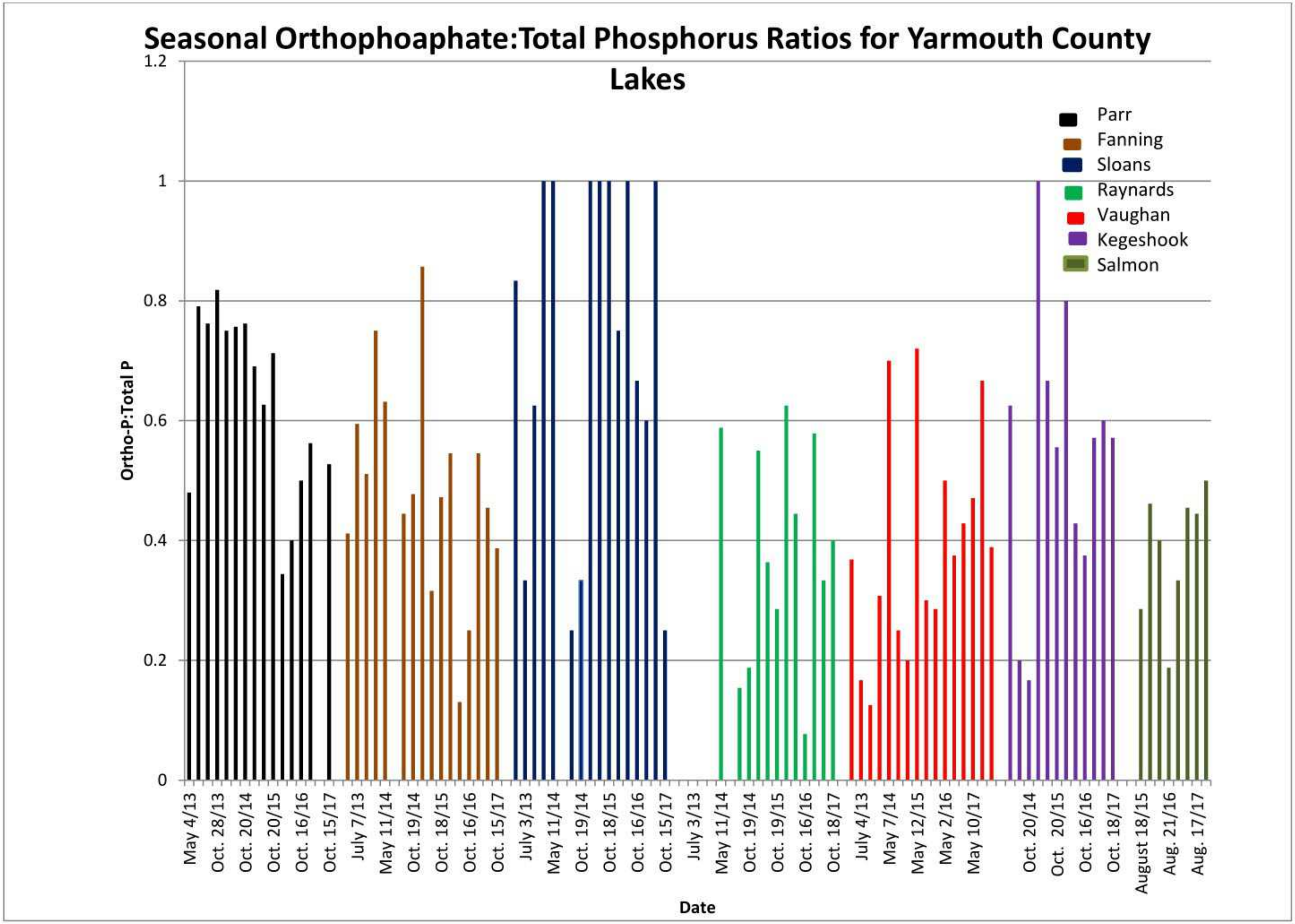


Seasonal Chlorophyll-a levels for Yarmouth County Lakes
Chlorophyll-a (µg/l)
35
30
25
20
15
10
5
0
Parr
Fanning
Sloans
Raynards
Vaughan
Kegeshook
Salmon
May 4/13
Aug. 12/13
May 13/14
Oct. 20/14
Aug. 20/15
May 1/16
Oct. 16/16
Aug. 20/17
July 7/13
Oct. 20/13
July 10/14
Oct. 19/14
Aug. 16/15
May 1/16
Oct. 16/16
Aug. 23/17
July 3/13
Oct. 20/13
July 10/14
Oct. 19/14
Aug. 16/15
May 1/16
Oct. 16/16
Aug. 21.17
July 3/13
Oct. 20/13
July 10/14
Oct. 19/14
Aug. 19/15
May 2/16
Oct. 16/16
Aug. 14/17
July 4/13
Oct. 29/13
Aug. 18/14
May 12/15
Oct. 19/15
Aug. 24/16
May 10/17
Oct. 19/17
May 14/14
Oct. 20/14
August…
May 3/16
Oct. 16/16
Aug. 28/17
August…
May 3/16
Oct. 18/16
Aug. 17/17
Date

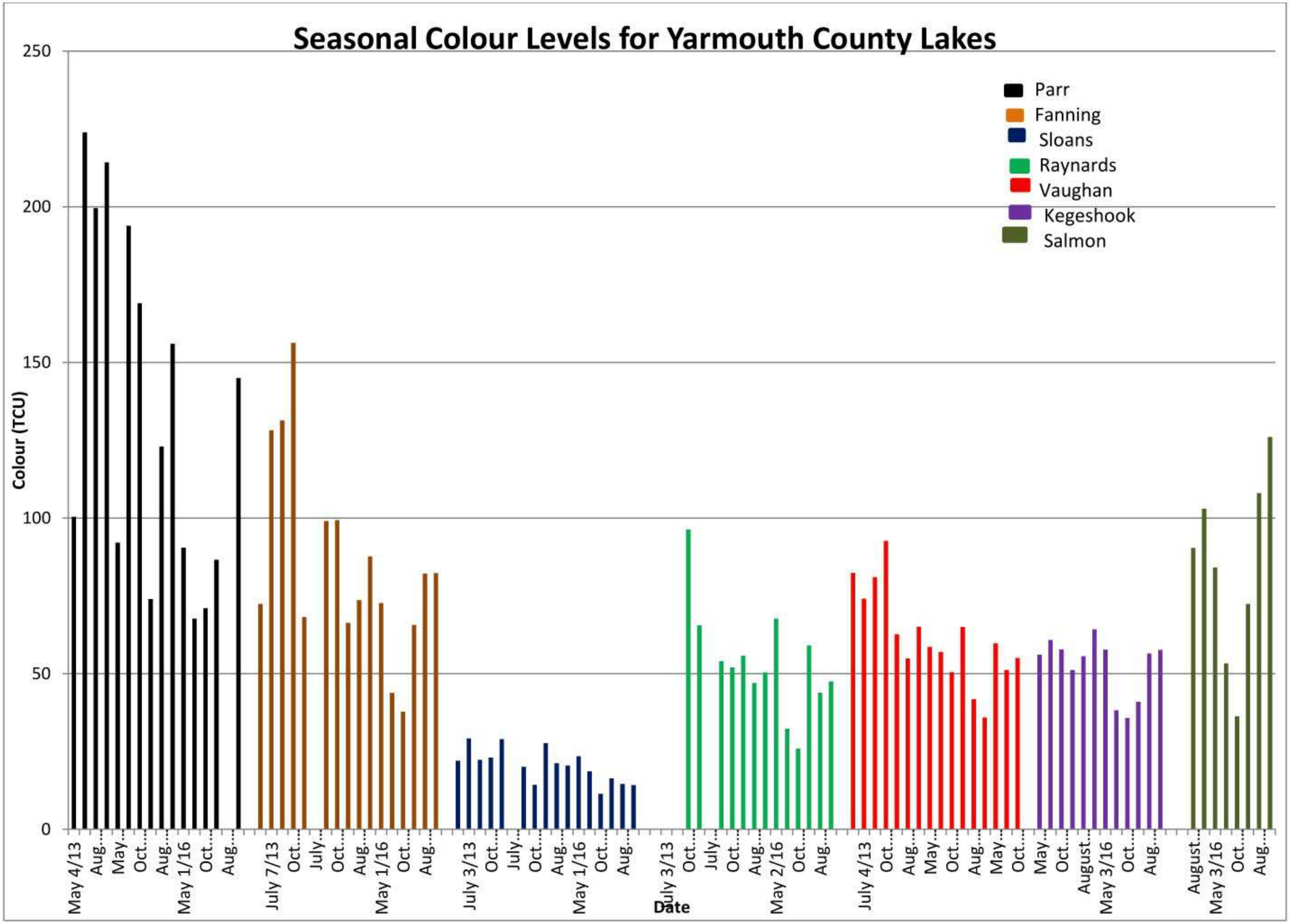


Seasonal Total Phosphorus levels for Yarmouth County Lakes
Total P (mg/l)
0.12
0.1
0.08
0.06
0.04
0.02
0
Parr
Fanning
Sloans
Raynards
Vaughan
Kegeshook
Salmon
May 4/13
Oct. 28/13
Oct. 20/14
Oct. 20/15
Oct. 16/16
Oct. 15/17
July 7/13
May 11/14
Oct. 19/14
Oct. 18/15
Oct. 16/16
Oct. 15/17
July 3/13
May 11/14
Oct. 19/14
Oct. 18/15
Oct. 16/16
Oct. 15/17
July 3/13
May 11/14
Oct. 19/14
Oct. 19/15
Oct. 16/16
Oct. 18/17
July 4/13
May 7/14
May 12/15
May 2/16
May 10/17
Oct. 20/14
Oct. 20/15
Oct. 16/16
Oct. 18/17
August 18/15
Aug. 21/16
Aug. 17/17
Date

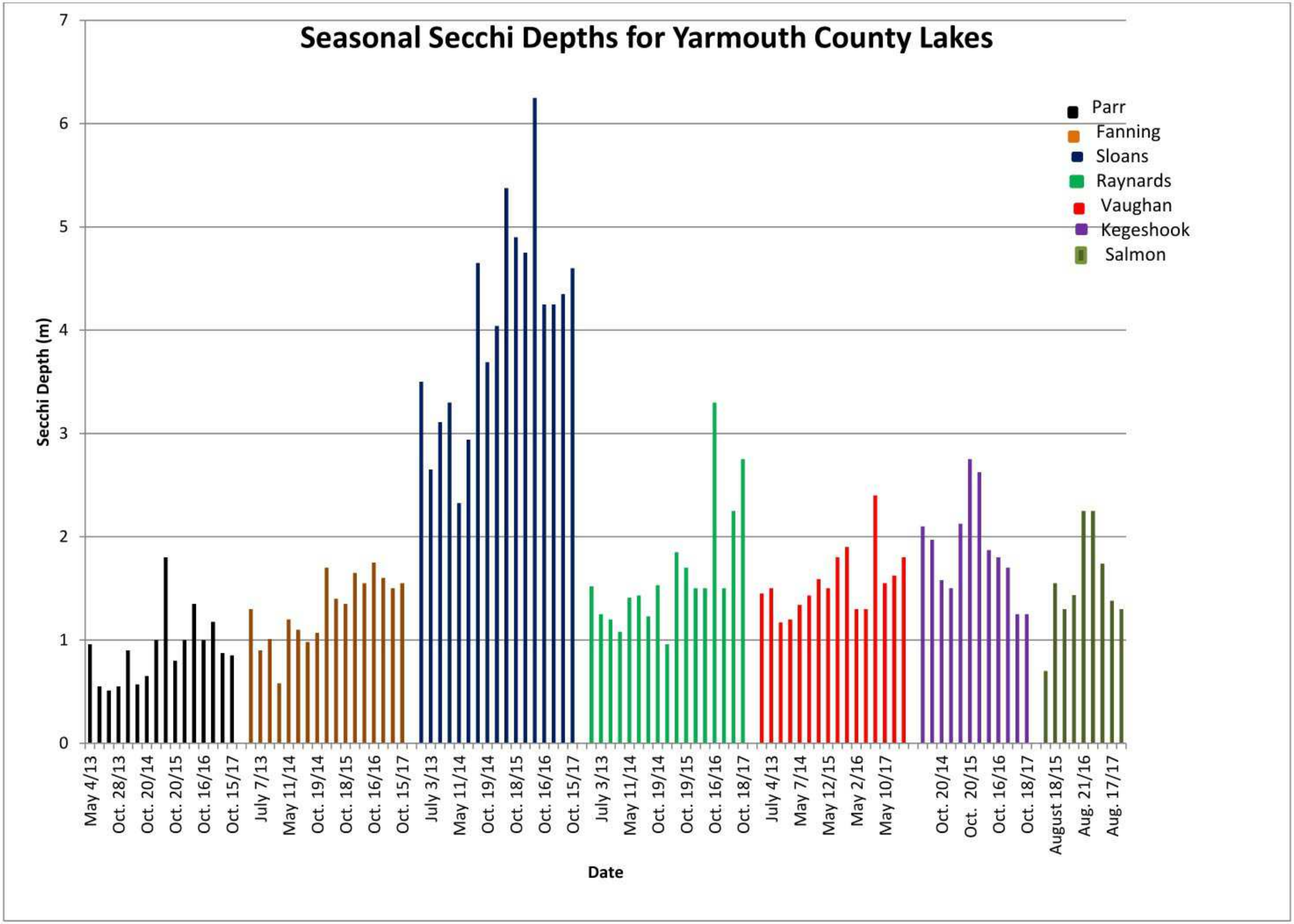

Seasonal Orthophoaphate levels for Yarmouth County Lakes
Ortho-P (mg/l)
Date
Parr
Fanning
Sloans
Raynards
Vaughan
Kegeshook
Salmon
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
May 4/13
Oct. 28/13
Oct. 20/14
Oct. 20/15
Oct. 16/16
Oct. 15/17
July 7/13
May 11/14
Oct. 19/14
Oct. 18/15
Oct. 16/16
Oct. 15/17
July 3/13
May 11/14
Oct. 19/14
Oct. 18/15
Oct. 16/16
Oct. 15/17
July 3/13
May 11/14
Oct. 19/14
Oct. 19/15
Oct. 16/16
Oct. 18/17
July 4/13
May 7/14
May 12/15
May 2/16
May 10/17
Oct. 20/14
Oct. 20/15
Oct. 16/16
Oct. 18/17
August 18/15
Aug. 21/16
Aug. 17/17

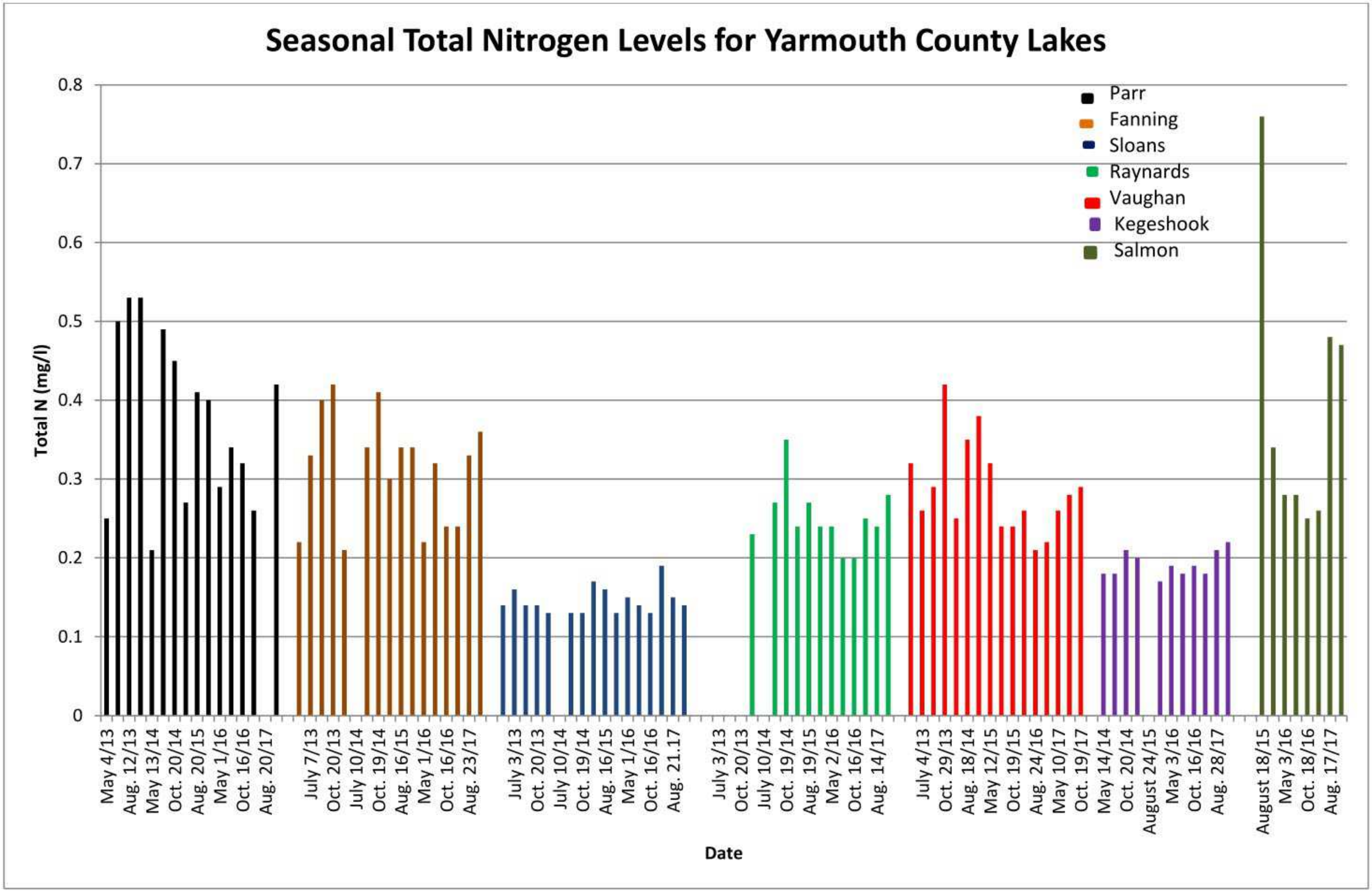


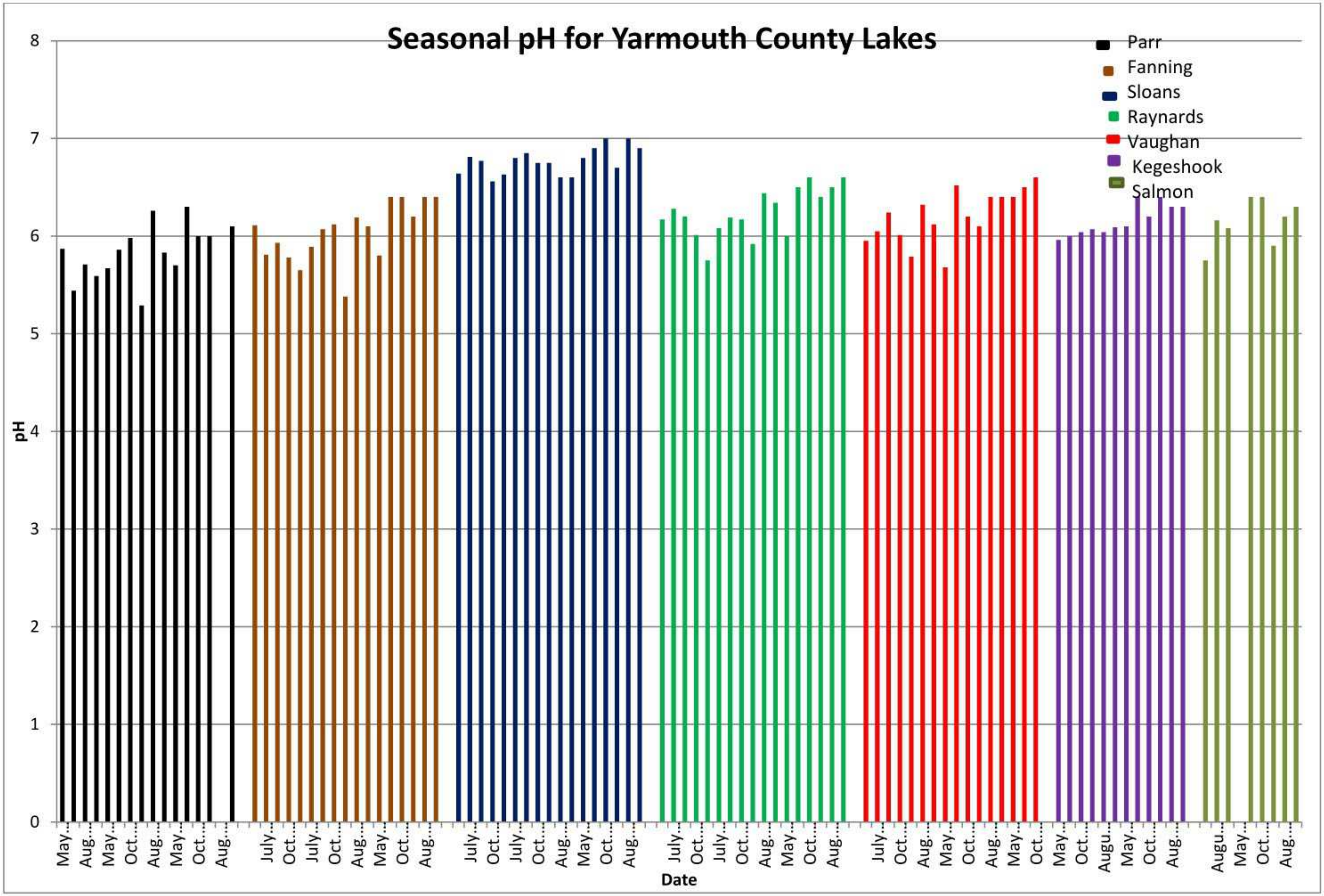
Seasonal Orthophoaphate:Total Phosphorus Ratios for Yarmouth County Lakes
Ortho-P:Total P
Date
Parr
Fanning
Sloans
Raynards
Vaughan
Kegeshook
Salmon
1.2
1
0.8
0.6
0.4
0.2
0
May 4/13
Oct. 28/13
Oct. 20/14
Oct. 20/15
Oct. 16/16
Oct. 15/17
July 7/13
May 11/14
Oct. 19/14
Oct. 18/15
Oct. 16/16
Oct. 15/17
July 3/13
May 11/14
Oct. 19/14
Oct. 18/15
Oct. 16/16
Oct. 15/17
July 3/13
May 11/14
Oct. 19/14
Oct. 19/15
Oct. 16/16
Oct. 18/17
July 4/13
May 7/14
May 12/15
May 2/16
May 10/17
Oct. 20/14
Oct. 20/15
Oct. 16/16
Oct. 18/17
August 18/15
Aug. 21/16
Aug. 17/17



Seasonal Colour Levels for Yarmouth County Lakes
Colour (TCU)
Date
Parr
Fanning
Sloans
Raynards
Vaughan
Kegeshook
Salmon
0
50
100
150
200
250
May 4/13
July 7/13
May 1/16
July 3/13
May 2/16
July 4/13
May 3/16


Seasonal Secchi Depths for Yarmouth County Lakes
Secchi Depth (m)
Date
Parr
Fanning
Sloans
Raynards
Vaughan
Kegeshook
Salmon


Seasonal Total Nitrogen Levels for Yarmouth County Lakes
Total N (mg/l)
Date
Parr
Fanning
Sloans
Raynards
Vaughan
Kegeshook
Salmon
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
May 4/13
Aug. 12/13
May 13/14
Oct. 20/14
Aug. 20/15
May 1/16
Oct. 16/16
Aug. 20/17
July 7/13
Oct. 20/13
July 10/14
Oct. 19/14
Aug. 16/15
May 1/16
Oct. 16/16
Aug. 23/17
July 3/13
Oct. 20/13
July 10/14
Oct. 19/14
Aug. 16/15
May 1/16
Oct. 16/16
Aug. 21.17
July 3/13
Oct. 20/13
July 10/14
Oct. 19/14
Aug. 19/15
May 2/16
Oct. 16/16
Aug. 14/17
July 4/13
Oct. 29/13
Aug. 18/14
May 12/15
Oct. 19/15
Aug. 24/16
May 10/17
Oct. 19/17
May 14/14
Oct. 20/14
August 24/15
May 3/16
Oct. 16/16
Aug. 28/17
August 18/15
May 3/16
Oct. 18/16
Aug. 17/17



Seasonal pH for Yarmouth County Lakes
Parr
Fanning
Sloans
Raynards
Vaughan
Kegeshook
Salmon
pH
Date

Appendix 4. Comparison of Surface and Bottom Total Phosphorus for Selected Lakes

Data base

Lake_ID	Level and Year	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Ortho-phosphate (mg/l)	OrthoP/ TotalP ratio	Total nitrate (mg/l)	Total Nitrogen (mg/l)	Colour (TCU)	pH
Hourglass	Surface08	Aug. 13/2008	1.3	15	0.069	0.034	0.493	0.03	0.57	60	6.20
Hourglass	Surface10	Sept. 25/2010	1.25	13	0.05	0.022	0.440	0.01	0.35	58	6.80
Hourglass	Surface11	Aug. 13/2011	1.4	2.1	0.045	0.018	0.400	0.04	0.64	89	6.80
Hourglass	Surface13	Aug. 12/2013	0.63	7	0.056	0.029	0.518	<0.01	0.56	161.7	6.07
Hourglass	Surface14	Aug. 18/2014	0.8	44	0.067	0.037	0.552	<0.01	0.45	145.2	6.31
Hourglass	Surface 15	Aug. 17/2015	0.93	19	0.065	0.038	0.585	<0.01	0.4	105	6.35
Hourglass	Surface16	Aug. 21/2016	0.925	44.9	0.08	0.026	0.325	<0.01	0.39	66.5	6.50
Hourglass	Surface 17	Aug. 24/17	1	49.8	0.073	0.028	0.383562	<.02	0.41	80.4	6.7
Hourglass	Bottom08	Aug. 13/2008	1.3	15							
Hourglass	Bottom10	Sept. 25/2010	1.25	13							
Hourglass	Bottom11	Aug. 13/2011	1.4	2.1	0.39	0.33	0.846	0.01		167	
Hourglass	Bottom13	Aug. 12/2013	0.63	7	0.374	0.172	0.460	<0.01	2.19	270.8	6.07
Hourglass	Bottom14	Aug. 18/2014	0.8	44	0.564	0.454	0.805	<0.01	1.35	316.4	6.31
Hourglass	Bottom15	Aug. 17/2015	0.93		0.429	0.383	0.893	0.02	1.05	280	6.10
Hourglass	Bottom16	Aug. 21/2016	0.925		0.442	0.357	0.808	<0.01	0.97	166	7.00

Lake_ID	**Level and Year**	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Ortho-phosphate (mg/l)	OrthoP/ TotalP ratio	Total nitrate (mg/l)	Total Nitrogen (mg/l)	Colour (TCU)	pH
Hourglass	Bottom17	Aug. 24/17	1		0.651	0.52	0.798771	<.01	1.86	205	7.1
Placides	Surface08	Aug. 13/2008	1.3	20	0.74	0.58	0.784	0.35	1.69	68	6.50
Placides	Surface10	Sept. 26/2010	0.7	15.5	0.82	0.705	0.860	0.47	1.23	90	6.90
Placides	Surface11	Aug. 22/2011		2.8	0.96	0.786	0.819	0.58	1.83	117	6.80
Placides	Surface13	Aug. 6/2013	0.4	52	0.792	0.764	0.965	0.52	1.34	227.8	6.80
Placides	Surface14	Aug. 25/2014	0.625	32	0.806	0.611	0.758	<0.01	0.57	149.5	
Placides	Surface 15	Aug. 26/2015	0.95	22	0.698	0.592	0.848	<0.01	0.5	126	
Placides	Surface 16	Aug. 30/2016	1.4	15.05	0.624	0.5725	0.917	<0.01	0.38	66	6.90
Placides	Surface 17	Aug. 22/17	3.375	8.28	0.618	0.506	0.81877	<.01	0.46	98.6	6.2
Placides	Surface 17	Aug. 29/17	1	4.01	0.609	0.512	0.840722	<.01	0.48	96.8	6.8
Placides	Bottom08	Aug. 13/2008	1.3	20	5.2	5.2	1.000	0.02	2.95	202	6.30
Placides	Bottom10	Sept. 26/2010	0.7	15.5	0.83	0.652	0.786	0.54	1.28	97	6.90
Placides	Bottom11	Aug. 22/2011		2.8	2.1	1.78	0.848	0.16	4.32	132.7	
Placides	Bottom13	Aug. 6/2013	0.4	52	2.600	2.600	1.000	0.35	1.68	393.9	7.10
Placides	Bottom14	Aug. 25/2014	0.625	39	4.46	3.92	0.879	<.01	3.22	305.6	
Placides	Botton 15	Aug. 26/2015	0.95	291	4.32	4.06	0.940	<.01	2.8	291	

Lake_ID	Level and Year	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Ortho-phosphate (mg/l)	OrthoP/ TotalP ratio	Total nitrate (mg/l)	Total Nitrogen (mg/l)	Colour (TCU)	pH
Placides	Bottom 16	Aug. 30/2016	1.4		3.02	2.78	0.920	0.01	1.47	148	7.20
Placides	Bottom17	Aug. 22/17	3.375		0.661	0.528	0.79879	<.01	0.54	106	6.9
Placides	Bottom17	Aug. 29/17	1		0.615	0.522	0.84878	<.01	0.46	97.3	6.8
Porcupine	Surface08	Aug. 12/2008	2.5	7.8	0.012	0.005	0.417	0.01	0.22	25	6.60
Porcupine	Surface10	Sept. 26/2010	1.95	2.8	0.021	0.005	0.238	0.01	0.25	39	6.80
Porcupine	Surface11	Aug. 14/2011	0.9	3.4	0.014	0.005	0.357	0.01	0.3	46.6	6.90
Porcupine	Surface13	Aug. 6/2013	0.59	7	0.032	0.014	0.436	0.02	0.42	105.3	6.90
Porcupine	Surface14	Aug. 25/2014	1.63	6.9	0.016	0.005	0.313	<.01	0.28	73.2	
Porcupine	Surface15	Aug. 26/2015	1.9	7.3	0.016	0.003	0.188	<.01	0.24	53.2	
Porcupine	Surface 16	Aug. 30/2016	2.3	3.2	0.018	0.0055	0.306	<.01	0.255	30.55	6.80
Porcupine	Surface 17	Aug. 22/17	0.875	2.41	0.017	0.013	0.764706	<.01	0.29	44.7	6.9
Porcupine	Surface 17	Aug. 29/17	2.5	1.13	0.013	0.004	0.307692	<.01	0.3	38.3	6.8
Porcupine	Bottom08	Aug. 12/2008	2.5	7.8	0.021	0.005	0.238	0.01	0.4	87	6.30
Porcupine	Bottom10	Sept. 26/2010	1.95	2.8		0.13		0.01	0.26		6.80
Porcupine	Bottom11	Aug. 14/2011	0.9	3.4				0.08		72.3	
Porcupine	Bottom13	Aug. 6/2013	0.59		0.044	0.027	0.614	0.14	0.5	89.5	6.90

Lake_ID	Level and Year	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Ortho-phosphate (mg/l)	OrthoP/ TotalP ratio	Total nitrate (mg/l)	Total Nitrogen (mg/l)	Colour (TCU)	pH
Porcupine	Bottom14	Aug. 25/2014	1.63		0.058	0.038	0.655	0.17	0.61	111.6	
Porcupine	Bottom 15	Aug. 26/2015	1.9		0.062	0.039	0.629	0.14	0.61	102	
Porcupine	Bottom16	Aug. 30/2016	2.3		0.056	0.034	0.607	<.01	0.44	47.8	7.00
Porcupine	Bottom17	Aug. 22/17	0.875		0.065	0.024	0.369231	0.05	0.46	52	6.9
Porcupine	Bottom17	Aug. 29/17	2.5		0.016	0.006	0.375	0.04	0.29	45.1	6.8
Wentworth	Surface13	Aug. 12/2013	0.46	14	0.16	0.138	0.863	0.01	0.58	250.6	5.58
Wentworth	Surface14	Aug. 18/2014	0.33	13	0.187	0.14	0.749	<.01	0.54	304.1	5.64
Wentworth	Surface 15	Aug. 17/2015	0.6	11	0.13	0.111	0.854	<.01	0.37	182	6.00
Wentworth	Surface 16	Aug. 21/2016	1.57	3.9	0.154	0.146	0.948	0.06	0.51	115	6.10
Wentworth	Surface17	Aug. 21/17	0.625	4.63	0.084	0.082	0.97619	<.01	0.46	158	6.3
Wentworth	Bottom13	Aug. 12/2013	0.46	14	0.174	0.144	0.828	0.02	0.58	252.5	5.54
Wentworth	Bottom14	Aug. 18/2014	0.33	13							
Wentworth	Bottom 15	Aug. 17/2015	0.6		0.139	0.123	0.885	<.01	0.53	192	5.72
Wentworth	Bottom 16	Aug. 21/2016	1.57		0.154	0.104	0.675	0.06	0.53	117	6.10
Wentworth	Bottom17	Aug. 21/17	0.625		0.128	0.092	0.71875	<.01	0.46	164	6.1
Parr	Surface08	Aug.	1.5	11	0.033	0.012	0.364	0.01	0.27	64	6.20

Lake_ID	**Level and Year**	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Ortho-phosphate (mg/l)	OrthoP/ TotalP ratio	Total nitrate (mg/l)	Total Nitrogen (mg/l)	Colour (TCU)	pH
		14/2008									
Parr	Surface10	Aug. 24/2010	1	6.7	0.075	0.075	1.000	0.01	0.03	97.2	6.20
Parr	Surface11	Sept. 26/2010	0.75	13	0.061	0.031	0.508	0.01	0.33	86	6.20
Parr	Surface13	Aug. 12/2013	0.51	6.1	0.105	0.08	0.762	0.04	0.53	199.6	5.71
Parr	Surface14	Aug. 25/2014	0.57	11	0.111	0.084	0.757	<.01	0.49	193.9	5.86
Parr	Surface 15	Aug. 20/2015	1.8	7.8	0.075	0.047	0.627	<.01	0.41	123	6.26
Parr	Surface 16	Aug. 21/2016	1.35	13.7	0.055	0.022	0.400	<.01	0.38	67.7	6.30
Parr	Bottom08	Aug. 14/2008	1.5	11							
Parr	Bottom10	Sept. 27/2010	1	6.7							
Parr	Bottom11	Aug. 25/2011	0.75	13	0.076	0.046	0.605	0.01	0.036	99	
Parr	Bottom13	Aug. 12/2013	0.51	6.1	0.107	0.082	0.766	0.04	0.54	216.6	5.54
Parr	Bottom14	Aug. 25/2014	0.57	11	0.124	0.091	0.734	<.01	0.46	203.1	5.81
Parr	Bottom 15	Aug. 20/2015	1.8		0.134	0.099	0.739	<.01	0.56	211	5.71
Parr	Bottom16	Aug. 21/2016	1.35		0.069	0.035	0.507	0.02	0.4	76.2	6.30
Ogden	Surface08	Aug. 14/2008	1.8	10	0.014	0.005	0.357	0.01	0.25	39	6.10
Ogden	Surface10	Sept.	0.95	18.8	0.029	0.008	0.276	0.05	0.35	58	6.30

Lake_ID	**Level and Year**	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Ortho-phosphate (mg/l)	OrthoP/ TotalP ratio	Total nitrate (mg/l)	Total Nitrogen (mg/l)	Colour (TCU)	pH
		27/2010									
Ogden	Surface11	Aug. 24/2011	1.2	12.5	0.022	0.005	0.227	0.01	0.28	59.2	6.10
Ogden	Surface13	Aug. 6/2013	0.6	9.4	0.052	0.035	0.673	0.02	0.41	145.3	6.40
Ogden	Surface14	Aug. 25/2014	0.66	26	0.046	0.021	0.457	<.01	0.44	126.5	6.20
Ogden	Surface 15	Aug. 20/2015	1.17	11	0.022	0.004	0.182	<.01	0.32	83.2	6.53
Ogden	Surface 16	Aug. 21/2016	1.25	4.46	0.024	0.004	0.167	0.02	0.33	41.6	6.30
Ogden	Bottom08	Aug. 14/2008	1.8	10	0.097	0.051	0.526	0.01	0.8	152	5.90
Ogden	Bottom10	Sept. 27/2010	0.95	18.8	0.26	0.194	0.746	0.01	1.79	206	7.00
Ogden	Bottom11	Aug. 24/2011	1.2	12.5	0.094	0.038	0.404	0.02	0.74	107.1	
Ogden	Bottom13	Aug. 6/2013	0.6	9.4	0.960	0.720	0.750	0.13	0.58	141.9	6.40
Ogden	Bottom14	Aug. 25/2014	0.66	26	0.102	0.074	0.725	0.02	0.75	198.4	5.95
Ogden	Bottom15	Aug. 20/2015	1.17		0.058	0.041	0.707	0.08	0.48	88.1	5.52
Ogden	Bottom16	Aug. 21/16	1.25		0.205	0.138	0.673	<.01	0.74	126	6.90
Fanning	Surface08	Aug. 16/2008	2.3	5.8	0.011	0.005	0.455	0.01	0.21	31	6.40
Fanning	Surface09	Sept. 12/2009	0.75	1.3	0.056	0.037	0.661	0.06	0.4	120	5.90
Fanning	Surface10	Sept.	1.15	21.9	0.021	0.005	0.238	0.06	0.35	55	6.40

Lake_ID	**Level and Year**	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Ortho-phosphate (mg/l)	OrthoP/ TotalP ratio	Total nitrate (mg/l)	Total Nitrogen (mg/l)	Colour (TCU)	pH
		29/2010									
Fanning	Surface11	Aug. 17/2011	1.3	19.2	0.023	0.005	0.217	0.01	0.05	63.1	6.20
Fanning	Surface13	Aug. 11/2013	1.01	3.8	0.045	0.023	0.511	0.01	0.4	131.4	5.93
Fanning	Surface14	Aug. 24/2014	0.98	8.7	0.027	0.012	0.444	0.02	0.34	99	6.07
Fanning	Surface15	Aug. 16/2015	1.4	14	0.019	0.006	0.316	<.01	0.34	73.6	6.19
Fanning	Surface 16	Aug. 21/2016	1.55	10.4	0.023	0.003	0.130	0.03	0.32	43.8	6.40
Fanning	Surface 17	Aug. 23/17	1.5	3.39	0.022	0.01	0.454545	<.01	0.33	82.2	6.4
Fanning	Bottom08	Aug. 16/2008	2.3	5.8	0.097	0.055	0.567	0.01	0.62	137	6.50
Fanning	Bottom09	Sept. 12/2009	0.75	1.3	0.06	0.037	0.617	0.06	0.4	122	5.90
Fanning	Bottom10	Sept. 29/2010	1.15	21.9							
Fanning	Bottom11	Aug. 17/2011	1.3	19.2	0.082	0.054	0.659	0.01	0.045	202.2	
Fanning	Bottom13	Aug. 11/2013	1.01	3.8	0.044	0.026	0.591	0.02	0.38	130.6	5.82
Fanning	Bottom14	Aug. 24/2014	0.98	8.7	0.036	0.02	0.556	0.02	0.4	105.7	5.89
Fanning	Bottom15	Aug. 16/2015	1.4		0.039	0.023	0.590	<.01	0.28	95.2	5.27
Fanning	Bottom16	Aug. 21/2016	1.55		0.041	0.016	0.390	0.02	0.46	65.2	6.60
Fanning	Bottom17	Aug. 23/17	1.5		0.01	0.005	0.5	<.01	0.33	91.8	6.4
Sloans	Surface09	Sept.	3.8	1.9	0.005	0.005	1.000	0.01	0.18	20	6.90

Lake_ID	**Level and Year**	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Ortho-phosphate (mg/l)	OrthoP/ TotalP ratio	Total nitrate (mg/l)	Total Nitrogen (mg/l)	Colour (TCU)	pH
		12/2009									
Sloans	Surface10	Sept. 30/2010	4.3	4.3	0.009	0.005	0.556	0.01	0.12	12	7.00
Sloans	Surface11	Aug. 15/2011	4.6	4.6	0.005	0.005	1.000	0.01	0.13	15.3	7.00
Sloans	Surface13	Aug. 11/2013	3.11	2.4	0.004	0.0025	0.625	<0.01	0.14	22.3	6.77
Sloans	Surface14	Aug. 24/2014	4.65	1.8	0.004	0.001	0.250	<0.01	0.13	20.1	6.85
Sloans	Surface 15	Aug. 16/2015	5.375	2.2	0.004	0.004	1.000	0.02	0.16	21.2	
Sloans	Surface16	Aug. 28/2016	6.25	1.78	0.004	0.004	1.000	0.01	0.14	18.6	6.90
Sloans	Surface 17	Aug. 21/17	4.35	1.35	0.004	0.004	1	<.01	0.15	14.6	7.0
Sloans	Bottom09	Sept. 12/2009	3.8	1.9	0.007		0.000	0.06	0.09	15	6.80
Sloans	Bottom10	Sept. 30/2010	4.3	4.3	0.007	0.005	0.714	0.01	0.08	18	6.90
Sloans	Bottom11	Aug. 15/2011	4.6	4.6	0.01	0.005	0.500	0.02	0.12	16.9	6.90
Sloans	Bottom13	Aug. 11/2013	3.11	2.4	0.004	0.0025	0.625	0.02	0.18	18.7	5.90
Sloans	Bottom14	Aug. 24/2014	4.65	1.8	0.008	0.001	0.125	0.01	0.17	32.9	5.93
Sloans	Bottom15	Aug. 16/2015	5.375		0.005	0.005	1.000	0.06	0.22	31	6.84
Sloans	Bottom16	Aug. 28/2016	6.25		0.032	0.005	0.156	0.03	0.27	25	7.00
Sloans	Bottom17	Aug. 21/17	4.35		0.006	0.006	1	0.04	0.21	15.3	6.9
Raynards	Surface13	Aug.	1.2	26.65797	0.021262						6.20

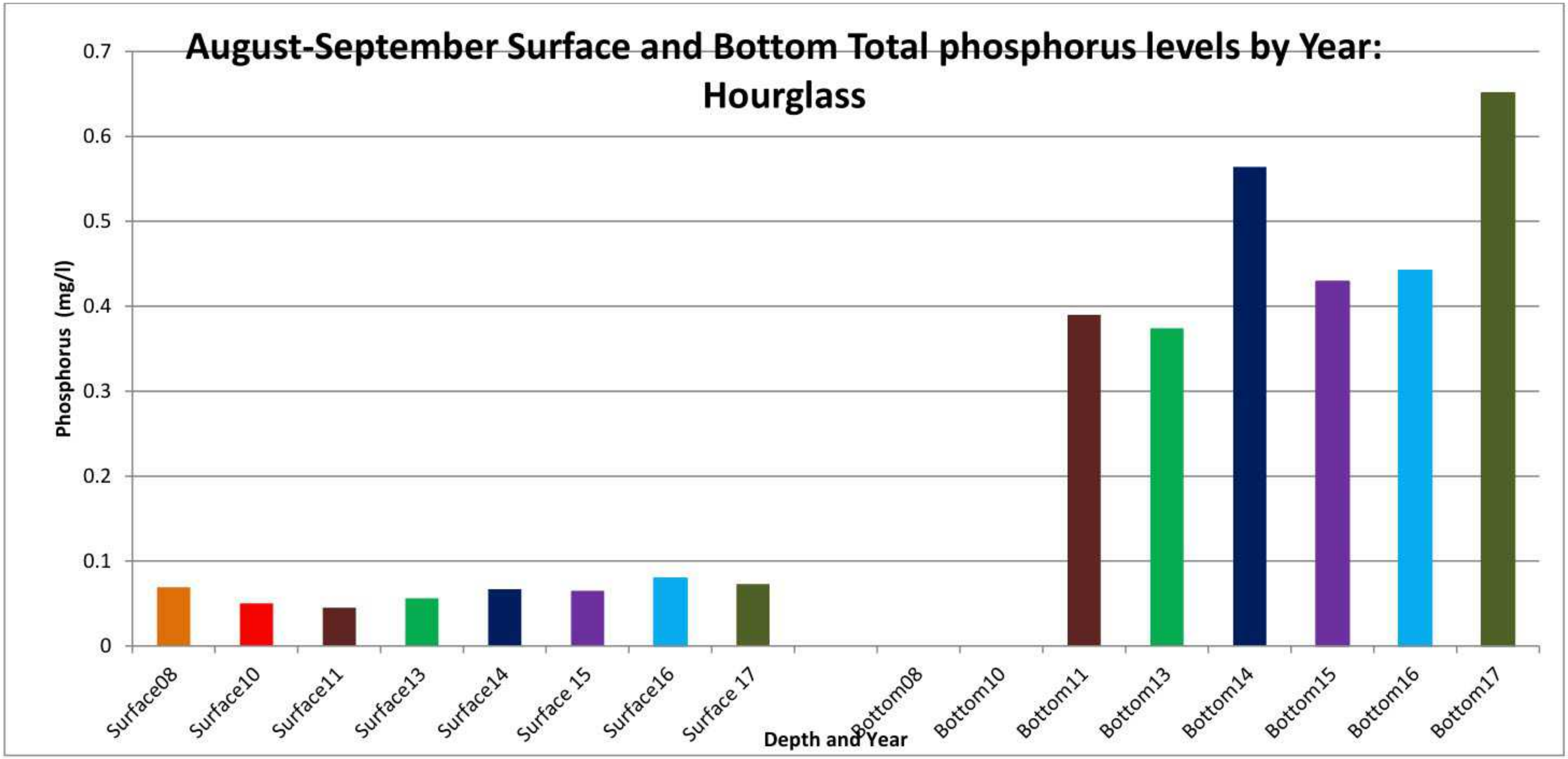
Lake_ID	**Level and Year**	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Ortho-phosphate (mg/l)	OrthoP/ TotalP ratio	Total nitrate (mg/l)	Total Nitrogen (mg/l)	Colour (TCU)	pH
		11/2013									
Raynards	Surface14	Aug. 24/2014	1.23	16	0.013	0.002	0.153846	<0.01	0.27	54	6.19
Raynards	Surface15	Aug. 19/2015	1.85	12	0.011	0.004	0.364	<0.01	0.27	47	6.44
Raynards	Surface16	Aug. 24/2016	1.5	4.27	0.009	0.004	0.444	<0.01	0.2	32.3	6.50
Raynards	Surface 17	Aug. 14/17	2.25	5.3	0.012	0.004	0.333333	<.01	0.24	43.9	6.5
Raynards	Bottom13	Aug. 11/2013	1.2								5.66
Raynards	Bottom14	Aug. 24/2014	1.23		0.017	0.010	0.588	0.05	0.23	65.5	5.75
Raynards	Bottom15	Aug. 19/2015	1.85		0.014	0.004	0.286	<0.01	0.46	81.6	6.20
Raynards	Bottom16	Aug. 24/2016	1.4		0.009	0.004	0.444	<0.01	0.22	33.7	6.60
Raynards	Bottom17	Aug. 14/17	2.25		0.024	0.008	0.333333	<.01	0.3	56.3	6.6
Vaughan	Surface08	Sept. 4/2008	3	3.9	0.012	0.005	0.417	0.01	0.17	22	7.20
Vaughan	Surface10	Sept. 30/2010	1.2	2.8	0.019	0.005	0.264	0.04	0.34	69	6.20
Vaughan	Surface11	Aug. 16/2011	1.9	2.6	0.01	0.005	0.5010	0.01	0.22	63	6.20
Vaughan	Surface13	Aug. 13/2013	1.17	14	0.02	0.0025	0.125	<0.01	0.29	81	6.24
Vaughan	Surface14	Aug. 18/2014	1.43	14	0.012	0.003	0.250	<0.01	0.35	54.9	6.32
Vaughan	Surface15	Aug. 18/2015	1.8	10	0.01	0.003	0.300	<0.01	0.24	57	6.52
Vaughan	Surface 16	Aug.	1.3	7.87	0.008	0.003	0.375	<0.01	0.21	41.8	6.40

Lake_ID	Level and Year	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Ortho-phosphate (mg/l)	OrthoP/ TotalP ratio	Total nitrate (mg/l)	Total Nitrogen (mg/l)	Colour (TCU)	pH
		24/2016									
Vaughan	Surface 17	Aug. 24/17	1.625	14.7	0.015	0.01	0.666667	<.01	0.28	51.2	6.5
Vaughan	Bottom08	Sept. 4/2008	3	3.9	0.045	0.005	0.111	0.01	0.73	148	6.30
Vaughan	Bottom10	Sept. 30/2010	1.2	2.8	0.078	0.043	0.551	0.01	0.5	181	7.10
Vaughan	Bottom11	Aug. 16/2011	1.9	2.6	0.087	0.061	0.701	0.01	0.65	112	7.20
Vaughan	Bottom13	Aug. 13/2013	1.17	14	0.015	0.0025	0.167	<0.01	0.27	79.8	6.43
Vaughan	Bottom14	Aug. 18/2014	1.43	14	0.04	0.02	0.500	<0.01	0.56	108.5	
Vaughan	Bottom 15	Aug. 18/2015	1.8		0.083	0.05	0.602	<0.01	0.81	238	6.28
Vaughan	Bottom 16	Aug. 24/2016	1.3		0.053	0.041	0.774	<0.01	0.53	88.1	7.00
Vaughan	Bottom17	Aug. 24/17	1.625		0.136	0.103	0.757353	<.01	0.91	189	7.2
Provost	Surface08	Aug. 14/2008	1.7	18	0.011	0.005	0.455	0.01	0.45	32	6.10
Provost	Surface10	Sept. 30/2010	1.7	20.3	0.016	0.005	0.313	0.04	0.29	36	6.00
Provost	Surface11	Aug. 14/2011	0.6	19.6	0.011	0.005	0.455	0.01	0.03	43.8	6.00
Provost	Surface13	Aug. 13/13	0.99	32	0.016	0.0025	0.156	0.05	0.48	74.3	5.96
Provost	Surface14	Aug. 24/2014	1.05	31	0.016	0.006	0.375	0.02	0.52	82.6	
Provost	Surface 15	Aug. 25/2015	2.65	4.8	0.016	0.002	0.125	<0.01	0.25	42.1	
Provost	Surface16	Aug.	2.4	5.675	0.017	0.0045	0.265	<0.01	0.27	19.7	6.30

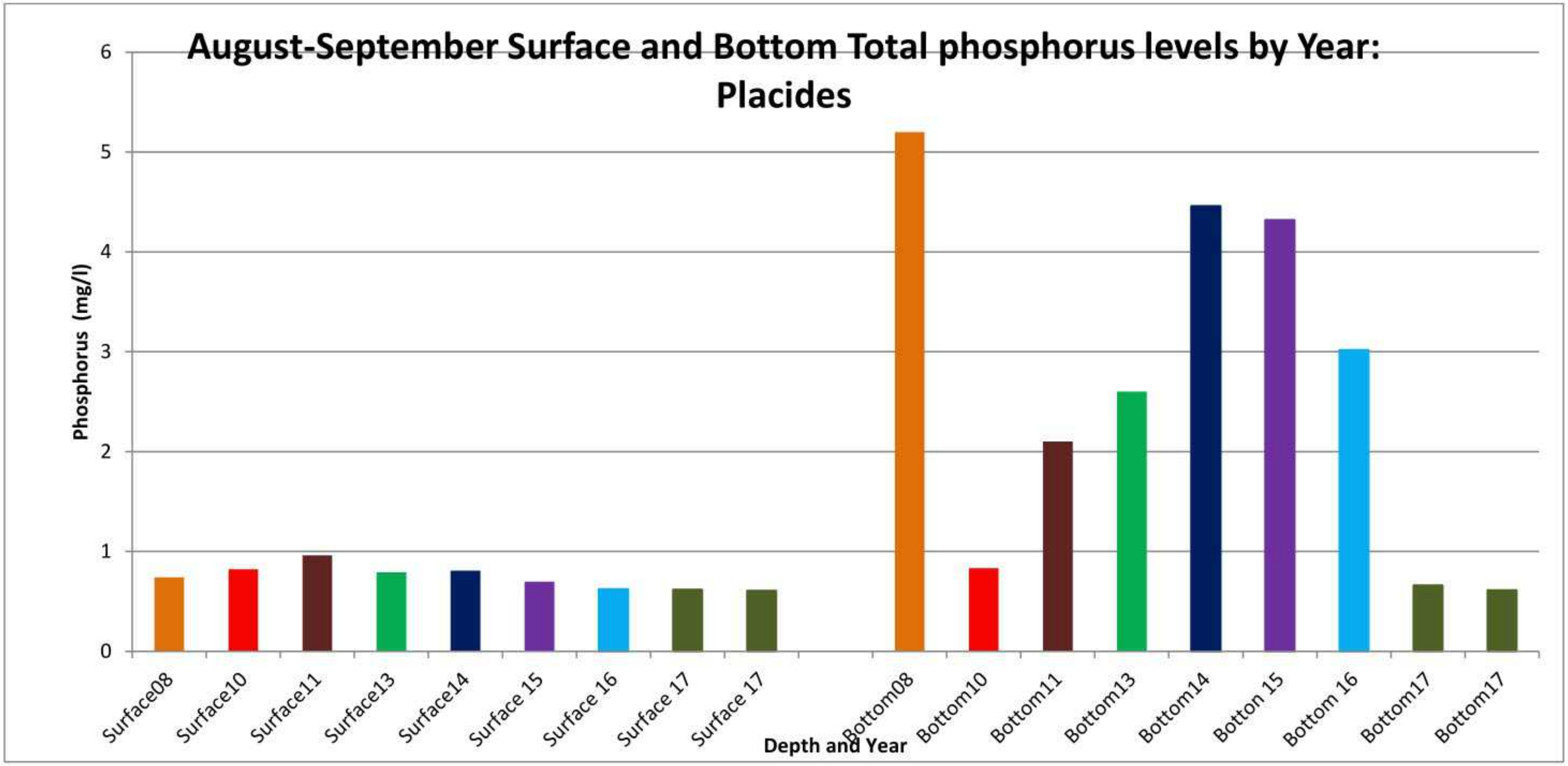
Lake_ID	**Level and Year**	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Ortho-phosphate (mg/l)	OrthoP/ TotalP ratio	Total nitrate (mg/l)	Total Nitrogen (mg/l)	Colour (TCU)	pH
		30/2016									
Provost	Surface 17	Aug. 22/17	2.2	4.15	0.008	0.004	0.5	<.01	0.29	34.3	6.4
Provost	Surface 17	Aug. 30/17	3	4.7	0.012	0.001	0.083333	<.01	0.27	34	6.2
Provost	Bottom08	Aug. 14/2008	1.7	18							
Provost	Bottom10	Sept. 30/2010	1.7	20.3							
Provost	Bottom11	Aug. 14/2011	0.6	19.6	0.016	0.005	0.313	0.01	0.03	55.4	
Provost	Bottom13	Aug. 13/2013	0.99	32	0.014	0.0025	0.179	0.05	0.54	86.4	5.59
Provost	Bottom14	Aug. 24/2014	1.05	31	0.166	0.098	0.590	<0.01	2.7	431	
Provost	Surface 15	Aug. 25/2015	2.65		0.091	0.045	0.495	<0.01	1.51	372	
Provost	Bottom16	Aug. 30/2016	2.4		0.022	0.006	0.273	<0.01	0.36	39.6	6.50
Provost	Bottom17	Aug. 22/17	2.2		0.014	0.003	0.214286	<.01	0.26	36.1	6.5
Provost	Bottom17	Aug. 30/17	3		0.045	0.014	0.311111	<.01	1.2	114	7.0
Nowlans	Surface 15	Aug. 25/2015	0.625	90	0.497	0.43	0.865	<0.01	0.77	58.9	
Nowlans	Surface16	Aug. 31/2016	0.85	73.9	0.556	0.525	0.944	<0.01	n/a	15.3	7.35
Nowlans	Surface17	Aug. 29/17	1	48.6	0.553	0.437	0.790235	0.01	n/a	25.4	7.3
Nowlans	Bottom15 15	Aug. 25/2015	0.625		2.16	1.98	0.917	<0.01	2.6	89.7	

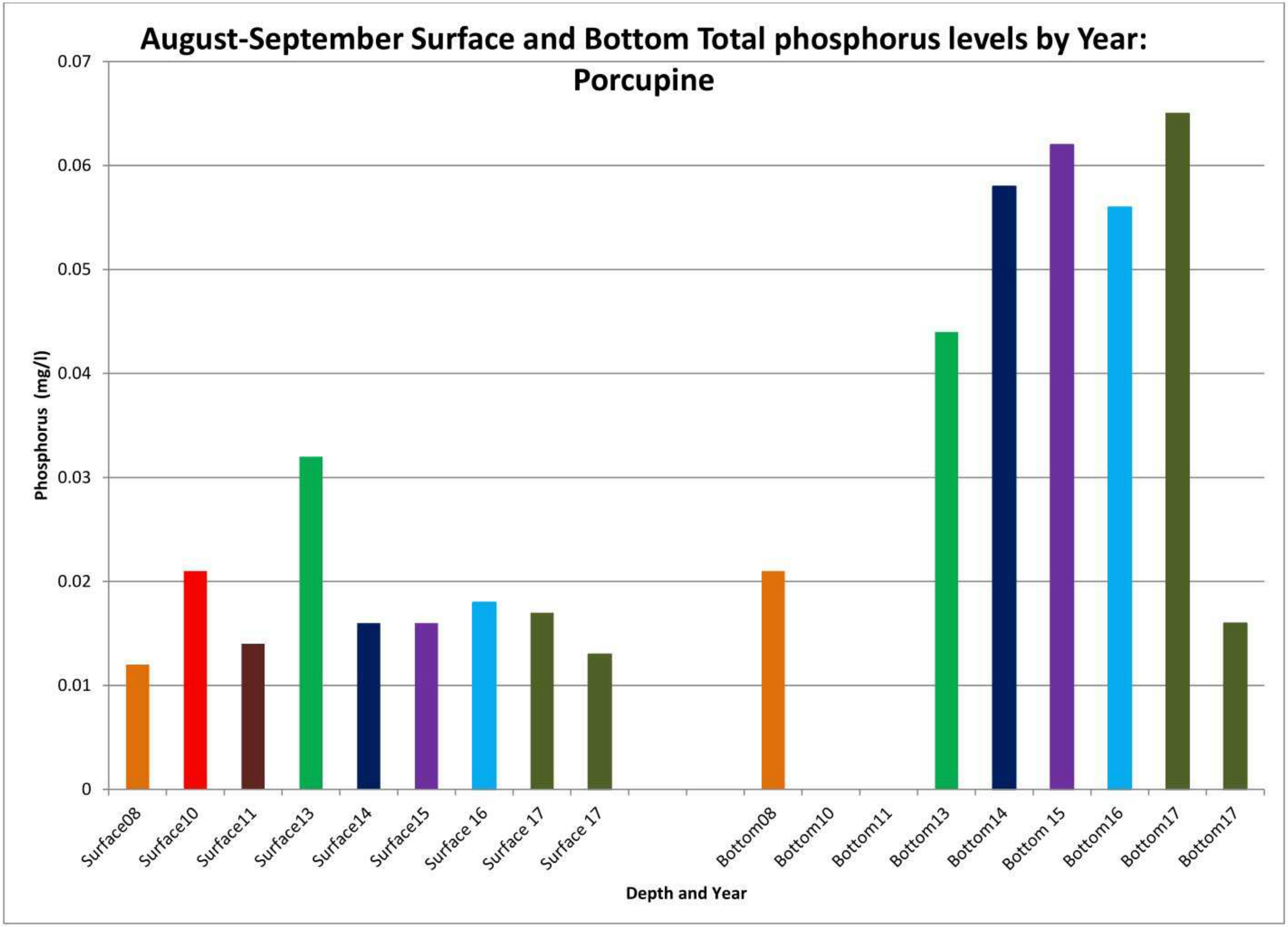
Lake_ID	Level and Year	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Ortho-phosphate (mg/l)	OrthoP/ TotalP ratio	Total nitrate (mg/l)	Total Nitrogen (mg/l)	Colour (TCU)	pH
Nowlans	Bottom16	Aug. 31/2016	0.85		4.18	3.73	0.892	<0.01	5.6	130	7.30
Nowlans	Bottom17	Aug. 29/17	1		0.764	0.522	0.683246	0.02	1.28	24.2	7.3
Kegeshook	Surface 14	August 21/2014	1.97	3.4	0.005	0.001	0.200	<0.01	0.18	60.8	5.96
Kegeshook	Surface/15	August 24/2015	2.215	5.1	0.006	0.004	0.667	<0.01	0.19	64.2	6.04
Kegeshook	Surface 16	August 21/2016	1.87	14.9	0.007	0.003	0.429	<0.01	0.18	38.2	6.4
Kegeshook	Surface 17	Aug. 28/17	1.25	2.75	0.005	0.003	0.6	<.01	0.21	56.5	6.3
Kegeshook	Bottom 14	August 21/2014	1.97		0.013	0.005	0.385	<0.01	0.02	88.2	5.42
Kegeshook	Bottom15	August 24/2015	2.215		0.009	0.009	1.000	0.02	0.2	55.6	5.34
Kegeshook	Bottom 16	August 21/2016	1.87		0.008	0.003	0.375	<0.01	0.18	45.1	6.4
Kegeshook	Bottom17	Aug. 28/17	1.25		0.051	0.006	0.117647	<.01	0.22	60.7	6.6
Salmon	Surface 15	Aug. 18/2015	1.55	4.9	0.014	0.004	0.286	<0.01	0.76	90.4	6.16
Salmon	Surface 16	Aug. 21/2016	2.25	9.99	0.016	0.003	0.188	<0.01	0.28	53.3	6.4
Salmon	Surface17	Aug. 17/17	1.38	2.28	0.009	0.004	0.444444	<.01	0.48	108	6.2
Salmon	Bottom 15	Aug. 18/2015	1.55		0.015	0.006	0.400	<0.01	0.77	98.5	5.69
Salmon	Bottom 16	Aug. 21/2016	2.25		0.018	0.004	0.222	<0.01	0.28	52.7	6.3

Lake_ID	Level and Year	Date	Secchi Depth (m)	Chlorophyll-a (µg/l)	Total Phosphorus (mg/l)	Ortho-phosphate (mg/l)	OrthoP/ TotalP ratio	Total nitrate (mg/l)	Total Nitrogen (mg/l)	Colour (TCU)	pH
Salmon	Bottom17	Aug. 17/17	1.38		0.01	0.001	0.1	<.01	0.38	106	6.3



No bottom phosphorus data for 2008 nor 2010.


August-September Surface and Bottom Total phosphorus levels by Year: Placides
Phosphorus (mg/l)
0
1
2
3
4
5
6
Surface08
Surface10
Surface11
Surface13
Surface14
Surface 15
Surface 16
Surface 17
Surface 17
Bottom08
Bottom10
Bottom11
Bottom13
Bottom14
Botton 15
Bottom 16
Bottom17
Bottom17
Depth and Year



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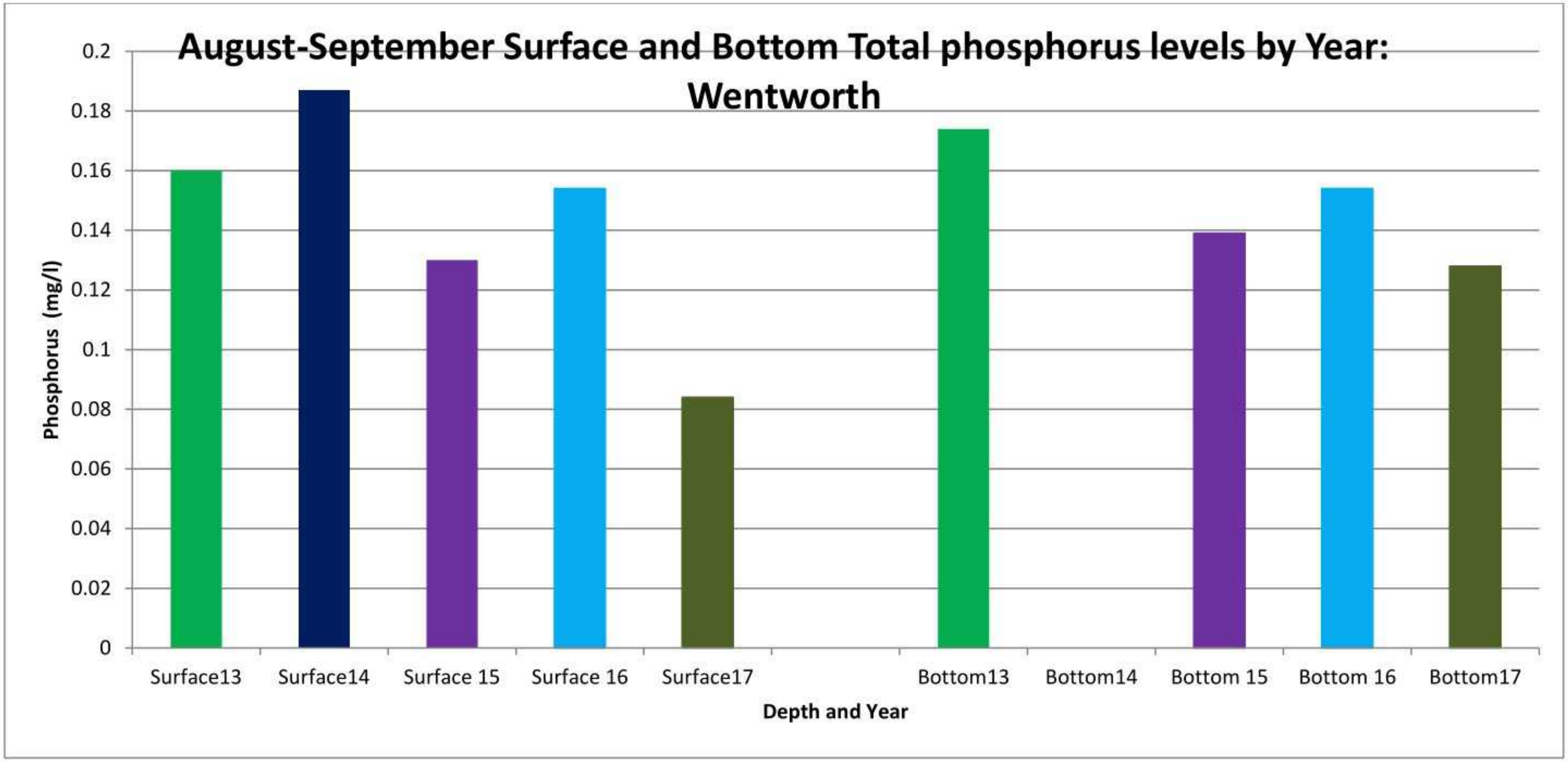
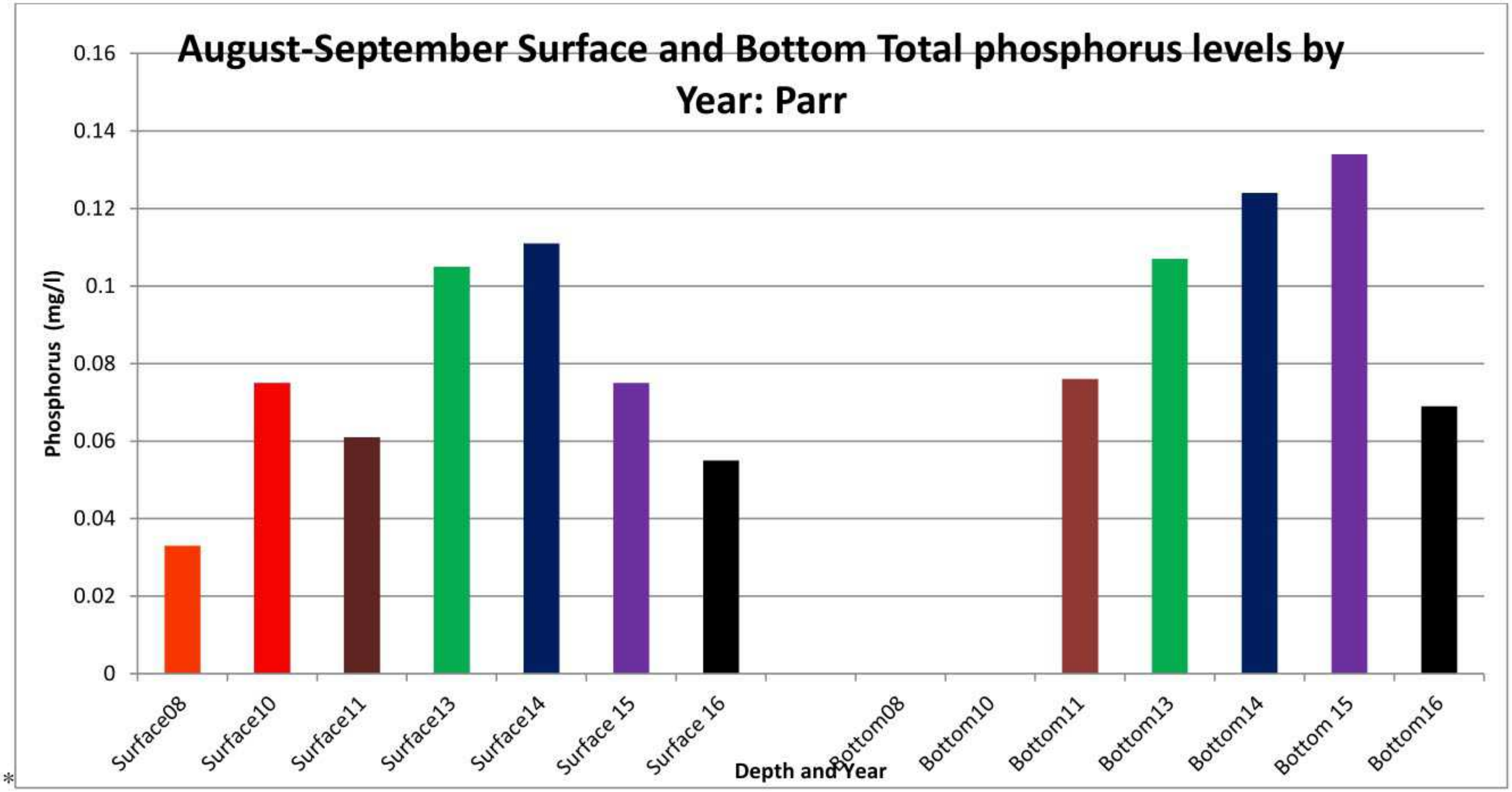


August-September Surface and Bottom Total phosphorus levels by Year: Wentworth
Phosphorus (mg/l)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Surface13
Surface14
Surface 15
Surface 16
Surface17
Bottom13
Bottom14
Bottom 15
Bottom 16
Bottom17
Depth and Year



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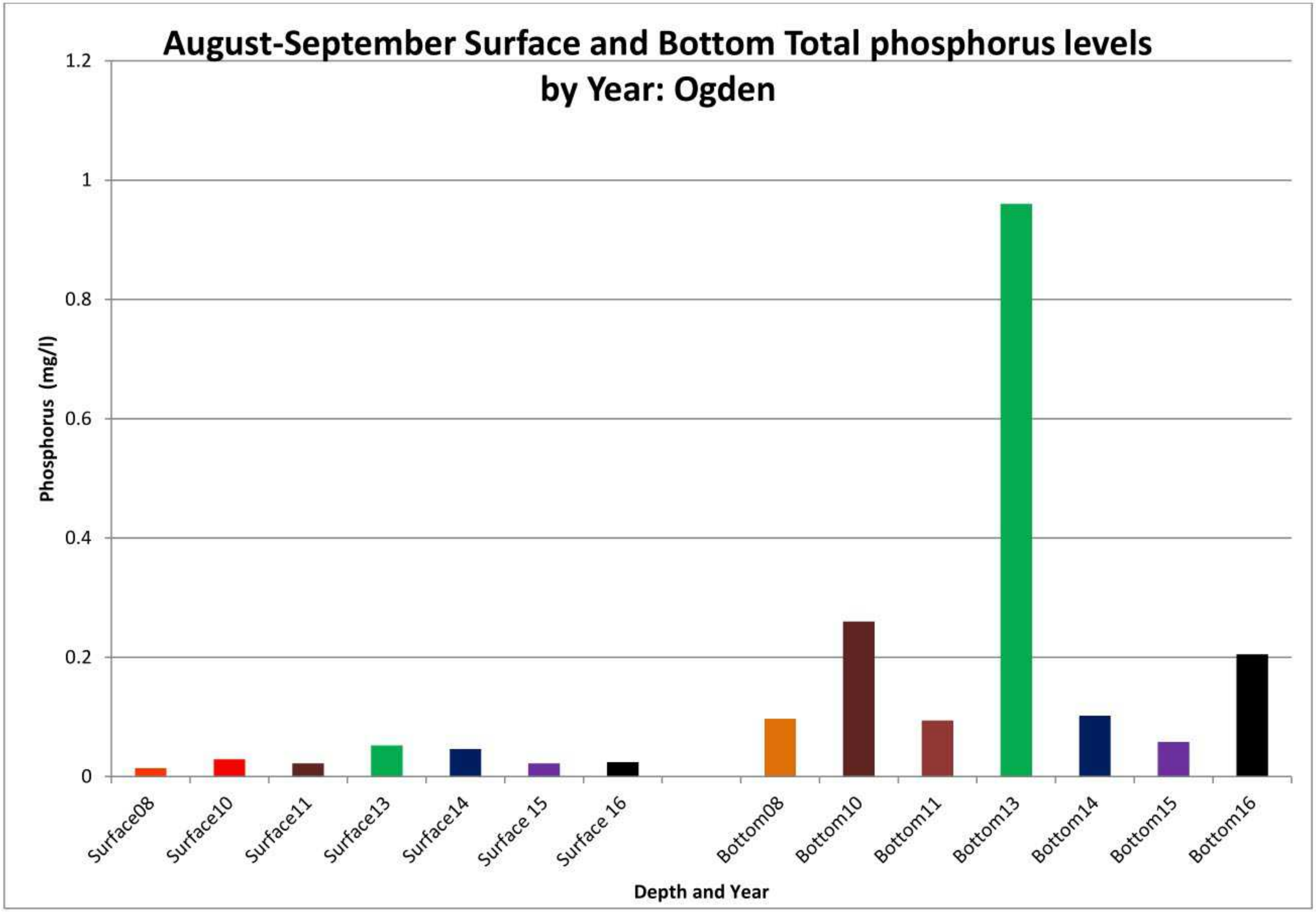
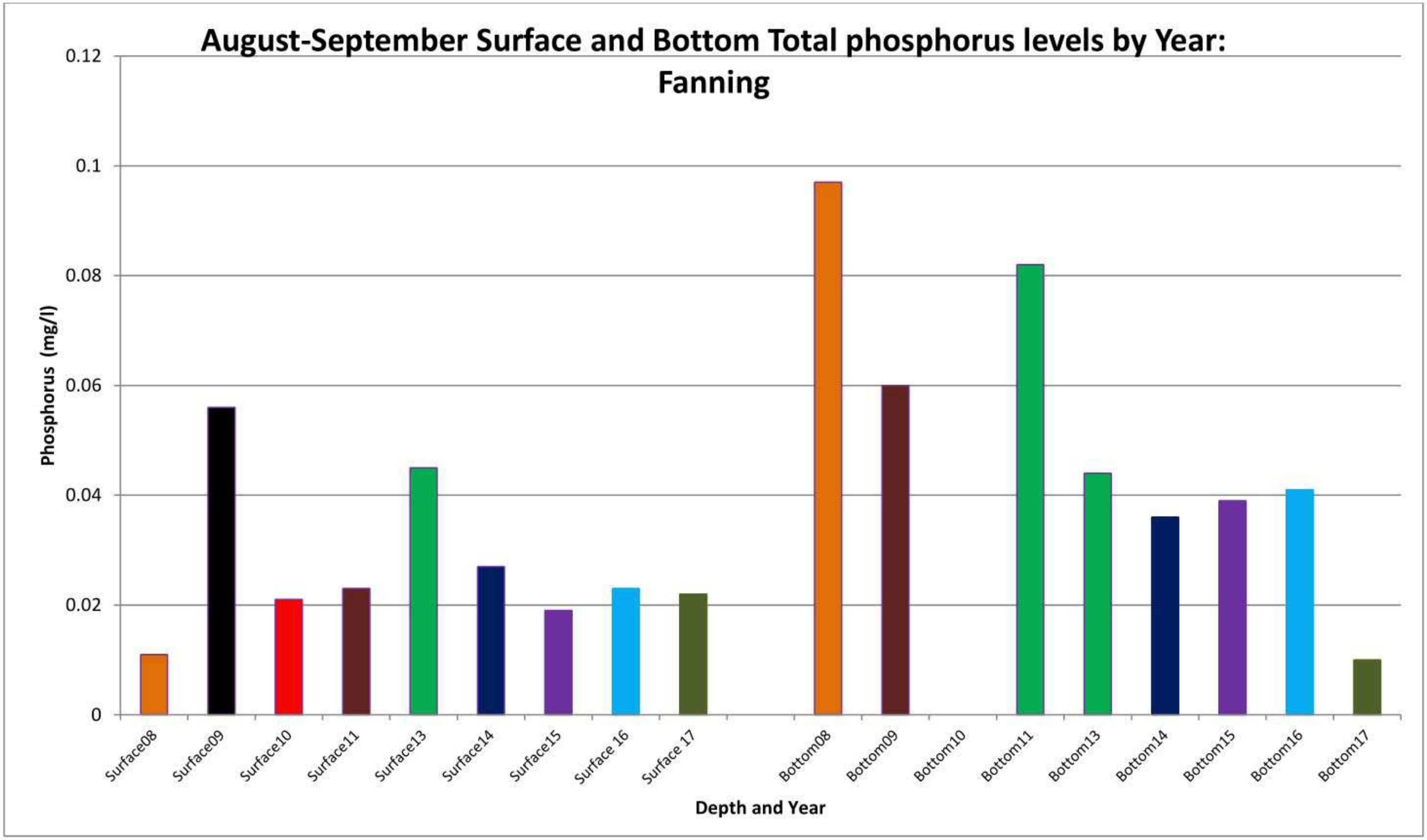
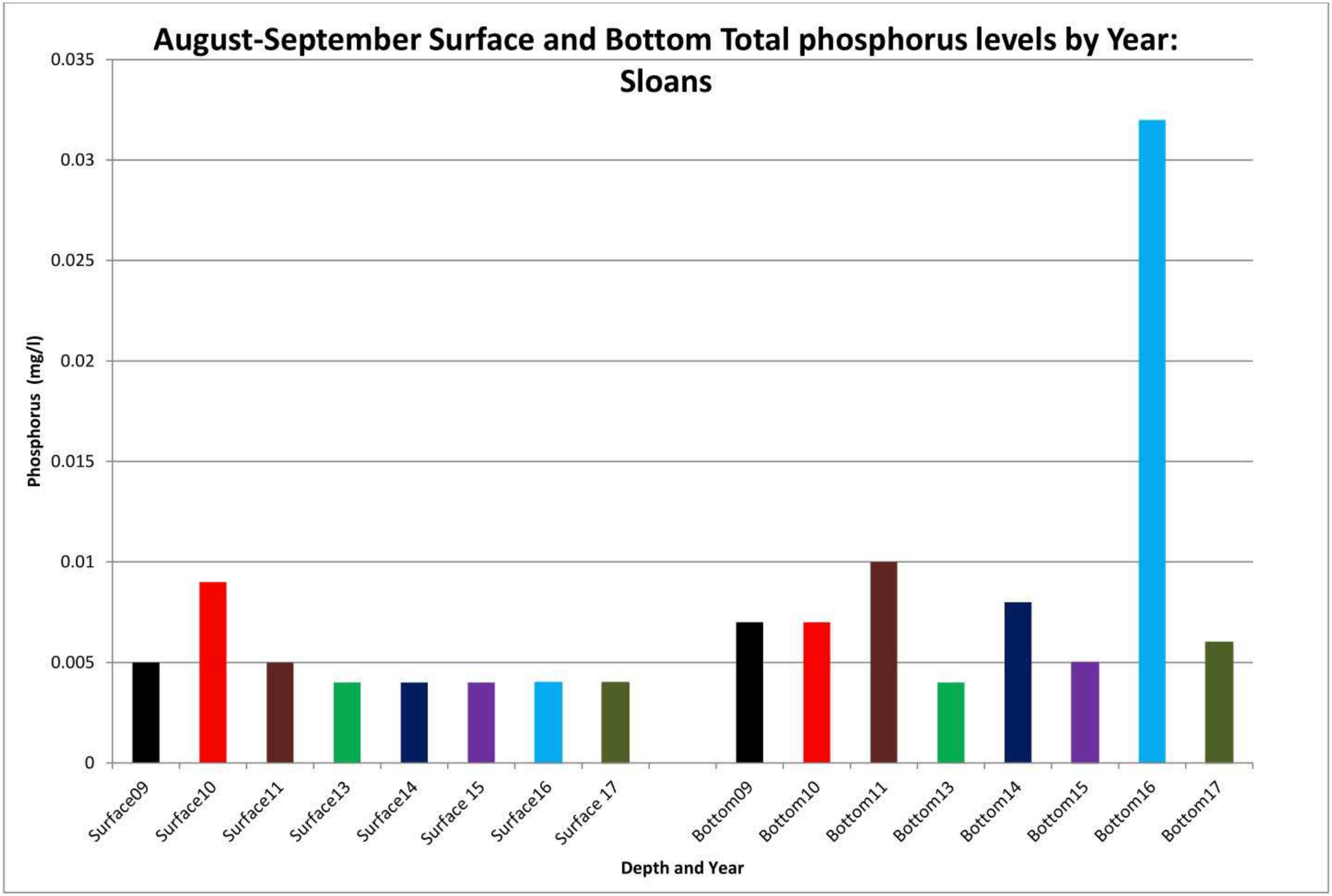
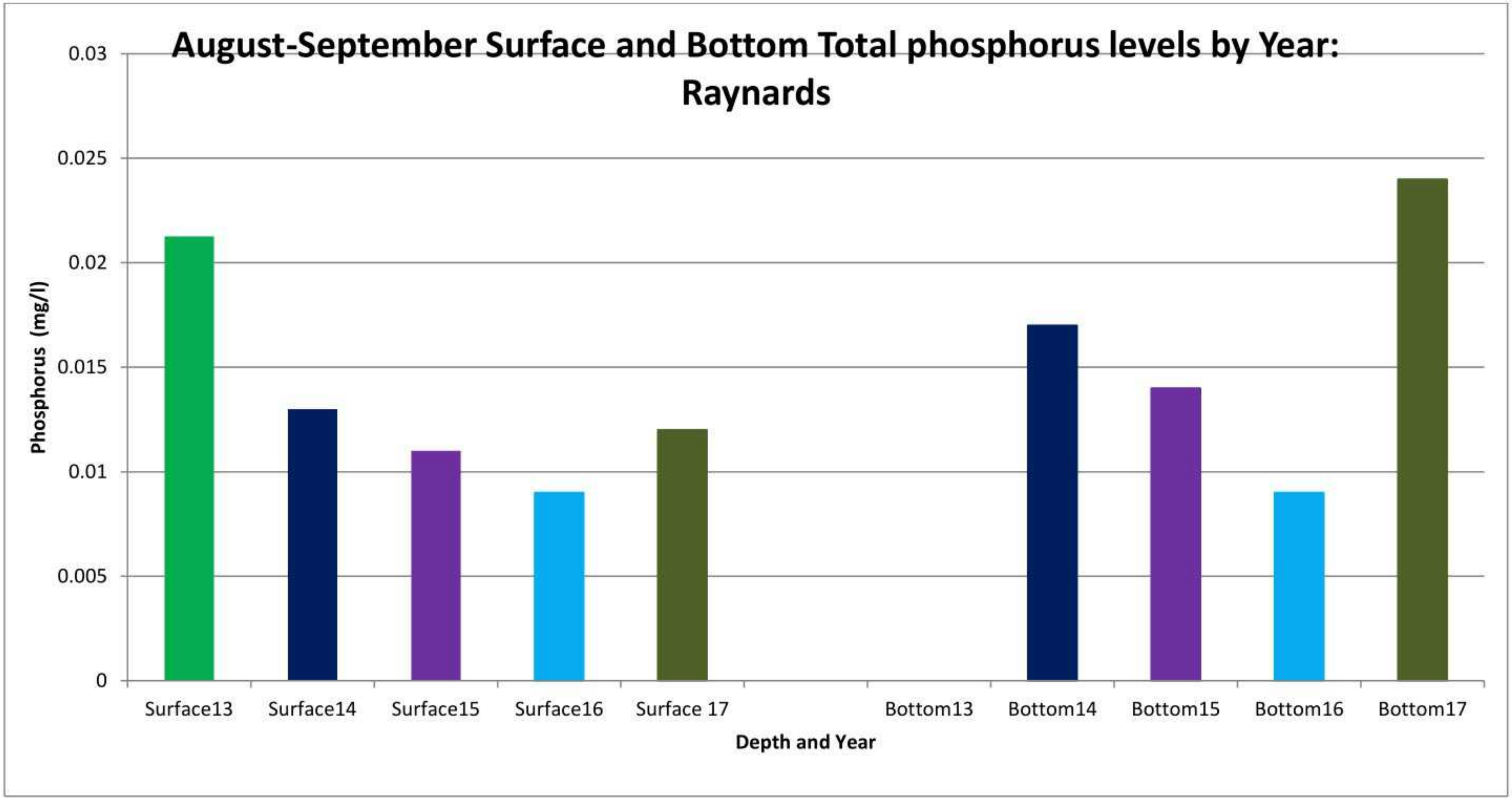
No bottom phosphorus data for 2008 nor 2010.


August-September Surface and Bottom Total phosphorus levels
by Year: Ogden
Phosphorus (mg/l)
1.2
1
0.8
0.6
0.4
0.2
0
Surface08
Surface10
Surface11
Surface13
Surface14
Surface 15
Surface 16
Bottom08
Bottom10
Bottom11
Bottom13
Bottom14
Bottom15
Bottom16
Depth and Year

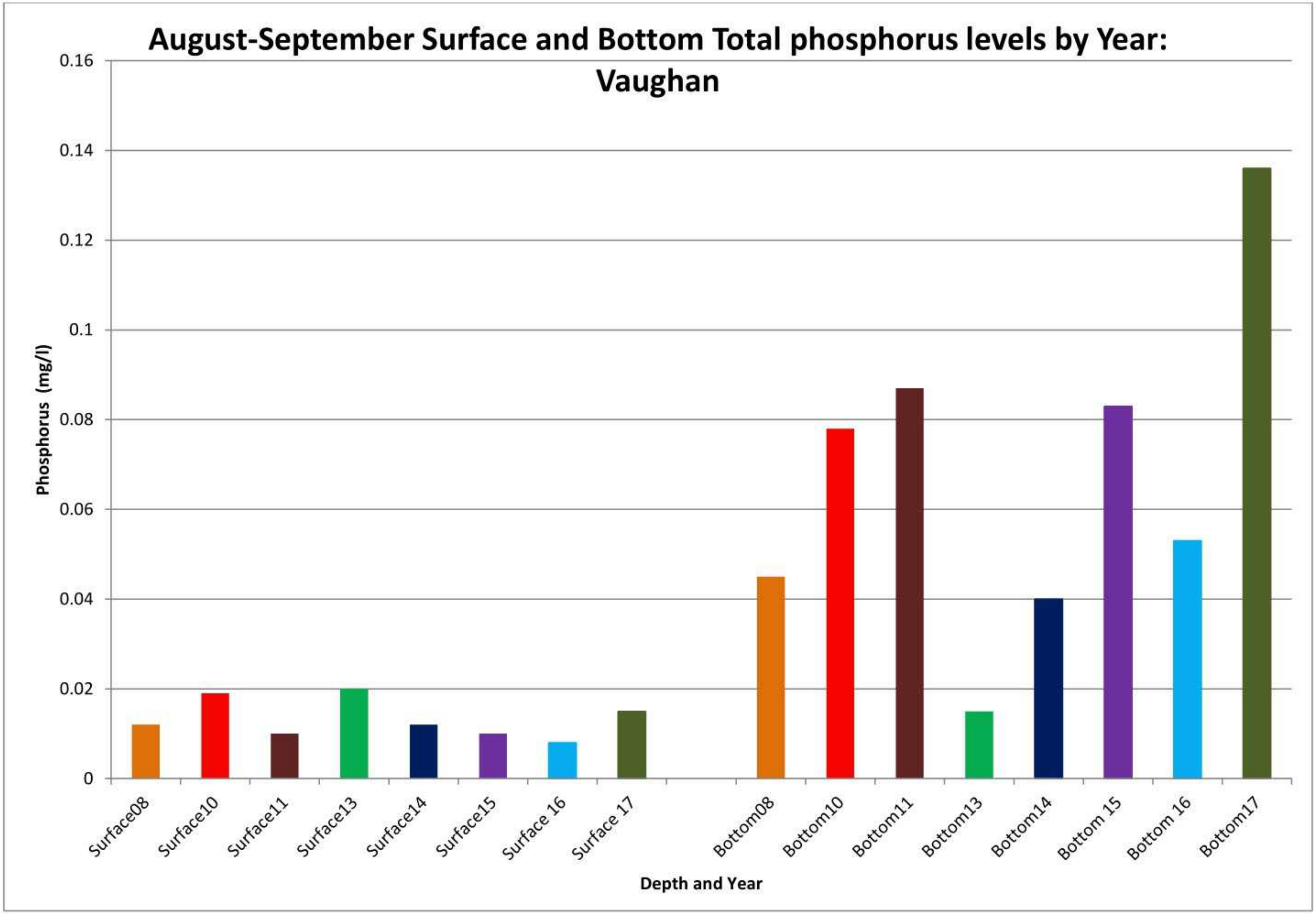


No bottom phosphorus data available for 2010.

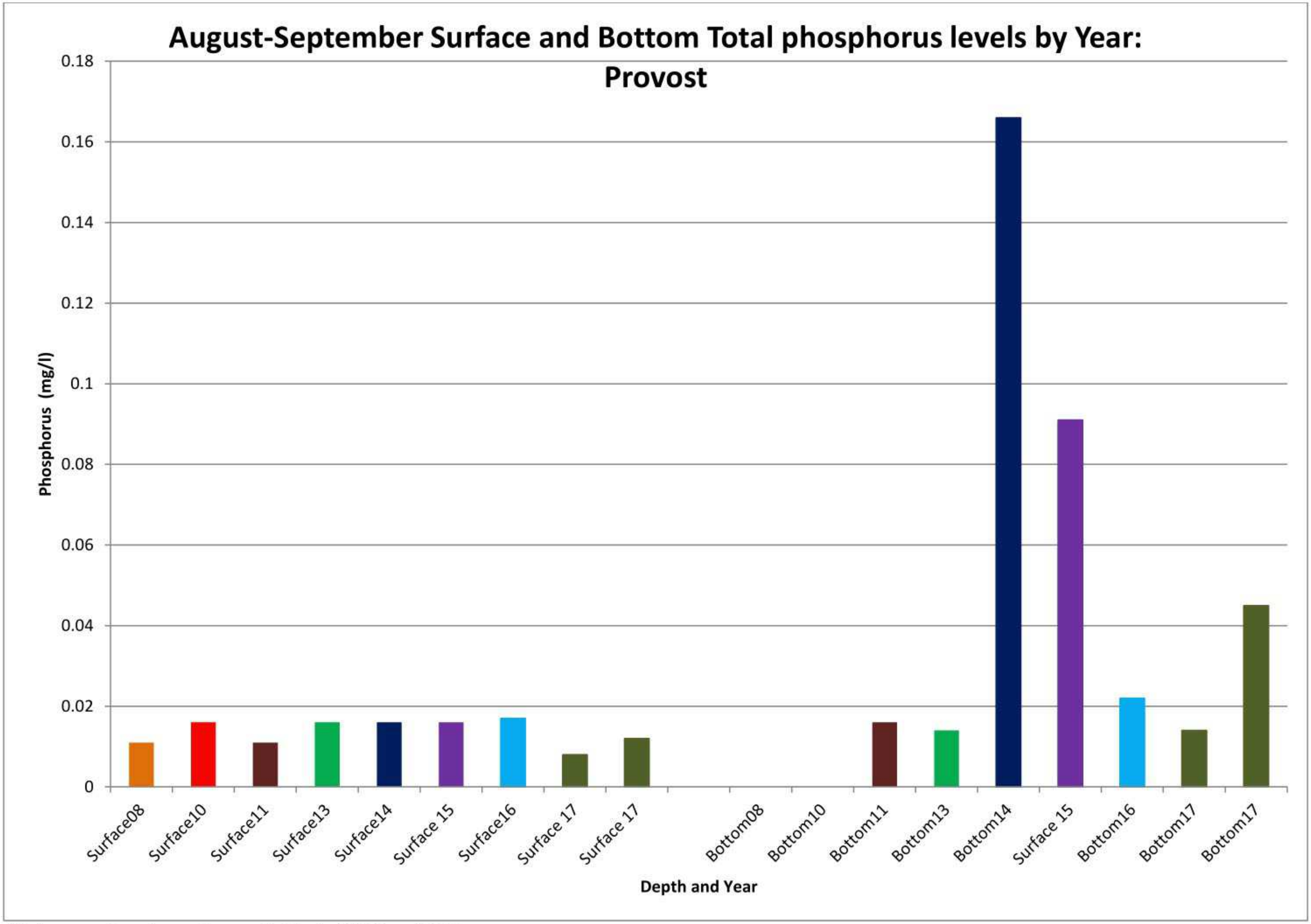

August-September Surface and Bottom Total phosphorus levels by Year: Sloans
Phosphorus (mg/l)
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Surface09
Surface10
Surface11
Surface13
Surface14
Surface 15
Surface16
Surface 17
Bottom09
Bottom10
Bottom11
Bottom13
Bottom14
Bottom15
Bottom16
Bottom17
Depth and Year



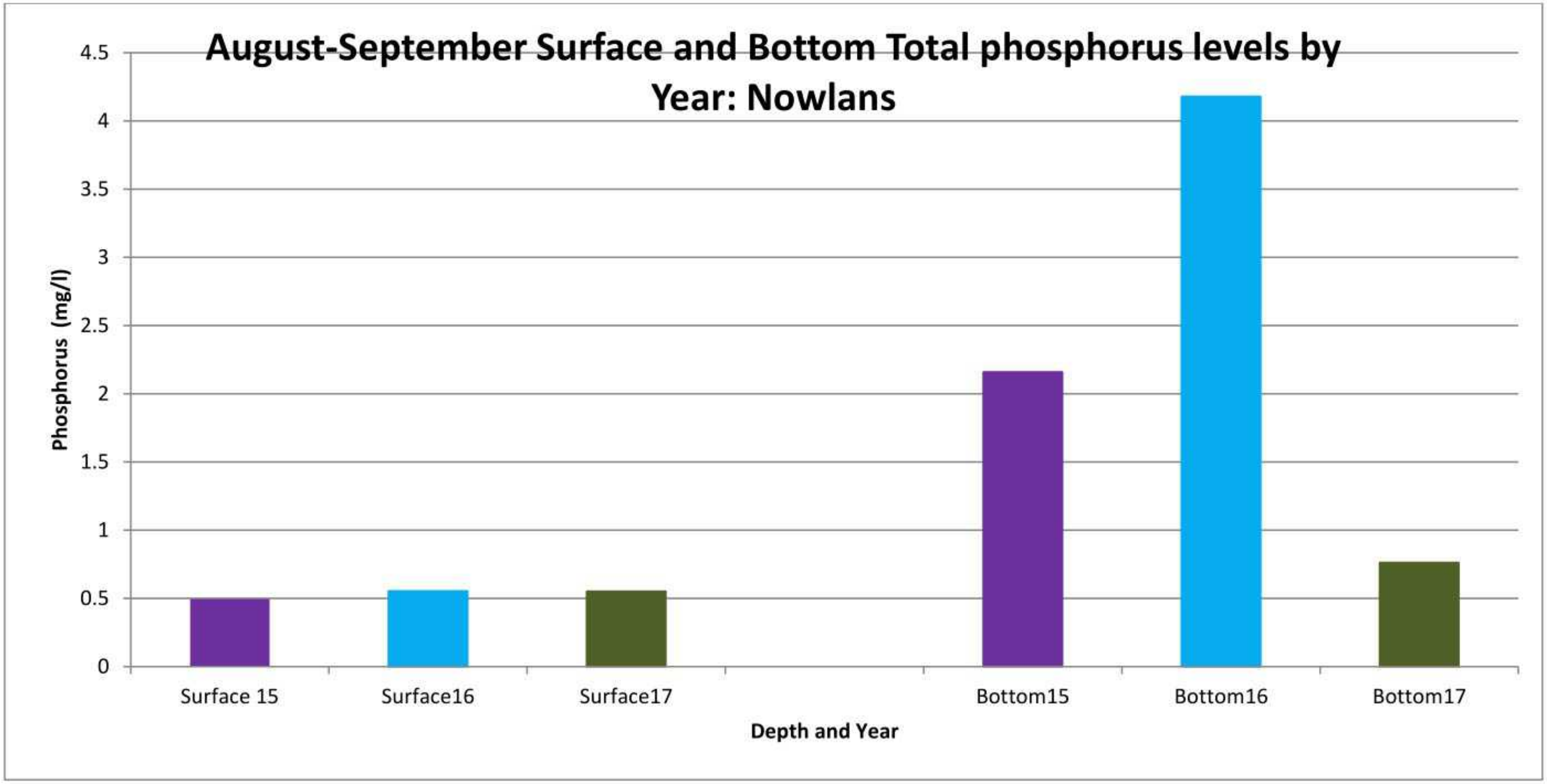
August-September Surface and Bottom Total phosphorus levels by Year:
Raynards
0.03
0.025
0.02
0.015
0.01
0.005
0
Phosphorus (mg/l)
Surface13
Surface14
Surface15
Surface16
Surface 17
Bottom13
Bottom14
Bottom15
Bottom16
Bottom17
Depth and Year



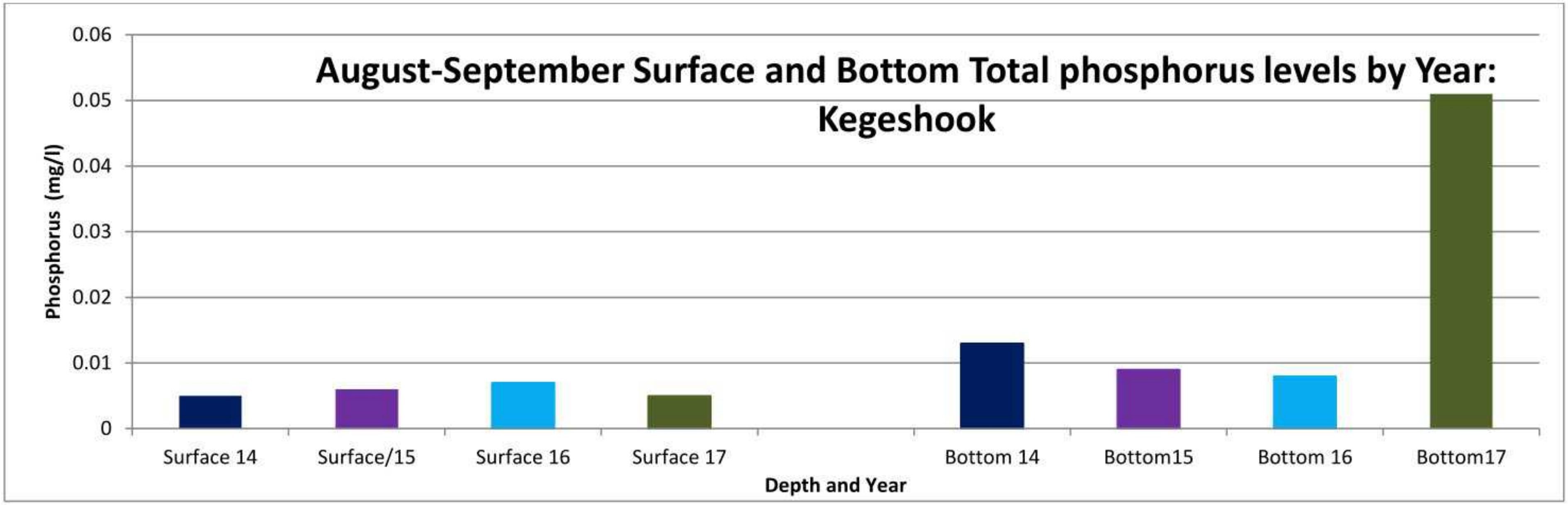
August-September Surface and Bottom Total phosphorus levels by Year: Vaughan
Phosphorus (mg/l)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Surface08
Surface10
Surface11
Surface13
Surface14
Surface15
Surface 16
Surface 17
Bottom08
Bottom10
Bottom11
Bottom13
Bottom14
Bottom 15
Bottom 16
Bottom17
Depth and Year

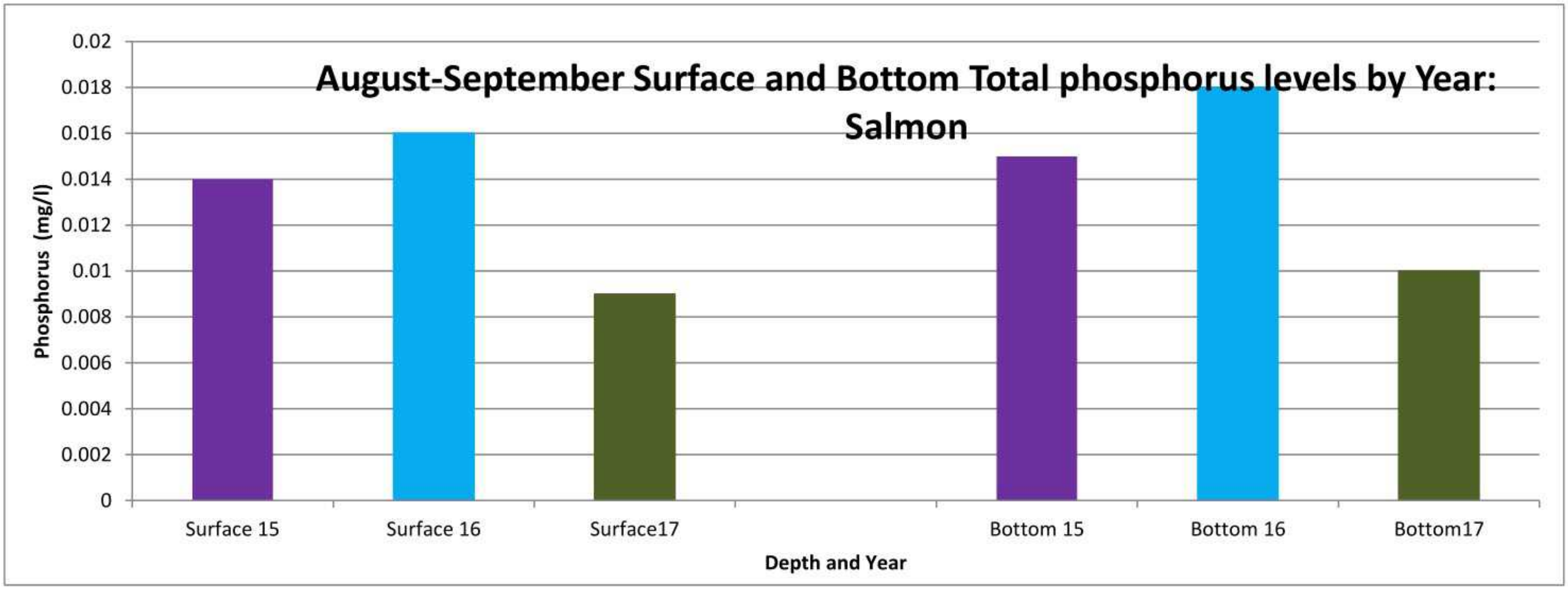


No bottom phosphorus data available for 2008 nor 2010.



August-September Surface and Bottom Total phosphorus levels by Year: Nowlans
Phosphorus (mg/l)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Surface 15
Surface16
Surface17
Bottom15
Bottom16
Bottom17
Depth and Year


August-September Surface and Bottom Total phosphorus levels by Year: Kegeshook
Phosphorus (mg/l)
0.06
0.05
0.04
0.03
0.02
0.01
0
Surface 14
Surface/15
Surface 16
Surface 17
Bottom 14
Bottom15
Bottom 16
Bottom17
Depth and Year


August-September Surface and Bottom Total phosphorus levels by Year: Salmon
Phosphorus (mg/l)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Surface 15
Surface 16
Surface17
Bottom 15
Bottom 16
Bottom17
Depth and Year

Appendix 5: Data on Cyanobacterial Abundance, Genus Composition and Microcystin

Lake	Date	Percent composition																	Microcystin (µg/l)	
		Anabaena	Aphanizomenon	Aphanocapsa	Aphanothece	Chroococcus	Coeliosphaerium	Eucapsis	Gomphosphaeria	Microcystis	Merismopedia	Oscillatoria	Planktolyngbya	Planktothrix	Spirulina	Woronichinia	Pseudoanabaena	Total	Free	Total
Provost	Aug. 27/08	98.374	1.626	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000		
	Oct. 27/09	0.000	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	100.000	100.000		
	Oct. 1/10	21.053	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	78.947	100.000		
	Aug. 15/11	57.778	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	42.222	100.000		
	Aug. 25/15	3.819	0.000	6.205	0.000				0.000	0.000	8.592	0.000	0.000		0.000	0.000	81.384	100.000	<.20	<.20
	Aug. 30/16	100.000	0.000	0.000	0.000		0.000		0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000		<.2
	Aug. 30/17	22.222	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	77.778	100.000		<.2
Nowlan's	Aug. 28/08	1.415	0.575	0.000	0.000				75.566	22.443	0.000	0.000	0.001		0.000	0.000	0.000	100.000	0.3	
	Oct. 15/08	1.652	0.620	0.000	0.000				96.872	0.857	0.000	0.000	0.000		0.000	0.000	0.000	100.000	<.2	
	Oct. 15/09	0.000	98.815	1.185	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000	<.2	
	Sept. 26/10	0.047	11.696	0.000	0.000				0.000	88.097	0.000	0.000	0.000		0.000	0.000	0.160	100.000	0.3	
	Aug. 26/11	0.236	0.152	0.000	0.000				0.000	98.280	0.000	0.000	1.332		0.000	0.000	0.000	100.000	<.2	11.82
	Aug. 7/13	1.049	2.380	4.513	0.000				0.000	92.058	0.000	0.000	0.000		0.000	0.000	0.000	100.000		<.2
	Aug. 25/15	2.423	9.546	0.000	0.000				0.000	8.893	0.000	0.000	0.000		0.000	79.138	0.000	100.000		0.37
	Aug. 31/16	2.586	21.160	73.668	0.000		0.000		1.293	1.293	0.000	0.000	0.000		0.000	0.000	0.000	100.000		0.27
	Aug. 29/17	22.293	48.819	2.953	0.000	0.000	0.000	0.000	0.000	25.935	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000		<.2
Hourglass	Aug. 27/08	0.000	100.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000	<.2	
	Oct. 20/09	0.000	0.000	0.000	0.000				0.000	0.000	0.000	0.000	100.000		0.000	0.000	0.000	100.000	<.2	
	Sept. 26/10	0.000	0.000	0.000	0.000				0.000	0.000	0.000	100.000	0.000		0.000	0.000	0.000	100.000	<.2	
	Aug. 14/11	0.000	0.000	0.000	0.000				0.000	34.483	0.000	0.000	48.276		0.000	0.000	17.241	100.000	<.2	<.2

	Aug. 12/13	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!				#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		<.2
	Aug. 17/15	0.000	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	100.000	100.000		<.2
	Aug. 22/16	86.916	0.000	0.000	0.000		0.000		0.000	0.000	0.000	0.000	0.000		0.000	0.000	13.084	100.000		<.2
	July 5/17	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
	Aug. 15/17	25.029	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	74.971	100.000		<.2
Placides	Aug. 27/08	0.000	100.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000	<.2	
	Oct. 21/09	0.000	0.000	0.000	0.000				0.000	0.000	0.000	0.000	84.670		0.000	0.000	15.330	100.000	<.2	
	Sept. 27/10	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!				#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	<.2	
	Aug. 23/11	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!				#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	<.2	<.2
	Aug. 5/13	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!				#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		<.2
	Aug. 26/15	12.162	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	87.838	100.000		<.2
	Aug. 30/16	0.000	0.000	100.000	0.000		0.000		0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000		<.2
	July 5/17	0.000	0.000	96.430	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.570	100.000		
	Aug. 29/17	0.000	0.000	23.077	76.923	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000		<.2
Porcupine	Aug. 28/08	0.000	0.000	0.000	0.000				0.000	0.000	0.000	100.000	0.000		0.000	0.000	0.000	100.000	<.2	
	Oct. 27/09	0.000	0.000	0.000	0.000				0.000	0.000	0.000	0.000	100.000		0.000	0.000	0.000	100.000	<.2	
	Sept. 27/10	0.000	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	100.000	100.000	<.2	
	Aug. 15/11	60.920	0.000	0.000	0.000				5.747	0.000	0.000	11.494	0.000		0.000	0.000	21.839	100.000	<.2	<.2
	Aug. 5/13	90.865	0.000	0.000	0.000				0.000	0.000	0.000	4.327	1.923		0.000	0.000	2.885	100.000		<.2
	Aug. 26/15	0.257	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	99.743	100.000		<.2
	Aug. 30/16	0.000	0.000	0.000	0.000		90.909		0.000	0.000	0.000	9.091	0.000		0.000	0.000	0.000	100.000		<.2
	July 5/17	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000		
	Aug. 29/17	0.000	4.762	0.000	95.238	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000		<.2
Wentworth	Aug. 17/15	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!				#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		<.2
	Aug. 22.16	100.000	0.000	0.000	0.000		0.000		0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000		<.2

	July 5/17	0.000	0.000	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000		
	August 15/17	40.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	60.000	100.000		<.2
Parr	Sept. 4/08	0.000	62.782	37.218	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000	<.2	
	Oct. 22/09	0.000	2.247	0.000	0.000				0.000	0.000	0.000	0.000	61.049		0.000	0.000	36.704	100.000	<.2	
	Sept. 27/10	21.569	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		78.431	0.000	0.000	100.000	<.2	
	Aug. 24/11	88.390	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	11.610	100.000	<.2	<.2
	Aug. 12/13	100.000	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000		<.2
	Aug. 20/15	100.000	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000		<.2
	Aug. 22/16	100.000	0.000	0.000	0.000		0.000		0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000		<.2
	July 5/17	89.130	0.000	10.870	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000		
	August 15/17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000	100.000		<.2
Ogden	Aug. 15/08	77.558	21.122	0.000	0.000				0.000	0.000	0.000	1.320	0.000		0.000	0.000	0.000	100.000	<.2	
	Oct. 22/09	0.000	0.000	0.000	0.000				0.000	0.000	0.000	0.000	33.333		0.000	0.000	66.667	100.000	<.2	
	Sept. 28/10	100.000	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000	<.2	
	Aug. 24/11	52.357	0.000	0.000	0.000				7.692	0.000	0.000	0.000	0.000		0.000	0.000	39.950	100.000	<.2	<.2
	Aug. 6/13	100.000	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000		<.2
	Aug. 20/15	99.748	0.000	0.000	0.168				0.084	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000		<.2
	Aug. 22/16	100.000	0.000	0.000	0.000		0.000		0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000		<.2
	July 11/17	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000		
	Aug. 15/17	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000		<.2
Fanning	Aug. 28/08	18.750	56.250	0.000	0.000				0.000	0.000	0.000	25.000	0.000		0.000	0.000	0.000	100.000	<.2	
	Oct. 15/08	99.670	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.330		0.000	0.000	0.000	100.000	<.2	
	Oct. 13/09	0.000	20.000	0.000	0.000				0.000	0.000	0.000	0.000	80.000		0.000	0.000	0.000	100.000	<.2	
	Sept. 30/10	94.654	0.000	0.273	0.000				0.000	0.000	0.000	5.074	0.000		0.000	0.000	0.000	100.000	<.2	
	Oct. 12/10	100.000	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000	<.2	

	Aug. 16/11	54.779	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	45.221	100.000	<.2	<.2
	Aug. 11/13	100.000	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000		<.2
	Aug. 16/15	100.000	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000		<.2
	Aug. 22/16	#DIV/0!	0.000	0.000	0.000		0.000		0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	#DIV/0!		<.2
	July 11/17	97.189	0.000	1.606	0.000	1.205	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000		
	Aug. 15/17	98.923	0.000	0.000	0.000	0.000	0.000	1.077	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000		<.2
Sloans	Sept. 9/09	0.000	0.000	0.000	44.914				47.824	0.000	0.000	0.000	5.363		0.000	0.000	1.900	100.000	<.2	
	Nov. 5/09	0.000	1.156	14.451	28.902				55.491	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000	<.2	
	Oct. 1/10	0.000	0.000	28.777	7.194				25.180	0.000	0.000	0.000	0.000		0.000	0.000	38.849	100.000	<.2	
	Aug. 16/11	0.000	0.000	11.682	0.000				75.935	11.682	0.000	0.000	0.000		0.000	0.000	0.701	100.000		<.2
	Aug. 11/13	0.000	0.000	0.000	45.455				54.545	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000		<.2
	Aug. 16/15	0.000	0.000	0.000	40.816				51.020	0.000	0.000	0.000	0.000		0.000	0.000	8.163	100.000		<.2
	Aug. 22/16	0.000	0.000	0.000	28.571		0.000		71.429	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000		<.2
	July 5/17	0.000	0.000	10.582	17.637	0.176	0.000	0.000	62.610	0.000	8.995	0.000	0.000	0.000	0.000	0.000	0.000	100.000		
	Aug. 15/17	0.000	0.000	0.000	43.103	0.000	0.000	0.000	51.724	0.000	0.000	0.000	0.000	5.172	0.000	0.000	0.000	100.000		<.2
Raynards	Aug. 19/15	96.970	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	3.030	100.000		<.2
	Aug. 22/16	0.000	0.000	0.000	0.000		0.000		0.000	0.000	0.000	0.000	0.000		0.000	0.000	100.000	100.000		<.2
	July 5/17	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000		
	Aug. 15/17	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000		<.2
Vaughan	Sept. 5/08	0.000	100.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	100.000	<.2	
	Oct. 28/09	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!				#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	<.2	
	Sept. 30/10	0.000	0.000	0.000	0.000				0.000	0.000	0.000	30.769	0.000		0.000	0.000	69.231	100.000	<.2	
	Aug. 17/11	0.000	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	100.000	100.000	<.2	<.2
	Aug. 13/13	83.333	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	16.667	100.000		<.2
	Aug. 19/15	0.000	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000		0.000	0.000	100.000	100.000		<.2

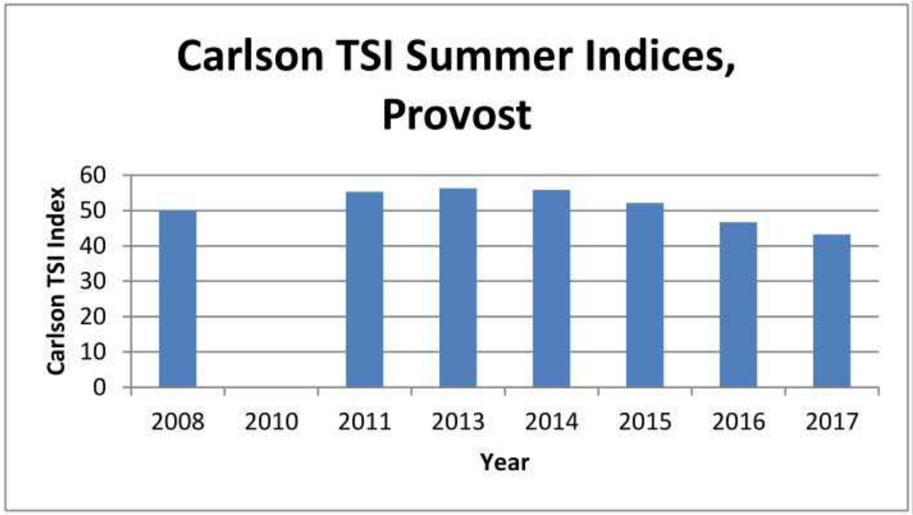
	Aug. 22/16	0.000	0.000	0.000	0.000		0.000		0.000	0.000	0.000	0.000	0.000		0.000	0.000	100.000	100.000		<.2
	July 5/17	97.597	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.364	0.000	0.000	0.000	0.000	2.039	100.000		
	Aug. 15/17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100.000	100.000		<.2
Kegeshook	June 27/17	2.633	0.000	0.311	92.247	0.000	0.000	0.000	0.643	0.000	4.115	0.000	0.000	0.000	0.000	0.000	0.052	100.000		
Salmon	July 4/17	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	#DIV/0!		

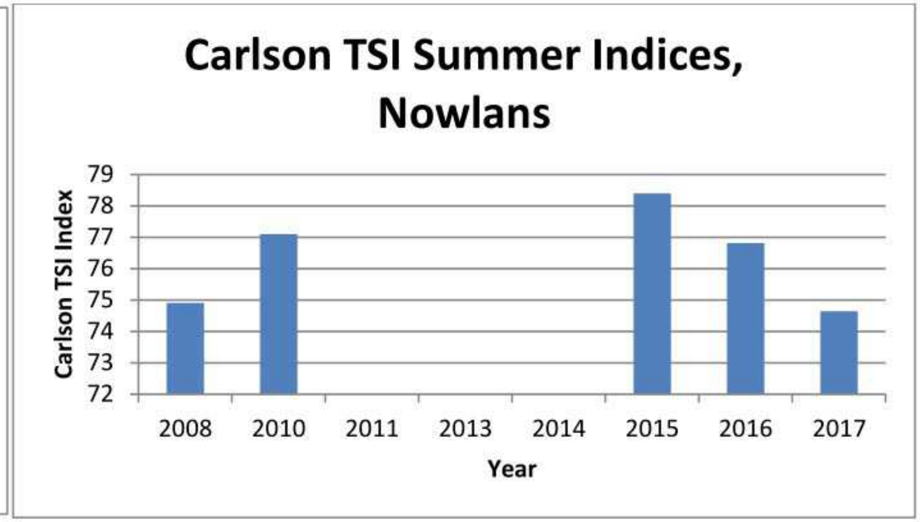
1Averaged among more than one collecting site

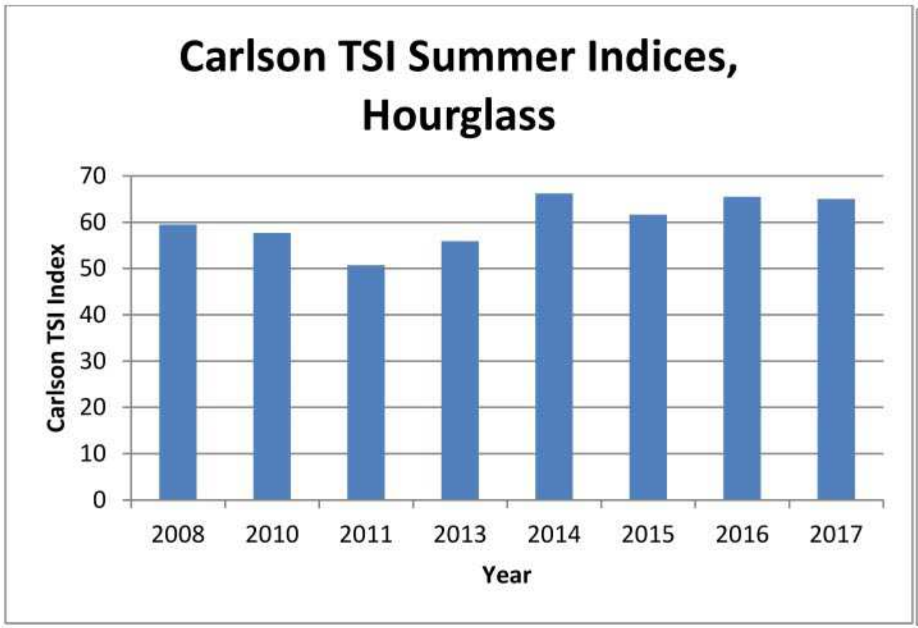
Appendix 6: Calculated Carlson Trophic State Indices, based on August Data

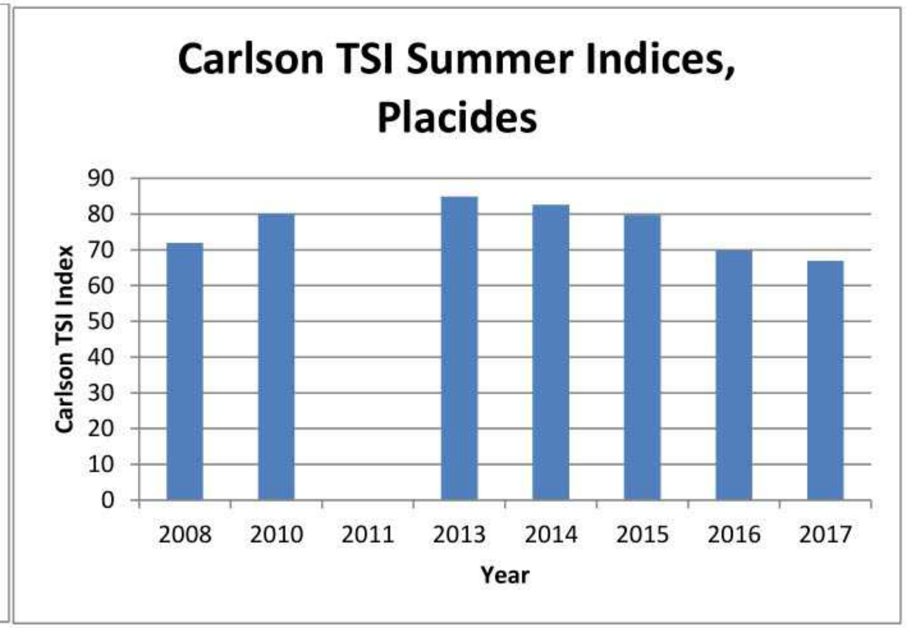
Year	Provost	Nowlans	Hourglass	Placides	Porcupine	Wentworth	Parr	Ogden	Fanning	Sloans	Raynards	Vaughan	Kegeshook	Salmon
2017	43.3	74.6	65.0	66.9	39.9	56.8			48.5	32.2	45.1	51.1	41.6	43.3
2016	46.7	76.8	65.5	69.8	45.3	58.1	58.0	50.7	52.2	31.3	44.9	47.1	46.8	48.5
2015	52.1	78.4	61.6	79.7	48.3	64.2	56.2	53.5	52.7	32.7	48.3	47.4	41.9	47.4
2014	55.9		66.2	82.6	48.9	67.7	63.1	61	54.6	32.8	52	50.3	40.1	
2013	56.3		55.9	84.9	57.1	66.8	59.8	56.9	51.4	35.5		53.9		
2011	55.3		50.7		48.8		58.6	53.8	55.1			42.7		
2010		77.1	57.7	80.2	46.4		61.1	57.6	55.6					
2008	50	74.9	59.5	71.9	45.8		54.3	49	44.9			38.5		

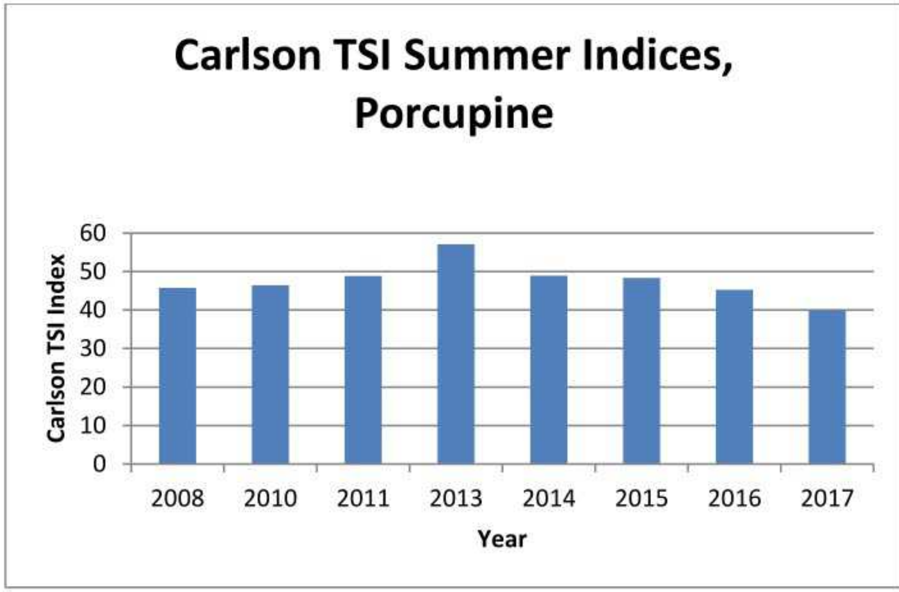
TSI Range	Trophic Status
<40	Oligotrophic (nutrient-poor)
40-50	Mesotrophic
50-70	Eutrophic (nutrient rich)
>70	Hypereutrophic

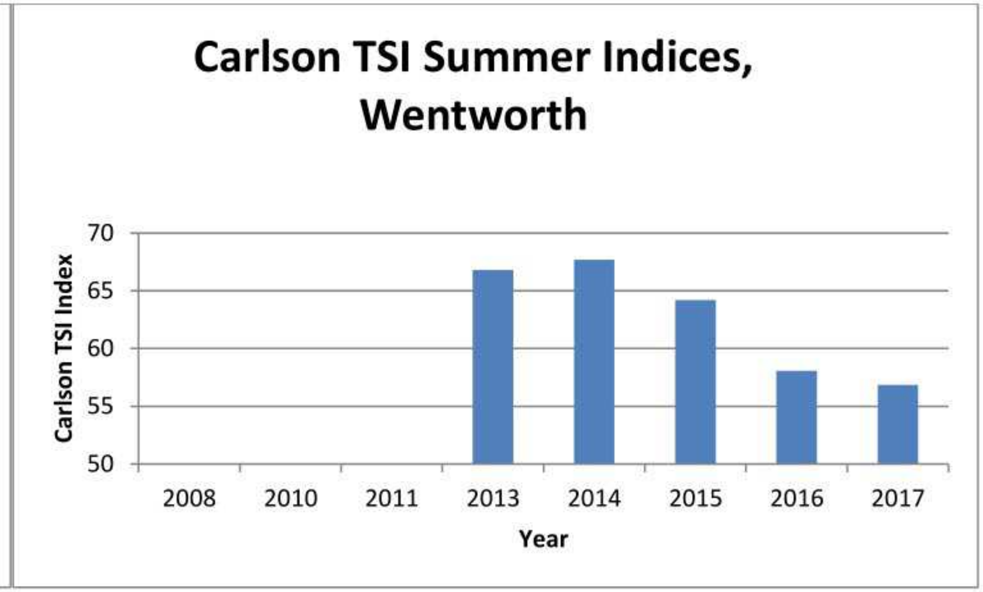

Carlson TSI Summer Indices, Provost
Carlson TSI Index
60
50
40
30
20
10
0
2008
2010
2011
2013
2014
2015
2016
2017
Year

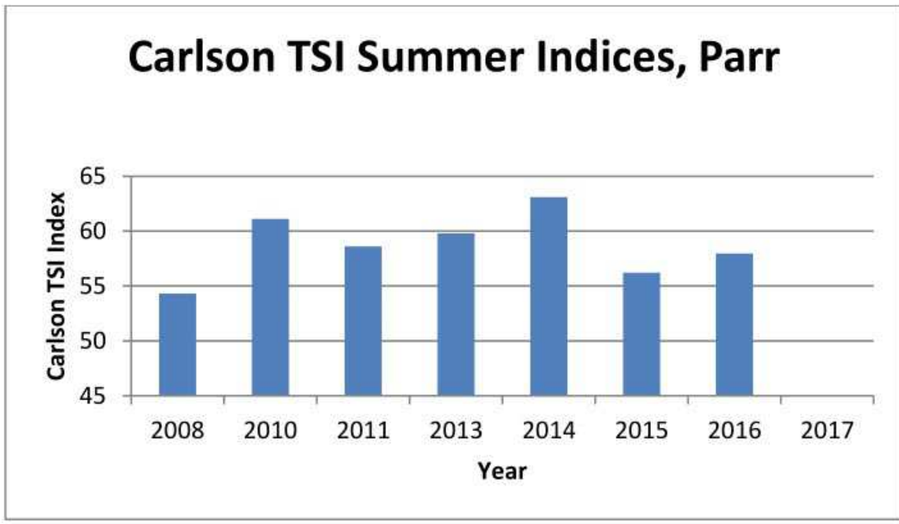

Carlson TSI Summer Indices, Nowlans
Carlson TSI Index
79
78
77
76
75
74
73
72
2008
2010
2011
2013
2014
2015
2016
2017
Year

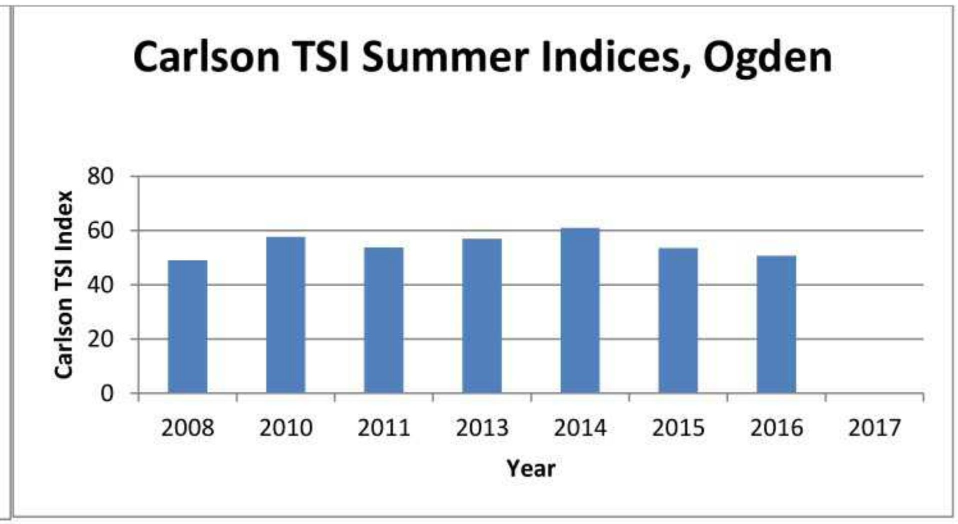

Carlson TSI Summer Indices, Hourglass
Carlson TSI Index
70
60
50
40
30
20
10
0
2008
2010
2011
2013
2014
2015
2016
2017
Year

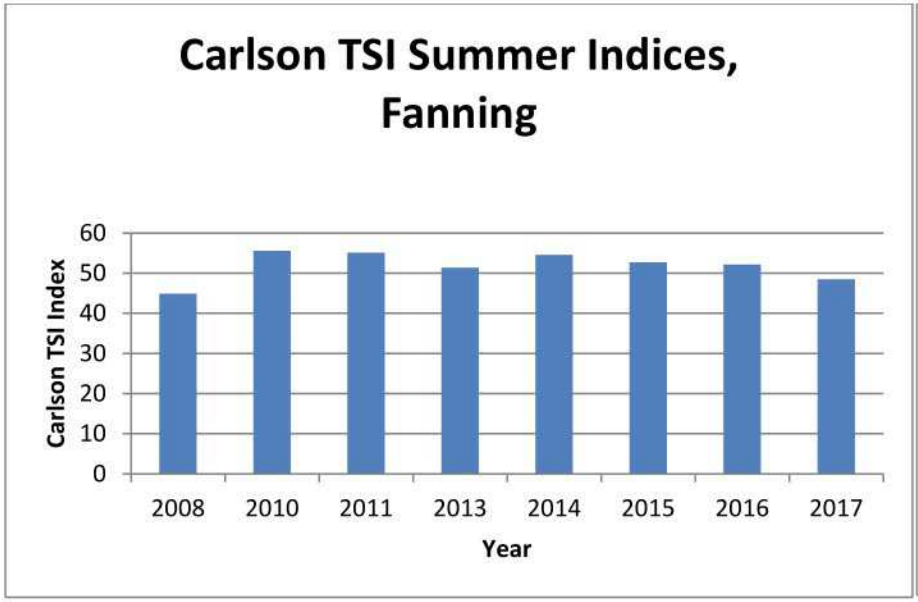

Carlson TSI Summer Indices, Placides
Carlson TSI Index
90
80
70
60
50
40
30
20
10
0
2008
2010
2011
2013
2014
2015
2016
2017
Year

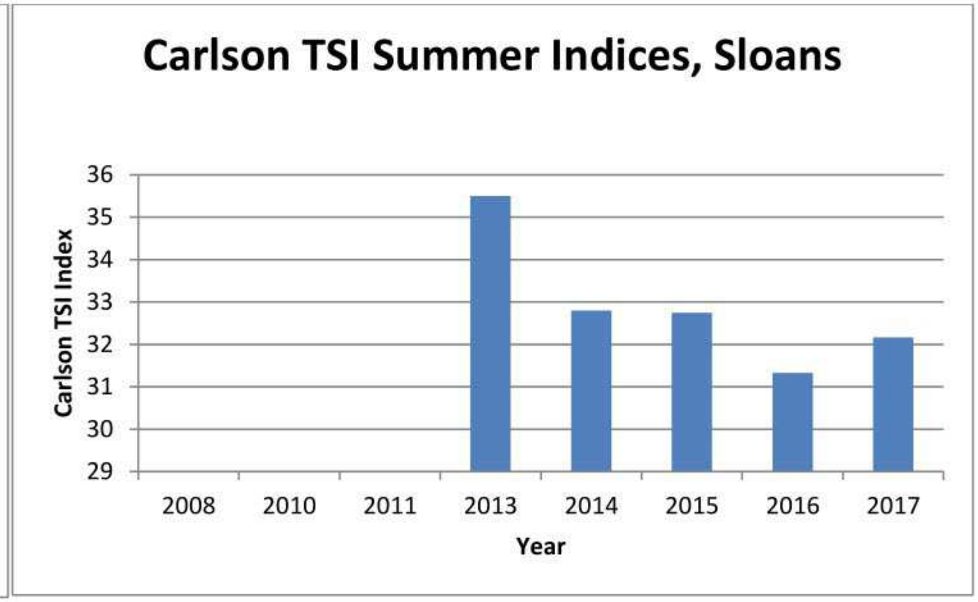

Carlson TSI Summer Indices, Porcupine
Carlson TSI Index
60
50
40
30
20
10
0
2008
2010
2011
2013
2014
2015
2016
2017
Year


Carlson TSI Summer Indices, Wentworth
Carlson TSI Index
70
65
60
55
50
2008
2010
2011
2013
2014
2015
2016
2017
Year


Carlson TSI Summer Indices, Parr
Carlson TSI Index
65
60
55
50
45
2008
2010
2011
2013
2014
2015
2016
2017
Year


Carlson TSI Summer Indices, Ogden
Carlson TSI Index
80
60
40
20
0
2008
2010
2011
2013
2014
2015
2016
2017
Year


Carlson TSI Summer Indices, Fanning
Carlson TSI Index
60
50
40
30
20
10
0
2008
2010
2011
2013
2014
2015
2016
2017
Year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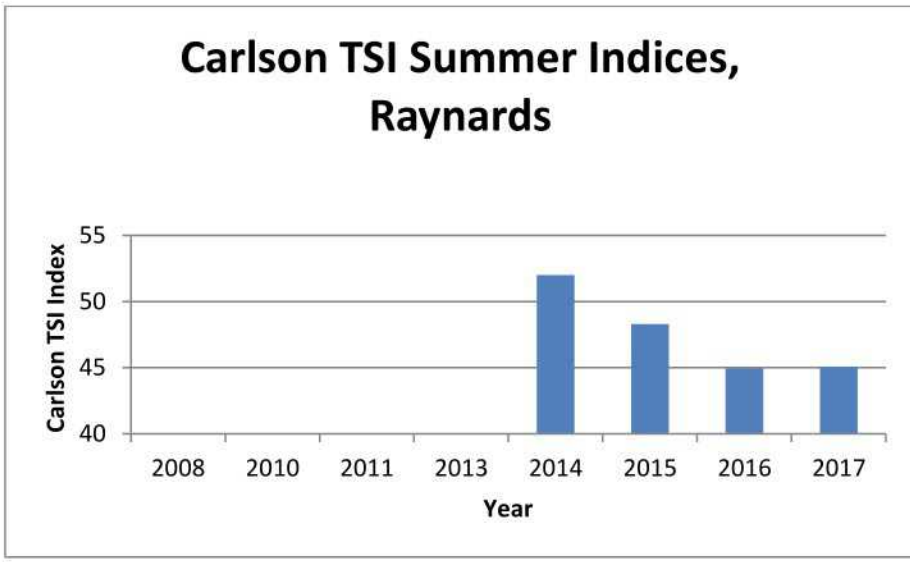
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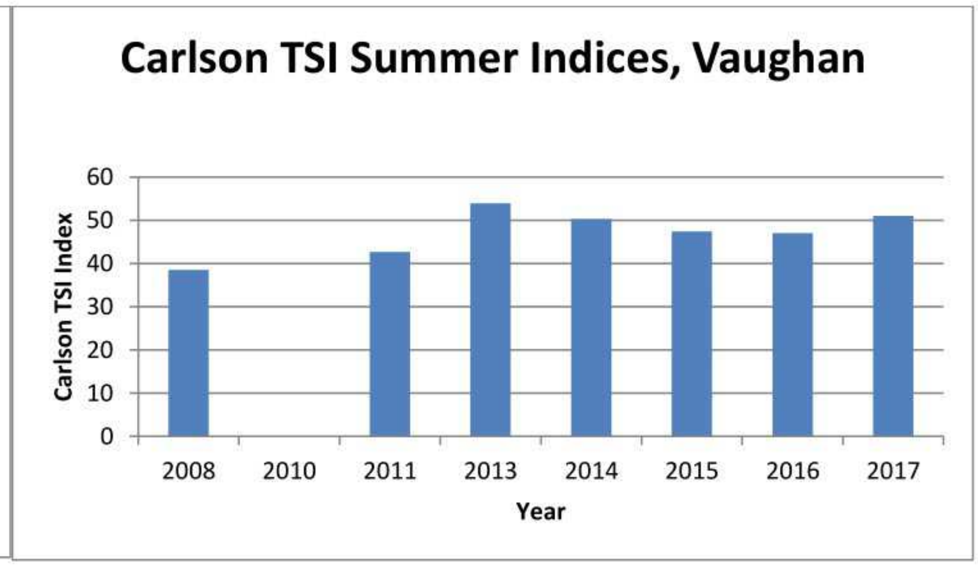
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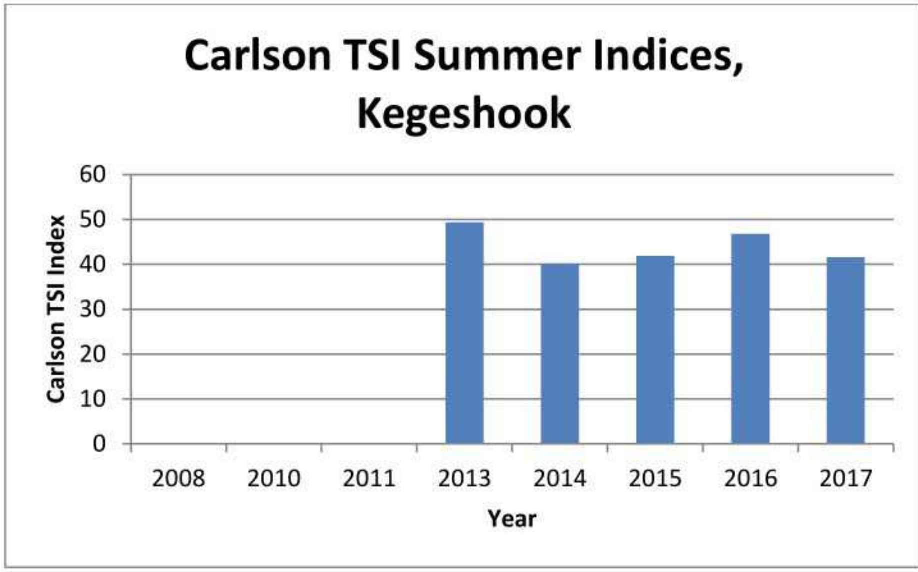
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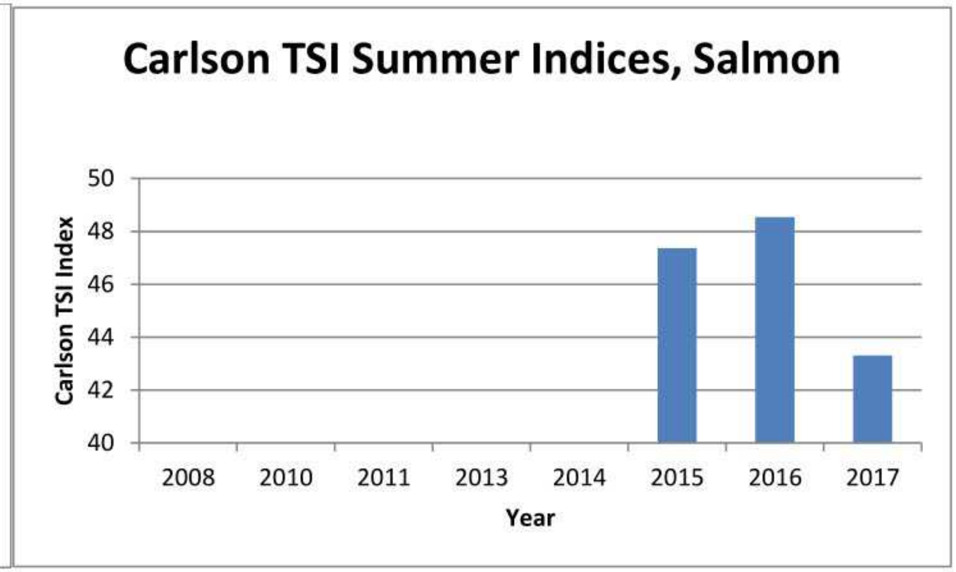
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Due to document sharing restrictions, the following report could not be included within Appendix A.2.

The report can be accessed from the following website:

https://www.district.yarmouth.ns.ca/images/PDF/Carleton%20River%20Watershed/Results%20of%20the%202017%20Water%20Quality%20Survey.pdf

Results of the 2017 Water Quality Survey of Eleven Lakes in Yarmouth and Digby Counties

Final Report

Project No. 121414433

Stantec

Prepared for:
Carleton River Watershed Area Water Quality Steering Committee

Prepared by:
Stantec Consulting Ltd.
102-40 Highfield Park Drive,
Dartmouth NS B3A 0A3

December 20, 2017

Stantec

2016

Lake Water Quality Summary

Lakes add to the quality of life and economic stability of the region

INTRODUCTION

The Twin Cities metropolitan area is fortunate to have a large number of lakes. These lakes are important recreational, aesthetic, and ecological resources that add considerably to the quality of life and economic stability of the region. Protecting the water quality of our lakes is a significant citizen concern.

Many state and local agencies have a role in managing and monitoring lake water quality. The Metropolitan Council operates the most extensive lake monitoring program in the region, and has been monitoring metro area lakes since 1980. During the 1980s, the Council typically monitored about 10 to 30 lakes per year. Metropolitan Council staff monitored 3 lake-sites on 3 lakes in 2016.

In 1993, the Council initiated the Citizen-Assisted Monitoring Program (CAMP) to help expand coverage of lake monitoring in the metro area and to provide information to support local water management efforts. This highly successful program collects data on the lakes each year through the efforts of trained, dedicated volunteers and their local sponsors. 2016 was the 24th year of the Council's volunteer program, with 117 citizen volunteers participating in the CAMP. The volunteers were sponsored by local partners, including 11 cities, 11 watershed management organizations and watershed districts, 2 counties, 1 basin planning team, and 1 conservation district. Through the dedicated efforts of the volunteers and local partners a total of 178 lake-sites on 164 lakes were monitored in 2016 through the CAMP. In total, Metropolitan Council staff and CAMP volunteers and sponsors monitored 181 lake sites on 167 lakes in 2016, including 5 lake sites and 5 lakes that were newly added to the Council's lake monitoring program. Since 1980, the Council's lake monitoring program has monitored 429 lake sites on 390 lakes.

WHY WE MONITOR

The Metropolitan Council is charged with creating a comprehensive regional development guide that minimizes the adverse impacts of growth, including adverse impacts on the environment. The monitoring data collected by the Council, its partners, and citizen volunteers are used to identify pollution problems, support regional planning efforts, and meet federal and state regulations. This Lake Water Quality Summary provides an annual synoptic assessment of the water quality of many of the metro area's lakes. Also,

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metrocouncil.org

the Council produces an annual River and Stream Assessment of the metro area which will report, in a separate document, the water quality data of the region's rivers and streams.

Most of the lake monitoring efforts focus on the assessment of eutrophication, which is the process of nutrient enrichment. Eutrophication increases the biological productivity of a lake by enhancing the growth of algae and other plants. Human activities in the watersheds of lakes (e.g. non-point sources) increase the delivery of nutrients to lakes beyond what occurs naturally. This acceleration of nutrient enrichment by humans is called cultural eutrophication. During cultural eutrophication, the population of algae increases and water clarity decreases. A variety of other problems may develop, including increases in nuisance algal blooms, odor problems, decreased desirability for recreation, decreased dissolved oxygen, fish kills, changes in the structure of fish and invertebrate communities toward low-oxygen tolerant species, and reductions in biodiversity. Furthermore, eutrophic lakes can develop blooms of toxic blue-green algae (cyano-bacteria), which can be a serious health concern for humans and animals (domesticated and wild). Cultural eutrophication is one of the leading water quality concerns facing the region.

METHODS

Lakes monitored by Council staff and volunteers are typically sampled at two-week intervals from mid-April through mid-October. Most lakes are sampled at one station located over the deepest spot in the lake. Field measurements taken during each monitoring event typically include temperature and water clarity (measured with a Secchi disk). In addition, surface water samples are collected for lab analyses, which include total phosphorus (TP), total Kjeldahl nitrogen (TKN), and chlorophyll-a (Chl-a). The routine chemical analyses are performed at the Metropolitan Council Environmental Services laboratory following U.S. EPA approved methods.

Each lake is assigned a lake grade using an A through F grading system as originally developed by Council staff in 1989. The objective of the lake grade system is to provide a tool for assessing lakes on a regional basis. The grading system allows comparisons of lake water quality across the metro area, yet is understandable to the public and non-technical audiences. The grading system uses percentile ranges of the summer-time (May-September) average values for three water quality indicators: total phosphorus, chlorophyll-a, and Secchi depth. Total phosphorus is a key nutrient measure; chlorophyll-a is a measure of algal abundance; and Secchi depth is a measure of water clarity. The lake's water quality grade is calculated as the average grade for the three individual parameter grades. Only lakes with a sufficient quantity of data are assigned a lake grade.

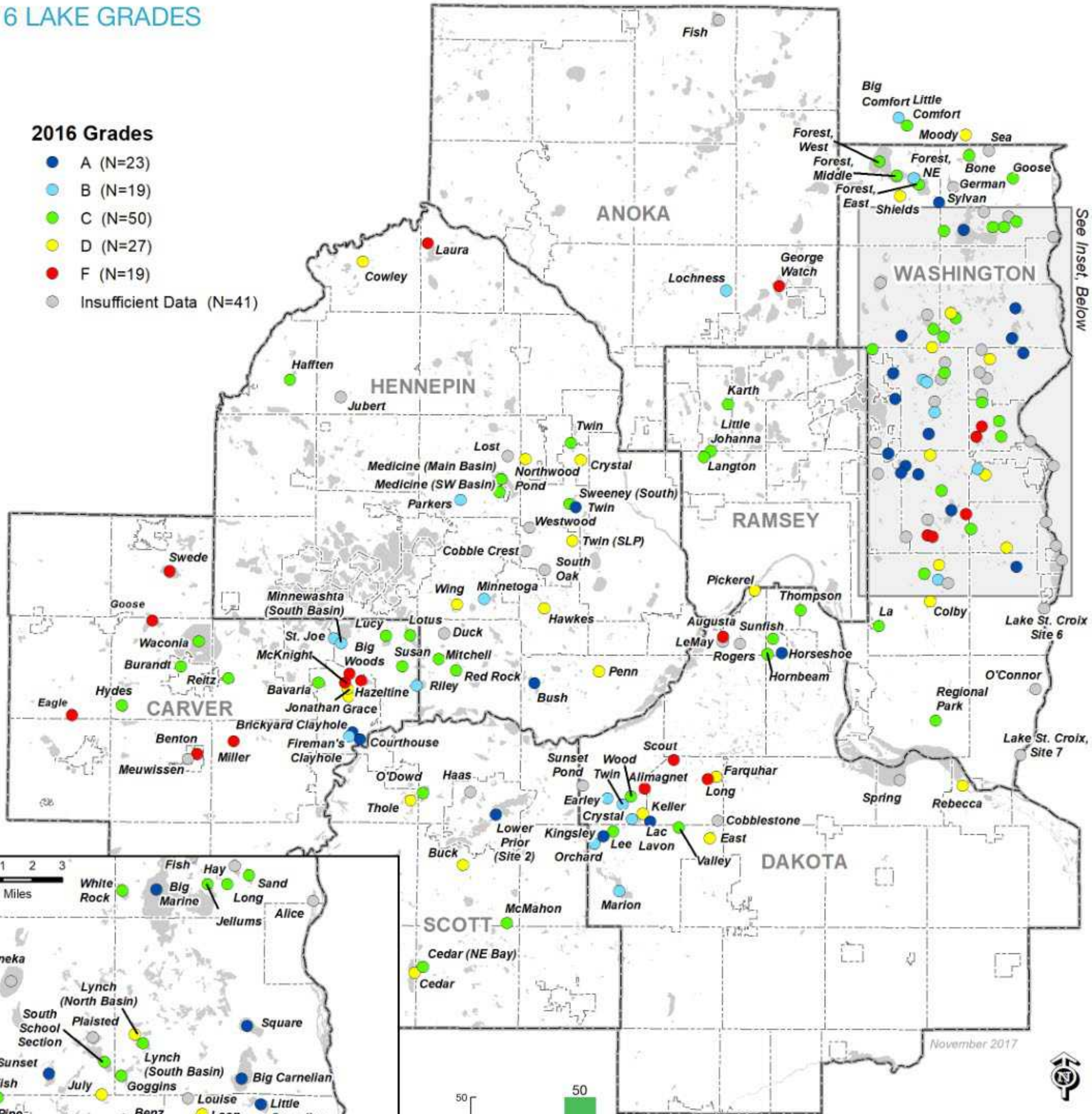
RESULTS

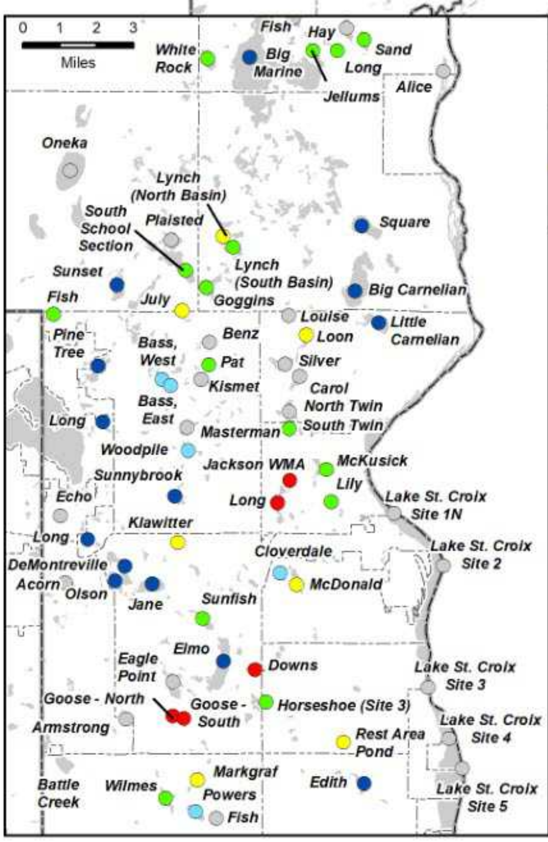
In 2016, 31% of the lake sites received a grade of "A" or "B", meaning that they had relatively good water quality. Another 36% of lake sites received a water quality grade of "C". The remaining 33% of lake sites received a water quality grade of "D" or "F", meaning that they had relatively poor water quality. Similar to that of past years, there was no distinct pattern within the TCMA as to where lakes with specific water quality are located.

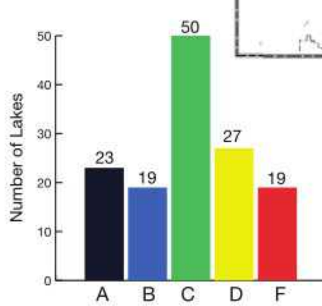
The Annual Lake Water Quality Summary Report can be accessed online at:
http://es.metc.state.mn.us/eims/related_documents/view_documents.asp

All of the Council's lake monitoring data can be accessed online using the Council's Environmental Information Management System, at:
http://es.metc.state.mn.us/eims.

2016 LAKE GRADES







Distribution of lake grades in 2016. Grades were assigned only for lake sites with an adequate database.

WATER QUALITY GRADING SYSTEM

Grade	Total Phosphorus (ug/l)	Chlorophyll -a (ug/l)	Secchi Depth (m)	Secchi Depth (ft)
A	<23	<10	>3	>9.8
B	23-32	10-20	2.2-3.0	7.2-9.8
C	32-68	20-48	1.2-2.2	3.9-7.2
D	68-152	48-77	0.7-1.2	2.3-3.9
F	>152	>77	<0.7	<2.3

(ug/L) is an abbreviation for microgram per liter

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To:

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Metropolitan Council
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Saint Paul, MN 55101
Main: 651.602.1000
TTY: 651.291.0904
Public Information: 651.602.1500
public.info@metc.state.mn.us

Appendix A.3

Sample Educational Resources

Kings County, Nova Scotia
Algae Monitoring Field Sheet
Lake Development Brochure
Water Sampling Handbook

Lake Partner Program - Ontario
Spring 2019 Sampling Instructions
Secchi Instructions
Guide to Interpreting TP and Secchi Data

ALGAE MONITORING FIELD SHEET

GENERAL INFORMATION ☐

Date: **Name of Lake and station**

Time & date of sample collected:

Collector name & contact info:

Lake or River Name/Location :

GPS coordinates (if available):

Photos (site, sampling location, surrounding area)

☐ yes ☐ no ☐ number

SAMPLE OBSERVATION DATA (check all that apply)

☐ green algae ☐ blue-green algae ☐ macrophyte ☐ don't know

1. Habitat or sample was collected/found:

☐ attached to bottom — floating on surface — ☐ throughout water column — ☐ attached to plants

notes:

Approximate surface area covered (m x m): ☐ x ☐

2. Growth form

☐ filament (hair-like strands) ☐ film (paint on water surface) ☐ globs ☐ plant-like (leaves, stem)

notes:

3. Colour

☐ green ☐ blue-green ☐ brownish ☐ red

☐ yellow ☐ other (please specify):

4. Odour

☐ musty ☐ sweet ☐ garlic ☐ other (specify)

5. Substrate from which algae was collected

☐ in water ☐ sand ☐ rock ☐ wood

☐ vascular plants notes:

SITE OBSERVATION DATA (check all that apply)

1. Type of waterbody

☐ lake ☐ stream ☐ river ☐ wetland

Specify where within waterbody sample was collected (i.e. middle of lake, or an embayment):

2. Shoreline (where sample was collected)

☐ sand beach ☐ hardened break wall or riprap ☐ rocky shore ☐ vegetated trees & shrubs

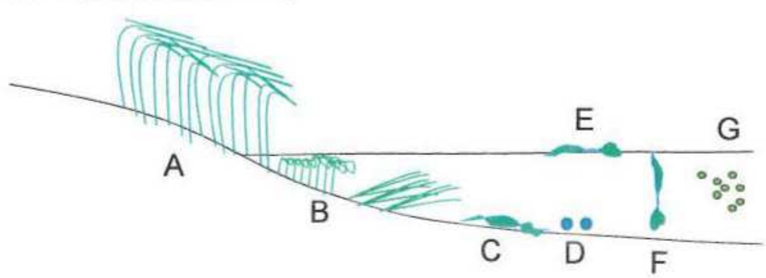
3. Surrounding landuse (where sample was collected)

☐ non-developed forested ☐ developed agricultural farm, fields ☐ developed residential home & cottages ☐ other

WEATHER CONDITIONS (last 48 hours) (wind, rain, sun etc):

Other comments (high/low flow, turbidity etc):

Aquatic vegetation classification key



A — Emergent macrophytes (rooted, stem, leaves)
B — Submerged macrophytes (rooted, stems & leaves)
C — Filamentous algae on bottom
D — Globular algae on bottom
E — Algae floating on surface (film or filamentous)

Guidelines for Improving Existing Development

Development that took place before the current regulations or widespread knowledge about lake ecology often took a form that may negatively impact lake water quality. The areas of these developments with the most potential for improvement are shoreline, dock, vegetation, and wastewater.

This brochure provides general advice. Please contact the Municipality and Nova Scotia Environment for approval before beginning any lakeshore project.

Shoreline

1 Worried about erosion? Use the power of plants. Root systems are great at holding soil together. If you choose to use plants, consider planting native species like Willow or Red Osier Dogwood.

2 Rethink the retaining wall. These destroy natural habitat and may actually contribute to erosion by redirecting wave energy toward the wall's foundation and surrounding shoreline. If your retaining wall is deteriorating, consider softening your shoreline by breaking up the wall or adding rocks and plants. The right mix of rocks and vegetation will protect against erosion and also preserve lake habitat.

Dock

3 Only take a quarter. If planning additions or alterations to your dock, boathouse, or lake access point, consider that together these should affect no more than 25% of your lot's shoreline.

4 Choose wisely. If you're thinking about building or replacing a dock, consider a floating design connected to shore by a raised walkway. This will be sensitive to habitat and aquatic life.

Vegetation

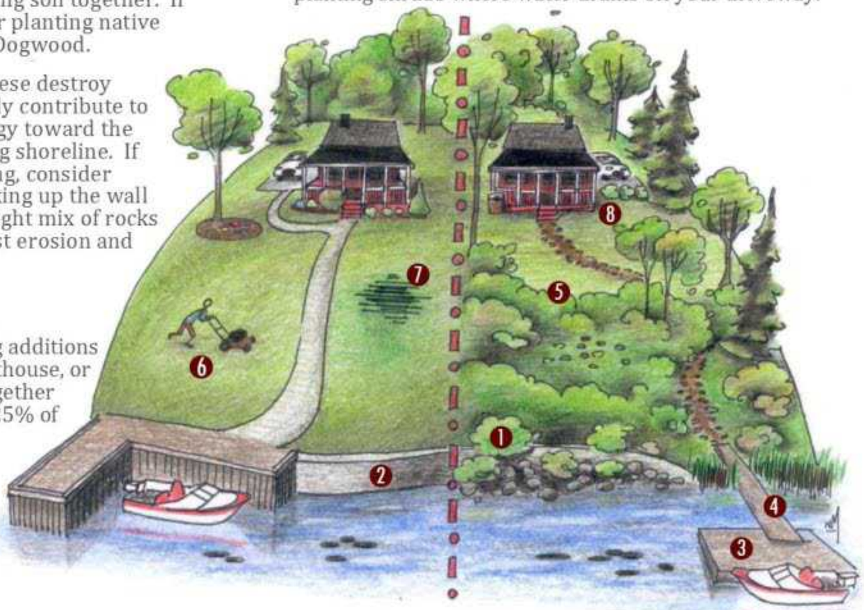
5 Let the buffer be. This is likely *the* most important thing you can do for your lake. You can start simply by not mowing near the lake. The buffer will start growing on its own.

6 Limit the lawn. Redesign your lawn so it's as small and far from the lake as possible. This not only helps minimize erosion and runoff, but maximizes your relaxation time at the lake.

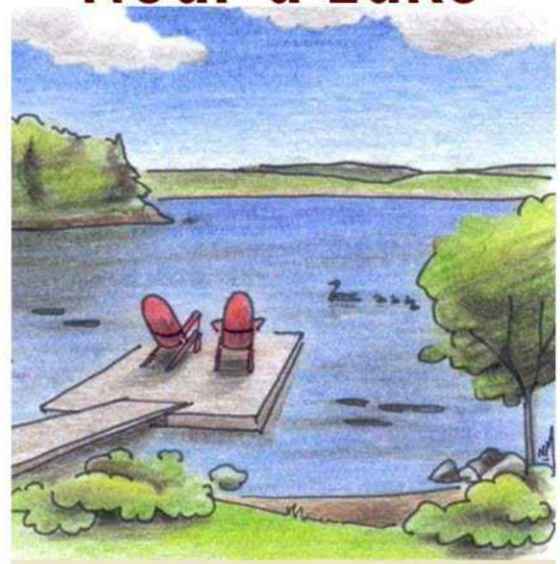
Wastewater

7 Don't forget what's gone down the drain. Making sure your septic system is working properly helps make sure harmful nutrients or chemicals aren't seeping into the lake.

8 Redirect runoff. The slower water drains off your lot, the more contaminants will be filtered out and the less chance it will erode your land. Slowing runoff may be as simple as placing a rain barrel under your downspout or planting shrubs where water drains off your driveway.



Developing Near a Lake



Guidelines for New Development

Guidelines for Improving Existing Development

MUNICIPALITY OF THE COUNTY OF KINGS
87 Cornwallis Street | Kentville NS | www.countyofkings.ca
2009

Lakeshore Development

Congratulations. You're one of the lucky few to own land near a lake. Besides plans to develop your land, you likely have plans to take long swims on hot summer afternoons, try your luck with your rod and reel, and kick back for long evenings enjoying the view. But imagine the same activities if the lake blooms with algae, the fish leave for cleaner water, and cottages seem to outnumber trees.

The Municipality's goal for lake shore development is to allow recreational and residential uses without harming the natural environment. To do this, the Municipality has adopted special land use regulations around the lakes on the South Mountain Plateau.

Most lakeshore properties can be developed ***as-of-right,*** meaning a building permit may be granted right away, as long as all requirements are met. In certain circumstances, properties can only be developed through a ***site plan approval***, a process that requires land owners to map out planned development before building permits are granted. Permits are also needed from Nova Scotia Environment to make alterations to the shoreline and build docks.

Contacts

Municipality of the County of Kings

To learn more about Lakeshore Planning in Kings County: **Will Robinson-Mushkat, Planner**
902-690-6173
wrobinson-mushkat@countyofkings.ca

To find out how your lot can be developed and for development permits: **Development Control**
902-690-6152
lburns@countyofkings.ca

Nova Scotia Environment

For information about environmental regulations and permits: **Kentville Office**
902-679-6086
http://www.gov.ns.ca/nse/permits

Guidelines for New Development

Whether you develop as-of-right or by site plan approval, below are guidelines for minimizing negative impact on lake water quality.

This brochure provides general advice. Please contact the Municipality and Nova Scotia Environment for approval before beginning any lakeshore project.

1 The Municipality requires that dwellings be set back at least 65 feet from the shoreline. This area, called a buffer, should be allowed to grow naturally. The thick vegetation will filter nutrients and pollution as well as create habitat.

2 The buffer should be left as natural as possible. Even dead vegetation creates food and habitat and combats erosion with its root systems. Municipal bylaws allow clearing only for a path and view of the lake.

3 Keep lawns and gardens as far from the lake and as small as possible, preserving the buffer and minimizing the amount of fertilizer or pesticide that may reach the lake. Keep in mind that the Land Use Bylaw only allows 50% of the lot to be cleared of natural vegetation.

4 Keep steep slopes naturally vegetated or plant as needed to prevent erosion.

5 There should only be one path through the buffer and it should be made of permeable material like wood chips or gravel.

6 Manage runoff from buildings or driveways by diverting it with landscaping so it has time to be absorbed.

7 Instead of altering natural terrain to build paths, consider using a raised boardwalk or steps to negotiate slopes or wet areas.

8 While not encouraged, Municipal bylaws do allow boathouses if they are at least 4 feet from the bank. Docks and boathouses together should affect no more than 25% of your lot's water frontage.

9 If building a dock, place it where it will have the least impact on existing features and choose an environmentally friendly floating design.

10 Don't alter the shoreline by building barriers, walls or even adding sand or fill. These deaden the shoreline by destroying habitat.

Illustrations by Nathan MacLeod

Taking Samples

Sampling water sounds pretty simple, doesn't it?

The volunteer paddles out in the lake, scoops up a bottle of water and turns it in. However, for the samples to be consistent and reliable, a set procedure must be followed time after time. Each month volunteers collect two composite samples. A composite sample is made up of water from the top and middle of the lake. The following steps explain how to take composite water samples for the Lake Monitoring Program.

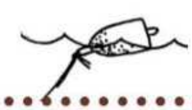
1 CHECK FOR SUPPLIES

Along with a boat and the required safe boating supplies, a volunteer needs the following sampling equipment:

- ✓ Cooler
- ✓ Thermometer
- ✓ Water Sampler
- ✓ Tape Measure
- ✓ Record Sheets
- ✓ Sample Bottles
- ✓ Bottle Labels
- ✓ Secchi Disk
- ✓ Second person for safety

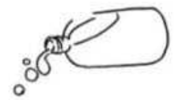
2 FIND SAMPLING STATION

Marked by a buoy, this should be the deepest part of the lake. Measure the depth and record it on your record sheet.



3 RINSE SAMPLING EQUIPMENT

Rinse 2 sample bottles and their caps, as well as the water sampler. Collect the rinse water from about 0.25m deep on one side of the boat and rinse the bottle and cap on the other side. Rinse the equipment 3 times.

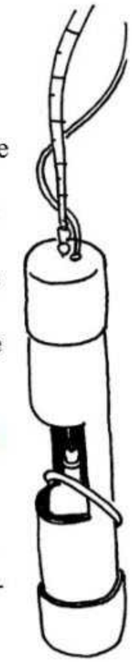


4 MEASURE SECCHI DEPTH

Remove sunglasses for this step, as they may influence results. Attach the Secchi disk to your tape measure and lower it into the water on the boat's shaded side. Remember to always tie equipment to the boat to prevent loss. Record the depth when you can no longer see the disk. Retrieve the disk, recording the depth when you can see it again. The average of the two is the Secchi depth.

5 SAMPLE TOP OF THE LAKE

Take a water sample from the other side of the boat. Put a rinsed bottle in the water sampler and lower the sampler until it is 0.25m deep (Make sure it's tied to the boat first!). Pull the cord to release the plug from the bottle. Retrieve the sample. Pour half the collected sample into the other sample bottle.



6 SAMPLE MIDDLE OF THE LAKE

Put one of the half-full bottles back into the sampler and take another sample to fill the bottle. This time, take the sample from 2 times the recorded Secchi depth or 1m from the bottom of the lake (whichever is farther from the bottom).

7 LABEL FIRST COMPOSITE SAMPLE

You now have one composite sample. Label the bottle, recording the lake name, sample depths, your name, and the date.

8 SAMPLE MIDDLE OF THE LAKE AGAIN

Repeat step 6 (fill the other sample bottle with a water sample from the appropriate depth).

9 LABEL SECOND COMPOSITE SAMPLE

This is the second composite sample. Label the second bottle, recording the lake name, sample depths, your name, and the date.

10 TAKE TEMPERATURE READINGS

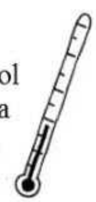
You'll need to measure the air temperature and water temperature at 0.25 metres deep and 1 metre from the bottom. Make sure you leave the thermometer enough time to get an accurate reading.

11 FILL OUT RECORD SHEET

Fill out the rest of the record sheet, filling in data like date and time, precipitation, cloud cover, and general observations like wildlife sightings.

12 KEEP SAMPLES COOL

Store the samples in a cool dark place (preferably a cooler with freezer packs, not ice!), until a municipal employee picks them up.



LAKE MONITORING PROGRAM

MUNICIPALITY OF THE COUNTY OF KINGS
www.countyofkings.ca/
87 Cornwallis Street
Kentville NS
B4N 3W3

THINGS TO CONSIDER:

TIME OF DAY

The best time of day for sampling is considered to be between 10:00am and 2:00pm. The sampling time should be as close to 12:00 noon as possible to get typical temperature readings.

WEATHER

Safety first. If for any reason the weather makes it unsafe to sample, or 25mm (1 inch) of rain has fallen in the past 24 hours, do not sample. Heavy rains will affect the reliability of the water samples. If either of these occur, let the volunteer coordinator know you will collect them on an alternative date. If you do take samples after a heavy rain, make a note of this on your record sheet.

CONTAMINATION

Some of the nutrients analyzed by the lab are present in very small quantities. As a result, the samples are very sensitive to contamination. Make sure the sampler and sample bottles don't come into contact with things like oil, sunscreen or cigarette ash.

SEDIMENT

Secchi depth readings and some lab tests can be influenced by sediment in the lake water. Try to avoid stirring up sediment by setting your anchor gently (or tying up to the buoy) and taking water samples from the opposite side of the boat from where you take Secchi and depth readings.

LAKE MONITORING PROGRAM

Water Sampling Handbook

LAKE PARTNER PROGRAM – detailed instructions 2019 (Spring)

General

Lakes within the Canadian Shield are sampled for total phosphorus **once per year** during May at the deep spot of your lake or bay. The instructions for taking the water sample for total phosphorus are provided on page 2 of this sheet.

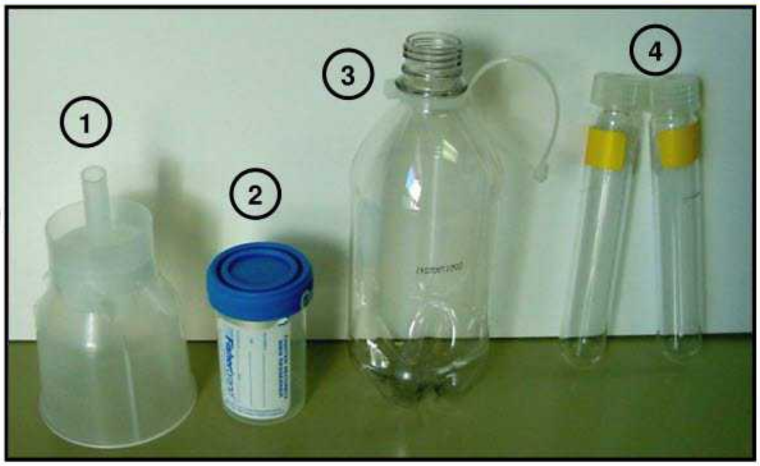
Because the transparency of a lake may vary through the year, Secchi disk observations are made, ideally, twice per month from May to October. Refer to the **sampling instructions** on the reverse side of the Secchi observation sheet for instructions on how to take a Secchi disk measurement. **Record** the Secchi depths on the enclosed observation sheet. **In November,** return the Secchi observation sheet to the Dorset Environmental Science Centre in the pre-paid envelope provided.

Please read these detailed instructions and the Secchi observation sheet before you sample.

Before You Sample

Water Sampling Materials include:

- one 80 micron filter with funnel **(1)**
- one 100mL sample jar (blue or orange cap)**(2)**
- one sample collection bottle **(3)**
- two glass sample tubes **(4)**
- Secchi observation sheet and return envelope
- return postage for samples with Dorset mailing address



NOTE: You will need to supply some materials to complete the collection bottle and Secchi disk (explained below).

1. Prepare the **collection bottle (3)** by attaching about 6 meters of clean rope to the neck ring (**photo A**). Mark the rope off in metres. Duct tape a suitable clean weight to the bottom of the bottle. Choose a weight heavy enough to sink the bottle (approximately 2Lbs/900g). A metal *pipe cap is shown in the photo below* (**A**). *Keep your ropes and weights to attach to a new bottle that is supplied each year.*

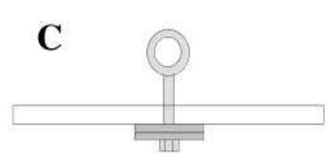
2. Assemble the **Secchi disk**. Attach a rope to the Secchi disk enclosed in your kit (for new volunteers). The rope length will depend on how transparent the lake is, but in general, lakes in Ontario have up to 10 metres of water clarity (usually 4-6 m). Mark the rope off in tenths of a metre (**photo B**). You will need to add an eye bolt (for the rope) and a few large washers, or other suitable weight, to the bottom (**photo C**). Some stores carry large square "dock hardware" washers that are ideal to use as weights.

Please keep your Secchi disk to use in following years. With time, some rope material will stretch. Each year check that the metre markings on the collection bottle rope and the tenths of a metre markings on the Secchi disk rope are still accurate.

A

B

C



At the Lake

*Secchi transparency readings and water samples must be taken at the **off-shore deep spot** of the lake or bay. It is best to sample when lake conditions are calm, between the hours of 10 am and 4 pm.*

Step 1. *Secchi Transparency Readings*

- Use your Secchi disk to measure water clarity. Record the depth (in **metres**) on the observation sheet (see instructions on how to take a Secchi measurement on the back of the Secchi observation sheet).
- **Keep** your observation sheet to make Secchi readings once or twice per month and return it to Dorset in November in the envelope provided.

Step 2. *Collect the Water Samples*

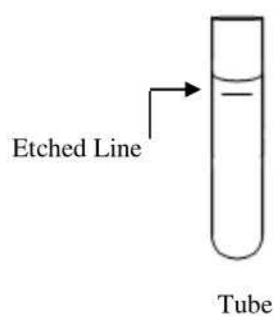
- **First, write the sampling date on the two glass tube labels and on the 100mL sample jar label (blue or orange cap)**
- Rinse the weighted sample bottle three times with lake water (does not need to be filtered). Next, lower the weighted sample bottle down to the Secchi depth and back up to the surface to fill it. In shallow lakes, lower the bottle no closer than approximately **1 metre** from the lake bottom.

Step 3. *Fill the 100mL sample jar (blue or orange cap)*

- Pour the water through the filter and rinse the small sample jar **THREE TIMES** with a small amount of water. After rinsing, fill the small sample jar with **filtered water.**
- **The funnel components are held together by friction. If they come apart, reassemble the two halves with the filter screen between the upper and lower sections.**

Step 4. *Fill both Glass Phosphorus Tubes*

- Pour more water through the filter and rinse both glass tubes and caps **THREE TIMES** with a small amount of water.
- **Pour water through the filter and fill both tubes to *1 cm above* the etched line on the glass sample tube** (if you run out of water, repeat S*tep 2 by collecting another water sample with the weighted sample bottle*)
- Make sure the lids are screwed on snugly.



Step 5. *Mail the samples to Dorset*

- Place the **funnel, sample collection bottle, 100mL jar and glass tubes** back into the box.
- Make sure the lids are securely screwed on and insert into the protective pipe wrap. Attach the return address label and postage provided to the outside of the box. Seal the ends of the box with tape and mail to Dorset.

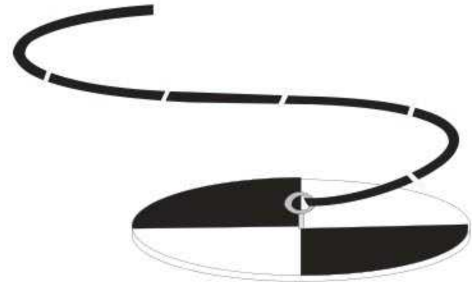
Questions? Call 1-800-470-8322 (or 705-766-1294 if outside Ontario) or email *lakepartner@ontario.ca*

PIBS 8104

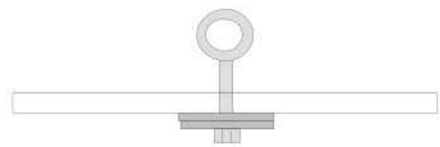
Note: *Please keep the samples refrigerated until the kit is mailed. Thanks!*

Secchi Disk Instructions

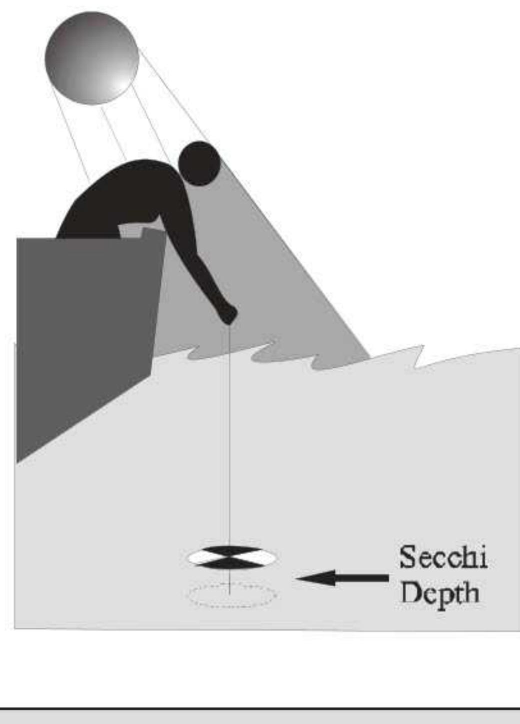
Making a Secchi Disk



The Secchi disk enclosed in your kit (for new volunteers) will need to have an eye bolt, weight and rope attached (marked in metres). The rope length will depend on how clear the lake is. Lakes in Ontario have between a few metres and upwards of 10 metres of water clarity. You can mark the rope in half metre intervals and estimate the tenth metre intervals between those marks. You will need to add enough weight to the bottom of the disk to sink it. This can be accomplished by adding an eye bolt through the centre hole (for the rope) and adding a few large washers to the bottom. Some stores carry large square "dock hardware" washers that are ideal to use as weights.



Determining the Secchi Depth



1. Lower the Secchi disk until it disappears.
2. Note the depth to nearest tenth of a metre.
3. Raise the Secchi until it reappears.
4. Note the depth.
5. The *Secchi depth* is the midpoint between these 2 depths. Record this depth with the other required information on the waterproof observation sheet in your kit.

NOTE:
Take the reading on the shady side of the boat. Do not wear sunglasses. Take the reading as close to mid-day as possible (10am - 2pm) in the same water & weather conditions. Record depths in tenths of meters i.e. 4.2m

Did you know?
The Secchi disk is named after Father Pietro Secchi(1818-1878), a scientific advisor to the Pope. The Secchi disk was first used in 1865 in the Mediterranean Sea.

Guide to Interpreting Total Phosphorus and Secchi Depth Data from the Lake Partner Program

The following information will assist with interpreting Lake Partner Program total phosphorus and Secchi depth data. These results are posted each year in separate tables on the Lake Partner Program webpage (www.Ontario.ca/LakePartner). Since 2002, total phosphorus (TP) analyses have been conducted at the Dorset Environmental Science Centre (DESC) chemistry laboratory. TP data based on DESC analytical methods are approximately ten times more precise than data collected before 2002.These data can be found in the **Pre-2002 TP Means** table and are expressed as annual means of all data collected. By averaging several years of these data, we can describe average concentrations prior to 2002, but the data should not be used to examine trends through time.

Chemistry Technician at the Dorset Environmental Science Centre performs total phosphorus analyses on Lake Partner Program water samples.

Total Phosphorus

TP concentrations are ideally used to interpret lake nutrient status since phosphorus is the element that controls the growth of algae in most Ontario lakes. Increases in phosphorus may decrease water clarity by stimulating algal growth. In extreme cases, algal blooms will affect the aesthetics of the lake and/or cause taste and odour problems in the water.

Many limnologists place lakes into three broad categories with respect to nutrient status. Lakes with less that 10 µg/L TP are considered oligotrophic. These are dilute, unproductive lakes that rarely experience nuisance algal blooms. Lakes with TP between 10 and 20 µg/L are termed mesotrophic and are in the middle with respect to trophic status. These lakes show a broad range of characteristics and can be clear and unproductive at the bottom end of the scale or susceptible to moderate algal blooms at concentrations near 20 µg/L. Lakes over 20 µg/L are classified as eutrophic and may exhibit persistent, nuisance algal blooms.

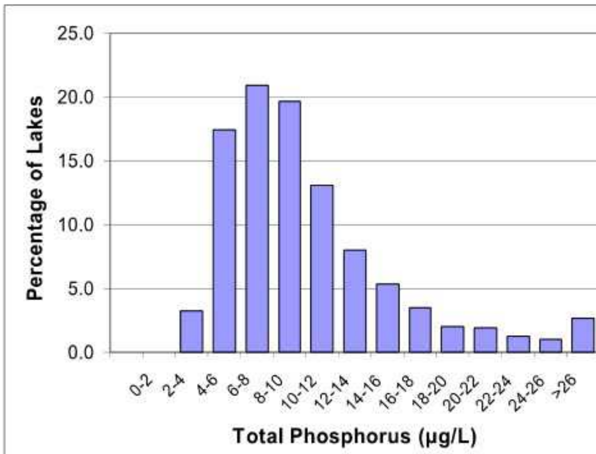


Figure 1. Distribution of total phosphorus concentrations in 1421 of Ontario's inland lakes. Lake concentrations are based on the lake-wide averages of spring turnover concentrations.

Note: Tea stained lakes, with high dissolved organic carbon (DOC), are called dystrophic lakes and do not share the algal/TP relationships described above. Generally there can be more TP in a dystrophic lake without the occurrence of algal blooms. The chemistry of these lakes is quite complex.

The Lake Partner Program database contains TP data from over a thousand of Ontario's inland lakes. Figure 1 shows the distribution of TP concentrations in over 1400 of Ontario's inland lakes based on data from the Lake Partner Program. You may find this useful in understanding how the TP concentrations of your lake compare to other lakes in the province. This figure shows that more than 50% of the lakes in this dataset have TP concentrations of 4-10 µg/L.

Water Clarity – Secchi Depth readings

As we know, increases in phosphorus may decrease water clarity by stimulating algal growth. However, water clarity cannot generally be used to infer nutrient status in Ontario's inland lakes. Light penetration in the lake can be controlled by dissolved organic carbon (DOC) or by non-biological turbidity, which influences the colour of the lake. Water clarity can also be altered by invading species such as zebra mussels. It is always best, therefore, to use TP to evaluate the nutrient status of the lake. Water clarity readings nonetheless are valuable to track changes in the lake that might be occurring that would not be noticed by monitoring TP concentrations alone, e.g. zebra mussel invasions or watershed disturbances.

A Lake Partner Program volunteer uses a Secchi disk to measure water clarity in a lake.

Between-year differences in TP concentrations

Once there are several years of data, volunteers may want to examine their results for trends through time. Three years of data are required to establish a reliable, long-term average to measure the current nutrient status of the lake. However, three years of data are not enough to examine trends. There are some lakes that show relatively large differences in TP between the years (e.g., Austin Lake, Figure 2) but unless there are tangible reasons for these differences (e.g. large differences in rainfall between years or a large watershed area compared to lake area), it is more likely that further data collection will identify these years as data anomalies. Most lakes do not usually show large, between-year differences, but this is the reason why we collect annual data, so that we can identify what the normal between-year differences should be. Although the three years of data may show distinct increases or decreases, the trends are probably due to normal between-year variability. It is interesting to note that once there are several years of high quality TP data, it is possible to identify long-term trends (trends that maintain

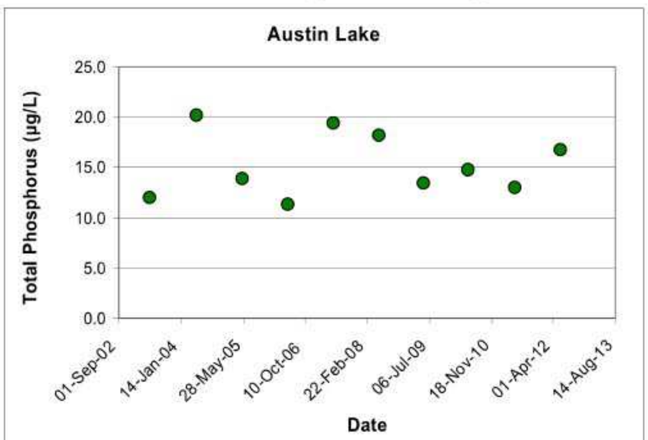


Figure 2. Between-year variation in total phosphorus (TP) concentrations for Austin Lake.

themselves through time), such as the slight downward trend noted for Runnings Bay in Charleston Lake (Figure 3).

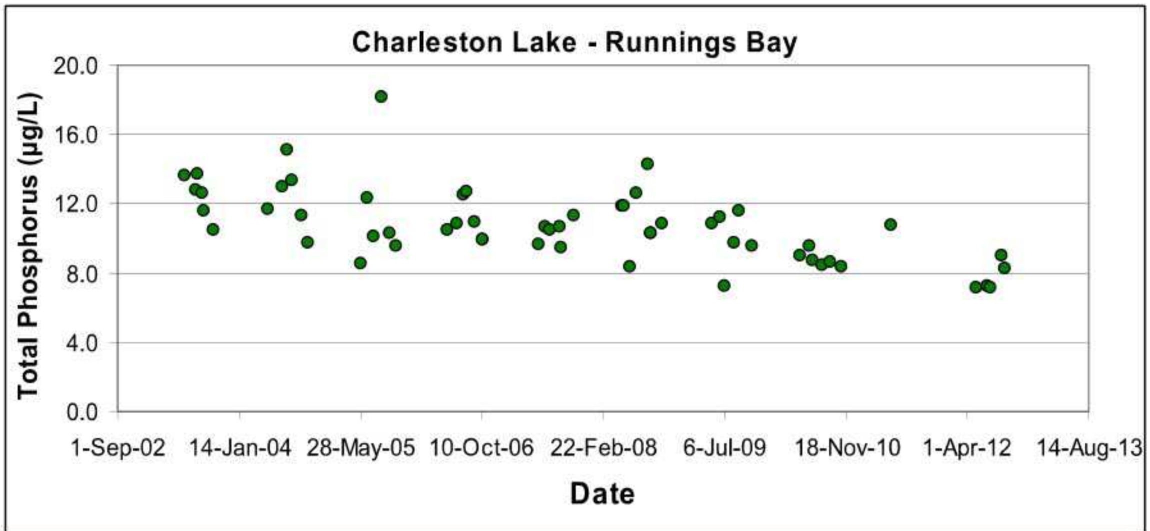


Figure 3. Long-term trend in monthly total phosphorus concentrations for 2003-2012 for Charleston Lake (Runnings Bay), sampled as part of the Lake Partner Program.

Seasonal differences in total phosphorus concentrations

Lakes that are off the Canadian Shield are sampled monthly because they are more likely to show seasonal differences in TP concentrations. In cases where concentrations increase towards the late summer, it is important to ascertain whether or not these concentrations could contribute to late summer algal blooms. In many cases, especially in the Kawartha Lakes, there are considerable increases in TP concentrations as the ice-free season progresses. In many cases, the concentrations span two or even all three of the classic trophic status categories (e.g., Figure 4). Many of the complex seasonal processes in these lakes would be difficult to assess without the data that volunteers collect on a monthly basis.

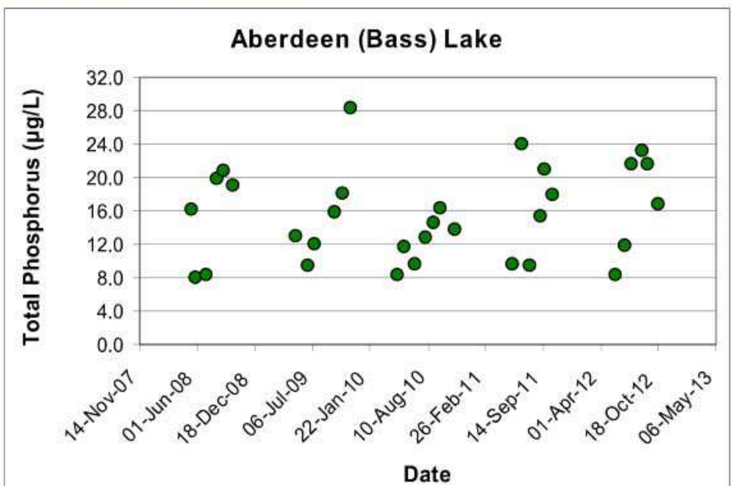


Figure 4. An example of a lake that shows seasonal differences in total phosphorus concentrations that span three of the classic trophic status categories (oligotrophic, mesotrophic and eutrophic).

Anomalous data points

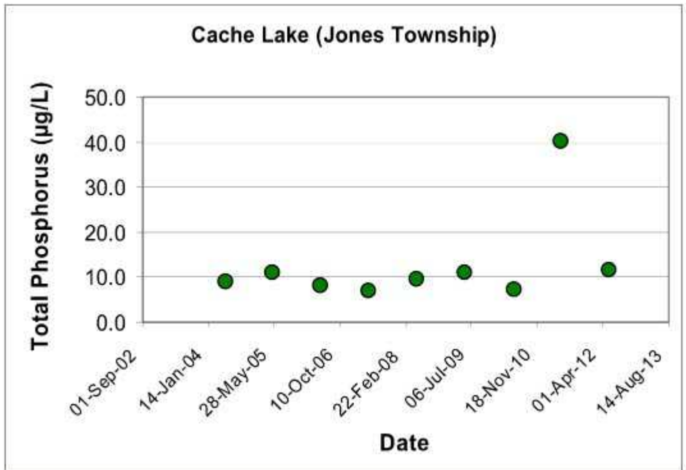


Figure 5. A lake that shows slight between-year trends in TP in the lake and one anomalous data point in 2011.

When there are several years of precise TP data, it is **less** likely that anomalous data points will interfere with the interpretation of the data. These "outliers" can be the result of sample contamination in the field, such as a single zooplankton that was left in the tube after rinsing with unfiltered surface water. Anomalous data points represent a small percentage of the total number of samples and are easy to identify, especially after several years of data have been collected. In some lakes, there may be a consistent source of contamination (high zooplankton densities) that affect some samples, but they should not have an effect on the overall data set. This situation can be seen in the Cache Lake dataset, which shows slight between-year trends in TP in the lake and one outlier in 2011 (Figure 5). This is an excellent data set that cannot likely be improved through any change in methods. We know that the percentage of outliers is approximately the same (2-5%) whether professionals or volunteers collect these data.

Common questions people ask about total phosphorus analysis:

What are TP1 & TP2? TP1 and TP2 are duplicate TP concentrations (sample pairs). These two "duplicate" samples help us to verify our confidence in the results. It is normal for there to be differences between TP1 and TP2. When there are major differences between TP1 and TP2, it is probably that one of the two samples was contaminated (usually the higher value). Contamination can occur when the sample water contains zooplankton or other debris. We submit two water samples for TP analysis. We know that about 5% of all TP samples submitted through the LPP are "bad splits," where there are major* differences between TP1 and TP2. Analyzing two samples is also a contingency against one sample being lost due to breakage during shipment or laboratory accidents.

Why are we filtering water samples? Large zooplankton will add disproportionate amounts of TP to a sample. For example, if your lake is 10 µg/L, a single zooplankton can increase the reading to 35 µg/L. Filtering the samples removes this source of variation. Normally there are very few large zooplankton in a water sample; however, the incidence of unusually high TP readings has dropped significantly since we began filtering samples in 2003.

Why do we take our water samples from the deep spot location on my lake or bay? There are many different ways to design a lake monitoring program. The Lake Partner Program is designed to answer two simple but important questions: "What is my lake's trophic status?" and "How are the TP concentrations changing between years and over time?" We know from other studies that a mid-lake, surface water sample is considered to be a good representative of the TP concentrations for the whole lake. Therefore, sampling at many different locations around the lake does not improve our understanding of the lake's nutrient concentrations with respect to TP.

* Major differences between duplicate samples are considered to be samples that differ by more than 30% from the lower of the two values, AND the absolute difference between duplicates is greater than 5 µg/L (MOE, unpublished data). Duplicate samples that were in poor agreement according to these criteria are highlighted in yellow in the published LPP dataset

Appendix B

Stakeholder Consultations

B.1 – Voluntary Sector Consultation – Blank Questionnaire

B.2 – Completed Questionnaires:

- Banook Area Residents Association
- Lake Mic Mac Residents Association
- Oathill Lake Conservation Society
- Portland Hills and Estates Residents Association
- Shubenacadie Lakes Watershed Protection Society -
- Sackville River Association
- Williams Lake Conservation Co.

B.3 – Meeting Minutes – Meeting with Lake User Groups and Community

Blank Questionnaire

Voluntary Sector Consultation with Lake, Community and User-Based Organizations with shared interests in HRM lakes.

Project Name: Water Quality Monitoring Policy and Program Framework Evaluation

Completed on behalf of: Halifax Regional Municipality
Led by: AECOM Canada Ltd.
Meeting Date: February 5, 2020; 6-8pm

Thank you for agreeing to participate in the volunteer-sector consultation meeting that is scheduled for Wednesday February 5th. There is a total of 9 groups who will be participating in this session. In preparation for the meeting, and to facilitate introductions of each participating organization, we are asking a representative of each organization to provide responses to the set of questions below.

This information is requested for: 1) information gathering purposes by the AECOM team; and, 2) as an introduction to your organization as it relates to current undertakings relating to water quality-related monitoring activities.

We ask that each group come to the meeting with the responses prepared to the information below. During the meeting, each group will be asked to share their responses to these questions, as a way of introducing your organization to the group of 8 other organizations present.

Organization Name: ____

1. Why did you organize as a group?

2. What monitoring activities are undertaken by your organization?

    a. Describe the monitoring activities:

Blank Questionnaire

b. How frequent are these monitoring activities completed?

c. What information is collected?

d. How are the monitoring activities funded?

e. How is your data shared, reported and interpreted?

Blank Questionnaire

f. What is the coordination mechanism involved for monitoring information collection? i.e. how many people are involved in these activities? Do you have a guide/manual that is followed for data collection?

3. What other lake management initiatives are conducted by your organization?

Blank Questionnaire

4. What are 3 things that you would like to implement that would improve your program?

Voluntary Sector Consultation with Lake, Community and User-Based Organizations with shared interests in HRM lakes.

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Organization Name: SOIL & WATER CONSERVATION SOCIETY OF METRO HALIFAX (SWCSMH)

1. Why did you organize as a group?

Stakeholdership.

* PLEASE REFER TO OUR WRITTEN SUBMISSION

2. What monitoring activities are undertaken by your organization?

    a. Describe the monitoring activities:

Shalom Mandaville Applied Limnologist
lakescience@outlook.com.

Soil & Water Conservation Society of Metro Halifax ('SWCSMH')
[redacted]
lakescience@outlook.com Tel: (902) 463-7777
http://lakes.chebucto.org -& https://1drv.ms/f/s!Au0xelA-MCofqT6hH_HmNC5EW7Oe

To:	AECOM, attn., Nora Doran P.Geo.	2 pg. & 7 pg. Exhibits
Cc:	Energy & Environment, Planning & Development, HRM, and Banook Area Residents Association (BARA)	
From:	S. M. Mandaville Post-Grad Dips. Co-Ordinator & Researcher in applied limnology	
Date:	January 30, 2020	
Subject:	AECOM's consultations re HRM's potential lake science/sampling	

Memorandum (Thank you kindly, and pardon any typos)

Recommendation #1 Sampling methodology/frequency; *cf.* Exhibit A (1 pg.):

Follow the OECD's recommendations since their 15-year research was conducted by approximately 80 of the world's leading limnologists of the time, at 50 research institutes in 18 of the western economies.

Recommendation #2 Hypolimnetic Oxygen Depletion-based trophic states; *cf.* Exhibit B (1 pg.):

Measure the DO/Temp/Conductivity during the applicable seasons. Then compute the RAHOD (relative areal hypolimnial oxygen deficits) and the trophic states based on oxygen deficits.

Recommendation #3 Data analyses; *cf.* Exhibit C (1 pg.):

Compare with the pre-cultural or at the least, with the pre-industrial values, especially in the case of Total Phosphorus. We can supply the pre-cultural values for approximately one thousand (1,000) lakes/ponds over 1 ha in size.

In addition, compare the parametre values with those of the 3 protected lakes, as applicable, in two of the Atlantic Canada National Parks (Exhibit C).

Mr. Paul Mandell, [redacted] The data of the protected lakes was obtained by him from the Environment Canada's data base except for the fecal coliform values.

Recommendation #4 OECD Probability Distributions; *cf.* Exhibit D (4 pg.):

We can supply you with a short 4-minute audio from the Environment Canada's Dr. Richard Vollenweider (deceased). Dr. Vollenweider was the lead scientist of the aforementioned OECD research. He has also been the first Canadian to have ever received the top international medal in limnology, the Naumann-Thienemann medal (1986/7), among many other international awards.

What emerged from the assessment of all information available, however, led to the conclusion that there is no possibility of defining strict boundary values between trophic categories. Whilst the progression from oligo- to eutrophy is a gliding one- as has been stressed many times in the literature- any one combination of trophic factors, in terms of trophic category allocation, can only be used in a probabilistic sense. Objective reasons exist for the uncertainty of classifying a given lake in different categories by two or more investigators, depending on the management of that body of water.

Average conditions, expressed by "average nutrient concentrations", "average biomass values", "average transparency", etc., do not necessarily express the degree of variability, particularly with regard to peak levels, frequency of their occurence, and their qualitative nature (type of phytoplankton).

From the management viewpoint, such situations and their frequency are as important as average conditions. For this reason, prediction uncertainties must be accounted for. The resulting probability distribution is given in Figures 3 to 6 of Exhibit-D for the main components: average lake phosphorus, average and peak chlorophyll *a* concentrations and average yearly Secchi disk transparency.

Also access http://lakes.chebucto.org/TPMODELS/OECD/probability.html

Recommendation #5: HRM should carry out occasional inter-laboratory testing for TP (Total Phosphorus) at the minimum with sample splitting, and not separate sampling. This is because some of the HRM's TP data during 2006 to 2011 appears to be out of sync with expectations, e.g., BELL Lake in Dartmouth.

The control lab should be a Federal lab, e.g., Environment Canada's lab in Moncton. Although we are a volunteer/scientific group, we had carried that out during the 1990's.

Encl. Exhibits A to D (7 pg.) [redacted]

"One of the most important aspects of the intellectual climate of the present time is the increasing tendency of scientific workers to pass the conventional boundaries of their subjects, ..., and to borrow, from diverse fields, information that can be related to the results obtained in their own special investigations. .... Pedantry will be forgiven more easily than vulgarity, and certain forgotten bushels will be overturned in the hope that they cover unsuspected bright lights. The writer believes that the most practical lasting benefit science can now offer is to teach man how to avoid destruction of his own environment, and how, by understanding himself with true humility and pride, to find ways to avoid injuries that at present he inflicts on himself with such devastating energy."

----------- Evelyn Hutchinson (Father of modern Limnology & the modern Darwin)
as quoted by W.T. Edmondson in Verh. Internat. Verein. Limnol. 1993. 25: 53-54

1. Data Base used in the OECD Eutrophication Programme

Sampling frequency

The success of the programme depended on well-coordinated monitoring projects. Therefore, great effort was devoted to the kind of variables measured, the selection of reliable practical analytical methods, sampling procedures and minimum sampling frequency. This was to ensure that adequate and comparable data could be obtained for later elaboration and analysis and that participants with relatively modest technical facilities could contribute.

Throughout the monitoring programme in 1975, the Technical Bureau issued guidelines to ensure uniform and comparable procedures for reporting the essential variables. These were revised in 1976 (OECD 1975, 1976).

V. Imp

It was stressed that several sampling stations were required to describe conditions in lakes with complex morphometry, but if this was not possible, the minimum provision was that the lake should be sampled at the deepest point (or points). Only this minimum provision was followed in many cases and often a distorted picture of the average lake concentration resulted. Guidelines were also given on the choice of depths at which to sample. It was proposed that during the period of stratification, samples are essential from above and below the thermocline and from lower down in the hypolimnion. Samples from the hypolimnion very close to the lake bottom were particularly important. An absolute minimum sampling frequency of four times per year was recommended (winter, summer, spring and autumn overturn) and a sampling frequency of at least once a month during periods of stratification. The frequency of sampling affects the various measurements differently. Infrequent sampling usually gives a distorted picture of the resultant variables which have short-term variability (Table 3.3) and it is inadequate for the determination of peak values of chlorophyll *a* and daily primary production.

The Technical Bureau also defined the units for the essential variables and clarified several uncertainties which arose during the workshps. The eutrophic zone was defined as the depth at which the light intensity of the photosynthetically active spectrum (400-700 nm) equals 1 per cent of the subsurface light intensity (from photometric measurements). Where this information is not available, a Secchi disc reading (in metres) in which z_e = 2.5 Secchi was used. The latter is of course only a rough estimation of the euphotic zone which may vary considerably, depending on the spectral composition (colour of the water). Calculation methods for annual mean and seasonal mean values were defined. The seasons were given as "winter, spring, summer and autumn". For water bodies showing irregular circulation patterns, it was recommended that breakdowns be made for two seasons only, "summer" and "winter". This made it possible to present the data in terms of annual means, which are essential for use in the nutrient loading formulae, while seasonal variation and seasonal peak values could still be recognised. Both these features are essential for understanding of the process of eutrophication.

The OECD research was a 15-year effort involving approx. 80 of the world's leading limnologists at 50 institutes in 18 countries of the western world.

The final report is cited as,

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

cf. **http://lakes.chebucto.org/TPMODELS/OECD/oecd.html**

EXHIBIT-A

Citation:-
Mandaville, S.M. 2019. Trophic state science. Electronic media.

Excerpts from Mackie, G.L. 2004. Applied Aquatic Ecosystem Concepts. Second Ed. Kendall/Hunt Publishing Company. 784 pp.
ISBN 0-7575-0883-9

The oxygen deficit in a lake is the amount of oxygen required to reach the saturation level. All calculations must account for the atmospheric pressure at the surface of the lake by using correction factors.

The most meaningful oxygen deficit measurement is the *relative hypolimnial oxygen deficit* because it accounts for oxygen deficits in layers below the hypolimnetic surface.

Essentially, one measures the dissolved oxygen contents of several vertical columns of water at the beginning and at the end of the stratification period. Each column has a cross-sectional area of 1 cm^2. The height (depth) of a column is usually 1 to 2 m. The difference in oxygen content for each layer (column) between the beginning and the end of the stratified period is summed to give a *relative areal hypolimnial oxygen deficit*, or RAHOD.

Oligotrophic lakes have RAHOD values of <0.017 mg O_2 lost cm^{-2} day^{-1}, and eutrophic lakes have >0.033 mg O_2 lost $cm^{-2}day^{-1}$.

The other two kinds of oxygen deficit are, *actual* and *absolute*, depending upon the saturation temperature used in the calculation. The main criticism of actual oxygen deficits is it assumes that the water was saturated at the observed temperature during spring turnover. The absolute oxygen deficit suffers the same criticism as the actual oxygen deficit in that it assumes saturation at 4°C, which is not necessarily true.

Hypolimnetic O_2 deficit

EXHIBIT—B

Mandell, P.R. 1994. The Effects of Land Use Changes on Water Quality of Urban Lakes in the Halifax/Dartmouth Region. M. Sc. Thesis, Dalhousie Univ., Halifax. xii, 171p.

Table 1 Reference lake types used as indicator thresholds for anthropogenic stressors of urban lakes

	Type 1 *Beaverskin Lake* *thin till*	*Type 2* *Bluehill Pond South* *thick till*	*Type 3* *Pebblelogitch* *dystrophic*
pH	5.40	6.92	4.30
conductivity (µsiemens)	24	35	34
colour (Hazen units)	5	22	87
alkalinity (µeq/l)	2.0	5.6	-25.5
total phosphorus (mg/l)	0.003	0.004	0.013
total nitrogen (mg/l)	0.23	0.23	0.32
sodium (mg/l)	2.59	2.90	2.80
chloride (mg/l)	4.24	4.90	3.90
sulphate (mg/l)	1.92	3.20	2.20
calcium (mg/l)	0.33	2.80	0.39
magnesium (mg/l)	0.34	0.50	0.37
potassium (mg/l)	0.23	0.60	0.27
turbidity (JTUs)	0.30	0.30	0.63
chlorophyll-a (mg/m^3)	1.38	1.20	1.80
DOC (mg/l)	2.0	2.0	11.9
fecal coliform (count/100ml)	18	18	18

Note: The data in the table were mostly taken from the Environment Canada's data base by Mandell (1994).

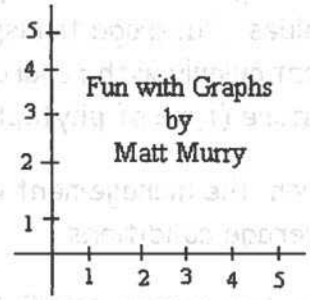
Shalom M. Mandaville Post-Grad Dip.
[redacted]

Email: [redacted]
Phone: [redacted]

EXHIBIT – C

Disclaimer & Copyright Notices; Optimized for the MS Edge

OECD Probability Distribution Diagrams- Vollenweider's dictum



Excerpts from the peer consensus, 16-year, 18-country Organization for Economic Co-Operation and Development (OECD) research

Soil & Water Conservation Society of Metro Halifax (SWCSMH)

Updated: April 12, 2019

HOME PAGE

Contents:

Shortcomings of the Fixed Boundary approach

cf. Janus and Vollenweider, 1981; Vollenweider and Kerekes, 1982

What emerged from the assessment of all information available, however, led to the conclusion that there is no possibility of defining strict boundary values between trophic categories. Whilst the progression from oligo- to eutrophy is a gliding one- as has been stressed many times in literature- any one combination of trophic factors, in terms of trophic category allocation, can only be used in a probabilistic sense. Objective reasons

EXHIBIT – D (4 pg.)

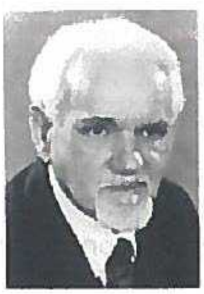
exist for the uncertainty of classifying a given lake in different categories by two or more investigators, depending on the management of that body of water.

Average conditions, expressed by "average nutrient concentrations", "average biomass values", "average transparency", etc., do not necessarily express the degree of variability, particularly with regard to peak levels, frequency of their occurence, and their qualitative nature (type of phytoplankton).

From the management viewpoint, such situations and their frequency are as important as average conditions.

For this reason, prediction uncertainties must be accounted for. This can be achieved by reinterpreting the summary values listed in Table-3 in terms of classification probabilities. The resulting probability distribution is given in Figures 3 to 6 for the main components: average lake phosphorus, average and peak chlorophyll concentrations and average yearly Secchi disk transparency.

Vollenweider's dictum



Click on the mp3 sound file (4-minute duration) to listen to the rationale behind the OECD Probability Distribution Diagrams relating to the scientifically credible methodology of ascertaining trophic states which can be achieved only in a `probabilistic sense' as described above.

Environment Canada's Dr. Richard Vollenweider has been the first Canadian (1986/7) to have ever received the top international medal in limnology, the Naumann-Thienemann medal.

Probability Distribution Diagrams

Figure-3: Probability distribution curve for the average lake phosphorus:

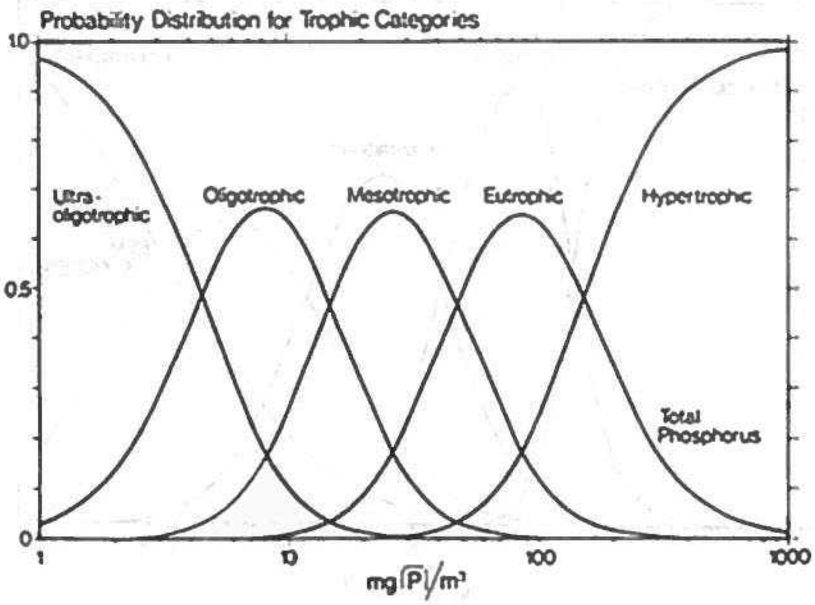


Figure-4: Probability distribution curve for the average chlorophyll *a*:

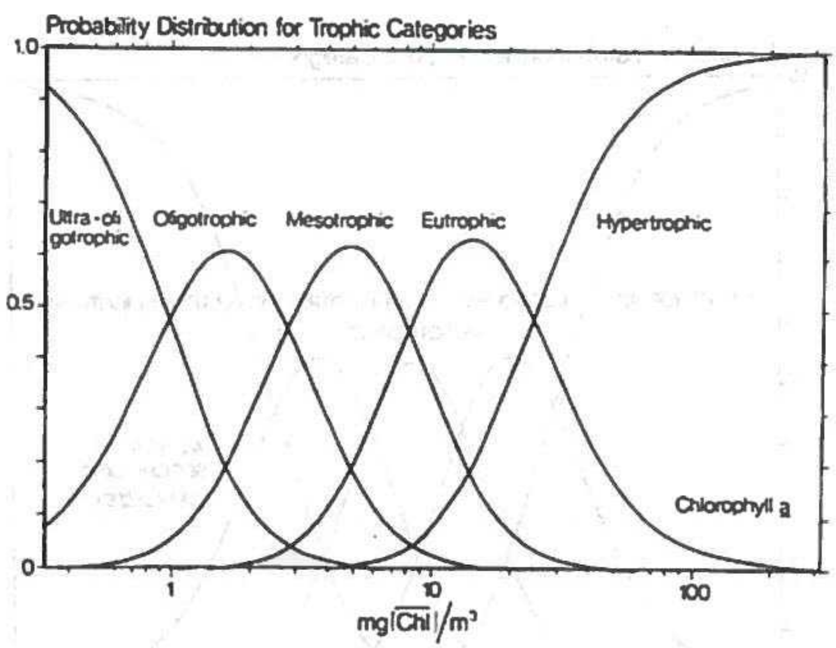


Figure-5: Probability distribution curve for the peak chlorophyll *a*:

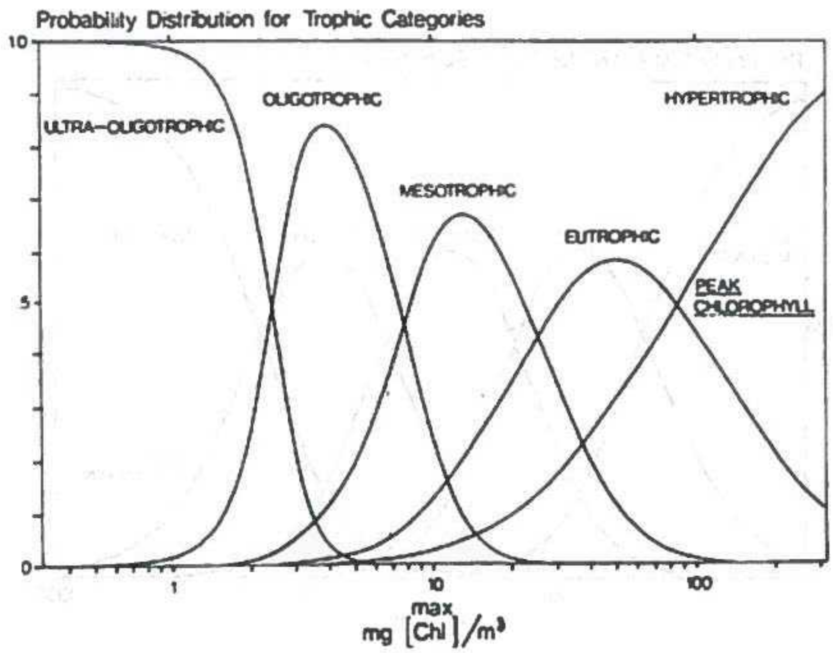
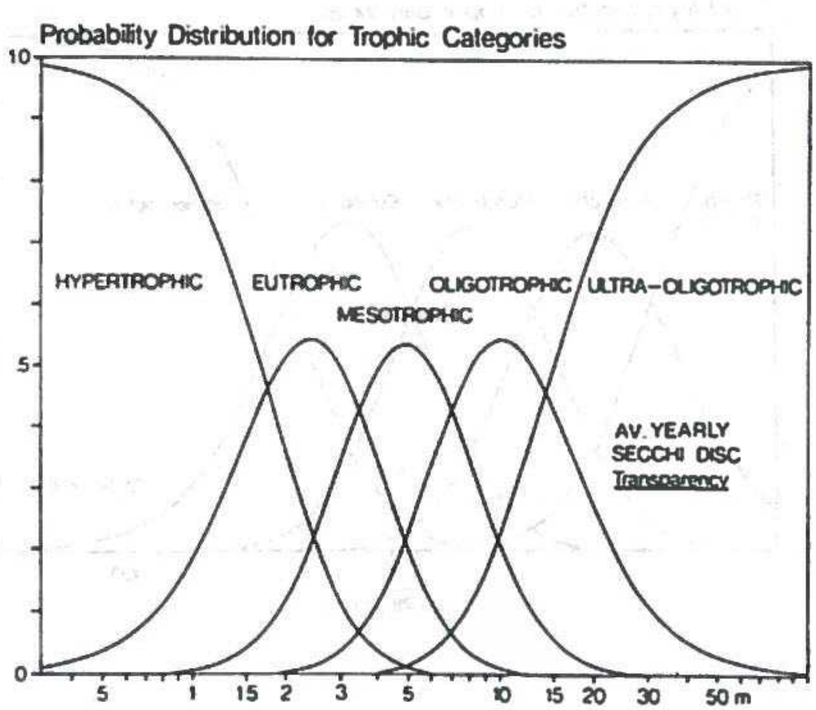


Figure-6: Probability distribution curve for the average yearly Secchi disk transparency:



Soil & Water Conservation Society of Metro Halifax ('SWCSMH')

[redacted]
lakescience@outlook.com Tel: (902) 463-7777
http://lakes.chebucto.org -& https://1drv.ms/f/s!Au0xelA-MCofgT6hH_HmNC5EW7Oe

To:	AECOM, attn., Nora Doran P.Geo.	2 pages
Cc:	Energy & Environment, Planning & Development, HRM, and Banook Area Residents Association (BARA)	
From:	S. M. Mandaville Post-Grad Dips. Co-Ordinator & Applied Limnologist	
Date:	February 05, 2020	
Subject:	AECOM's consultations (overall) re HRM's lake aspirations	

Memorandum_Overall (Thank you kindly, and pardon any typos)

This should be read in conjunction with our accompanying submission dated January 30, 2020.

A 'limited number' of consultations can never truly represent the valued residents of our beloved HRM.

We state this from our own experience of holding well-advertised public discussions across several districts of HRM during the 1980's and 90's. We request the following major amendments to the *modus operandi*:-

Recommendation #1: Surveys all across the HRM to gauge public opinion on recreational water quality and the public's aspirations:

Establish a well-advertised web survey right on the homepage of HRM (halifax.ca). The survey should last for a minimum of six (6) months.

In addition, a paper survey should be mailed to all the householders including rental units. Six (6) months should be allowed for responses.

Recommendation #2: Select precedents in North America:

We (vaguely) recall somewhat similar consultations having been held in Ontario, Manitoba, and British Columbia.

In the USA, over the decades, it has been relatively common place to include lake management aspects and costs as one of the items that the public was able to 'vote on' during their municipal elections, This is per the former USEPA Clean Lakes Program documents, and our own past verbal communications with the relevant agencies.

The Lake

Its surface reflecting its creator, God
Or humankind
Its depths formed by nature
Or machine

Origins aside, a provider of life
To those who draw from, or inhabit
This pool
A Garden of Eden
Immersed

A cove of rest for the spirit
Or a whirlpool of conflict
A spring of union or
Strife among men

Desert spread or canyon cradled
Both playground and home
Under winter ice or summer wave
A living cup

---- *Danny L. King* ----

Voluntary Sector Consultation with Lake, Community and User-Based Organizations with shared interests in HRM lakes

Project Name: Water Quality Monitoring Policy and Program Framework Evaluation

Completed on behalf of: Halifax Regional Municipality
Led by: AECOM Canada Ltd.
Meeting Date: February 5, 2020; 6-8pm

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Organization Name: **Lake Mic Mac Residents Association**

1. Why did you organize as a group?
   We organized as a group because we were concerned with the obvious deterioration of our lake quality. We are a relatively new organization, having just formed in the past 6 months. We do have a Steering Committee and Executive in place and have developed an association charter with goals focused on improved lake heath, education and coordination.

2. What monitoring activities are undertaken by your organization?

   a. Describe the monitoring activities:
      We have not undertaken monitoring activities todate and don't see that as a major mandate of our organization. We are trying to understand the data that exists from the various sources. We do not have membership fees and are entirely volunteer. We would likely be in a position to assist, on a volunteer basis, with the monitoring activities of other organizations.

b. How frequent are these monitoring activities completed?

N/A

c. What information is collected?

N/A

d. How are the monitoring activities funded?

N/A

e. How is your data shared, reported and interpreted?

N/A

f. What is the coordination mechanism involved for monitoring information collection? i.e. how many people are involved in these activities? Do you have a guide/manual that is followed for data collection?

3. What other lake management initiatives are conducted by your organization?

4. What are 3 things that you would like to implement that would improve your program?

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Organization Name: Oathill Lake Conservation Society

1. Why did you organize as a group?

The group organized due to an observed decline in the overall health of the Lake, including

- the loss of amphibians, & eels
- heavy stocking of rainbow trout in a put and take fishery that was open year-round that was creating an imbalance in the natural food web and bringing large numbers of fishermen in the days after stocking who were damaging the riparian areas
- user conflicts between the anglers and swimmers and other recreational users
- the final trigger was a sewage spill from an unknown source that closed the Lake

2. What monitoring activities are undertaken by your organization?

   a. Describe the monitoring activities:

i. We use a YSI and other sensors to collect water quality information on a routine basis, and send water samples for chemical and biological analysis once or twice per year

ii. We work with Provincial fisheries to maintain an ecologically sound trout stocking program

iii. Ad hoc observations on fish and wildlife use of the lake

iv. Ad hoc observations on recreational use of the Lake

v. Ad hoc observations on road salting

vi. Monitor activities in the riparian area

vii. Monitoring invasive plant species in the riparian area

b. How frequent are these monitoring activities completed?

i. During the ice-free seasons, we do bi-weekly vertical profiles of the lake in 3 locations

ii. and sample several of the storm sewer outfalls in the lake

iii. During the winter the profiles and outfall sampling are repeated when it is safe to go on the ice

c. What information is collected?

i. YSI information each meter depth– Crew, Date, Time, Location, Depth (m), Water Temp (ºC), Pressure (mmHg), DO (%), DO (mg/l), SPC (ms/-cm), Conductivity (ms/-cm), Salinity(ppt), pH, secchi disc.

ii. Temperature logger array in the deepest part of the Lake with loggers at 1.5m intervals

iii. If funds are available lab water quality (AGAT) for standard water quality, metal scan and coliform in summer samples. Timing of these are determined based on changes seen the YSI data and surface and depth samples as required to identify source of the change.

iv. Live internet water surface water temperature during the summer

d. How are the monitoring activities funded?

    i. Volunteer mainly

    ii. Apply for grants for maintenance

    iii. Member dues

e. How is your data shared, reported and interpreted?

    i. On excel sheets emailed to volunteers

    ii. Access via our web page

    iii. Atlantic Data Stream

f. What is the coordination mechanism involved for monitoring information collection? i.e. how many people are involved in these activities? Do you have a guide/manual that is followed for data collection?

    i. Volunteer

    ii. Varies about 10

    iii. Data collected using the standards from St Mary's University Community Based monitoring/ Atlantic Data Stream

3. What other lake management initiatives are conducted by your organization?

- Lake restoration – during the ice-free seasons we operate an Aquago to circulate the water and improve oxygen levels in the lake leading to better trout habitat and less internal cycling of nutrients
- We have had good success down to a depth of 5m and are making changes to extend this down to the deepest part of the Lake 8.5m
- We have installed a storm water pond with vegetation to remove nutrients from one of the storm drain outfalls
- Removal of invasive plants in the riparian areas
- Provide better access to the lake
- Garbage cleanup
- Facebook, web page and yearly newsletter public/community awareness

4. What are 3 things that you would like to implement that would improve your program?

- We need some base funding to maintain equipment (YSI and Aquago) and funding to pay for water sample analysis at the Lab.
- We need coliform sampling as we have a lot of swimmers
- The lake does not turn over in the spring most years due to road salt build up in the deep water – we need a solution

Oathill Lake Conservation Society Recommendations for HRM's Lake and Watercourse Policy

Our recommendations have been grouped below under four main themes – Public Education, Storm Water Treatment, Maintenance and Development Policy, Monitoring and Research.

Public Education

- HRM should initiate and implement a public education program regarding things that negatively impact the ecology of lakes and watercourses (e.g. phosphorous and other nutrients, salt, hydrocarbons, pesticides and other chemicals). We recommend a strong focus on the relationship of storm water system discharge to deleterious effects on lakes and streams.

- the reduced use of artificial (non-natural) lawn and garden care products such as pesticides, herbicides and fertilizers should be encouraged.
    - the public should be educated to reduce their level of use of these garden care materials and to maintain a buffer zone around their property edge so that the transfer of these materials to the storm-sewer system is lessened during rainfall events.
    - this would include the encouragement of lawn care companies in the use of low-impact treatments such as highly mixed seeding and only minimal use of natural fertilizers.
    - the use of low or phosphate-free fertilizers should be encouraged[1].

- the public should be educated as to the importance of the reparation and maintenance of ecologically healthy riparian zones around all lakes and watercourses.
    - as a part of this, we are suggest that the city encourage and assist residents who have built lawns and structures that run to the waters edge to re-vegetate those areas immediately abutting the shoreline. Prime examples may be seen in the area along Lake MicMac where it connects to Banook. Property owners should be required to maintain an appropriate "natural" buffer zone adjacent to any lake or waterway within HRM. However, the best HRM can probably now do is to educate and encourage these landowners to ameliorate the impact their area shoreline may have on the lakes.

- the owners of large hard-surface areas such as the parking lots at MicMac, Penhorn and Dartmouth Crossing should be educated and encouraged to use salt (or alternative deicers) at levels determined by HRM to have less effects on downstream waterways.

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[1] We recognize that there are many other sources of nutrients that may play an equal or greater role in the nutrient enrichment of HRM's lakes and waterways.

Storm Water Treatment

- all large hard-surface areas (such as mall parking lots) should have their storm water runoff biologically or otherwise filtered in some manner before release into streams, lakes or the groundwater.
    - this should be a requirement for all new developments and already existing large hard-surface areas should be retro-fitted.

- in the short-term (2-5 years) HRM should work with Halifax Water to identify all storm sewer outlets putting effluent directly into lakes and streams (e.g. as seen on Oathill Lake, where one outlet is under the surface of the lake and others provide effluent to the lake with little or no filtering opportunity). Once the most "troublesome" of these outlets are identified, HRM and HW should develop a plan and work together to fund and expedite remedial modifications to these outfalls.

- in the short to medium-term, all other large storm sewers should have their runoff treated using oil/grit separators and wetland filtering. The latter should include a significant amount of seepage for groundwater recharging. Where possible smaller storm sewers should be wetland filtered.

- HRM should work with Halifax Water to develop long-term plans for the discontinuance of the current practice of having storm sewer effluent directed into lakes and streams. Clearly, this is a complex undertaking since at present water levels in our lakes and streams are to some degree dependent on this runoff. Filtration into the groundwater would seem necessary if water levels are to be maintained.

To further explain this issue - we need the water to be released into wetlands, lakes and streams at the same rate, including peak flows, as if the watershed was forested. This can be done with water retention ponds that charge the ground water and regulate the outflow to watercourses. Wetlands need to have their water supply protected and maintained – it is no good to build all around them and then divert all of their required inflow away in pipes. Current practice in HRM is to collect all the water in storm sewers and pipe it under riparian areas and directly into lakes. This dries up the streams and wetlands and uses the lakes as water retention ponds. This is not an acceptable practice and defeats most reasons for the riparian zone and for any buffers applied within them. In addition, to the retention ponds and the flow controls mentioned above, ideally the water should pass through an area of wetland where excess nutrients will be removed.

- as a precautionary[2] measure the city's road clearing program should be revamped and road salting reduced (today we often see repeated applications where a single application was entirely sufficient). A Salt Management Plan should be designed with the aim of evolving salting practice towards levels less likely to have negative environmental

---

[2]We use the word precautionary since, while it is generally considered that increased salt in lakes and streams is ecologically damaging, we have no direct evidence that this is the case.

effects. Such an approach would also have economic benefits for HRM both in salt volumes used and in lowered trucking costs. Streets could be categorized as to traffic flow, traffic patterns, speed and grade and levels of treatment varied in accordance with usage. The upper part of Lorne Ave. bordering the lake is an example. One night in January of this year, it was salted four times despite already having a layer of salt on it. This area of the street is virtually flat and, being a dead end, is used almost entirely by local traffic. Resources are being wasted and additional ecological damage is being incurred as a result of excessive salting and indiscriminant application.

Maintenance and Development Policy

- on HRM properties where shoreline vegetation has been destroyed, the city should undertake restorative action by replanting with naturally-growing native species. By way of example, there are areas around Oathill, Penhorn, Maynards and many other city lakes that have been severely damaged and, in some cases, denuded of vegetation by years of heavy foot traffic.
    - many such areas could be identified and inventoried during the field operations of the water quality monitoring program. From such an inventory, HRM could then prioritize and plan restorative actions.

- where appropriate, HRM should promote or carry out the planting of Acadian forest trees along watercourses and lake edges to provide shading and maintenance of cooler summer water temperatures.

- any future "development" bordering lakes or streams should by law be required to maintain a 30 metre "buffer zone" extending inland from the shore's edge where disturbance of the natural biota is minimized.

- consideration should be given, where possible and economically feasible, to the day-lighting of watercourses that have been buried. We suggest this since we think it likely to encourage biodiversity within the streams and their riparian zones.

- where man-made obstructions such as dams and culverts interfere with fish passage, properly functioning fishways should be installed or culverts modified to allow passage.

- infilling of wetlands should be prohibited. Where infilling has been pre-emptively (or surreptitiously) carried out, the landowner should be required to remediate the situation and reconstitute the wetland. As a basis for establishing its policy, HRM should review the province's Wetland Policy and adapt it to the management of those wetlands falling within HRM's boundaries (NS Wetland Conserv. Policy Draft. 2009).

- the vegetative stripping of large land parcels by developers should not be allowed. In developing such areas, developers must adhere to Nova Scotia's Erosion and Sedimentation Control Handbook for Construction Sites (Nova Scotia Environment 1988). Areas being stripped must be quickly stabilized to prevent sediment mobilization in runoff. Additionally, HRM needs to enforce its already existing bylaws related to the discharge from developments of sediment-laden water into HRM storm water systems.

- fish stocking activities within HRM should be restricted to the use of only native species such as brook trout and Atlantic salmon and levels of stocking kept at sustainable levels which do not overtax the carrying capacity of the lakes or streams being stocked (e.g. on the order of 50 stocked fish per hectare of lake surface – see New Brunswick DNR's Fish Stocking and Brood Stock Collection Procedures). Such an approach will provide adequate fishing opportunity without stressing the ecological health and biodiversity of our lakes and streams. Overstocking can lead to heavy top-down predation and negatively-cascading effects on the ecological health of lakes and streams (Eby et al. 2006).

- in any fish-stocking project within HRM, the responsible party (Inland Fisheries/DFO) should ensure that non-indigenous species (plant or animal) are not transferred and introduced in the hatchery-sourced transport water. This will require scientific evaluation of the donor waters by qualified specialists.

- where an invasive species has been introduced (e.g. floating yellow heart into Little Albro Lake) every effort should be made to eradicate it before the inevitable spread to other lakes can occur. Where practicable and necessary, this could involve extreme measures such as "killing off" the lake in question and subsequently reviving it through the reintroduction of native species (both plant and animal).

Monitoring and Research

- HRM should undertake an inventory and delineation of all wetlands within its boundaries. While this is a major undertaking, it is necessary to the future protection of these wetlands and their contribution to the health of the water systems within HRM.

- in the interest of public health safety, all lakes frequented by swimmers should be regularly tested for *E. coli*, fecal coliforms and blue green algae. Currently this testing is regularly carried out only at what HRM has designated as public beaches. Despite heavy swimmer and boating use, some smaller lakes such as Oathill are less regularly tested.

- HRM should ensure that the limnological and biological sampling and studies necessary for the provision of scientifically-based management options to the city are carried out. HRM staff responsible for the provision of such advice should liaise and work with universities, fisheries agencies and community groups in the planning and conduct of the necessary monitoring and studies.

  - a scientific advisory committee, under the chairmanship of an appropriately qualified member of staff, should be set up to provide watershed, lake and stream management advice to HRM.

- a review should be made of current water quality sampling and data analyses to ensure that the data being collected is sufficiently detailed to provide an understanding of the main "ecological stressors" and allow the development of remedial management actions.

- water-quality monitoring should take account not only of suspended biological indicators such as Chlorophyll a but also the periphyton (attached plants).

- indicator species should be used as "the canary in the coal mine" to provide early warning indications of declining lake and stream health (see the Canadian Aquatic Biomonitoring Network (CABIN) website). In the case of lakes, amphibian species such as frogs may provide early indications of stressors through easily observed (both visual and aural) indicators of population decline. Large numbers of deformities among frogs are also a likely indicator of chemically induced stress.

- HRM should encourage and support volunteer citizens' groups in taking an active role in the monitoring and management of our lakes and watercourses. Such activities could be assisted through groups such as the Saint Mary's University's Community-Based Environmental Monitoring Network (CBEMN) and its recently-funded five-year Community-University Research Alliance project (CURA H2O).

Terence Rowell
May 4, 2012

References

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New Brunswick Dept. of Nat. Res. 2009. DNR Fish Stocking and Brood Stock Collection Procedures. 26 p. + append.

Nova Scotia Environment. 1988. Erosion and Sedimentation Control – Handbook for Construction Sites. Available online at:
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Nova Scotia Wetland Conservation Policy (Draft). 2009. 17 p.

Voluntary Sector Consultation with Lake, Community and User-Based Organizations with shared interests in HRM lakes.

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Organization Name: Portland Estates and Hills Residents Association (PEHRA)

1. Why did you organize as a group?
   PEHRA has been in the community for 25 years. PEHRA was formed in 1990 as the Portland Estates Residents' Association (PERA) and changed its name in Fall 2007 to reflect the growth of the community and its widened mandate. The association acts as an environmental watchdog, organizes community events (e.g. clean-ups, skating parties, summer picnics, dances), and has built an extensive trail system. We keep residents informed through our website and through quarterly newsletters delivered to all community households. In the Fall of 2018 PEHRA formed a subcommittee of our Environment Committee to respond to the concerns of residents about significant negative changes in the conditions of Morris and Russell Lakes. The committee was named the Morris and Russel Lakes Conservation Committee.

2. What monitoring activities are undertaken by your organization?

    a. Describe the monitoring activities:
    Due to limited resources our monitoring activities only include testimonial observations by residents. It is our position that due diligence monitoring is the responsibility of our elected governments and regulatory agencies. Either to conduct analytical monitoring and study themselves or to provide resources to community groups to conduct the activity.

    b. How frequent are these monitoring activities completed?
    On occupation or during specific events, e.g. discoloration of the streams or lakes. Swimmers itch etc.

    c. What information is collected?
    Currently only testimonial observation of Stream and Lake conditions. E.G, weed growth, odours, algae blooms, sediment loads, suspicious activity etc.

    d. How are the monitoring activities funded?
    Refer to the above comments. PEHRA is a non-profit fully funded by paying memberships.

    e. How is your data shared, reported and interpreted?
    Select information is posted on our Websites and social media sites. Information is shared within the PEHRA committees, to regulatory authorities when required, and to elected members at times.

f. What is the coordination mechanism involved for monitoring information collection? i.e. how many people are involved in these activities? Do you have a guide/manual that is followed for data collection?
See previous.

3. What other lake management initiatives are conducted by your organization?
We are primarily are focused on public education through social media, information signage, news, presentations, events, and outreach to regulatory authorities and elected officials. We have in the past conducted tree planting and worked Clean Foundation to support Stream Restoration projects.

4. What are 3 things that you would like to implement that would improve your program?

    a. *Analytical monitoring program to collect data frequently to assess lake condition and understand the impacts of human and weather-related events on the lake. Information to inform the residents and stakeholders about the human health and environmental conditions of the lakes and streams.*
    b. *Environmental study of the lakes and streams to understand the conditions, sources of impacts, and possible mitigation measures.*
    c. *A source of resources and a multi governmental collaborative effort for the community group, either in the form of direct or indirect funding or human resources from the various government stakeholders.*

5.

Voluntary Sector Consultation with Lake, Community and User-Based Organizations with shared interests in HRM lakes.

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Organization Name:
_____SWEPS_____________________________

1. Why did you organize as a group?
   The **Shubenacadie Watershed Environmental Protection Society** (**SWEPS**), is a non-profit community-based organization concerned with the quality of life and the environment in the Shubenacadie Watershed. Our main area of focus is the headwaters of the Shubenacadie Watershed, concerned with water quality, habitat protection and trail construction

2. What monitoring activities are undertaken by your organization?

   a. Describe the monitoring activities:

Quarterly water quality monitoring of lakes and streams in the watershed. Using a YSI and then collecting samples to be sent to an external lab for additional testing.

b. How frequent are these monitoring activities completed?

Quarterly

c. What information is collected?

All YSI data, as well as specific data relevant to a site (metals, nitrates, phosphates, micro....etc)

d. How are the monitoring activities funded?

Typically from external grants

e. How is your data shared, reported and interpreted?

We post it on our web site, and share our data with anyone who requests it.

f. What is the coordination mechanism involved for monitoring information collection? i.e. how many people are involved in these activities? Do you have a guide/manual that is followed for data collection?

We have monthly meetings to plan our activities. We have the equipment for testing which includes a basic SOP so that testing is quick and simple.

3. What other lake management initiatives are conducted by your organization?

Stream restoration, habitat management, monitoring of biodiversity, maintenance of associated trails.

4. What are 3 things that you would like to implement that would improve your program?

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Organization Name: Sackville Rivers Association

1. Why did you organize as a group?

We formed as a group of concerned community members over the state of the Sackville River.

2. What monitoring activities are undertaken by your organization?

   a. Describe the monitoring activities:

We collect river water quality data at nine locations across the Sackville River Watershed. On a periodic basis, we also collect biological data in the form of fish abundance at several locations.

We have developed a comprehensive monitoring plan which involves runoff sampling for turbidity; lake water quality sampling, contaminant and nutrient sampling and invertebrate sampling.

   b. How frequent are these monitoring activities completed?

During the summer months, we collect stream water quality data every two weeks. The rest of the year we collect data once a month.

Lake sampling has been initiated Sandy and McCabe with Webber and Big sandy to be added this year.

What information is collected?

Water temperature, pH, dissolved oxygen, salinity and conductivity in streams. And those same parameters with depth in lakes.

Fish abundance is collected by electrofishing.

c. How are the monitoring activities funded?

This activity is funded through general revenues, primarily donations.

d. How is your data shared, reported and interpreted?

We share out data with DataStream and St. Mary's University Atlantic Water Network. The last comprehensive review of the data was 2016 which resulted in an interpretive report.

e. What is the coordination mechanism involved for monitoring information collection? i.e. how many people are involved in these activities? Do you have a guide/manual that is followed for data collection?

Our Board of Directors established a monitoring plan, and it is implemented by our coordinator and our summer work crew.

3. What other lake management initiatives are conducted by your organization?

None.

4. What are 3 things that you would like to implement that would improve your program?

We would like have resources sufficient to implement our proposed monitoring plan which includes:

1. Continued stream sampling with increased parameters – nutrients and contaminants.
2. Better characterization of fish populations
3. Rain induced runoff sampling
4. Lake water quality measurements.
5. Invertebrate sampling.

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This information is requested for: 1) information gathering purposes by the AECOM team; and, 2) as an introduction to your organization as it relates to current undertakings relating to water quality-related monitoring activities.

We ask that each group come to the meeting with the responses prepared to the information below. During the meeting, each group will be asked to share their responses to these questions, as a way of introducing your organization to the group of 8 other organizations present.

Organization Name: Sackville Rivers Association

1. Why did you organize as a group?

We formed as a group of concerned community members over the state of the Sackville River.

2. What monitoring activities are undertaken by your organization?

    a. Describe the monitoring activities:

We collect water quality data at a number of locations across the Sackville River Watershed.

    b. How frequent are these monitoring activities completed?

During the summer months, we collect data every two weeks. The rest of the year we collect data once a month.

    c. What information is collected?

Water temperature, pH, dissolved oxygen, salinity and conductivity

d. How are the monitoring activities funded?

This activity is unfunded.

e. How is your data shared, reported and interpreted?

We share out data with DataStream and St. Mary's University Atlantic Water Network. There is no analysis or interpretation done on this data.

f. What is the coordination mechanism involved for monitoring information collection? i.e. how many people are involved in these activities? Do you have a guide/manual that is followed for data collection?

Our Board of Directors established a monitoring plan, and it is implemented by our coordinator and our summer work crew.

3. What other lake management initiatives are conducted by your organization?

None.

4. What are 3 things that you would like to implement that would improve your program?

We would like to monitor more often, with more sites, and a larger suite of collected data across more water quality parameters.

Voluntary Sector Consultation with Lake, Community and User-Based Organizations with shared interests in HRM lakes.

Project Name: Water Quality Monitoring Policy and Program Framework Evaluation

Completed on behalf of: Halifax Regional Municipality
Led by: AECOM Canada Ltd.
Meeting Date: February 5, 2020; 6-8pm

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We ask that each group come to the meeting with the responses prepared to the information below. During the meeting, each group will be asked to share their responses to these questions, as a way of introducing your organization to the group of 8 other organizations present.

Organization Name: WILLIAMS LAKE CONSERVATION CO.

1. Why did you organize as a group?

Ongoing stewardship of lake and its shores for maintenance of water quality and local ecology. This extends to parkland and backlands.

2. What monitoring activities are undertaken by your organization?

   a. Describe the monitoring activities:

   Annual monitoring of minerals
   Irregular ecological studies by volunteers - water flow, conductivity, oxygen.

b. How frequent are these monitoring activities completed?

Annually
E. Coli three time

c. What information is collected?

Minerals (iron especially, Mn, Mg etc)
Coliforms.

d. How are the monitoring activities funded?

WLCC funds (most of them)

e. How is your data shared, reported and interpreted?

Executive meetings
and membership meeting.

f. What is the coordination mechanism involved for monitoring information collection? i.e. how many people are involved in these activities? Do you have a guide/manual that is followed for data collection?

Annual General Meeting Report
Newsletter report

3. What other lake management initiatives are conducted by your organization?

Lakeside monitoring
Community education
~~Coll~~ Engaging Council Members

4. What are 3 things that you would like to implement that would improve your program?

(1) Moratorium on lakeside development pending complete environmental review of lake health and watershed stress.

(2) A responsive department in HRM that enforces existing bylaws affecting riparian zones, watershed, roads.

(3) Review of lakes and lakeside ecology

AECOM

DRAFT

Minutes

Meeting name		Attendees	Circulation list	Apologies
Meeting with Community and Lake-User Groups				

Subject
HRM Water Quality Monitoring Policy and Program Development

Meeting date
February 5, 2020

AECOM project number
60617813

Time
6pm – 8pm

Venue
HECC

Prepared by
J. Shea

Meeting Attendees		
Banook Area Residents Association	Jeff Weatherhead	Shalom Mandaville
Lake Charles	Rene Leclerc	
Lake Mic Mac Residents' Association	Debbie Windsor	Dennis Bowie
Oathill Lake Conservation Society	Jim Kennedy	Bob Rutherford
Portland Estates and Hills Residents Association (PEHRA)	Richard Loughery	
Sackville Rivers Association	Walter Regan	Bill Ernst
Shubenacadie Watershed Environmental Protection Society (SWEPS)	Graeme Soper	
Williams Lake Conservation Company	Kathleen Hall	Robin Whyte
Halifax Regional Municipality	Jim Hunter	Thea Langille
AECOM Canada	Nora Doran	Janice Shea
CanDetec Inc.	Dennis Gregor	
Regrets		
PEHRA	Norman Steele	
Atlantic Division – CanoeKayak Canada	Robin Thomson	

Introductory Presentation by AECOM– 6:05 to 6:21

Round table participant introductions – 6:21 to 6:56

Portland Estates and Hills Residents Association – Richard: Lives on Morris Lake. Norm is the main contact.

- Very active community group for 20 years – active in developing parks and rec. areas
- Norm has tried unsuccessfully over the years to get the city to enforce bylaws when they see silt, etc. running into the lakes via recent development
- Seeing significant weed growth, bacteria, algae. So much change in the last 5 years
- Very active lake
- Subgroup formed within the community group to look at water quality issues
- Not actively monitoring – still in brainstorming stage. Knows about past studies and gathering information.
- Looking to know what information to gather and measurements to take
- Wastewater management, stormwater runoff, enforcement of existing bylaws for development

Oathill Lake - Bob

- No new development within the lake – full watershed
- Surfacewater all comes into the lake with stormwater
- Nutrient loading problems
- Over the years people have seen the ecology go down (loss of fish, frogs, eels, etc.)
- What triggered formation of the group was a sewage leak. Lakes was closed due to high coliform levels.
- Started monitoring health of the lake – community-based monitoring through SMU Cathy Conrad which is now Atlantic Data Stream, use the YSI from them for weekly monitoring at 3 locations, profiles completed, work with provincial fisheries, ad-hoc look at the lake i.e. recreational use, road salting, ecological life, no lake turning in spring due to heavy road salt after winter. Monitor riparian area too with invasive species. Vertical profiles bi-weekly, sample storm sewer outfalls with YSI, temp loggers in the lake down to 8 ½ metres logging water temp variations, when we have funds available, they send water samples to AGAT laboratory, water surface temps in the summer but no coliform testing.
- All of this data is on Atlantic Data Stream
- Their hey finding is volunteer burnout.

Lake Charles – Rene

- Recently formed in last 2 years
- Lots of commercial and industrial development
- No active monitoring program. We are talking about doing that. City did fund one small study – benthic study. Gentleman on the lake doing his on testing ad-hoc with his own money
- There is a need for sampling and want to develop something.

- SWEPS – Graham
  - Fairly large group
  - Quarterly testing for everything they can – YSI and nutrients generally as needed
  - Receives funding from Halifax water to do some of their testing
  - Also has trails association – species monitoring, stream restoration
  - Trying to do a lot of community involvement
  - Main priorities- expand group with community, better sharing of Atlantic Data Stream resources and data. Hopefully can get a template that everyone can share across HRM to use.

- MicMac residents - Dennis
  - Concerned about our lakes – this is why group was formed. They have ideas but are still developing.
  - Concerned about: weeds, shut down a number of times from e. coli, human e. coli coming into our lakes, and blue / green algae
  - They do not think algae was handled very well – all they put up was signs. They want this testing to be going on.
  - Banook and MicMac are show lakes of HRM – very important for economic view (tourism dollars), Indigenous games – are they going to swim in the water? They will not come back.

- Jeff
  - Copied Oathills plan – borrowed their YSI. 26 month bi-weekly study on Dartmouth lakes (9 lakes) and streams - 50 test locations.
  - They have 3 dimensional view of the YSI results.
  - Look at oxygen levels at bottom of every lake.

- Sackville Rivers Association – Walter
  - $5M dollars a year will do the whole municipality
  - Watershed group – group of volunteers
  - We need continuous funding
  - Stantec functional plan is very important
  - Who is actually doing the analysis if we are doing the monitoring?

- 20 years + data – measure YSI parameters in stream, in 2016 they did analysis of data – report is available. Out of the report they developed monitoring proposal or plan that is ambitious. Want to extend monitoring of lakes (4 lakes are profiled once per years), they do biological – electrofishing. Want to move into invertebrate sampling and runoff as a major sedimentation problem, along with expanding parameters into nutrients and contaminants which we can't afford at the moment.

- Banook - Shalom
  - Phytoplankton, benthic analysis
  - All data is available through DAL and Sexton library's – all data is on one-drive.
  - There should be a survey on HRM website for 6 months asking what they want for their lakes.
  - He is going to make this an election issue.
  - None of the consultants are comparing pre-cultural or pre-industrial values. lakescience@outlook.com

- William's Lake - Kathleen
  - Est. in 1968. Water testing since early 1970's.
  - Check for coliform and mineral testing
  - Recently had salt study – a lot of salt it coming in
  - Their concern is that the lake is already maxed out – no more development. Water changing, silt issues.
  - Did succeed developer to develop a park which is now owned by HRM
  - Another piece of land for sale – do not want this developed – nothing has been done and there are no laws around this.
  - Ecology action centre – 60 members. AECOM should investigate this. Also the group from Sandy lake.
  - Requested to email the participants and contact information from everyone who attended the meeting.

Break-out Group Discussions – 7:00 to 9:00 pm

Question 1 – What do you see as the water quality monitoring priorities within HRM?

- Following standardized guidelines
- Enforcement of existing bylaws and federal/provincial regulations
- Follow OECD guideline since it was the brain of 80??
- Enforce development plans
- Salt loading from roads
- Sedimentation and recognizing that it is not just the lakes but the watershed too
- Climate change effects
- Human health issues
- Hard surface runoff
- Phosphorous loading – key point was the idea that shallow lakes behave differently
- Use data logger where-ever possible – conductivity, blue/green algae, temp, etc.
- Phosphate, e.coli, blue green algae, weeds, sediment, swimming
- Stress modelling by lake – max capacities at a lake level – models developed. Discovering when a lake is maxed out from development.
- Watershed mapping
- Buffer zones
- Holding ponds
- Overall lake health – water ecology and survival
- Trophic state
- Storm water control. Flow levels and testing with urban lakes - quality and quantity.

Question 2 – How can HRM collaborate and coordinate with community and lake/user-based groups?

- Reactive regional watershed advisory board
- Lab funding – budgets
- Lot user charges as it relates to development
- Regional breakout – councillor lead

- Setting up separate committed office for all lake health – committed responsive body
- Consult all stakeholders across HRM
- HRM to take lead on standardizing monitoring methods and data to be collected – forms etc
- Providing money to groups to do regular testing. Full spectrum of tests including clarity.
- Have an office that group can communicate with, get information, work with.
- Sponsor citizen-based science efforts
- Idea that it is the whole watershed for consideration – needs to include rivers + streams, not just lakes.
- Collaboration - regular meetings / information exchange / communication
- 5-year lake specific grants – summer students from universities

Question 3 – What can community and lake/user-based organizations offer to HRM to assist/support HRM in achieving their mandate?

- Salary free testing – volunteer monitoring
- Identify problems and provide volunteer support
- Expertise, volunteer and labour
- There is a will to do something within these groups
- Offer access and guidance on lakes - day to day observations. Enforcement officer may come 3 days later but the issue may be present then.
- Local point of contact
- Advice – information about issues, suggestions for improvements.

Question 4 – Do you have knowledge of other municipalities within Canada that conduct municipal-led monitoring? If so, what lessons can be learned from these undertakings?

- Functional water quality plan – 4 cities (Waterloo and 3 others)
- Hamilton – blue green algae and groundwater testing
- Quebec municipalities have programming as well
- Muskoka, Halliburton, Lake Simcoe
- Newfoundland has live water monitoring program

Question 5 – Is implementing more effective mitigation programs more important than monitoring?

- No – IT IS BOTH. Can't do one without the other – cannot be separated. Without data it is difficult to justify anything. Enforcement should exist. *** agreement with all
- Question isn't fair – trying to divide us
- If there is no mitigation the volunteers aren't going to sample/monitor forever if nothing is going to be done.
- Effective mitigation – you can't just stop monitoring once you theoretically address the problem
- Depends on the watershed / water body – different issues at each (i.e. if underdevelopment or not)

Question 6 – How can HRM more effectively communicate information relating to water resources?

- Publish annual report detailing water quality by watershed. Be able to probe back up and speak up with results of these reports.
- Centralized website – needs to be easily accessed – its own website like hrmwatersampling.com
- Direct communication and education with those on the lake

- Open data sources
- Periodic reports
- Use Atlantic Data Stream – already a multimillion-dollar website- why not use it?
- Problems with 311 – they did not know all information about blue-green algae – this should be posted on website. HRM has something like this on website.
- Shalom says we need to measure aerosols when sampling for the blue-green algae. Neurodegeneration can happen when exposed.

Additional comments (Group 1):

- Daylighting
- More environment staff
- Halifax Water must be part
- Phosphorus testing
- Road runoff testing
- Report back to the group
- Biological and chemical testing
- Stormwater testing and treatment
- Waste management
- Lime the rivers and lakes
- Stream governing flow
- Actual analysis of water monitoring
- Lost service charges
- Salmon testing
- Start 100 watershed groups
- Remediation of results
- Sedimentation + stream restoration
- Work to get NSE developers to pay for testing
- Storm surge for small feeder brooks
- Groundwater testing
- Sewer testing – trailer park, schools??
- Green plan
- Floodplain mapping + zoning
- Green, red and white book

Additional comments (Group 2):

- Model the lakes, identify with risk scores, develop existing load models
- Enforce riparian zones management
- Serious collaborative and stewardship with a protective service
- Protective plan for lake-side development

<u>Next Steps</u>

AECOM report to be prepared and submitted to HRM in March, 2020.
Shalom wants this extended by 6 months – terms of reference tripled.
AECOM is requested to share everyone's emails. One participant declined.

Appendix C

Development Specific Monitoring Agreements – Overview and Lessons Learned

Appendix C - Development Specific Monitoring Agreements – Overview and Lessons Learned

1.1 Overview of Development Agreements – Existing and Planned

1.1.1 Russell Lake Development West

The Russell Lake West Development is a development along the western shore of Russell Lake in Dartmouth, Nova Scotia. The development consists primarily of single unit dwellings and townhouses. The development agreement required pre-construction, construction and post-construction monitoring in Russell Lake for TSS, TP, chlorophyll α, fecal coliforms, and some metals at three inlets, the outlet and an in-lake station. Sampling was initially conducted monthly but reduced to four times per year. During the initial two years, rain events greater than 25 mm/day triggered a sampling event in the lake. Samples were collected by a consultant and results were forwarded to HRM (Stantec, 2010). Direct monitoring of stormwater runoff quality or quantity from locations on the development site was apparently not required by the development agreement. While the samples were collected and analysed and the data transmitted to HRM, reporting on the results in relation to impacts from the development seem limited.

Community concerns regarding stormwater management on the site have been documented by the Soil & Water Conservation Society of Metro Halifax (SWCSMH) as recently as Feb. 2020[1], with reports of siltation problems in early stages of the project and a lack of effective control of stormwater throughout the lifetime of the project.

1.1.2 Morris Lake

Morris Lake Estates is a residential development in Dartmouth, Nova Scotia, is adjacent to Morris Lake and consists of single unit housing. In 1996, the Portland Estates and Hills Resident's Association (PEHRA) was asked to provide input to the proposed construction of Portland Hills alongside Morris Lake by Clayton Developments Limited. An Environment Committee under the auspices of PEHRA was formed and meetings took place to discuss environmental protection measures proposed by the developer. The primary focus was to minimize sediment transport from erosion at the development site to the lake. There were one-on-one meetings with HRM's mayor, and engineering and planning heads, and then with Clayton Developments to discuss best management practices for watershed protection. Partly as a result of such pressure, regular sampling of the two lakes in the community - Russell Lake and Morris Lake – was reportedly historically performed by both the municipality and the developer.[2] Historically, the committee routinely obtains the results of testing, analyzes them, and provides summaries to the community.[3]

The water quality monitoring program agreed to was initiated with pre-, current-, and post-development monitoring. Due to ongoing development in the area surrounding Morris Lake, HRM included the lake in its corporate water q quality monitoring program (2006 to 2011). An extensive suite of field and chemical

[1] http://lakes.chebucto.org/WATERSHEDS/COWBAYR/RUSSELL/russell.html#news

[2] It should be noted that these past monitoring initiatives were independent of one another. From approximately 2006 to 2012, the Developer hired qualified consultants to perform monitoring on Russell Lake. For the period of 2006 to 2011, Halifax monitored Morris Lake. These efforts operated independently of one another.

[3] (https://cch.novascotia.ca/sites/default/files/inline/documents/spirit/portlandestateshills.pdf).

parameters was included in the program including TSS, total organic phosphorus, ortho-phosphate, meta and polyphosphorus, TP, chlorophyll α, fecal coliforms and other variables. Field measurements for temperature, pH, conductivity, dissolved oxygen (DO) and Secchi disk depth were also completed. Temperature profiling was carried out at the in-lake stations. Sampling occurred in the spring, summer, and fall at all seven locations. Parameters were altered in 2006 to include phaeophytin while reducing phosphorous analysis to a measure of total phosphorous only. The results obtained by the consultant carrying out the sampling were provided to HRM (Stantec, 2010). This monitoring program did not include "at source" requirements to assess stormwater runoff quality and quantity focusing on downstream effects.

PEHRA continues to report concerns with the quality of the lake and a lack of response from HRM and other governments. In Dartmouth and Portland Estates, the impacts from changing natural conditions into land developments (homes, streets, sewers) has accelerated. Reports are increasing in frequency about lake closures, weed issues, toxic algae blooms, and invasive species. A September 2019 town hall, with over 150 residents attending, expressed concerns over these very issues. The key messages from attendees, PEHRA and the Oathill Lake Conservation Society were that "*HRM and the Province were not listening, not providing the support and resources to tackle the issues, and not acknowledging their regulatory and decision-making roles in contributing to the declining conditions of our Dartmouth lakes. It is land use control and management that has the greatest negative effects and these responsibilities are mostly those of HRM and the Province. The objective is to start getting action and support from our elected governments. With the right support we can make a difference and take action to save our Lakes*" [4]. The Bedford West Secondary Planning Strategy

Starting in 2002, Regional Council directed that a master planning study be undertaken on lands on the west side of the Bicentennial Highway, in the vicinity of Hammonds Plains Road and Kearney Lake Road – Bedford West. With respect to the protection of the environment within the study area, the planning strategy took full recognition of the fact that a vast majority of the study area is within the Paper Mill Lake watershed which includes Washmill, Quarry and Suzie Lakes. The historic dam structures that control water elevations at the outlets of Paper Mill Lake, Kearney Lake and Quarry Lake are a critical component of the watershed and support passive and active recreational activities and contribute significantly to the aesthetic and socio-cultural essence of the surrounding communities. Accordingly, the Municipality supports preservation of the dams and the introduction of flow control mechanisms which reduce flood risks and which further good stormwater management practices, provided that lake levels are maintained within ranges appropriate to the maintenance of recreational activities and shoreline aesthetics.

In order to implement the Strategy, specific policies have been put in place that support the achievement of the objectives toward more detailed stormwater Management plans, including:

- to undertake storm water management planning on a watershed basis with community design based on natural drainage patterns;
- to prevent flooding of properties and safeguard flood plains;
- to preserve the water quality of lakes and rivers;
- to preserve groundwater flows; and,
- to support regional initiatives in solid waste recovery, Halifax Harbour remediation and water-shed management.

[4] *PEHRA Website Accessed online* https://pehra.info/assets/2019fall.pdf

In the context of this report, Policy BW-3 states that:

"A water quality monitoring program shall be undertaken for the Paper Mill Lake watershed, illustrated on Schedule BW-2 to track the eutrophication process. The program is to be designed in accordance with national guidelines established by the Canadian Council for Ministers of the Environment (the CCME guidelines) and undertaken by qualified persons retained by the Municipality and financed in whole or in part by developers within the watershed area. Specifics of the program are to be negotiated under the terms of a development agreement in consultation with the Bedford Watershed Advisory Board. The monitoring program shall:

a) specify the duration of monitoring for the pre-construction, construction and post-construction phases of development. Pre-construction phase means a period of time before construction activity starts. Post-construction phase means a period of time that commences at full build out of the area permitted by a development agreement. Construction phase means the full time period between the pre-construction and post-construction phase);
b) specify the physical and chemical water quality indicators to be measured, the location and frequency of testing and the format of submissions to the Municipality in each phase referenced under clause (a);
c) establish physical and chemical water quality indicator threshold levels for the recreational uses of the lakes which would be used as a basis for re-evaluating watershed management controls and future development potential within the area. The threshold indicators are to be established prior to any development approvals being granted; and
d) conform with all water quality policies, specifications, protocols and review and approval procedures approved by Regional Council."

Further, Policy BW-5 states that:

"*In the event that water quality threshold levels, as specified under clause (c) of policy BW-3, for Paper Mill Lake or Kearney Lake are reached, the Municipality shall undertake an assessment and determine an appropriate course of action respecting watershed management and future land use development in the area. An assessment shall consider the CCME guidelines. Water quality thresholds and any assessment reports shall be made available to the public."*

Additional policies refer in a general way to the requirements of a stormwater management plan, activity setbacks from water courses and lakes, preservation of trees, vegetation restoration plans as well as the designation of lakes, watercourses, endangered species habitat and other significant environment features as non-disturbance areas. Development on slopes in excess of 25% would not be permitted.

The water quality monitoring program for Bedford West required under BW-3 has been reported on by CBCL (2015) and the situation at that time was reviewed by CWRS (2016) and the dataset from 2019 was summarized by SNC-Lavalin Inc. (SNC, 2019). This water quality monitoring program for the development area has been continuing since 2009 at a total of 11 stations as illustrated in **Figure 1**.

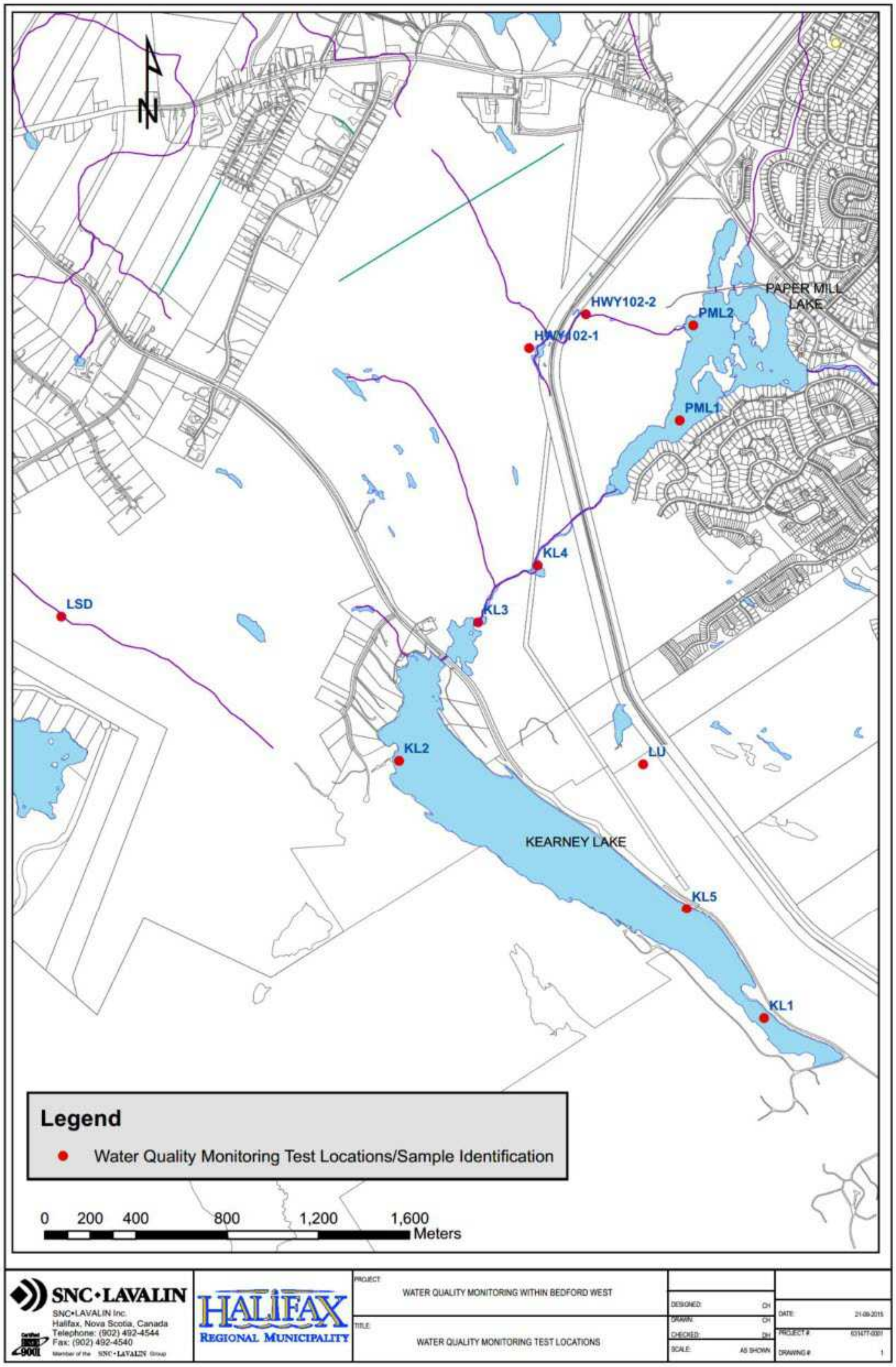

Figure C- 1: Water Quality Monitoring Locations for Bedford West, as reported in SNC (2019)

CBCL (2015) was commissioned to characterize the recent increases in TP levels in Kearney and Paper Mill Lakes where concentrations since at least 2012 had exceeded the TP threshold of 0.010 mg/L. Measured TP levels in both lakes during the 2006-2011 period displayed little variation, with levels in the oligotrophic range (<0.010 mg/L). Average TP values from the 2009-2014 period were higher than averages from the 2006-2011 period while three sites that were monitored showed a statistically significant linear increases in TP over time. The threshold of 0.010 mg/L was exceeded several times in the 2009-2014 with levels moving into the mesotrophic range, and on some occasions, into the eutrophic range (> 0.035 mg/L) at some locations in both Paper Mill Lake and Kearney Lake. Concentrations of TP showed increased variability during the 2009-2014 period which was stated to be expected in oligotrophic lakes such as Kearney and Paper Mill Lakes, as they become initially more enriched (CBCL, 2015). Comparison of the two sampling periods was limited by the fact that different sampling locations were used in 2006-2011 than were used between 2009-2014 with only a two-year overlap (2009-2011). This variability may also result from variable timing of sampling relative to conditions in the lake, a change in sampling methodology, seasonal differences or insufficient numbers of samples to characterize the lake.

The CWRS (2016) report was a desktop assessment of the Paper Mill Lake (PML) Watershed, with a specific focus on characterizing sources of phosphorus (P) loading and approaches for monitoring trophic state drivers and indicators within the watershed. This study was undertaken because the dataset considered by CBCL (2015) indicated that TP concentrations in Kearney Lake (KL) and PML were exceeding the early warning threshold of 0.010 mg/L. CWRS (2016) endeavoured to develop answers to several questions, specifically:

1. What are the largest sources of TP to KL and PML?
2. What role do internal phosphorus loading (e.g., from sediment) have on TP concentrations in KL and PML?
3. What type of monitoring program would be required to track TP loading over time from the Bedford West Subdivision?
4. How can TP export coefficients for the PML Watershed be validated?
5. How should the trophic state of KL and PML be monitored?
6. What are the consequences of adopting alternative water quality thresholds for regulating activities within the PML Watershed?

Our discussion below, as it is relevant to this report, focuses on questions 1, 3 and 5.

CWRS (2016) estimated that upstream sources account for approximately 31 % of the total P load to KL, with sub-watershed sources contributing 69% of the total load. With respect to PML, upstream sources account for 78% of the TP load and only 22% of the load is from the sub-watershed. They concluded therefore that TP in PML is dominated by TP sources that originate upstream of the PML sub-watershed. The three largest sources of TP in decreasing order of load in Kearney Lake were determined to be septic systems, runoff export from residential lands followed by runoff from industrial developments. The three largest sources of TP in Paper Mill Lake in decreasing order were exports from residential and industrial developments followed by loadings from forested landscapes. The authors noted that the repeated draining of Paper Mill Lake in 2012, 2013 and 2014 due to construction works may have resulted in increased TP concentrations in those years but this could not be assessed with the available data generated from the Bedford West monitoring program. Internal loadings of TP due to anoxia in the bottom waters may be an annual occurrence which was not monitored effectively.

As both Kearney and Paper Mill Lake are influenced by several other sources of TP in addition to Bedford West, CWRS (2016) suggested that directly measuring the TP load leaving the Bedford West site would be a more appropriate monitoring approach. The type of monitoring program required to adequately capture TP loading from the Bedford West site would in turn require intensive monitoring of flow and quality during runoff events throughout the year. However, this was not considered to be practical at all 27 individual stormwater discharge locations that are influenced by Bedford West. In turn, they suggested intensive monitoring of selected sub-watersheds representative of different types of land-uses and BMPs that could be extrapolated to the site as a whole. This would require a period of monitoring of at least 2 to 4 years.

With respect to monitoring the trophic state of both Kearney and Paper Mill Lakes, CWRS (2016) noted that Paper Mill Lake, and to a lesser extent Kearney Lake, did not fit some of the key criteria for natural lake characteristics developed by the Organization for Economic Cooperation and Development (OECD (Vollenweider & Kerekes (1982)[5]. CWRS recommended a sampling program that included biweekly sampling of the euphotic zone during the ice-free period at 2 deep stations within each lake for Chlorophyll α and TP.

SNC (2019) took over the sampling program on behalf of HRM in 2015 and completed an annual monitoring report for 2019 which provided graphical presentations of historical data from 2009 – 2019. The monitoring program includes a broad range of analytical variables including field data, nutrients and inorganics, a full suite of metals (not including mercury) as well as chlorophyll α and *E. coli.* SNC differentiated between spring data and all data for each year to assess trends.

Importantly, SNC (2019) made no mention of the possible effect of the repeated draining of Paper Mill Lake in 2012, 2013 and 2014 as noted by CWRS (2016).

1.1.3 Port Wallace Secondary Planning Strategy

The Port Wallace planning strategy is still in the process of development. Draft policies with a relationship to environmental protection, water quality and stormwater management will likely address the following areas:

- Open space or conservation zone protection for wetlands, steep slopes and other hazards;
- A minimum requirement of a 30 m buffer riparian zone for wetlands and water courses;
- Tree retention and tree planting requirements;
- Advance stormwater treatment and the use of Best Management Practices (BMPs) and Low impact techniques to mitigate stormwater impacts;
- Manage storm water for quantity and quality on-site;
- On public lands, promote the use of naturalized systems which serve to manage stormwater as well as passive and active recreation;
- Incorporate a water quality monitoring program for outfalls to monitor the impact of development on surface water quality and the effectiveness of the BMPs by considering pre-development, construction, and post development flow rates and water quality; and,
- Regular street cleaning to reduce the ongoing input of sediment and other contaminants.

5

1.1.4 The River Lakes Secondary Planning Strategy

Protecting the water quality of the Shubenacadie Lakes is one of the key goals of the River-lakes Secondary Planning Strategy. This system is of value to the region from a socio-economic perspective providing cultural and recreational resources and supporting a high value lifestyle as well as providing important ecological resources for the Region. Numerous shoreline residents take their water from lakes within the Shubenacadie system. Grand Lake, which receives the upstream flows from this chain of lakes system, also serves as a municipal water supply to the neighbouring Municipality of East Hants. HRM strives to maintain the present trophic status of these lakes to the greatest possible extent through the River-lakes Secondary Plan, in conjunction with the Regional Plan. One of the key strategies for achieving this goal is through the control of phosphorus loadings from large scale residential and commercial developments through the provisions of a development agreement within the River-lakes Secondary Plan Area.

To complement and strengthen the River-lakes Secondary Plan with respect to specifically managing TP, HRM developed the Phosphorus Net Loading Assessment (PNLA) (River Lakes Policy RL22 – No Net Increase in Phosphorous Export) which is required for residential and commercial developments that may be considered by Development Agreement within the River-lakes Secondary Plan Area (Hutchinson and AECOM, 2014). RL- 22 is intended to provide confidence to the developer, the community and to HRM Council, that the goal of this policy can be achieved prior to achieving Development Agreement approval. The SWMP, ESCP and PNLA submitted at the Development Agreement Stage shall be prepared to a sufficient level of detail to give the Qualified Person(s) (QP) preparing the documents and the QP(s) reviewing the document on behalf of HRM, adequate information to judge whether there will be a no net increase in phosphorus from the site if the proposed development takes place. The objectives of the PNLA and the associated report required to be submitted along with the SWMP and the ESCP that are required to support a Development Agreement are:

1. To prevent an increase in phosphorus export from future large scale residential and commercial developments that may be considered through the provisions of a Development Agreement under the River-lakes Secondary Plan;
2. To identify and minimize potential impacts of the privately-owned portions of the proposed development such that the development has no negative impact on existing surface flows from the development to watercourses and receiving water bodies and sensitive features (e.g. wetlands) or decreased infiltration to groundwater through on site management of stormwater and sediment and erosion control through the development of a SWMP and an ESCP plans that are acceptable to HRM and form part of the Development Agreement;
3. To extend the SWMP and the ESCP to include low impact development practices that manage runoff and phosphorus loadings from the Site during construction and the life of the development by identifying on-site mechanisms for mitigating potential increases to net loadings from the developed area; and
4. To document and quantify the pre-construction and post-construction phosphorus loadings from the Site to demonstrate the net loading assessment to the satisfaction of HRM.

Refinement of the PNLA, SWMP and ESCP may occur after the Development Agreement is approved and as the developer proceeds with subsequent detailed design and permitting. The details (e.g. the blend of on-site Low Impact Development (LID) practices, their location, sizing) may change but at no stage after Development Agreement approval can the outcome be reduced to something less than “no net increase in phosphorus export”. Modifications to the PNLA will have to be approved by HRM to ensure conformity with the goal of the original TP model assessment for the site.

In turn, the SWMP **is** required to assess pre-development conditions and demonstrate through the application of control measures and LID that the stormwater quantity control maintains peak post-development runoff rates comparable to peak pre-development runoff rates for the 1 in 2, 1 in 5, 1 in 10 and 1 in 100 year storm events. Simulation software shall be used to quantify pre- and post-development runoff rates and the effectiveness of control measures and LID.

Similarly, the designer shall submit an ESCP in conformity with all applicable municipal and provincial regulations and guidelines as required under RL-23. The plan shall include both short-term measures applicable during construction and long-term measures after completion of development. Appropriate lot grading measures shall be developed for application through the provisions of a Development Agreement. Consideration should be given in the Site design to make optimum use of existing topography and vegetation and minimize cut and fill operations. During construction, Site design shall prevent/ minimize surface water flows across or from the construction site. Development of the Site shall be based on exposing a minimum area of the Site for the minimum time.

HRM may prescribe additional information, including but not limited to:

- A septic system survey for existing systems;
- A surface water drainage survey including confirmation of flood hydrographs; and,
- A water quality survey to determine existing phosphorus loadings.

Additional work to collect baseline monitoring information may be requested by HRM if there is a high potential for significant changes to surface water runoff and TP exports from the Site. Details regarding the level of this assessment and the expected contents of the report will be documented by HRM. Also, HRM reserves the right to require post-development monitoring to verify the predictions of the effectiveness of the mitigation measures implemented with costs to be negotiated. This information will serve to guide HRM with respect to the actual effectiveness of the mitigation measures installed as opposed to depending solely on non-local data. The collection of local information regarding the effectiveness of LID practices will benefit residents, developers and HRM in the future with respect to identifying site specific best practices.

1.2 Observations for Effective Monitoring Programs for Development Agreements

This section specifically looks at maximizing the benefits that can be gained from monitoring programs associated with development agreements. This will be developed first by a brief review of the Bedford West Secondary Planning Strategy monitoring program and what can be learned there. Second, the objectives of the HRM and Halifax Water integrated stormwater management policy framework (ISMPF) (Halifax, 2017) will be reviewed with respect to identifying the priorities for monitoring programs within future development agreements. Finally, based on the assumption that a lake monitoring framework, as discussed later in this report, will be implemented by HRM, a framework for effective development agreement monitoring will be proposed.

1.2.1 Lessons from Russell Lake West Development and Morris Lake Estates

Complete synthesis of data from these two development agreements does not appear to have occurred although PEHRA and the Oathill Lake Conservation Society continue to report and monitor lake water quality in the lakes respectively. The major limitation in these agreements is the absence of at-source control requirements and associated monitoring with respect to runoff during and following construction. It is well documented that urban development will impact on the quantity and quality of the receiving waters without at source management. Development monitoring agreements should focus directly on the effects of the development and not on the ultimate impacts on the downstream receiving waters where control or management cannot be directly linked to construction and development. In short, development agreement monitoring should not be used to replace ongoing lake monitoring requirements and must consider source and mitigation effectiveness monitoring as its first priority.

1.2.2 Lessons from the Bedford West Monitoring Program

The Bedford West monitoring program developed as part of the Bedford West Secondary Planning strategy now provides ten years of data that has been reviewed in three different reports, notably CBCL (2015) and CWRS (2016) that considered data up to 2014 and SNC (2019) that briefly summarized the data from 2019. It is noted that this 10-year dataset has not been fully evaluated and post development monitoring has not commenced at the present time as work continues at the Bedford West development. Based on the reporting to date we noted the following:

1. The approach to presenting data and synthesizing the data to provide an ongoing evaluation of the success, limitations or gaps in the monitoring program needs to be established early in the program and followed through in all subsequent reports. Just as the monitoring program needs to be consistent, so must the reporting. If modifications are proposed to the interpretation of the data, they have to be documented and compared effectively to previous reports;
2. None of the reports addressed a QA/QC component to the sampling program and accordingly, it would appear that there has been no internal program for the verification of the quality of the data and this needs to be addressed;
3. Interpretive reports must effectively consider broader activities in the study area that could affect the water quality data, not just limit the scope of the report to the initial purpose of the monitoring program (i.e. the Bedford West Development). This is made abundantly clear by the fact that only the CWRS (2016) report commented on the possible effect of the repeated draining of Paper Mill Lake (2012, 2013, and 2014) and the possible effects of this significant activity on the overall lake water quality.
4. If anoxia of bottom waters is anticipated to be a concern, such as identified by CWRS (2016) as a contributor to loadings, appropriate profiling is required to assess the relative importance of this source of TP.
5. The overall rigor in reporting must be commensurate with the monitoring effort. The interpretation and reporting of the Bedford West monitoring dataset has, in our opinion, not been adequately assessed to-date to evaluate the monitoring program and to use this program as a best practice for other development agreements.
6. Development monitoring must be able to target directly the impacts associated with construction activities and the overall effects of the development directly which requires detailed monitoring close to the source.

1.2.3 Lessons from the River Lakes Secondary Planning Strategy

At the present time only one PNLA for a development has been completed and approved. This has been a learning process for the developers, their consultants and for HRM but the approach seems to be effective at least at the planning stage. The PNLA included a stormwater hydrologic model to demonstrate that pre-development hydrologic conditions would be maintained following construction using on-site stormwater BMPs and LID techniques. Water quality modeling was also used to demonstrate that with the BMPs and LID techniques that TP and TSS for non-point sources and advanced sewage treatment would not result in increased export of TP from the site compared to pre-development conditions. The erosion and sediment control plan developed to manage the site during construction included developer commitments such as:

- Topsoil and grubbings piles on the site will be covered with tarps prior to rainfall events to limit exposure to precipitation and surface water;
- Other erosion and sedimentation controls (e.g. sediment fence) will be installed and maintained on the site during construction for exposed soils that cannot be easily covered or removed from the site;
- Short-term measures that are proposed for this site include silt fencing, enhanced grass swales with temporary check dams, temporary spill-off ditches, and strawbale berms around catch basins;
- These short-term measures are to be removed or cleaned once suitable vegetation is established near project completion;
- When sediment gathers within the sediment and erosion control features during construction, it is important that they be regraded and revegetated after construction has completed to establish the design cross section and ensure proposed nutrient removal characteristics;
- The contractor shall monitor meteorological conditions and forecasts as a proactive means to minimize the potential for erosion; and
- The contractor must have a person on site daily who has successfully completed the Erosion and Sediment Control course by NSTIR, NSE, DFO and Dalhousie University.

The monitoring requirements or inspection reporting procedures that will be required as part of this development agreement have not been finalized at this time but the process of the PNLA and the contractor commitments show real progress in managing runoff, TP and solids at source thereby protecting the natural environment at the development site as well as downstream.

1.2.4 Relevant Observations from Stantec (2009)

Stantec (2009) undertook the development of the Water Quality Monitoring Functional Plan (WQMFP). The WQMFP is one of a series of functional plans mandated by the HRM Regional Municipal Planning Strategy (August 2006). Functional Plans were intended to be management guides considering the detailed elements of policy programming. However, the WQMFP was only reviewed as an Information Report by Halifax Regional Council and not adopted by the HRM. Nevertheless, re-visiting some of the recommendations from this report is appropriate here; however, in some cases, they have been updated to reflect the evolution of planning over the past decade as outlined in this report. Relevant recommendations applicable to the monitoring requirements of secondary planning documents based on the WQMFP include:

1. Adopt a standardized process to create consistency for developers and for HRM staff that effectively considers the variations in development, the nature of the land to be developed and the differences among the receiving water bodies;
2. At the present time HRM has no mechanism for enforcement, in so far as the municipality can require developers through the development agreement process to undertake water quality monitoring, there is no real means to enforce compliance or apply fines, particularly once construction has been completed. This could be addressed with the application of modeling existing conditions and expected conditions with BMPs and LID practices in place and designing the monitoring programs to confirm the predictions with the requirement that further mitigation would be required if predicted goals were not achieved[6];

[6] *This is the approach undertaken within the PNLA (Section 5.3.3) of the River Lakes Planning Strategy except that the PNLA does not require confirmatory monitoring.*

3. While it is important to differentiate between monitoring the impacts and managing the form of new development versus managing the impacts of existing development on water quality due to the difficulty of retrofitting existing developments, opportunities where infrastructure is being rehabilitated should be pursued and the effectiveness of these rehabilitations evaluated (e.g. the proposed "Prince Albert Road Diet" project and the Spring Garden Road project both expected to be constructed in 2021);
4. The lack of sufficient expertise and technical support at the municipal level to adequately design, evaluate and assess, and provide both technical and plain language reports on monitoring programs undertaken within development agreements should be addressed by the municipality to assure timely consideration of applications from an impact monitoring perspective when negotiating development agreements;
5. Clearly defined roles and responsibilities of all stakeholders are essential (e.g., each HRM staff department involved in the development process, the Regional Watershed Advisory Board, the Province, and the developers) with clear assignment of responsibility for monitoring to the developer (not to general contractor or sub-contractors). The developer is clearly responsible for maintenance during the construction period of the development as well as being responsible for ensuring a mechanism for maintaining all mitigation measures incorporated into the design that are on private property. Further, the developer must ensure trained and qualified personnel are undertaking the monitoring done as part of the development;
6. HRM and Halifax Water will need to address maintenance issues on public lands;
7. Integrated management at the watershed scale is needed, including management of the overlap between watercourse and wetland protection measures and other integrated management programs within HRM[7];

Stantec (2009) also provided a summary of published recommendations regarding water quality monitoring by an ad-hoc subcommittee of the Halifax Watershed Advisory Board (HWAB). These are reiterated here as they are worthwhile considering. The subcommittee considered the physical, chemical and biological indicators of water quality, the nature, methodology and costs of monitoring water quality, and the potential users of the resulting data.

The AHS recommendation as it relates specifically to development agreements has been quoted here to ensure that we are true to the recommendation. The AHS recommended:

> *"…any proposed development, arising from a development agreement, be classified as one of three categories in terms of potential impact on freshwater quality in any stream or lake: (i) substantial, (ii) moderate, or (iii) unlikely to impact to any significant extent. Where impact of development is potentially substantial, the AHS recommended that initial baseline monitoring be carried out, followed by on-going monitoring of a shortlist of key indicator parameters. Where potential for impact is moderate, the AHS recommended that sampling for only the shortlist of key parameters be carried out by trained volunteers under a part-time coordinator. It was suggested that developer and construction organizations be approached to provide the necessary support funding, in return for which they would have the right to advertise their patronage and to use the results for promotional purposes. Further it suggested that all data must have quality assurance, be assessed within a reasonable period, and that the data and assessment be readily accessible to all interested parties."*

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[7] *This has been achieved we believe within the River-Lakes PNLA requirements.*

Considerable progress has been made by HRM since these recommendations were made. The HWAB tiered approach to the monitoring plan for development agreements based on the potential impacts on the receiving water environment has a logical appeal. However, it requires that a systematic and transparent approach to evaluating the effects of the development and ranking these against other developments. This would appear to be an unnecessary hurdle at this time as the focus on BMPs and LID techniques in all situations, as proposed here, will be better addressed through the credit against stormwater service charges or storm water management credit banking as discussed below. In this way, the developer will want to implement and deliver an improved monitoring program to achieve their maximum credits over the course of the development.

This project has not discussed developing monitoring agreements with development companies directly. However, the observations from Stantec (2009) are instructive. Three development companies were contacted for input based on issues experienced under the current system (as of 2009) and for ideas for moving forward. The messaging from all three developers was quite consistent. An overall summary of key feedback is provided:

- Clearly defined roles and responsibilities of all stakeholders are essential (e.g., each HRM staff department involved in the development process, the Watershed Advisory Boards, the Province, and the developers);
- Effective division of responsibility i.e., determine responsibility for monitoring during the different phases of construction (developer, general contractor, sub-contractor);
- Integrated management at the watershed scale is needed, including management of the overlap between watercourse and wetland protection measures and other integrated management programs within HRM such as “HRM By Design” (e.g., can credits be given for development in one area that creates green space or improves hydrology or habitat quality, to off-set work in other areas?);
- Clarification of watercourse designation/definition;
- Clarification of responsibility for maintenance costs for stormwater management and water quality maintenance infrastructure (e.g., HRM versus the development company);
- Important for private companies to maintain the ability to control timelines and be vigorous in the market (e.g., be able to carry out their own monitoring programs);
- Use of qualified individuals and companies for monitoring program implementation;
- Would like to see prescriptive approach to monitoring program parameters, frequency and methods to minimize inconsistency in level of effort among programs;
- Improve consistency at Watershed Advisory Board level, or minimize “case-by-case” recommendations;
- Development companies will pay for certainty and the current process includes many uncertainties at multiple stages; and, it should also be noted that there were consistent comments related to fecal coliform and E. coli issues on construction sites in that construction was perceived not to be the direct cause of bacterial contamination[8].

[8] *Stantec (2009) countered this comment with the statement that “…However, the report authors would like to stress that as the potential for soil erosion increases, the potential for bacterial (e.g., E. coli) transport is also increased. As such, while development activities may not be a “source” of E. coli, they are facilitating the transport of microbial contaminants that are present within the soil environment, due to a host of other sources such as pets and wildlife.” They encouraged HRM to better educate developers regarding the sources of bacteria and gain their support for on-site management and mitigation of erosion.*

1.3 Monitoring Associated with Future Developments

The evolution of stormwater management over the past 20 years is evident in the above discussion. Gradually there has been a migration away from the objective of preventing "*loss of life and to protect structures and property from damage due to a major storm event*" (Halifax Water, 2016) as discussed to an increasing emphasis on better control of stormwater at source and simultaneously protecting the natural environment from both quantity and quality perspectives. This has been in part implemented through development policies that apply to specific growth areas within the Region as well as the adoption of initiatives to document background water quality, predict impacts of development on water quality, influence community design, and provide a framework to monitor impacts within the Regional Plan. The ongoing development of the Joint Stormwater Standards under the integrated stormwater management policy framework between HRM and Halifax Water will support the management of stormwater and the protection of the natural environment.

However, in the context of this report, a challenge remains for elaborating on the policies and framework for lake water quality monitoring. Observations based on the Bedford West Secondary Planning Strategy as well as the other documents reviewed, provide guidance for maximizing the benefits that could be expected from secondary planning strategy monitoring programs. These are built on the assumption that a lake monitoring framework as discussed in the next section of the report is implemented.

1.3.1 Designing the Monitoring Program

Lessons can be learned for the design of future development agreement monitoring programs. In this project we did not meet with developers to discuss the agreements however, Stantec (2010) did and the comments from developers at that time remain relevant.

The success of a monitoring program for development agreements depends on a clear objective that directly links impacts of development to effects on receiving waters. Consistency and transparency, to the greatest extent possible, are essential to gain the support of the developers by demonstrating that all are treated fairly and they have full, advanced awareness of expectations. Transparency also assures this and has the added benefit of demonstrating to the community that Halifax is protecting the natural water systems from development impacts. For example, this was an objective of the River-Lakes PNLA, whereby developer applicants were required to prepare and submit technical documents (i.e. phosphorus net loading assessments, erosion and sediment control plans and stormwater management plans), specific to the development demonstrating there would be no net increase in phosphorus exported from the site, in advance of any development agreements. The PNLA was presented as a policy available to all. Thus, we propose that HRM:

> **Adopt a standardized process to create consistency for developers and for HRM staff that effectively considers the variations in development, the nature of the land to be developed and the differences among the receiving waterbodies.**

Storm water management should not take an "end of pipe" approach. HRM and developers pay for stormwater discharges released off-site. Rather, storm water management is most cost-effective and beneficial to the natural environment by managing stormwater on-site both for the short term and the long term through the integration of BMPs and LID practices into the developments. This practice should be encouraged by:

Full implementation of the ISMPF (Halifax, 2017) requirement that "a new property must retain the first inch of rainfall on site, as well as remove 80% TSS, using green stormwater infrastructure. These standards will be backed by a new by-law and will be triggered with development permits". Monitoring programs implemented under development permits need to confirm the achievement of these requirements and provide documentation of the best practices as they apply to the Halifax area.

Implementing the approved HRWC stormwater service charge exemptions and the stormwater credit program to encourage users including HRM to pursue BMPs to reduce their loading to the system by managing stormwater to the extent possible on their own sites, including roadways. The approved credits result in a reduction to the stormwater service charges.

Consideration should be given to expanding the current approved credit program against stormwater service charges to include "credit banking" such that developers who exceed minimum targets in one area can apply them in others or sell them to a municipally operated credit bank as a means of encouraging developers to go beyond the minimum standards. Credit banking could move stormwater management to another level with promising results from other jurisdictions.

The objective of development agreement-based monitoring programs should be restricted to establishing existing conditions and effectively measuring impacts of the development and the benefits of the BMPs and LID practices incorporated into the development plan. Accordingly, it is proposed that HRM consider that:

Any monitoring program designed to assess the impact of development or the effectiveness of mitigation measures including BMPs and LID should not be used as a replacement of well-planned and ongoing lake monitoring programs. Development agreement monitoring programs must be used to measure the effectiveness of these planning initiatives in order to demonstrate their benefits.

As suggested by CWRS (2016) a practical approach for evaluating TP loading from the Bedford West site would have been to monitor a sub-set of small catchments that represent the dominant types of land-uses and BMPs within the site. These data could be used to develop validated TP export coefficients and BMP performance estimates with respect to the management of stormwater and suspended sediments. The export coefficients could then be applied to predicting benefits across the entire site as well as evaluating TP loading to receiving waters from this and other current and proposed developments throughout the Municipality. This approach can also be applied to managing stormwater such that no net change in stormwater hydrographs are realized post-development and TSS is controlled as required under the ISMPF (Halifax, 2017). Accordingly, it is suggested that;

The PNLA approach for the River Lakes Planning District be adopted or adapted to other developments such that the developer must demonstrate in advance that there will be no significant change to water quality and quantity exports from the project through the application of BMPs and LID practices on-site and incorporate a monitoring program appropriate to measuring benefits and confirming model predictions.

It is apparent from the reporting undertaken for Bedford West Planning Strategy that there are shortcomings in the implementation of monitoring program design and, in particular, the reporting.

Sufficient expertise and technical support at the municipal level is necessary to adequately design, evaluate and assess, and provide both technical and plain language reports on monitoring programs undertaken within development agreements. The municipality needs to assure timely consideration of applications from an impact monitoring perspective when negotiating development agreements and to ensure timely and adequate documentation of the value of the monitoring program. The Municipality should:

Enhance the staff complement to ensure sufficient resources are available to provide the necessary input to the design of the monitoring program. The staff may also provide the technical and plain language reporting or provide effective oversight of this reporting by others as reporting is critical to obtaining the ongoing support from HRM Council, citizens and developers;

If reporting is to be contracted out, HRM staff need to ensure that expectations are clearly specified and followed, and that preceding reports and data are effectively considered, and analytical methodologies are consistent and relevant to the available data and the purpose of the monitoring.

Recommendations 1 and 2 from Bedford West review are also applicable here:

The approach to presenting data and synthesizing the data to provide an ongoing evaluation of the success, limitations or gaps in the monitoring program needs to be established early and comprise an integral part of the development monitoring agreement from pre-development, construction and through post-development phases.

Interpretive reports must effectively consider broader activities in the study area that could affect the water quality data, not just limit the scope of the report to the initial purpose of the monitoring program.

Perhaps one of the biggest hurdles in moving forward is the definition of roles and responsibilities of the multiple pieces of government, the developer and the community in successfully implementing the development-based monitoring programs. Specifically:

Clearly defined roles and responsibilities of all stakeholders are essential (e.g., each HRM staff department involved in the development process, the Regional Watersheds Advisory Board, the Province, and the developers). The responsibility for monitoring must be the obligation and responsibility of the developer (not the general contractor or sub-contractors). Additionally, the developer must ensure trained and qualified personnel are undertaking the monitoring and the developer is clearly responsible for maintenance during the construction period of the development as well as being responsible for ensuring a mechanism for maintaining all mitigation measures incorporated into the design that are on private property.

HRM and Halifax Water will need to address the long-term maintenance of BMPs and LID technologies on public property.

Finally, and it is worth repeating again, the monitoring data and reporting must be shared in a timely and effective manner both satisfying technical quality as well as providing plain language documentation of the effectiveness of the monitoring program and how these monitoring programs are benefiting the broader environment (i.e. lakes) and the people of the entire community. Lake associations and environmental interest groups need access to this information. Critically, HRM Council and the citizens of the municipality must be provided with the opportunity of understanding the outcomes of this monitoring and how this investment is benefitting all in the community through plain language reporting. Reporting is essential and is discussed in the main report Section 8.4.

Appendix D

Lakes for a Proposed Future Monitoring Program

D.1 – Lakes by Vulnerability Class and Priorities
- Tables D-1 to D-6
D.2 – Lakes by Watershed Areas for Monitoring
- Figures D-1 to D-10

Table D-1: Class A Lakes - High Vulnerability

Lake Name	Secondary Watershed
Albro	1EJ-AL
Banook	1EJ-2
Bell	1EJ-1
Charles	LC-2
Chocolate	1EJ-P
Cranberry	LC-2
Five Island	1EJ-13
Fletchers	FL-1
Governors	1EJ-P
Kearney	1EJ-5
Kidston	1EJ-6
Long Pond	1EJ-6
Loon	LC-2
Maynard	1EJ-2
McQuade	1EK-2
MicMac	1EJ-2
Morris	1EJ-1
Oathill	1EJ-2
Paper Mill	1EJ-5
Penhorn	1EJ-2
Russell	1EJ-1
Sandy (Bedford)	1EJ-4
Settle	1EJ-1
Springfield	GL-1
Williams (Spryfield)	1EJ-P
Total Class A Lakes	**25**

Table D-3: Reference Lakes

Lake Name	Secondary Watershed
Ash	1EJ-5
Topsail	1EJ-1
Big Cranberry	1EH-1
Total Reference Lakes	**3**

Table D-2: Class B Lakes - Moderate Vulnerability

Lake Name	Secondary Watershed
Albert Bridge Lake	1EJ-13
Anderson	1EJ-3
Barrett	GL-1
Bayers	1EJ-6
Beaver Bank	GL-1
Beaver Pond	GL-1
Bissett	1EJ-1
Black Point	1EJ-13
Brand	GL-1
Charlotte	1EL-5
Echo	1EK-5
Elbow	1EH-1
Fenerty	GL-1
First	LW-1
First Chain	1EJ-6
Hatchet	1EJ-9
Hubley Big	1EJ-13
Kinsac	GL-1
Lamont	1EJ-1
Little Springfield Lake	1EJ-4
Long	1EJ-6
McCabe	1EH-2
Mill	1EH-2
Miller	LT-1
Moody	1EJ-8
Petpeswick	1EK-3
Porters (North)	1EK-4
Porters (Middle)	1EK-4
Porters (South)	1EK-4
Powder Mill	LW-1
Quarry (Birch Cove)	1EJ-5
Rocky (North East Basin)	LW-1
Sandy (Glen Arbour)	1EJ-4
Scots	1EK-2
Second	LW-1
Sheldrake	1EJ-13
Shubenacadie Grand	GL-1
Stillwater	1EH-1
Susies (Birch Cove)	1EJ-5
Third	LW-1
Thomas (North Basin)	LT-1
Thomas (South Basin)	LT-1
Tucker	GL-1
Whites	1EJ-10
William	LW-1
Wrights	1EH-2
Total Class B Lakes	**46**

Table D-4: Priority Eutrophication Lakes

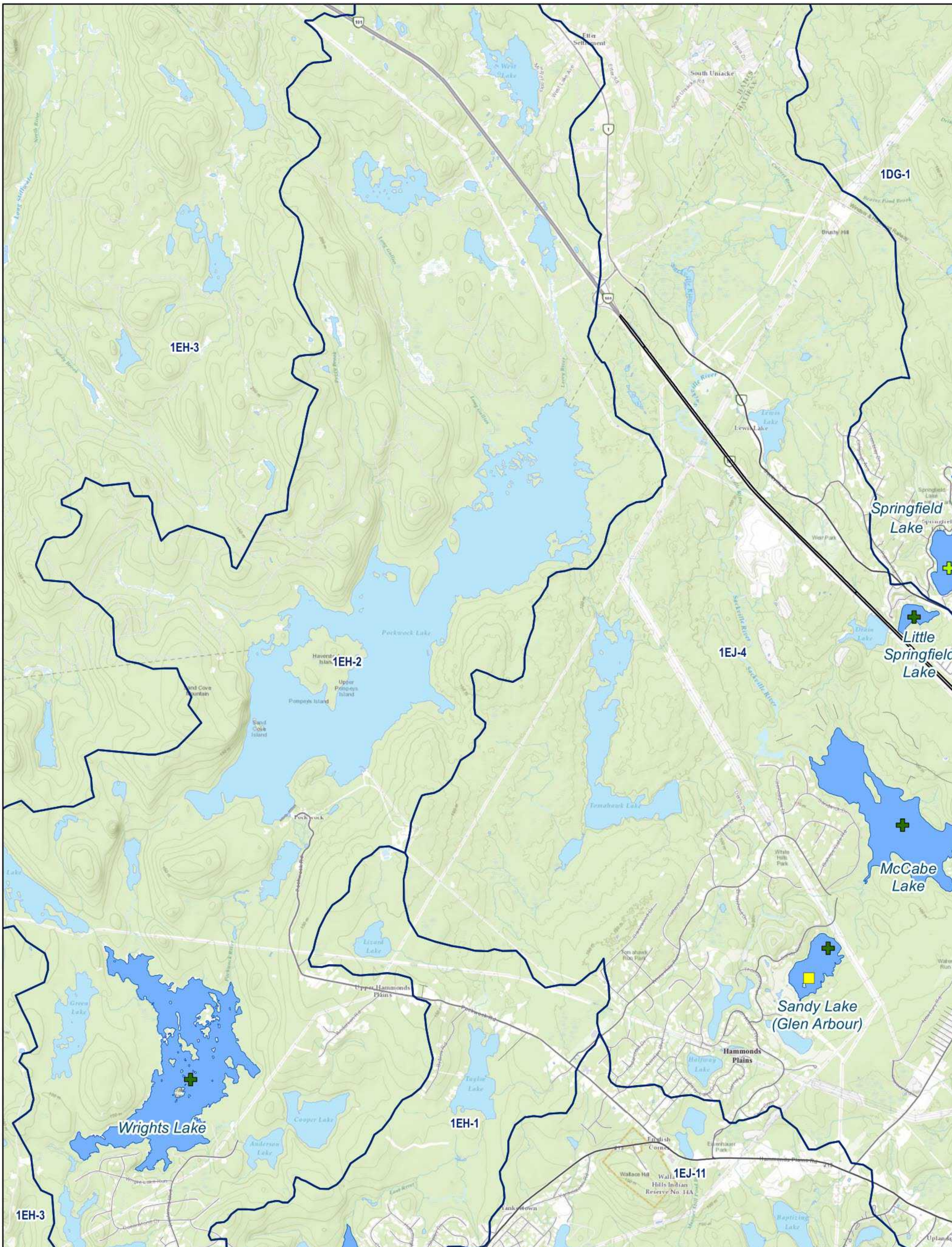
Lake Name	Secondary Watershed	Vulnerability Class	Priority Eutrophication Metrics	Reported Algal Blooms or Nuisance Aquatic Plants
			Total Phosphorus >20 ug/L	
Albro	1EJ-AL	A	yes	
Banook	1EJ-2	A	no	yes
Bell	1EJ-1	A	yes	
Bissett	1EJ-1	B	yes	
Charles	LC-2	A	no	yes
Cranberry	LC-2	A	yes	
Fenerty	GL-1	B	yes	
Governors	1EJ-P	A	yes	
MicMac	1EJ-2	A	no	yes
Paper Mill	1EJ-5	A	no	yes
Russell	1EJ-1	A	ND	
Sandy (Bedford)	1EJ-4	A	ND	yes
Sandy (Glen Arbour)	1EJ-4	B	ND	yes
Springfield	GL-1	A	no	
Total Priority Eutrophication Lakes		**14**		

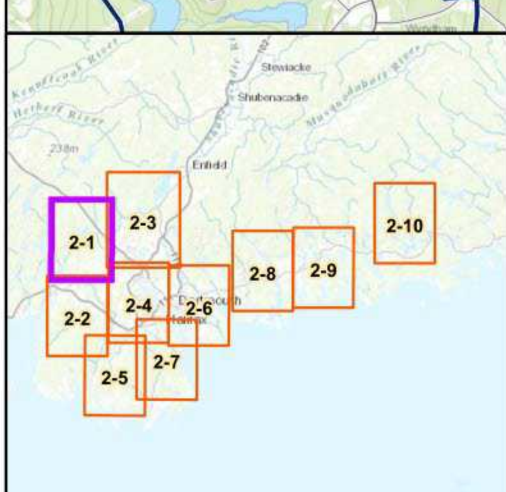
Table D-5: Priority Chloride Enrichment Lakes

Lake Name	Secondary Watershed	Vulnerability Class	Priority Chloride Enrichment
			Chloride >100 mg/L
Albro	1EJ-AL	A	yes
Banook	1EJ-2	A	yes
Bissett	1EJ-1	B	yes
Chocolate	1EJ-P	A	yes
Cranberry	LC-2	A	yes
Governors	1EJ-P	A	yes
MicMac	1EJ-2	A	yes
Morris	1EJ-1	A	yes
Oathill	1EJ-2	A	yes
Penhorn	1EJ-2	A	yes
Settle	1EJ-1	A	yes
Total Priority Chloride Enrichment Lakes		**11**	

Table D-6: Priority Bacteria - Public Beaches

Lake	Secondary Watershed	Vulnerability Class	Priority Bacteria Contamination
			Public Beach
Albro	1EJ-AL	A	yes
Banook	1EJ-2	A	yes
Charles	LC-2	A	yes
Charlotte	1EL-5	B	yes
Chocolate	1EJ-P	A	yes
Echo	1EK-5	B	yes
First	LW-1	B	yes
Hatchet	1EJ-9	B	yes
Kearney	1EJ-5	A	yes
Kidston	1EJ-6	A	yes
Long Pond	1EJ-6	A	yes
Paper Mill	1EJ-5	A	yes
Penhorn	1EJ-2	A	yes
Petpeswick	1EK-3	B	yes
Porters (South)	1EK-4	B	yes
Sandy (Bedford)	1EJ-4	A	yes
Shubenacadie Grand	GL-1	B	yes
Springfield	GL-1	A	yes
Total Priority Bacteria - Public Beaches - Lakes		**18**	





Legend

Vulnerability Class

- Class A - High Vulnerability Lakes
- Class B - Moderate Vulnerability Lakes

Priority Lakes

- Priority Eutrophication Lakes
- Priority Chloride Enrichment Lakes
- Priority Bacteria Contamination / HRM Supervised Beaches

Reference Lakes

- Reference Lakes
- Lake Sampling Program
- Waterbodies
- Atlantic Ocean
- Secondary Watersheds

Note: the location of lake vulnerability symbol does not necessarily depict the proposed sampling location for the proposed lakes. The symbol is placed to denote the assigned lake vulnerability classification. Lake specific sampling locations will be based upon historic sampling locations for each lake, or information on lake bathymetry to select the deepest point of the lake. In some cases, access limitations may prevent collection of a deep-station sample and in this case, a surface sample will be collected at the lake outlet.

N

0 0.5 1 2
Kilometers

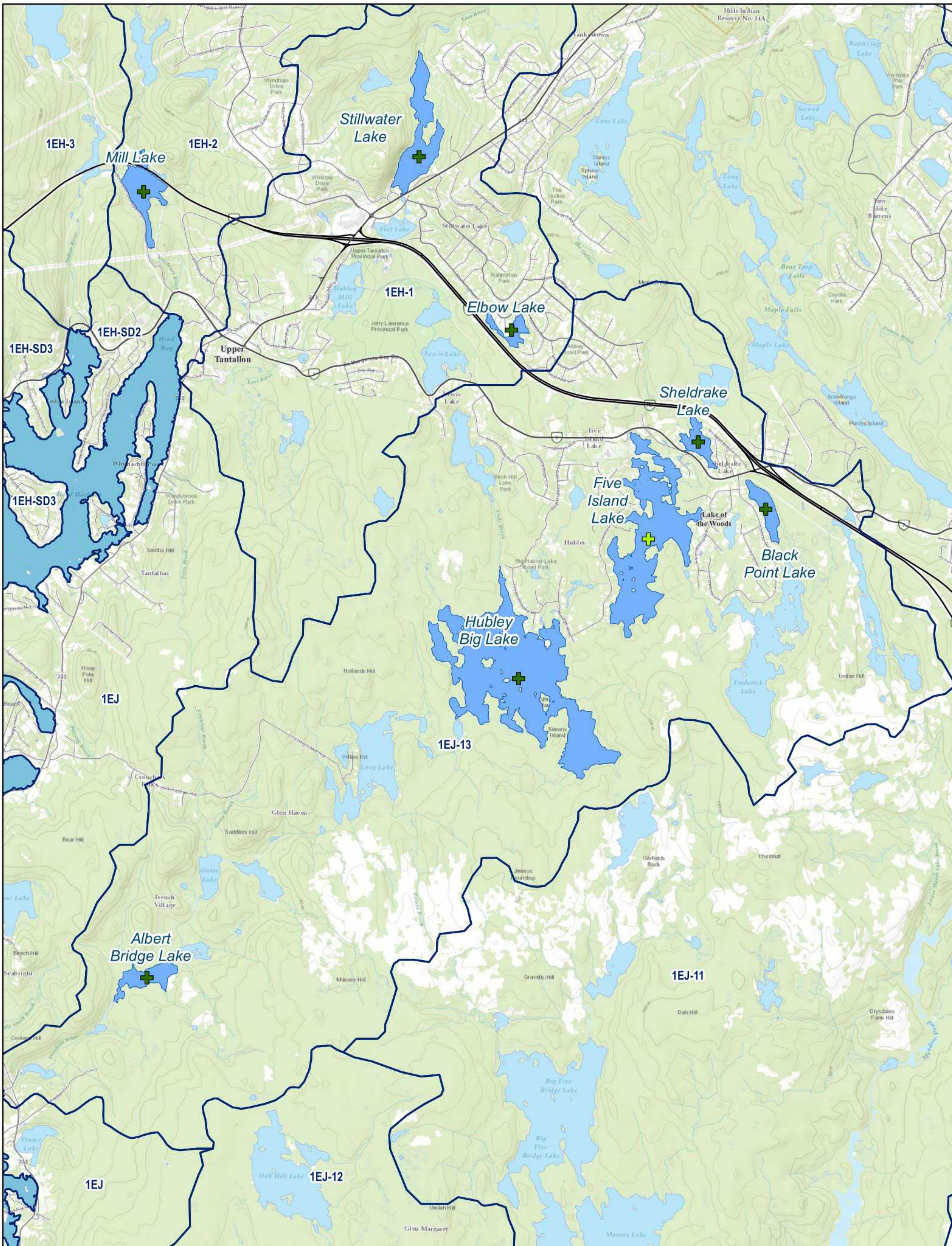
Proposed Future Potential Monitoring Program

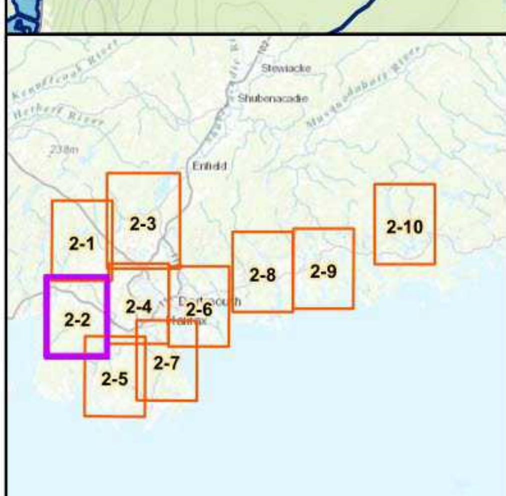
Pockwock and Hammonds Plains Area Lakes

9/3/2020	1:50,000	Datum: NAD 83 Zone 20 Source:
P#: 60617813	V#:	

AECOM

Figure D-1





Legend

Vulnerability Class

- Class A - High Vulnerability Lakes
- Class B - Moderate Vulnerability Lakes

Priority Lakes

- Priority Eutrophication Lakes
- Priority Chloride Enrichment Lakes
- Priority Bacteria Contamination / HRM Supervised Beaches

Reference Lakes

- Reference Lakes
- Lake Sampling Program
- Waterbodies
- Atlantic Ocean
- Secondary Watersheds

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N

0 0.5 1 2
Kilometers

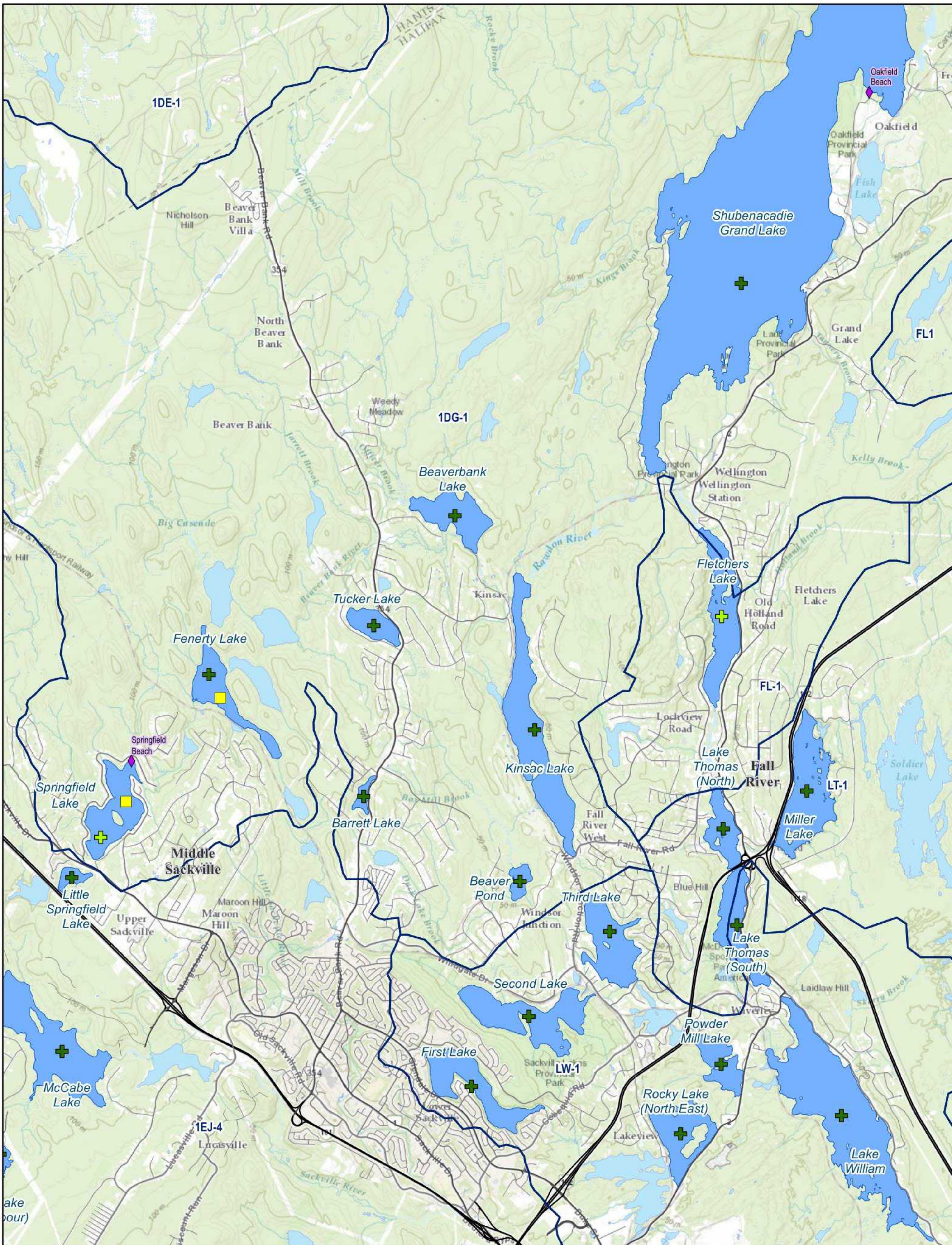
Proposed Future Potential Monitoring Program

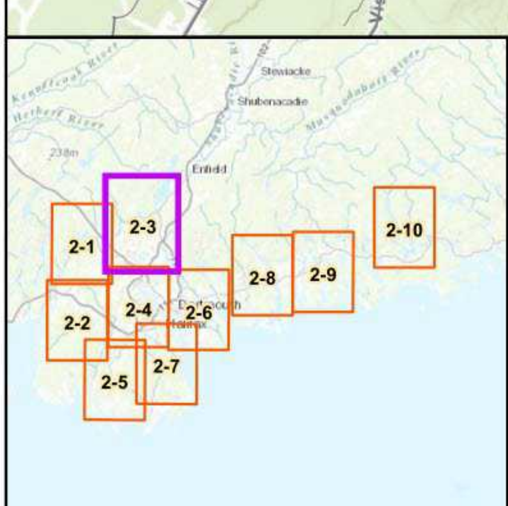
Tantallon and Hubley Area Lakes

9/3/2020	1:50,000	Datum: NAD 83 Zone 20 Source:
P#: 60617813	V#:	

AECOM

Figure D-2





Legend

Vulnerability Class

- Class A - High Vulnerability Lakes
- Class B - Moderate Vulnerability Lakes

Priority Lakes

- Priority Eutrophication Lakes
- Priority Chloride Enrichment Lakes
- Priority Bacteria Contamination / HRM Supervised Beaches

Reference Lakes

- Reference Lakes
- Lake Sampling Program
- Waterbodies
- Atlantic Ocean
- Secondary Watersheds

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N

0 0.75 1.5 3
Kilometers

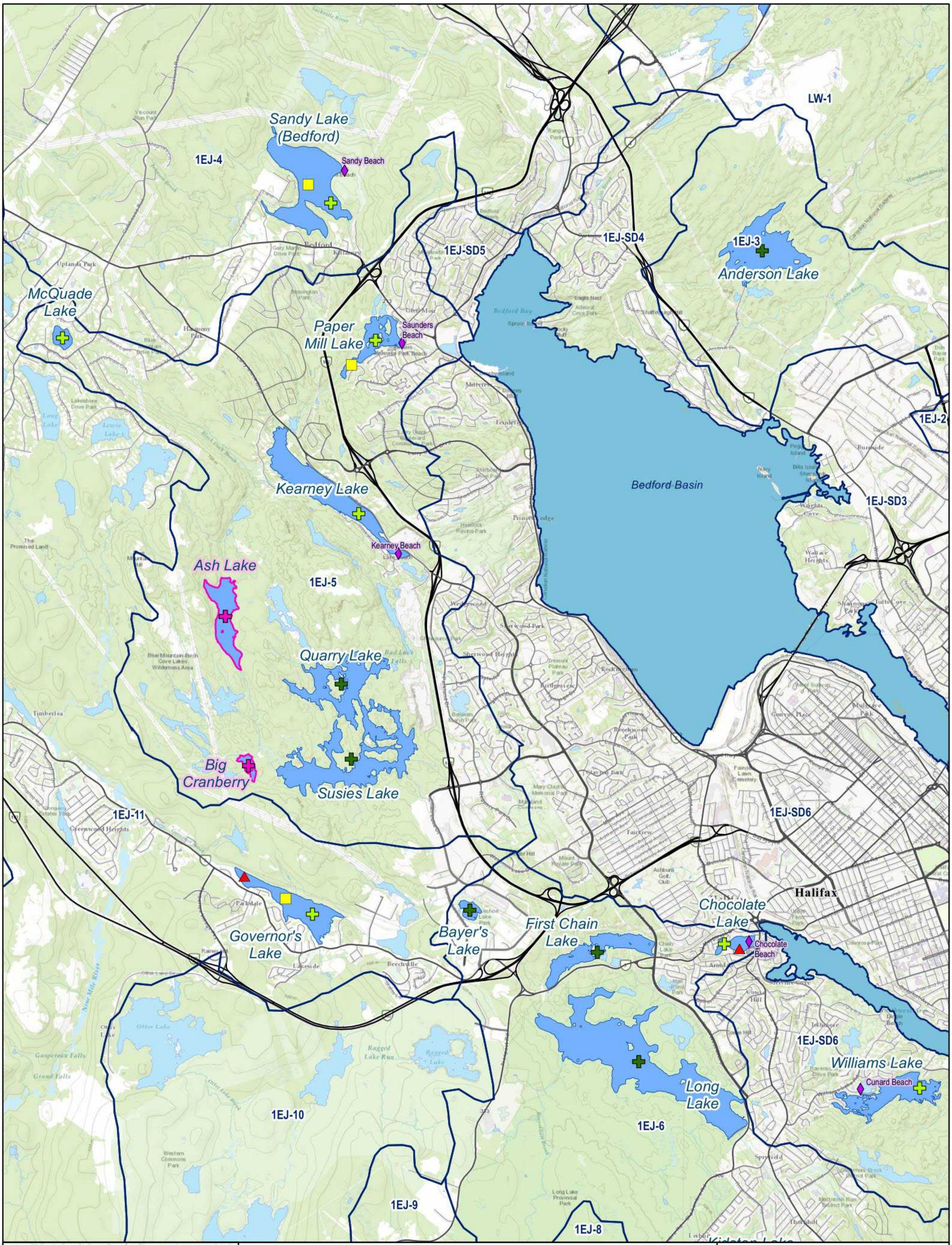
Proposed Future Potential Monitoring Program

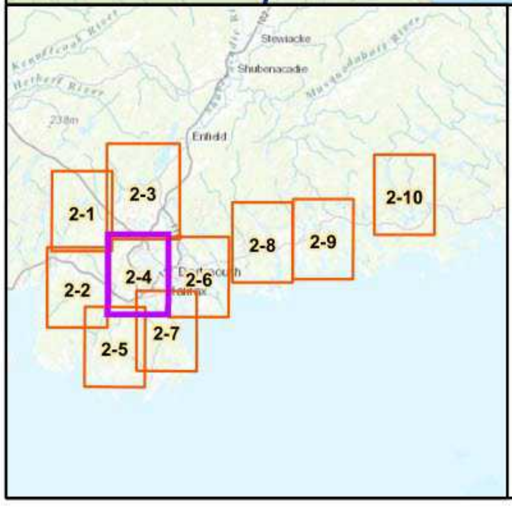
Bedford East, Sackville and Fall River Area Lakes

9/3/2020	1:60,000	Datum: NAD 83 Zone 20 Source:
P#: 60617813	V#:	

AECOM

Figure D-3





Legend

Vulnerability Class

- Class A - High Vulnerability Lakes
- Class B - Moderate Vulnerability Lakes

Priority Lakes

- Priority Eutrophication Lakes
- Priority Chloride Enrichment Lakes
- Priority Bacteria Contamination / HRM Supervised Beaches

Reference Lakes

- Reference Lakes
- Lake Sampling Program
- Waterbodies
- Atlantic Ocean
- Secondary Watersheds

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N

0 0.5 1 2
Kilometers

Proposed Future Potential Monitoring Program

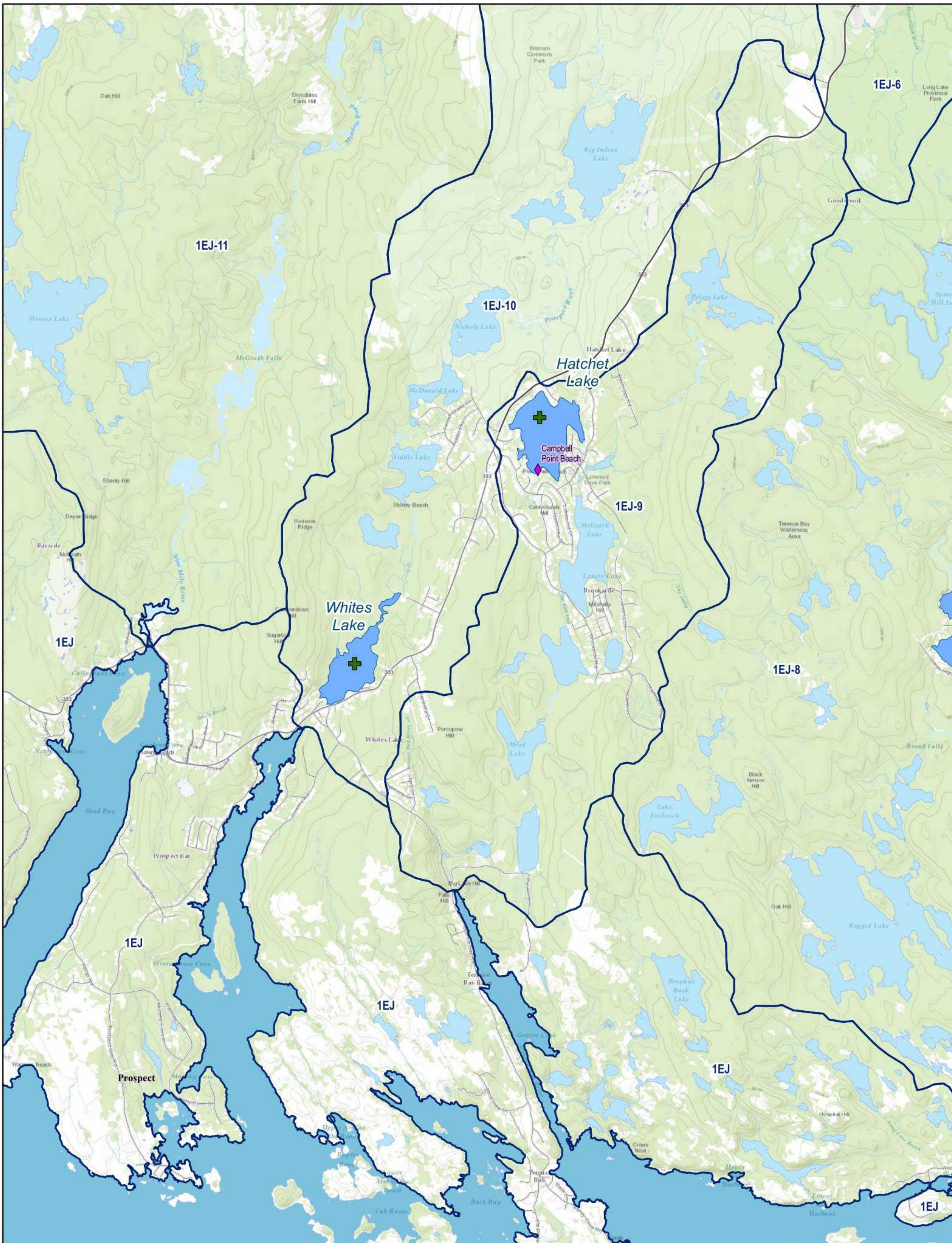
Mainland Halifax and Bedford West Area Lakes

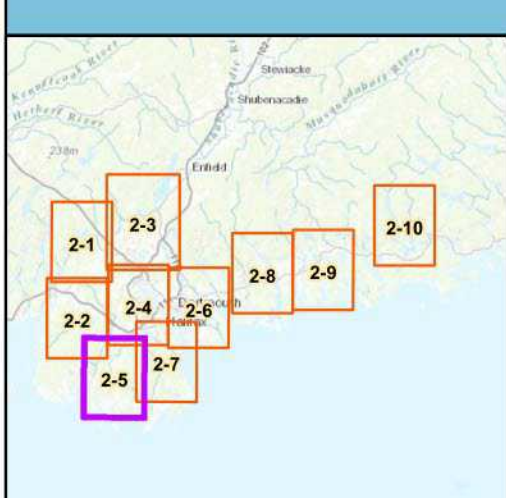
9/3/2020	1:50,000	Datum: NAD 83 Zone 20 Source:
P#: 60617813	V#:	

AECOM

Figure D-4

Map location: D:\AECOM-Work\HRM_WaterQuality\REPORT\HRM_Sampling_Lakes_R02_2020042...
Date Saved: 5/11/2020 8:12:37 PM





Legend

Vulnerability Class

- Class A - High Vulnerability Lakes
- Class B - Moderate Vulnerability Lakes

Priority Lakes

- Priority Eutrophication Lakes
- Priority Chloride Enrichment Lakes
- Priority Bacteria Contamination / HRM Supervised Beaches

Reference Lakes

- Reference Lakes
- Lake Sampling Program
- Waterbodies
- Atlantic Ocean
- Secondary Watersheds

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N

0 0.5 1 2
Kilometers

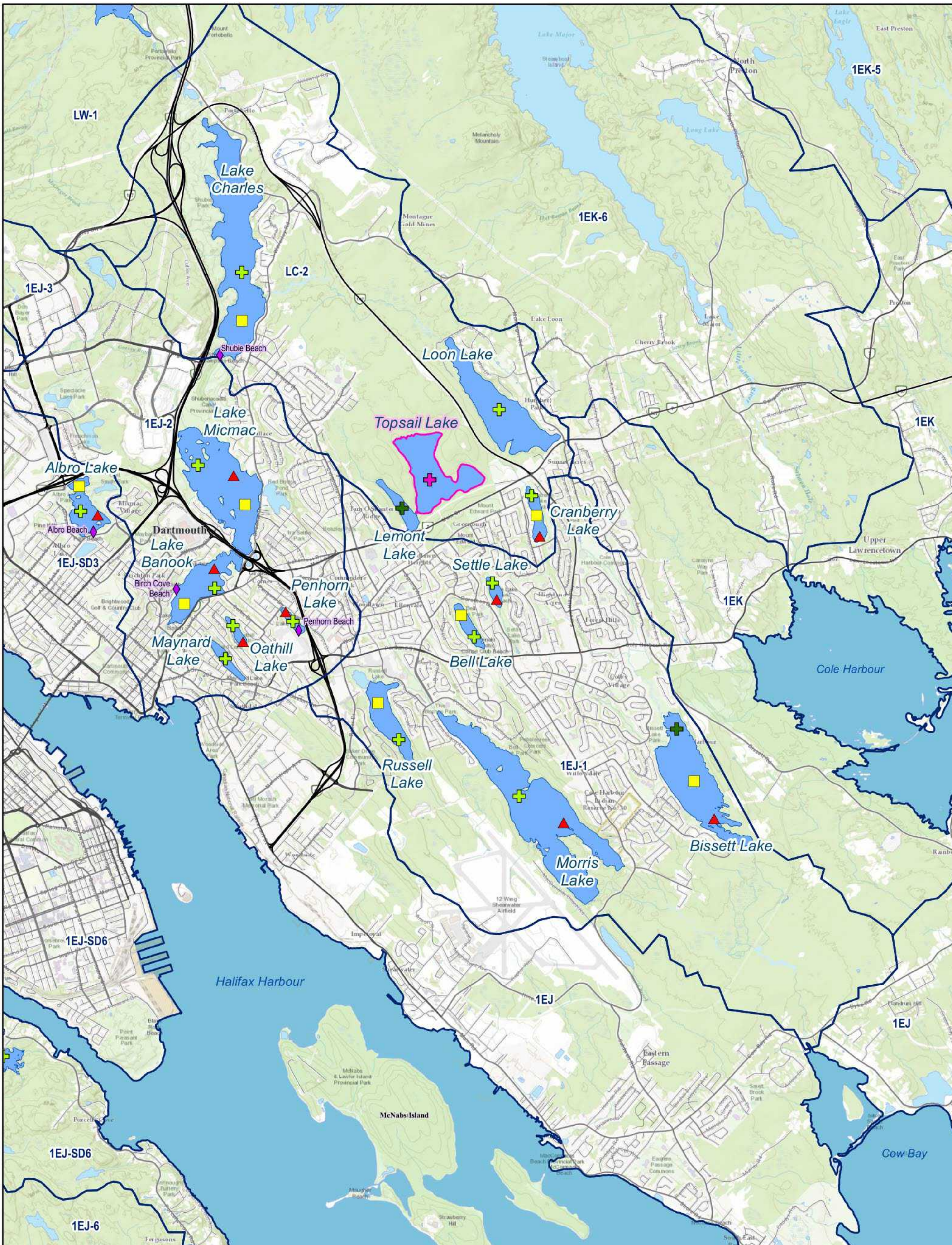
Proposed Future Potential Monitoring Program

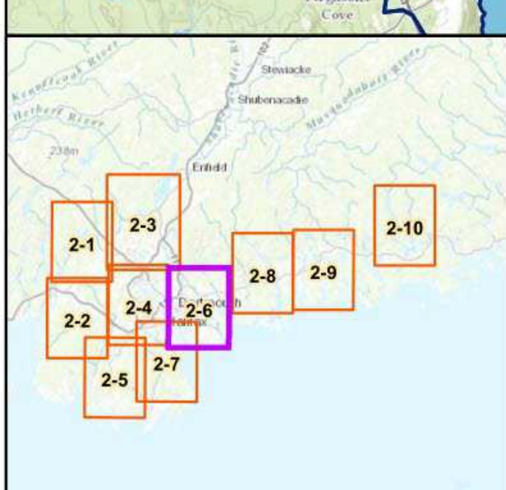
Hatchet Lake and Whites Lake and Area

9/3/2020	1:50,000	Datum: NAD 83 Zone 20 Source:
P#: 60617813	V#:	

AECOM

Figure D-5





Legend

Vulnerability Class

- Class A - High Vulnerability Lakes
- Class B - Moderate Vulnerability Lakes

Priority Lakes

- Priority Eutrophication Lakes
- Priority Chloride Enrichment Lakes
- Priority Bacteria Contamination / HRM Supervised Beaches

Reference Lakes

- Reference Lakes
- Lake Sampling Program
- Waterbodies
- Atlantic Ocean
- Secondary Watersheds

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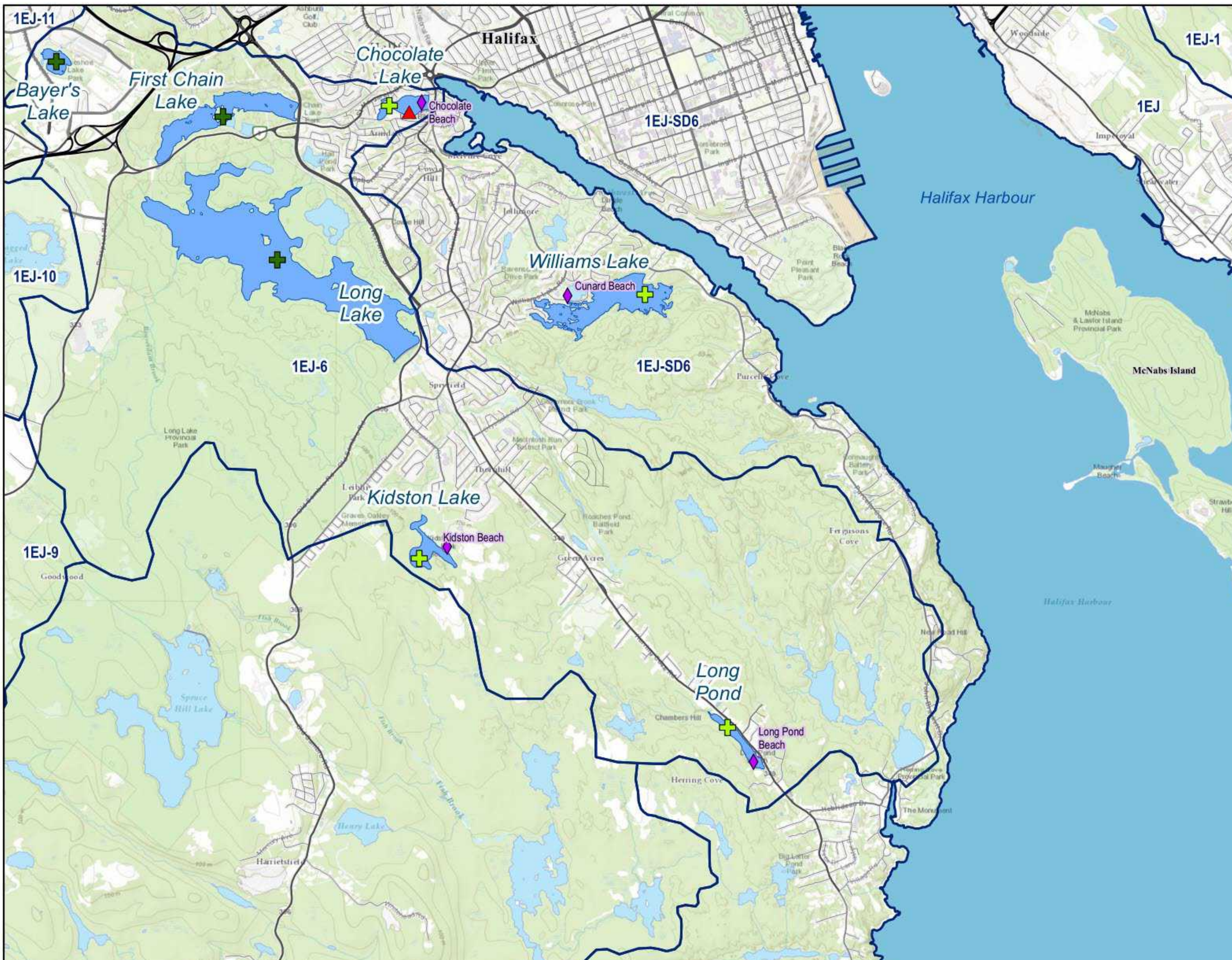
0 0.5 1 2
Kilometers

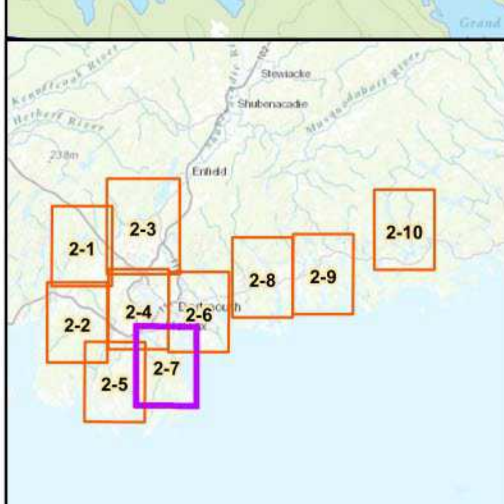
N

Proposed Future Potential Monitoring Program

Dartmouth Area Lakes

9/3/2020	1:50,000	Datum: NAD 83 Zone 20 Source:
P#: 60617813	V#:	
AECOM		Figure D-6





Legend

Vulnerability Class

- Class A - High Vulnerability Lakes
- Class B - Moderate Vulnerability Lakes

Priority Lakes

- Priority Eutrophication Lakes
- Priority Chloride Enrichment Lakes
- Priority Bacteria Contamination / HRM Supervised Beaches

Reference Lakes

- Reference Lakes
- Lake Sampling Program
- Waterbodies
- Atlantic Ocean
- Secondary Watersheds

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N

0 0.5 1 2
Kilometers

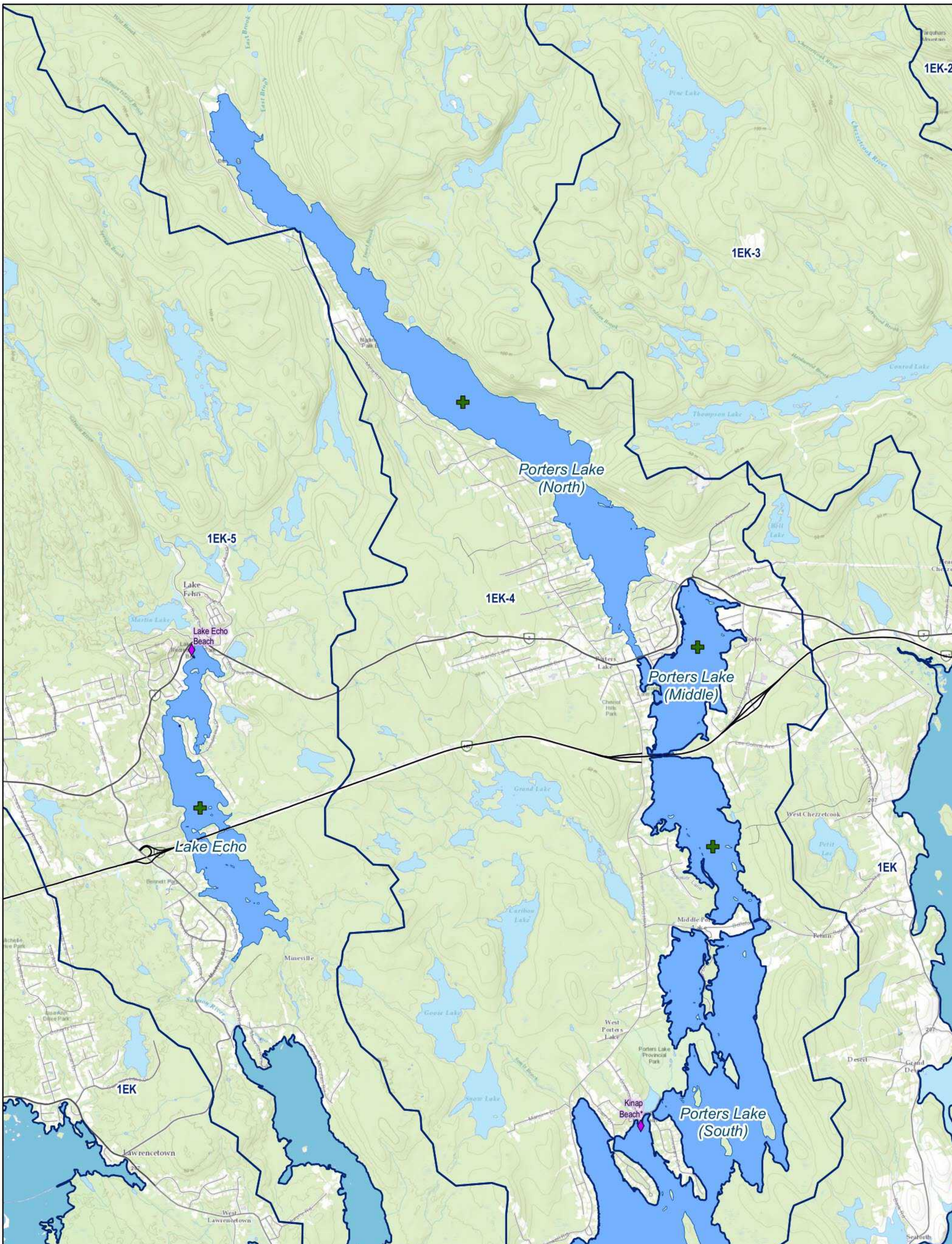
Proposed Future Potential Monitoring Program

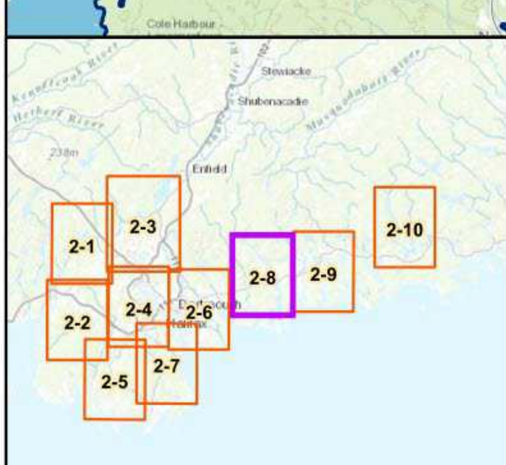
Spryfield, Sambro and Harrietsfield Lakes

9/3/2020	1:50,000	Datum: NAD 83 Zone 20 Source:
P#: 60617813	V#:	

AECOM

Figure D-7





Legend

Vulnerability Class

- Class A - High Vulnerability Lakes
- Class B - Moderate Vulnerability Lakes

Priority Lakes

- Priority Eutrophication Lakes
- Priority Chloride Enrichment Lakes
- Priority Bacteria Contamination / HRM Supervised Beaches

Reference Lakes

- Reference Lakes
- Lake Sampling Program
- Waterbodies
- Atlantic Ocean
- Secondary Watersheds

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N

0 0.5 1 2
Kilometers

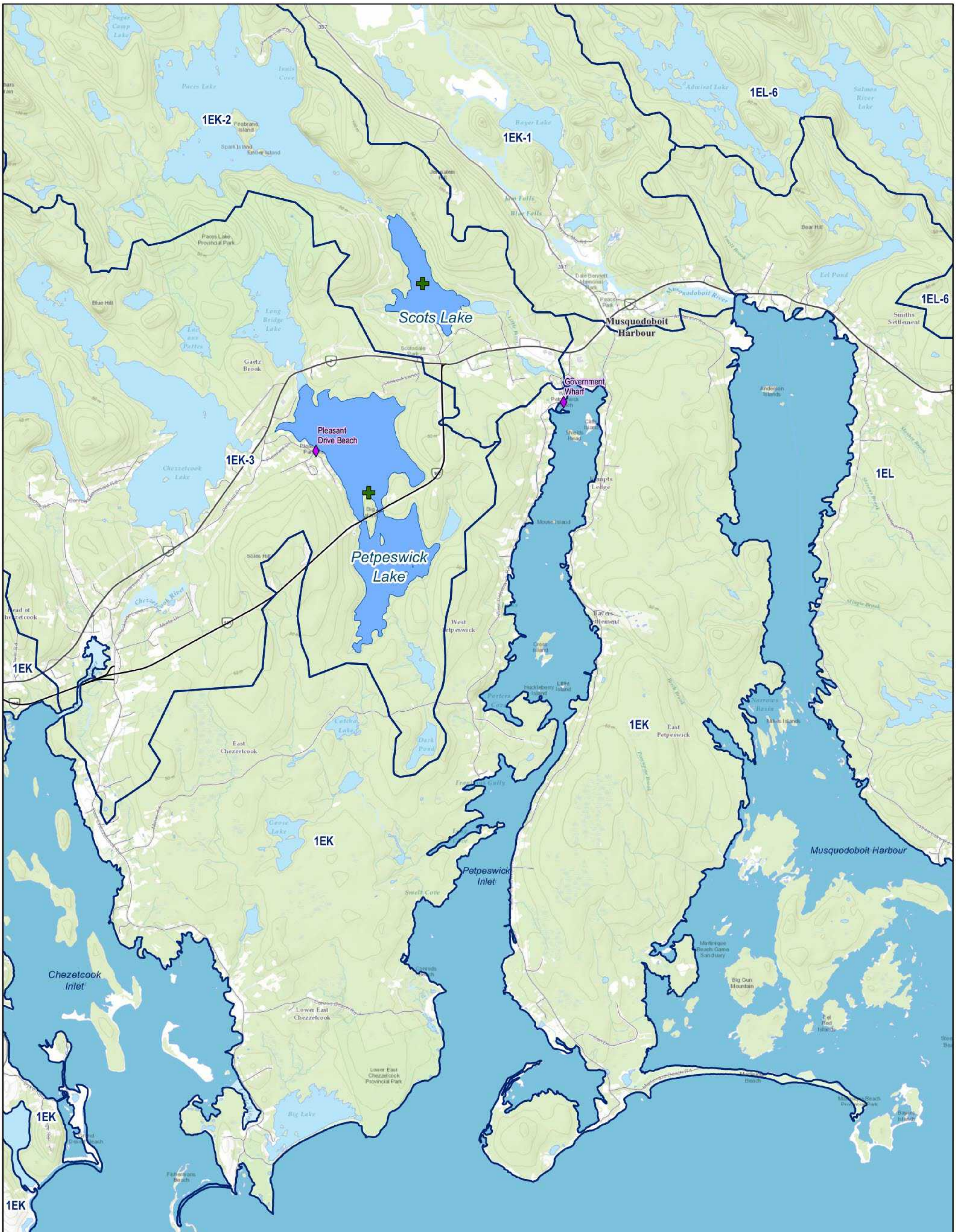
Proposed Future Potential Monitoring Program

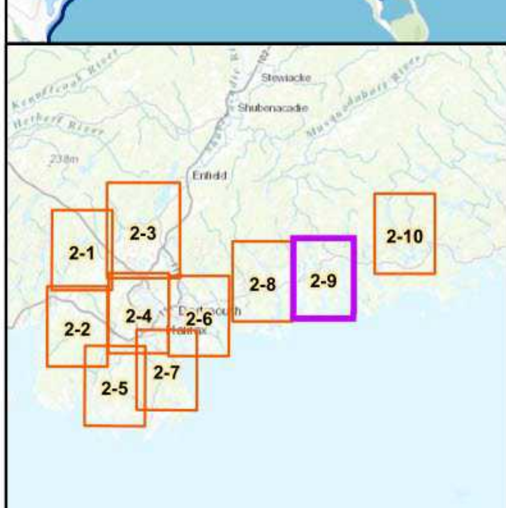
Lake Echo and Porters Lake

9/3/2020	1:50,000	Datum: NAD 83 Zone 20 Source:
P#: 60617813	V#:	

AECOM

Figure D-8





Legend

Vulnerability Class
- Class A - High Vulnerability Lakes
- Class B - Moderate Vulnerability Lakes

Priority Lakes
- Priority Eutrophication Lakes
- Priority Chloride Enrichment Lakes
- Priority Bacteria Contamination / HRM Supervised Beaches

Reference Lakes
- Reference Lakes
- Lake Sampling Program
- Waterbodies
- Atlantic Ocean
- Secondary Watersheds

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N

0 0.5 1 2
Kilometers

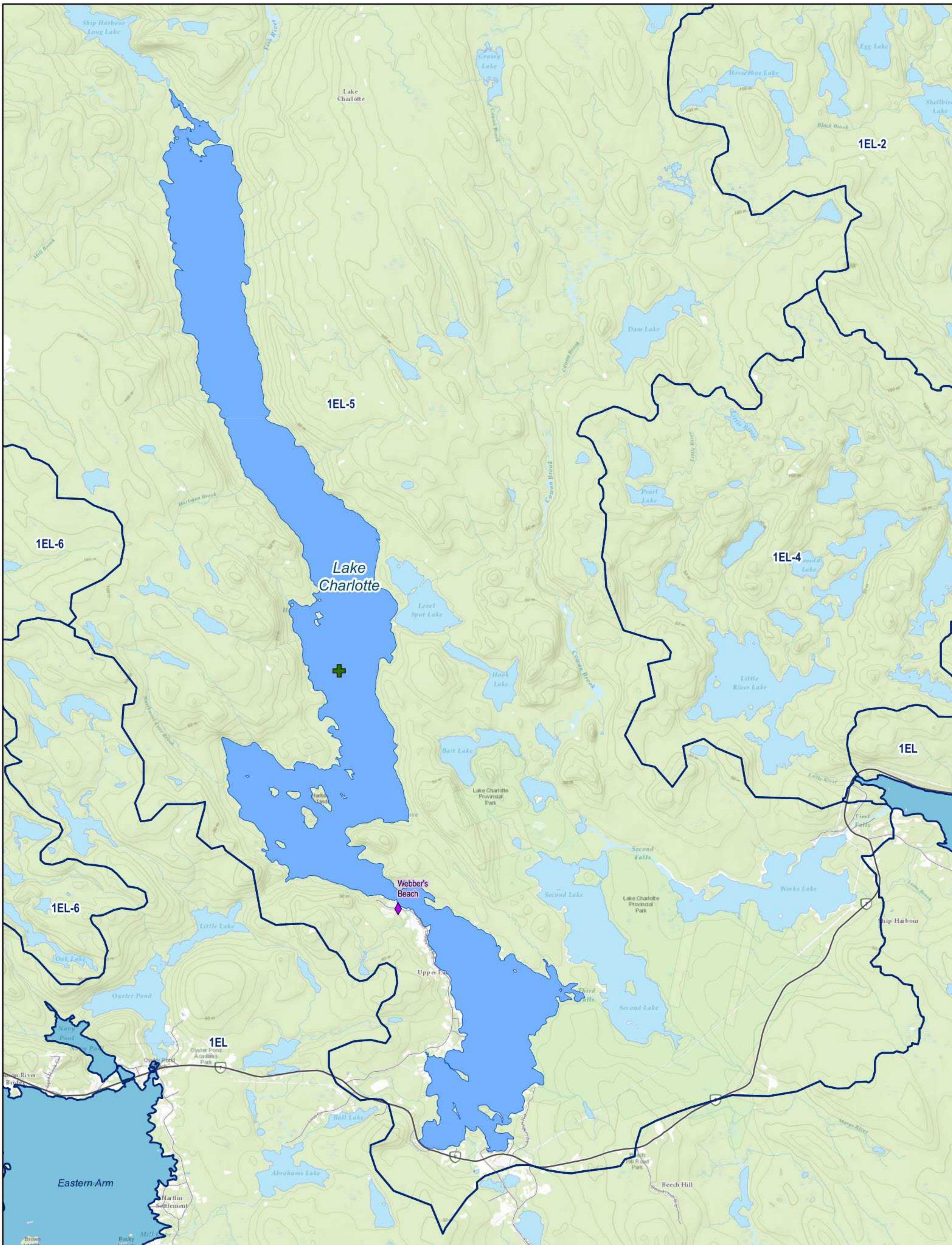
Proposed Future Potential Monitoring Program

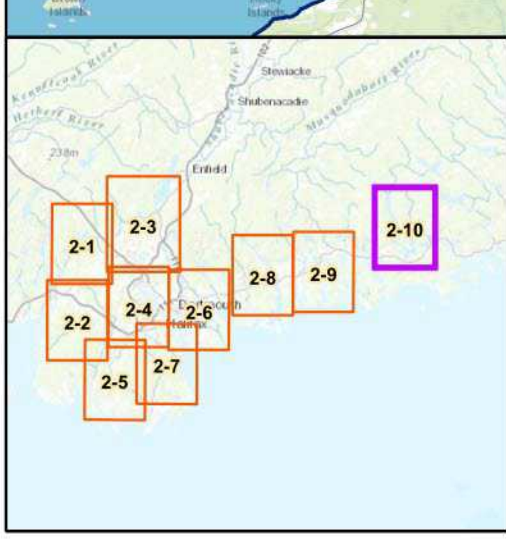
Musquodoboit Harbour Area Lakes

9/3/2020	1:50,000	Datum: NAD 83 Zone 20 Source:
P#: 60617813	V#:	

AECOM

Figure D-9





Legend

Vulnerability Class

- Class A - High Vulnerability Lakes
- Class B - Moderate Vulnerability Lakes

Priority Lakes

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- Priority Chloride Enrichment Lakes
- Priority Bacteria Contamination / HRM Supervised Beaches

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- Waterbodies
- Atlantic Ocean
- Secondary Watersheds

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N

0 0.5 1 2
Kilometers

Proposed Future Potential Monitoring Program

Lake Charlotte

9/3/2020	1:50,000	Datum: NAD 83 Zone 20 Source:
P#: 60617813	V#:	

AECOM

Figure D-10

Appendix E

Data Management

E.1 – EQuIS by Earthsoft
E.2 – Envirodata by Geotech Systems Inc.

Appendix E.1

Data Management

E.1 – EQuIS by Earthsoft

Appendix E.2

Data Management

E.2 – Envirodata by Geotech Systems Inc.

Geotech
Computer Systems, Inc.

12200 E. Briarwood Ave., Suite 152
Centennial, CO 80112
Toll Free: (877)740-1999
Phone: (303)740-1999

Data Management GIS Graphics Internet

www.geotech.com

Price List

Enviro Data® **Enviro Spāse®**

Geotech Products:

Enviro Data®	
Single Use Client License	4,800
Single Use Client License Maintenance[4]	960
Concurrent Use Client License[1]	6,000
Concurrent Use Client License Maintenance[4]	1,200
Upgrade from Single Use to Concurrent Use license	1,200
Single Use Viewer Client License[5]	1,200
Single user Viewer Maintenance[4]	240
Concurrent Use Viewer Client License[5]	2,400
Concurrent Use Viewer Maintenance[4]	480
Server License - SQL Server[3]	6,000
Server License Maintenance - SQL Server[4]	1,200
Server License - Oracle[3]	9,000
Server License Maintenance - Oracle[4]	1,800
Lab Data Checker[6]	1,200
Lab Data Checker Maintenance	240
Low-Risk Starter Package[2]	7,200
Enviro Spāse	
Single user client license	1,200
Enviro Spase Maintenance [4]	240

Geotech Services:

Service	Price
Software training	$1,440 / day + exp.
Data loading – Senior technical level	$125 - $150 / hour + exp.
Custom reports and programming	$125 - $150 / hour + exp.
Other consulting and database services	Call
Additional support hours (during maint.)	$1,500/10 hours
Support hours (lapsed maint.)	$240/hour
Service prices do not include travel time or expenses. Travel time will be billed hourly, and expenses at cost.	

Note:
Prices are subject to change without notice.

Revised 12/24/18

[1] The concurrent use license allows users to share a license, but only as many users at one time as licenses purchased. [2] The Low-Risk Starter Package includes a copy of Enviro Data Single Use, a year of maintenance, and a day each of data loading assistance and training (must be used within 6 months of purchase). Travel time and expenses (if any) are not included. Can be upgraded to Concurrent for an additional $1,440. [3] The server license is required to implement the Enviro Data model on your client-server database system. Enviro Data client licenses (single or concurrent) are still required, as is a SQL Server or Oracle license for your server. [4] Annual maintenance for each product is recommended, and can be obtained for 20% of the list price per year. Maintenance includes any new software releases during the maintenance period, and email/phone support on software usage issues, up to a maximum number of hours per license per year, by product: Single Use, 8; Concurrent Use and Server, 10; Concurrent Viewer, 4; Enviro Spase and Single User Viewer, 2. A $600 reinstatement fee will be charged to renew expired maintenance agreements. [5] The Viewer can be used to view but not manipulate data. [6] Available to laboratories to check data consistency using our Reference File system on projects for clients using Enviro Data. A 4% surcharge will be charged on credit card purchases.

Geotech's products are customizable, and new capabilities can be added. Some customization can be done by the user, or we can do it for you for a fee. Geotech can even build complete custom graphical, non-graphical, and web-based applications to address specific business or technical needs for which there is no off-the-shelf solution. We have created solutions in a variety of industries using most of the major software development tools. Call us to discuss how these services can be of value to you.

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Geotech

Computer Systems, Inc.

Data Management and Validation Workflow

2019 DoD Environmental Monitoring & Data Quality Workshop

Dr. David W. Rich
drdave@geotech.com
Mr. Russ Wendell
rwendell@geotech.com

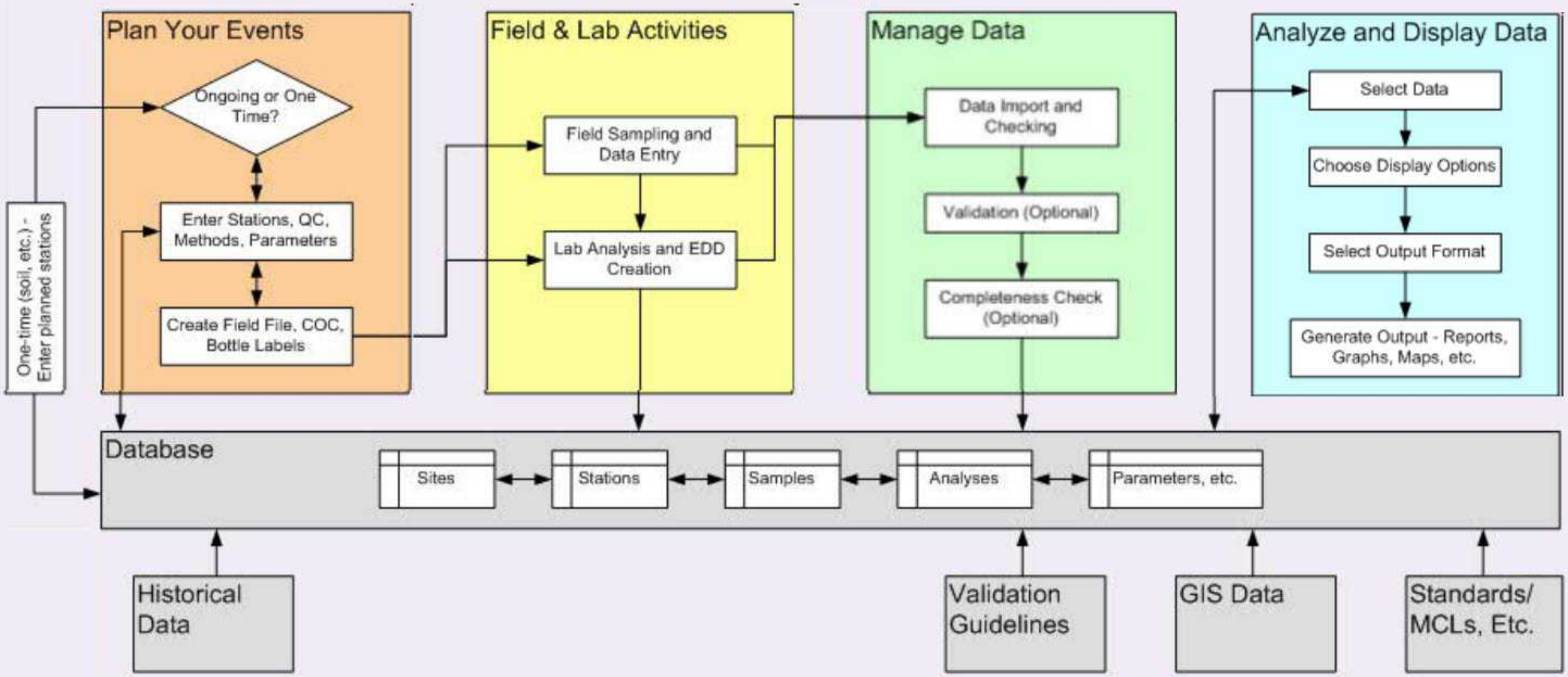
Orlando, FL
May 15, 2019

shades OF green on WALT DISNEY WORLD® Resort

Topics

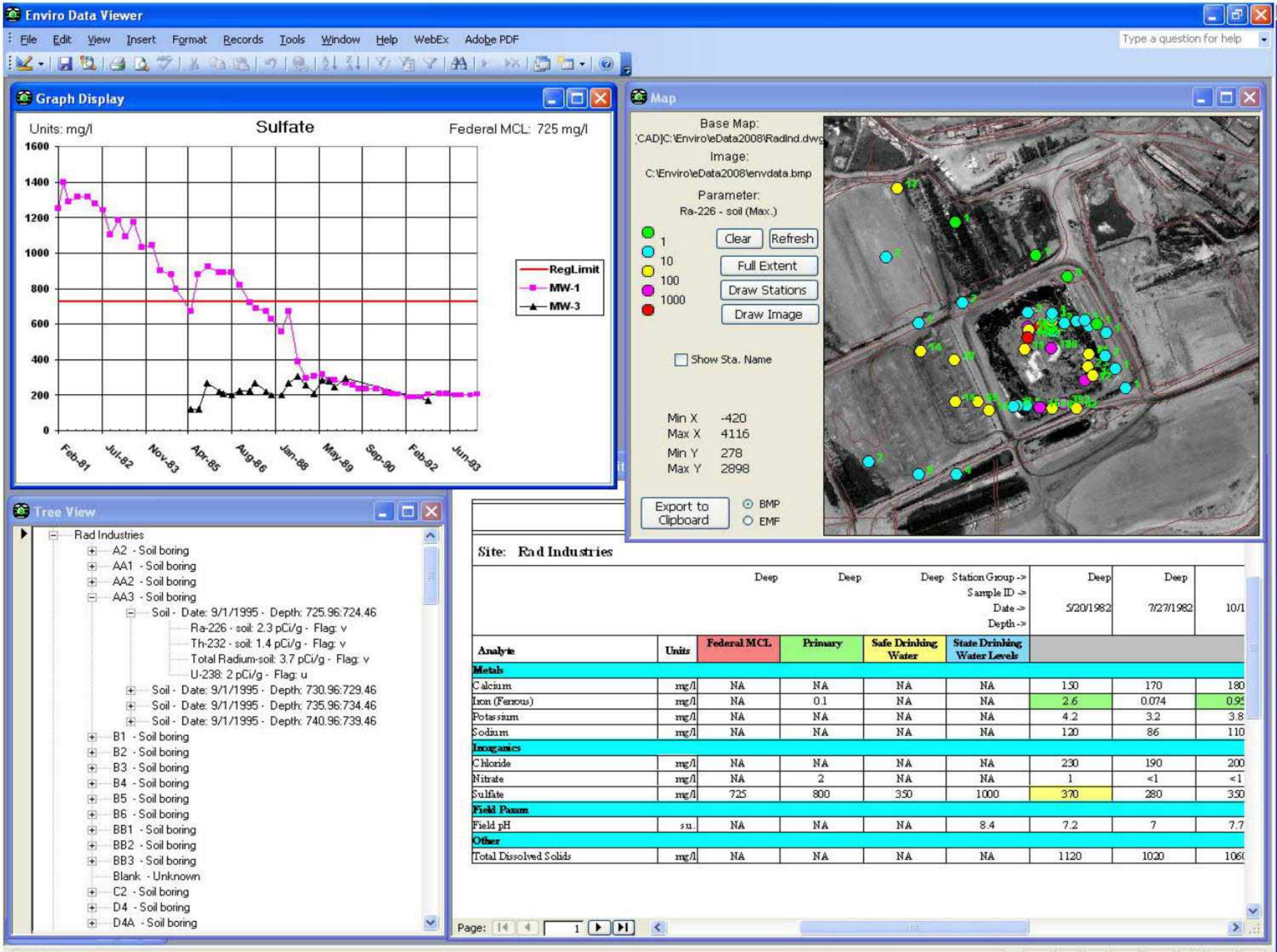
- High level view of the process
- Setting up the database
- Managing field events
- Importing lab and other data
- Data review and validation
- Data selection
- Formatting
- Displays
- Mapping and GIS
- Business justification

High level view of the process

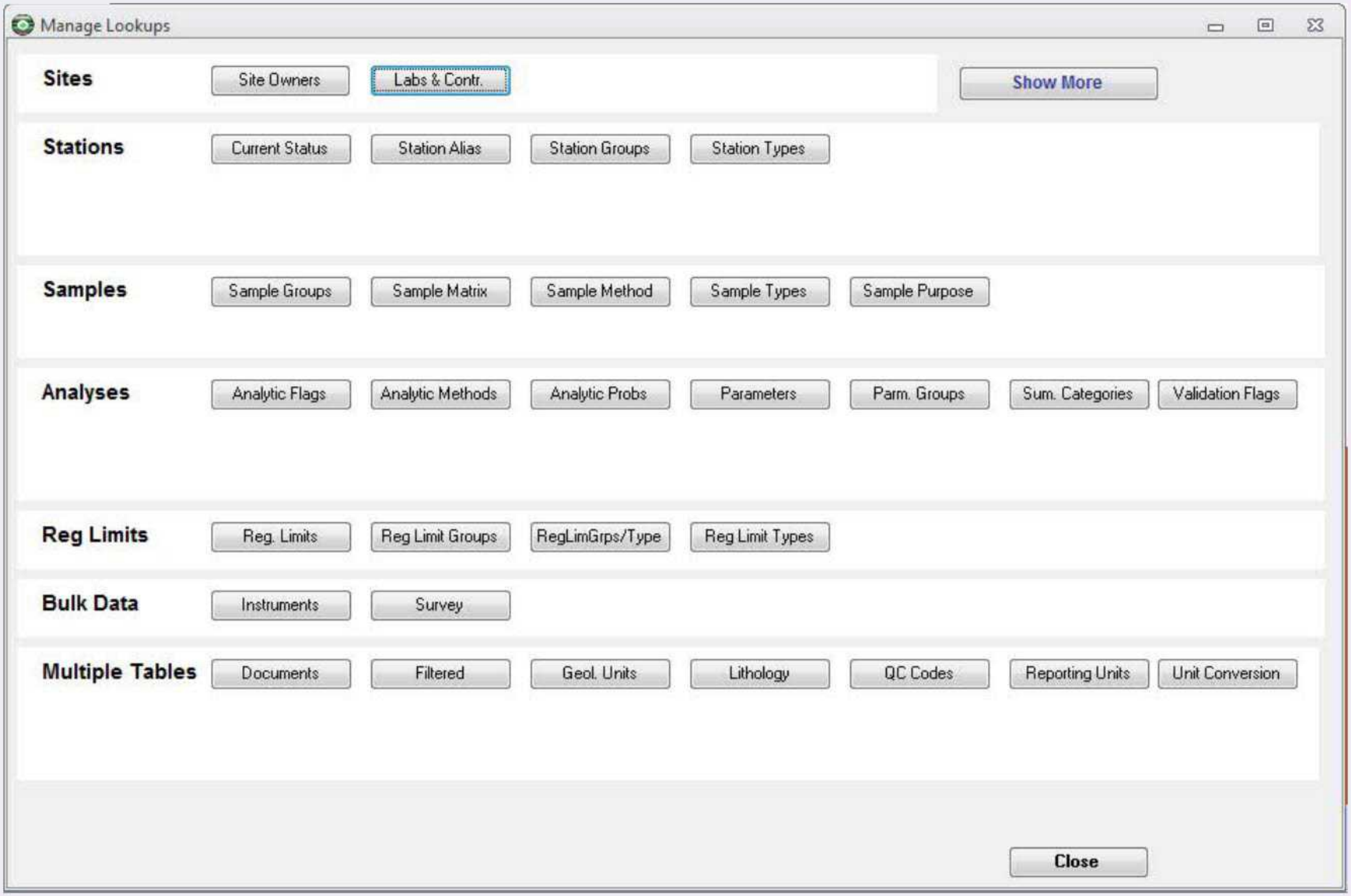


Plan your sample events
Manage field and lab activities
Manage data and quality

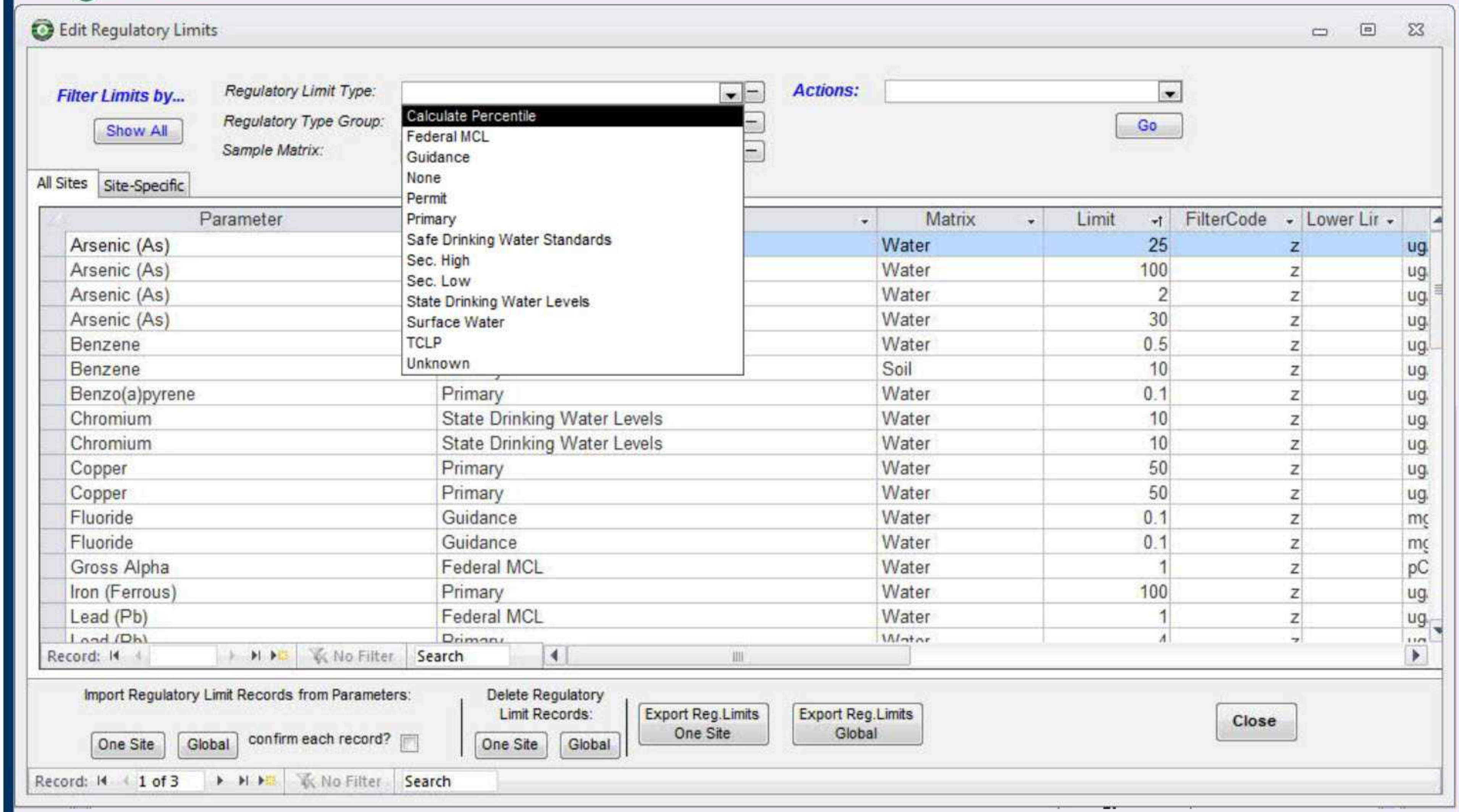
Store in a robust repository
Analyze and display data
It's all in one location


Enviro Data Viewer
File Edit View Insert Format Records Tools Window Help WebEx Adobe PDF
Type a question for help
Graph Display
Units: mg/l
Sulfate
Federal MCL: 725 mg/l
1600
1400
1200
1000
800
600
400
200
0
Feb-81
Jul-82
Nov-83
Apr-85
Aug-86
Jan-88
May-89
Sep-90
Feb-92
Jun-93
RegLimit
MW-1
MW-3
Map
Base Map:
CAD|C:\Enviro\eData2008\RadInd.dwg
Image:
C:\Enviro\eData2008\envdata.bmp
Parameter:
Ra-226 - soil (Max.)
1
10
100
1000
Clear
Refresh
Full Extent
Draw Stations
Draw Image
Show Sta. Name
Min X -420
Max X 4116
Min Y 278
Max Y 2898
Export to Clipboard
BMP
EMF
Tree View
Rad Industries
A2 - Soil boring
AA1 - Soil boring
AA2 - Soil boring
AA3 - Soil boring
Soil - Date: 9/1/1995 - Depth: 725.96:724.46
Ra-226 - soil: 2.3 pCi/g - Flag: v
Th-232 - soil: 1.4 pCi/g - Flag: v
Total Radium-soil: 3.7 pCi/g - Flag: v
U-238: 2 pCi/g - Flag: u
Soil - Date: 9/1/1995 - Depth: 730.96:729.46
Soil - Date: 9/1/1995 - Depth: 735.96:734.46
Soil - Date: 9/1/1995 - Depth: 740.96:739.46
B1 - Soil boring
B2 - Soil boring
B3 - Soil boring
B4 - Soil boring
B5 - Soil boring
B6 - Soil boring
BB1 - Soil boring
BB2 - Soil boring
BB3 - Soil boring
Blank - Unknown
C2 - Soil boring
D4 - Soil boring
D4A - Soil boring
Site: Rad Industries
Deep Deep Deep Station Group -> Deep Deep
Sample ID ->
Date -> 5/20/1982 7/27/1982 10/1
Depth ->
Analyte | Units | Federal MCL | Primary | Safe Drinking Water | State Drinking Water Levels
Metals
Calcium | mg/l | NA | NA | NA | NA | 150 | 170 | 180
Iron (Ferrous) | mg/l | NA | 0.1 | NA | NA | 2.6 | 0.074 | 0.95
Potassium | mg/l | NA | NA | NA | NA | 4.2 | 3.2 | 3.8
Sodium | mg/l | NA | NA | NA | NA | 120 | 86 | 110
Inorganics
Chloride | mg/l | NA | NA | NA | NA | 230 | 190 | 200
Nitrate | mg/l | NA | 2 | NA | NA | 1 | <1 | <1
Sulfate | mg/l | 725 | 800 | 350 | 1000 | 370 | 280 | 350
Field Param
Field pH | s.u. | NA | NA | NA | 8.4 | 7.2 | 7 | 7.7
Other
Total Dissolved Solids | mg/l | NA | NA | NA | NA | 1120 | 1020 | 1060
Page: 1
Form View
NUM

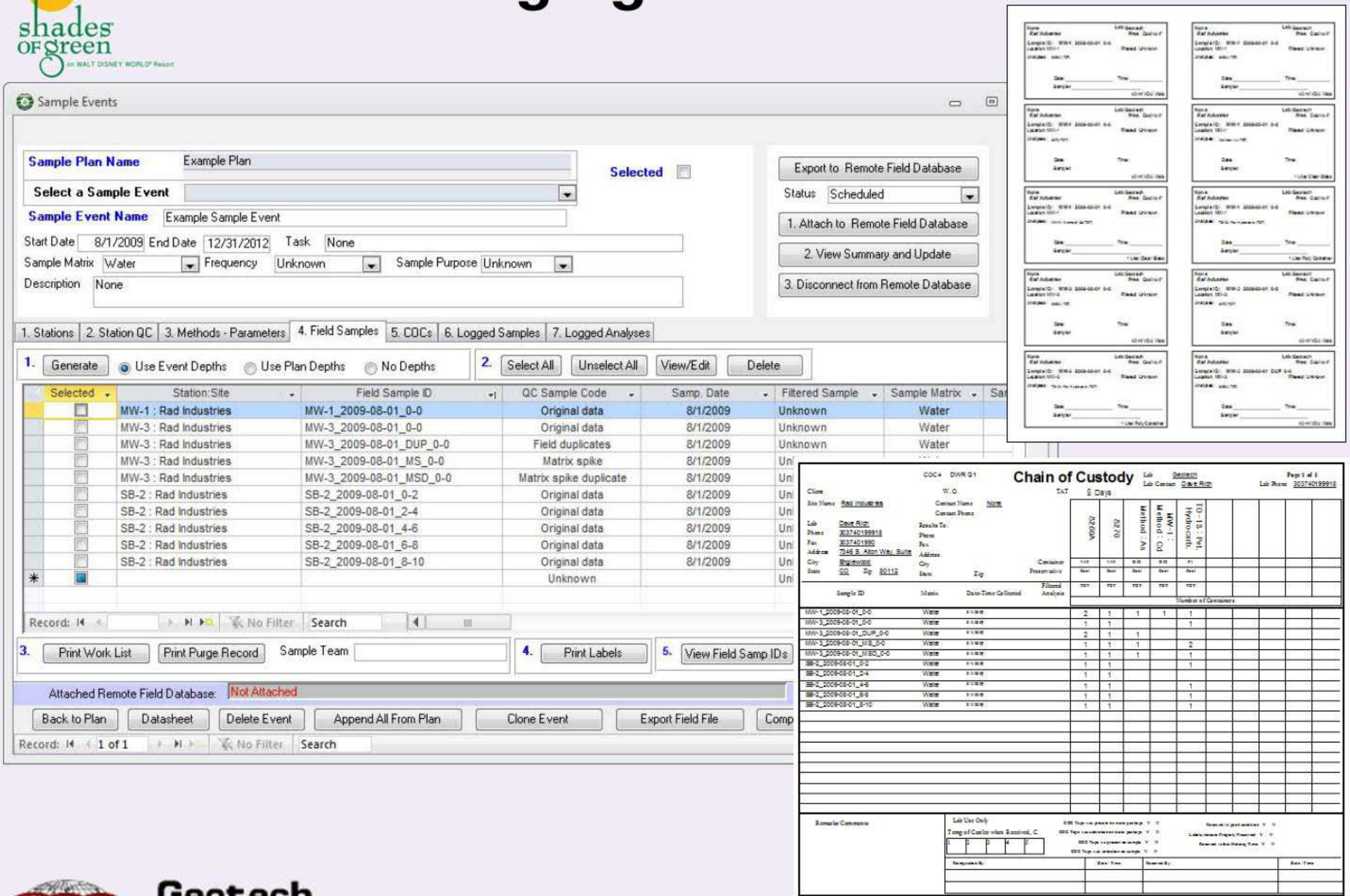
Lookup tables



Regulatory limits



Managing field events



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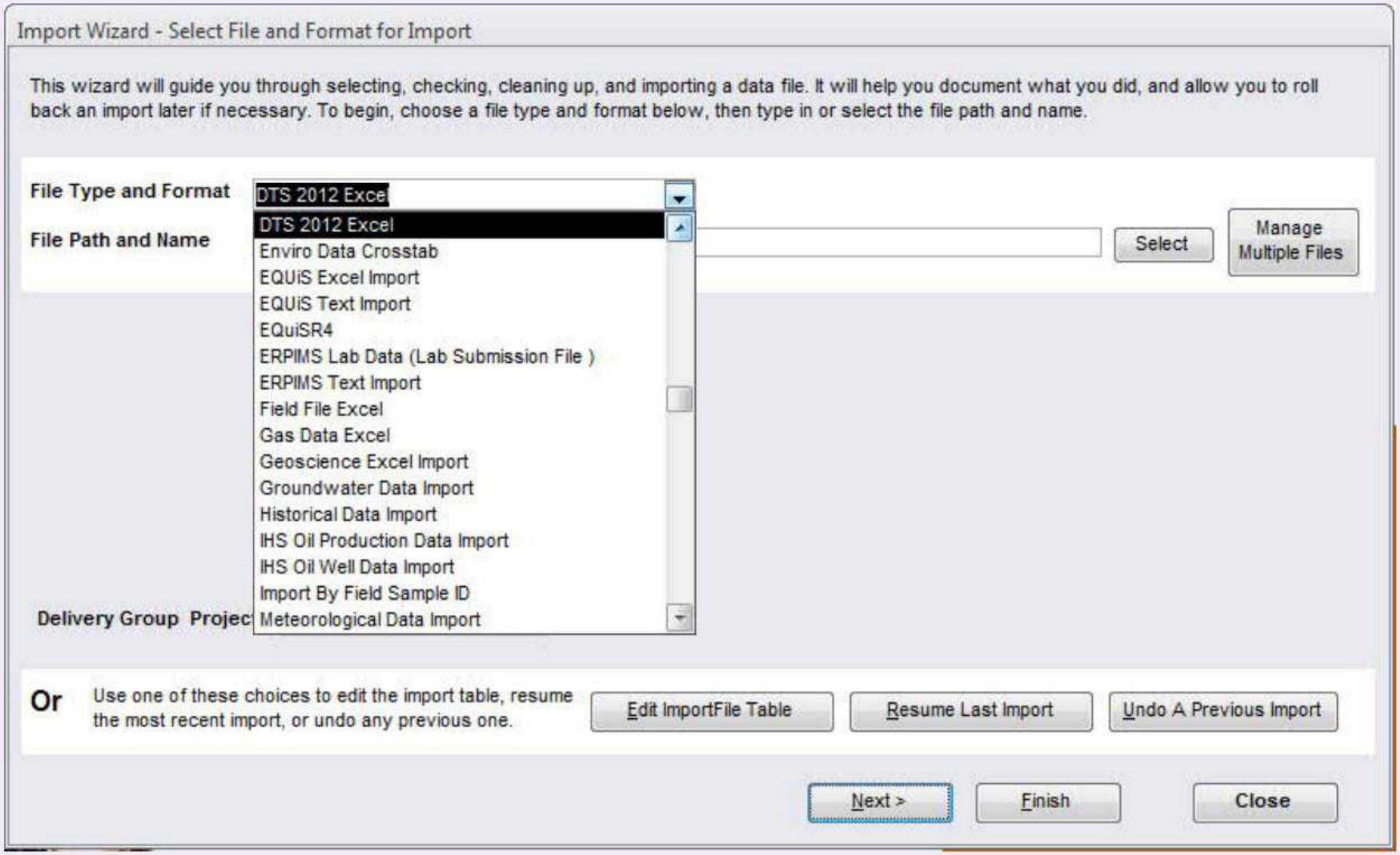
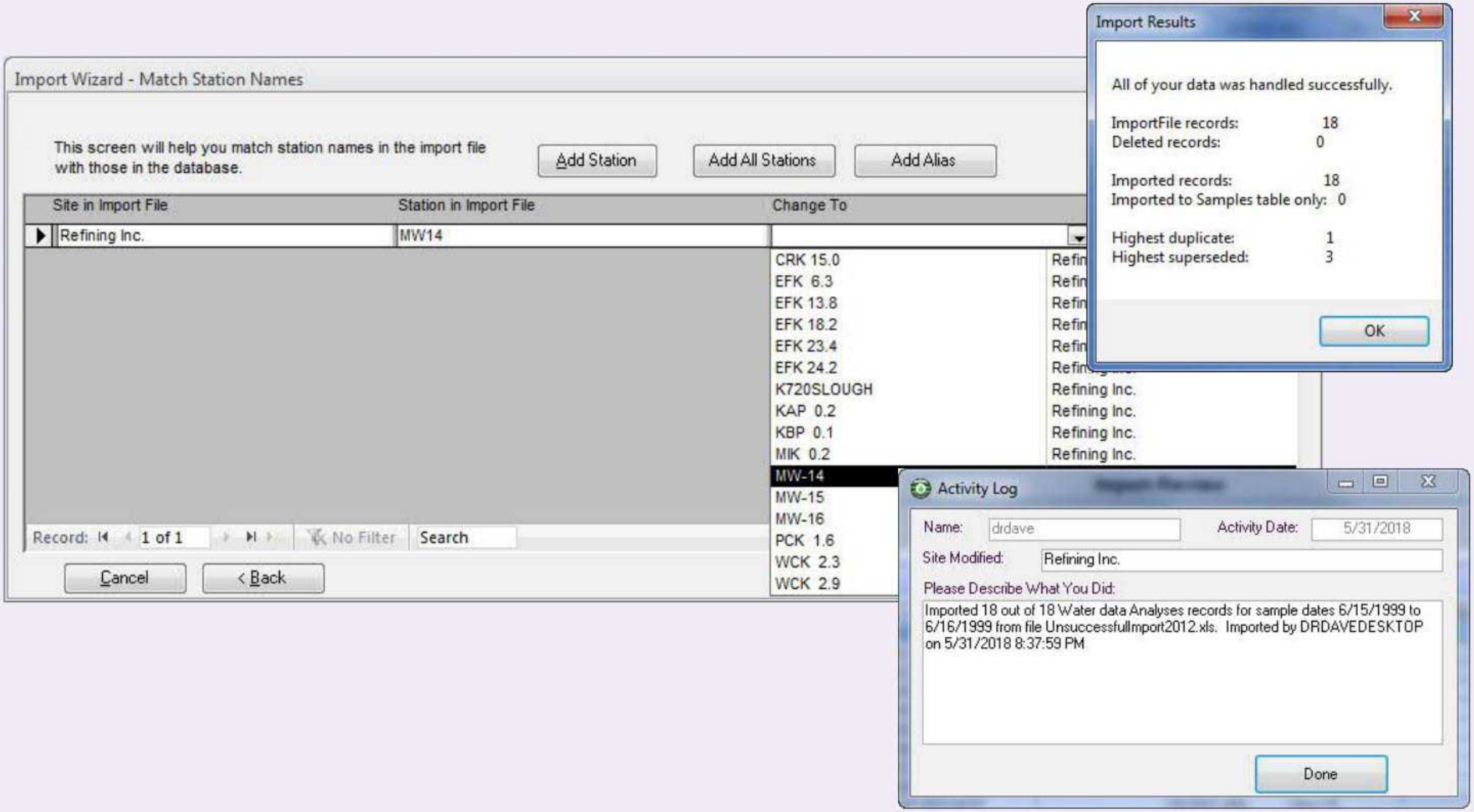
Importing lab and other data



Quality control - consistency checking during import



Data review and validation

Project | Validation Data | Delivery Grp | SDG-43417 | Analytic Method | Analytical Batch | Validatior

Select Data | QC Tasks | Validated Analyses | Validation Checklist | Reports and Other Tasks

Load Data | Append to existing data

Delivery Group	Analytical Batch	Analysis #	Station Name	Field Sample ID	Value	Samp. Date	QC Sample Code	ParameterName
SDG-43417	442705	57910	MW-05D	MW-05D DUP	0.026	11/13/2018	FD	Chromium, Hexavalent
SDG-43417	442649	57919	MW-05D	MW-05D DUP		11/13/2018	FD	Lead (Dissolved)
SDG-43417	442482	57918	MW-05D	MW-05D DUP	0.1	11/13/2018	FD	Lead
SDG-43417	442616	57917	MW-05D	MW-05D DUP	50	11/13/2018	FD	Iron (Dissolved)
SDG-43417	442473	57916	MW-05D	MW-05D DUP	50	11/13/2018	FD	Iron (Ferric)
SDG-43417	442649	57914	MW-05D	MW-05D DUP	1.3	11/13/2018	FD	Copper (Dissolved)
SDG-43417	442482	57913	MW-05D	MW-05D DUP	0.34	11/13/2018	FD	Copper
SDG-43417	442473	57898	MW-05D	MW-05D DUP	37.4	11/13/2018	FD	Barium
SDG-43417	442482	57911	MW-05D	MW-05D DUP	0.059	11/13/2018	FD	Cobalt
SDG-43417	442616	57923	MW-05D	MW-05D DUP	5	11/13/2018	FD	Manganese (Dissolved)
SDG-43417	442649	57909	MW-05D	MW-05D DUP	0.16	11/13/2018	FD	Chromium (Dissolved)
SDG-43417	442482	57908	MW-05D	MW-05D DUP	0.36	11/13/2018	FD	Chromium
SDG-43417	442649	57905	MW-05D	MW-05D DUP	0.08	11/13/2018	FD	Cadmium (Dissolved)
SDG-43417	442482	57904	MW-05D	MW-05D DUP	0.08	11/13/2018	FD	Cadmium
SDG-43417	442616	57903	MW-05D	MW-05D DUP	307	11/13/2018	FD	Boron (Dissolved)
SDG-43417	442649	57901	MW-05D	MW-05D DUP	0.1	11/13/2018	FD	Beryllium (Dissolved)
SDG-43417	442616	57899	MW-05D	MW-05D DUP	32.8	11/13/2018	FD	Barium (Dissolved)
SDG-43417	442649	57912	MW-05D	MW-05D DUP	0.054	11/13/2018	FD	Cobalt (Dissolved)
SDG-43417	442482	57934	MW-05D	MW-05D DUP	0.5	11/13/2018	FD	Selenium

Record: 1 of 1646 | No Filter | Search

First select the data to be reviewed

Data review and validation

Method Blank Detects

DeliveryGrou	AnalyticalBatch	AnalyticMetl	LabSampleID	Parameter Name	QCSampleCode	DetectedResult	Value	Detect	LimitTy	Detect2	LimitType2	DilutionFa
SDG-43417	442482	16	2428770	Chromium	MB	Y	0.12	0.5	RL	0.09	MDL	
SDG-43417	442482	16	2428770	Lithium	MB	Y	0.11	2.5	RL	0.07	MDL	
SDG-43417	442649	16	2429649	Chromium (Dissolved)	MB	Y	0.096	0.5	RL	0.09	MDL	

AnalyticalBatch	QCSampleCode	LabSampleID	FieldSampleID	LongName	DilutionFact	FlagCode	DetectedResult	ValidationC	ValReason1	Value
442482	O	92407161008	BG-03BRU	Chromium	1	j	Y	B	MB>RL	0.17
442482	O	92407161009	MW-03D	Chromium	1	j	Y	B	MB>RL	0.27
442482	O	92407161010	AB-05SL	Chromium	1	j	Y	B	MB>RL	0.24
442482	O	92407161011	AB-05S	Chromium	1	j	Y	B	MB>RL	0.26
442482	O	92407161013	MW-05D	Chromium	1		Y	B	MB>RL	0.8
442482	O	92407161018	GWA-13D	Chromium	1		Y	B	MB>RL	0.66

Record: 1 of 6 No Filter Search

Show query view of exceedances

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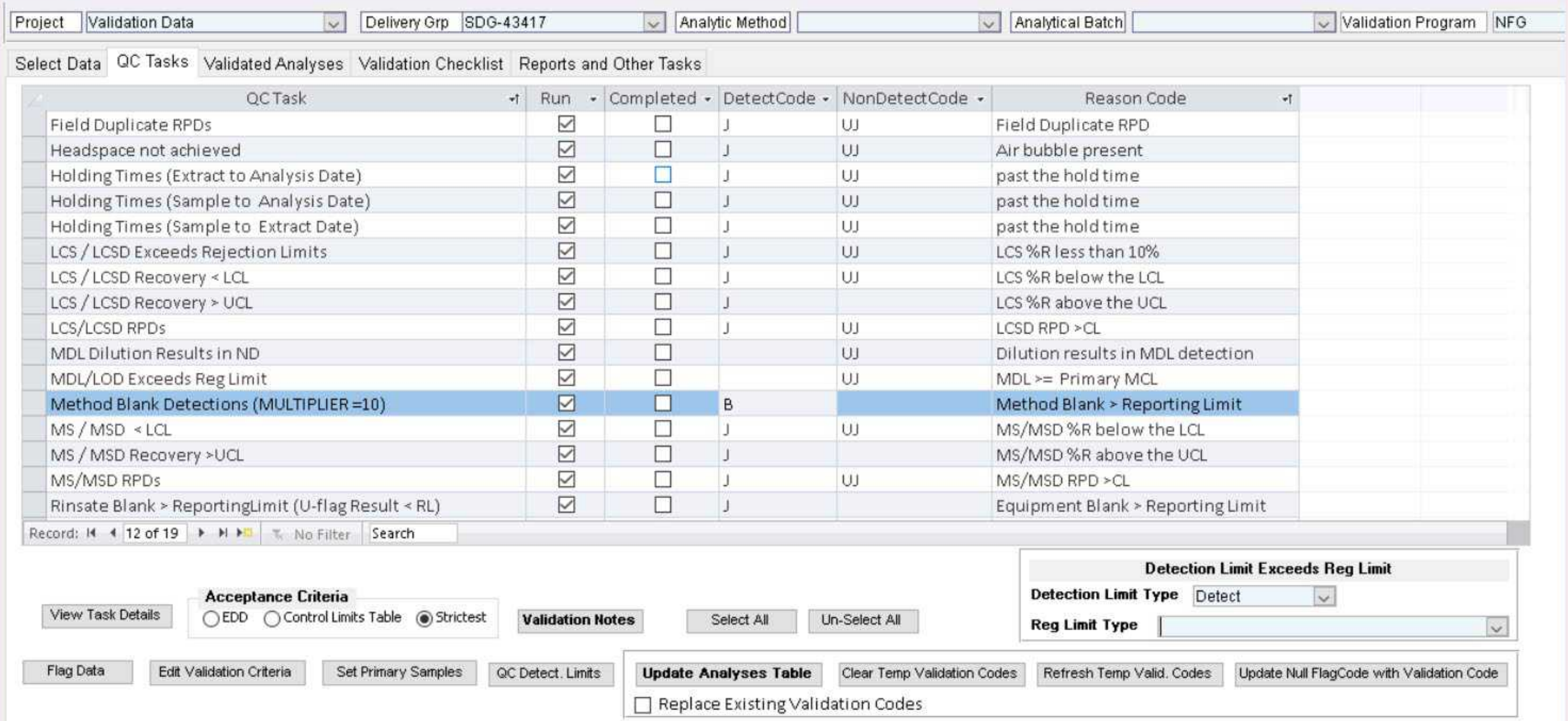
Data review and validation



QC Task	Run	Completed	DetectCode	NonDetectCode	Reason Code
Field Duplicate RPDs	☑	☐	J	UJ	Field Duplicate RPD
Headspace not achieved	☑	☐	J	UJ	Air bubble present
Holding Times (Extract to Analysis Date)	☑	☐	J	UJ	past the hold time
Holding Times (Sample to Analysis Date)	☑	☐	J	UJ	past the hold time
Holding Times (Sample to Extract Date)	☑	☐	J	UJ	past the hold time
LCS / LCSD Exceeds Rejection Limits	☑	☐	J	UJ	LCS %R less than 10%
LCS / LCSD Recovery < LCL	☑	☐	J	UJ	LCS %R below the LCL
LCS / LCSD Recovery > UCL	☑	☐	J		LCS %R above the UCL
LCS/LCSD RPDs	☑	☐	J	UJ	LCSD RPD >CL
MDL Dilution Results in ND	☑	☐		UJ	Dilution results in MDL detection
MDL/LOD Exceeds Reg Limit	☑	☐		UJ	MDL >= Primary MCL
Method Blank Detections (MULTIPLIER =10)	☑	☐	B		Method Blank > Reporting Limit
MS / MSD < LCL	☑	☐	J	UJ	MS/MSD %R below the LCL
MS / MSD Recovery >UCL	☑	☐	J		MS/MSD %R above the UCL
MS/MSD RPDs	☑	☐	J	UJ	MS/MSD RPD >CL
Rinsate Blank > ReportingLimit (U-flag Result < RL)	☑	☐	J		Equipment Blank > Reporting Limit

Choose which tests to run

Data review and validation

Project	Validation Data	Delivery Grp	SDG-43417	Analytic Method		Analytical Batch		Validation Program	NFG

Select Data | QC Tasks | Validated Analyses | Validation Checklist | Reports and Other Tasks

AnalyticMethod	Analytical Batch	QCSampleCode	LabSampleID	LongName	Temp Validation Code	Reason	DetectedResu
16	442648	MS	2429639	Selenium (Dissolved)	J	MS_LCL(%R=53)	Y
16	442648	MSD	2429640	Selenium (Dissolved)	J	MS_LCL(%R=52)	Y
16	442648	MSD	2429640	Molybdenum (Dissolved)	J	MS_LCL(%R=48)	Y
16	442651	MSD	2429674	Fluoride	J	MS_RPD(RPD=27.7);(%R=113)	Y
16	442482	MS	2428774	Arsenic	J	MS_UCL(%R=321)	Y
16	442651	MS	2429673	Fluoride	J	MS_UCL(%R=147)	Y
16	442653	MS	2429684	Fluoride	J	MS_UCL(%R=123)	Y
16	442651	MS	2429673	Sulfate	J	MS_UCL(%R=117)	Y
16	442653	MSD	2429687	Sulfate	J	MS_UCL(%R=117)	Y
16	442651	MS	2429673	Chloride	J	MS_UCL(%R=116)	Y
16	442653	MSD	2429687	Chloride	J	MS_UCL(%R=116)	Y
16	442653	MSD	2429685	Fluoride	J	MS_UCL(%R=114)	Y
16	442653	MS	2429686	Sulfate	J	MS_UCL(%R=113)	Y
16	442653	MS	2429686	Chloride	J	MS_UCL(%R=113)	Y
16	442651	MSD	2429676	Chloride	J	MS_UCL(%R=111)	Y
16	442651	MSD	2429676	Sulfate	J	MS_UCL(%R=111)	Y
16	442651	O	92407161004	Chloride	J	MS_UCL	Y
16	442651	O	92407161004	Sulfate	J	MS_UCL	Y
16	442625	MSD	2429445	Chromium, Hexavalent	J	MS_LCL(%R=89)	Y
16	442625	MS	2429442	Chromium, Hexavalent	J	MS_LCL(%R=88)	Y
16	442625	MSD	2429443	Chromium, Hexavalent	J	MS_LCL(%R=84)	Y
16	442653	MS	2429684	Chloride	J	MS_LCL(%R=83)	Y

Record: No Filter Search

Review the flagged data

1	**Laboratory Report Data Review e-Checklist**					
2	**Laboratory Report ID:**					
3	Laboratory Name:	Phoenix	Report Package Date:			
4	Project Name:		Review Date:			
5	SDG:	GBV16132				
6	Reviewer Name:		No. of Environ. Sples?			
7	Parameters:	Hydrocarbon, MA VPH, Metals, Other, PCBs, Pesticides, Semi-VOCs,	No. of QC Sples?			
8	Method IDs:	CTETPH 8015D, MA VPH 5/2004, SW6010C, SW7470A, SW7471B,	Rejected Results?			
9	Matrix:					

		Yes	No	N/A	Comment
10	***Attach copy of lab report showing sample IDs and corresponding lab IDs (Att 1)***				
31	***Laboratory Method Blanks and Field Blanks***				
32	1 Were appropriate types of laboratory method blanks analyzed?	X			
33	2 Were the laboratory method blanks analyzed at the appropriate frequency?				
34	3 Was the method blank free of contamination (i.e., less than the MDL or RL)?		X		
35	4 Did the method blank contamination affect the final results? If so, note on page 2.		X		
36	5 Was a trip blank required and submitted with the samples?			X	
37	6 Was the trip blank free of contamination (i.e., less than the MDL or RL)?			X	
38	7 Did the trip blank contamination affect the final results? If so, note on page 2.			X	
39	8 Was an equipment blank required and submitted with the samples?			X	
40	9 Was the equipment blank free of contamination (i.e., less than the MDL or RL)?			X	
41	10 Did the equipment blank contamination affect the final results? If so, note on page 2.			X	
42	11 Were Continuous Calibration Blanks (CCBs) analyzed?		X		
43	12 Were CCBs within the control window?				
44	13 Did the CCB contamination affect the final results? If so, note on page 2.				
45	***Surrogates***				
46	1 Were surrogates added prior to extraction for all appropriate methods?	X			
47	2 Were surrogate percent recoveries within laboratory control limits?	X			
48	3 Did the surrogate percent recoveries affect the final results? If so, note on page 2.		X		
49	***Laboratory Control Samples***				
50	1 Were Laboratory Control Sample (LCS) analyzed at a frequency of one per batch?	X			
51	2 Were LCSs spiked with appropriate list of target compounds?		X		
52	3 Were LCS percent recoveries within laboratory control limits?		X		
53	4 Did the LCS percent recoveries affect the final results? If so, note on page 2.	X			
54	5 If performed, was LCS Duplicate data provided?	X			
55	6 Were the LCS/LCSD RPD values within laboratory control limits?			X	
56	***Matrix Spikes***				
57	1 Were MS/MSDs analyzed at a frequency of one per batch?	X			
58	Sample used/methods: B-113 6-6.7 MSD, B-114 0.5-2 MS, B-121 0-2 MS, B-121 0-2 MSD, B-125 5-6.5 MS,				
59	2 Were MS/MSDs performed on a project sample selected by the laboratory?	X			
60	Sample used/methods: B-113 6-6.7 MS, B-113 6-6.7 MSD, B-114 0.5-2 MS, B-121 0-2 MS, B-121 0-2				
61	3 Were MS/MSDs spiked with appropriate list of target compounds?		X		
62	4 Were MS/MSD percent recoveries within laboratory control limits?		X		
63	5 Did the MS/MSD percent recoveries affect the final results? If yes, narrate		X		
67	1 Was a field duplicate submitted with this SDG?		X		

Output a quality control e-Checklist

Val_MSD_Report

Matrix Spike / Matrix Spike Duplicate Recovery and RPD Outlier Report

Method Batch : 442651 **Analytic Method :** 16 **Analysis Date :** 11/16/2018

Lab Prep Batch : **PrepMethod:** EPA 300.0 Rev 2.1 1993 **Preparation Date :** 11/16/2018

Delivery Group : SDG-43417 **Lab:** PACE

Client Sample ID	Lab Sample ID	Matrix	Analyte Name	Reported * Percent Recovery	Reported * RPD	Project Limits (Percent) Rejection Point**	Lower Limit	Upper Limit	RPD Limit
2429674 MSD	2429674	W	Fluoride	113	27.7	0.00	90.00	110.00	10.00
2429676 MSD	2429676		Chloride	111		0.00	90.00	110.00	10.00
			Sulfate	111		0.00	90.00	110.00	10.00

Analytic Method : 16

Associated Field Samples

Field Sample ID	QCSampleCode	Lab Sample ID
AB-05S	O	92407161011
AB-05SL	O	92407161010
BG-03BRU	O	92407161008
BG-03S	O	92407161007
GWA-02BRA	O	92407161002
GWA-02BRU	O	92407161003
GWA-02S	O	92407161001
GWA-16BR	O	92407161005
GWA-16D	O	92407161004
GWA-16S	O	92407161006
MW-03D	O	92407161009

Or view one of several other validation reports

Page: 5 No Filter

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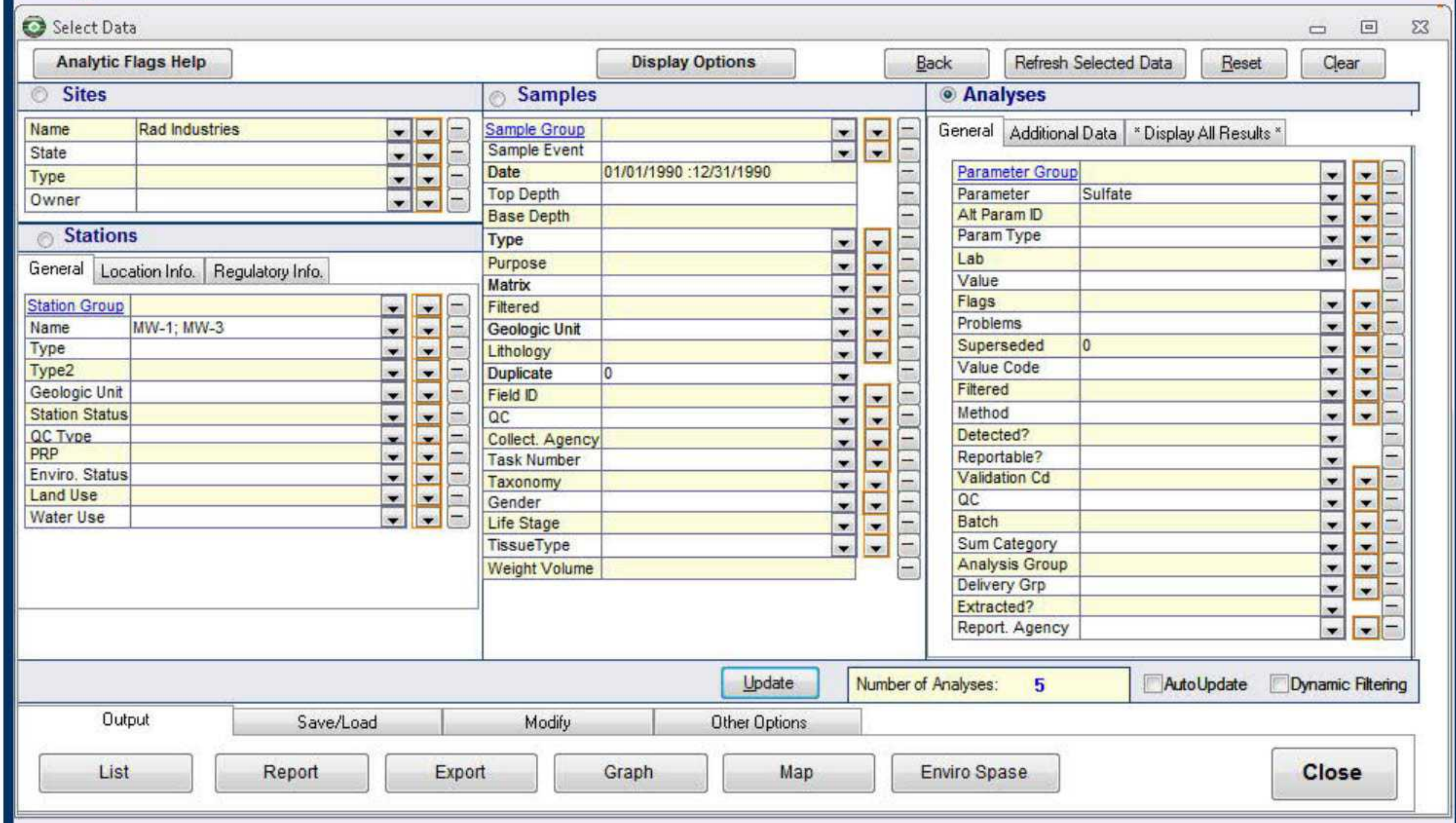
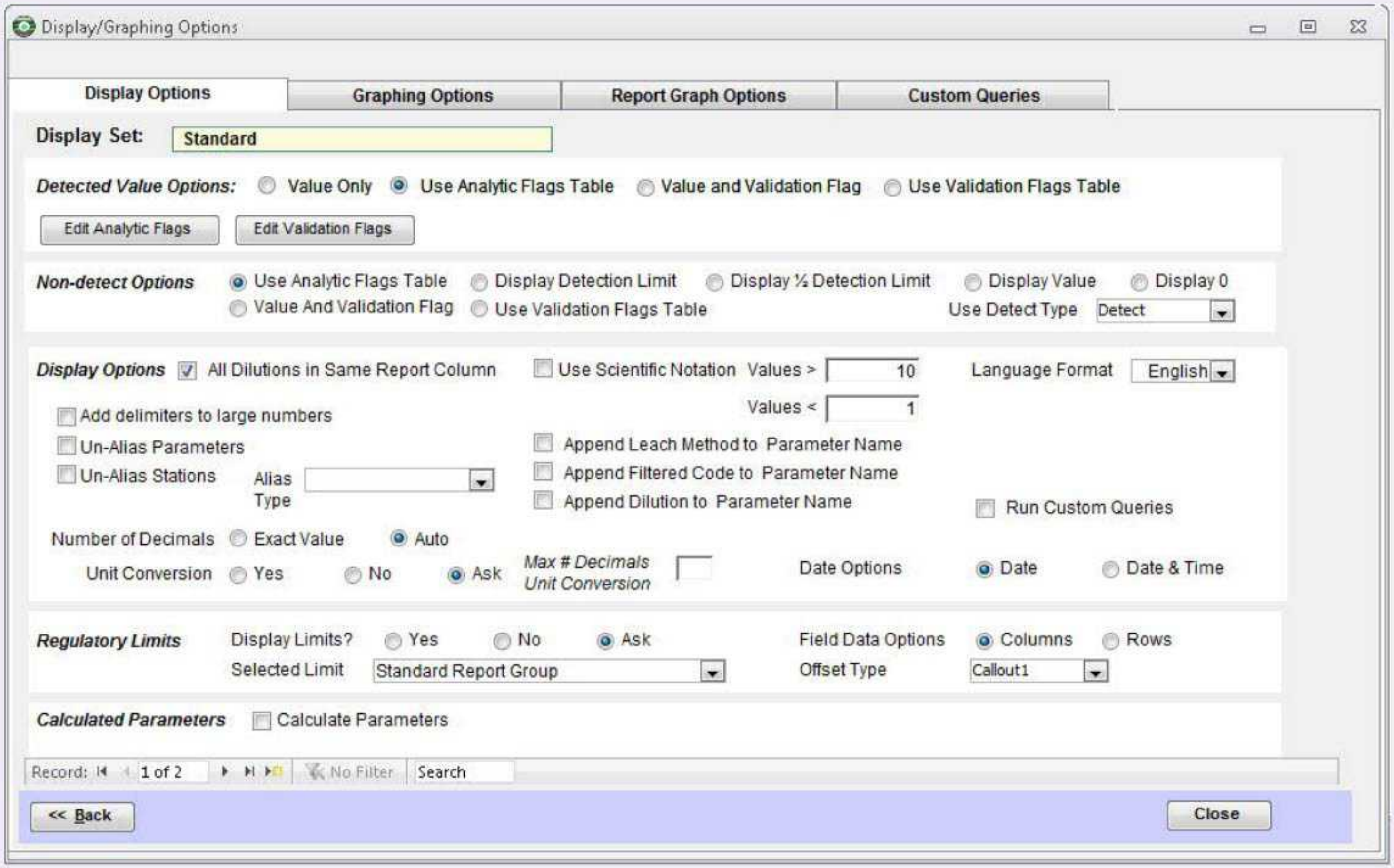
Data selection



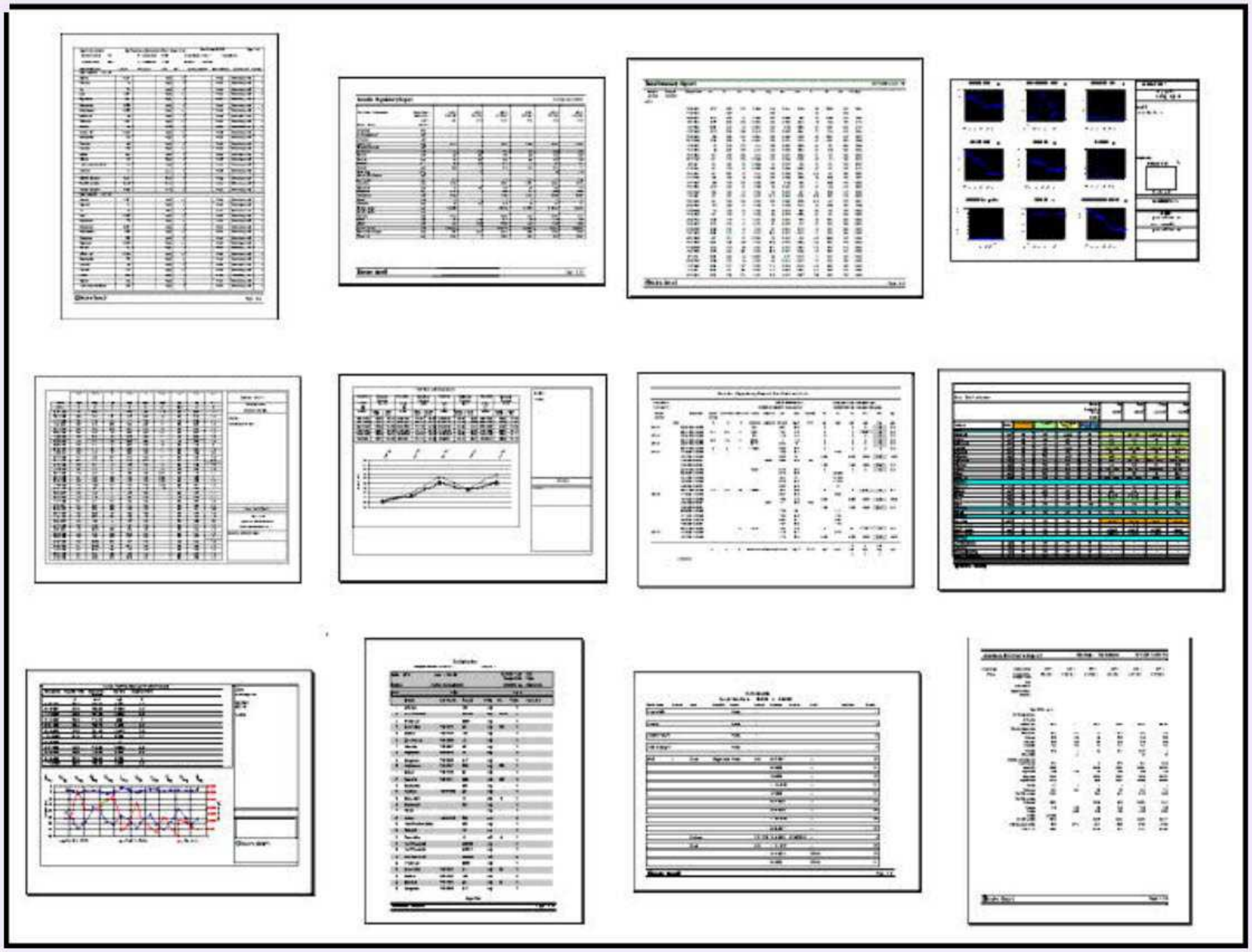
Display options determine how your results are displayed

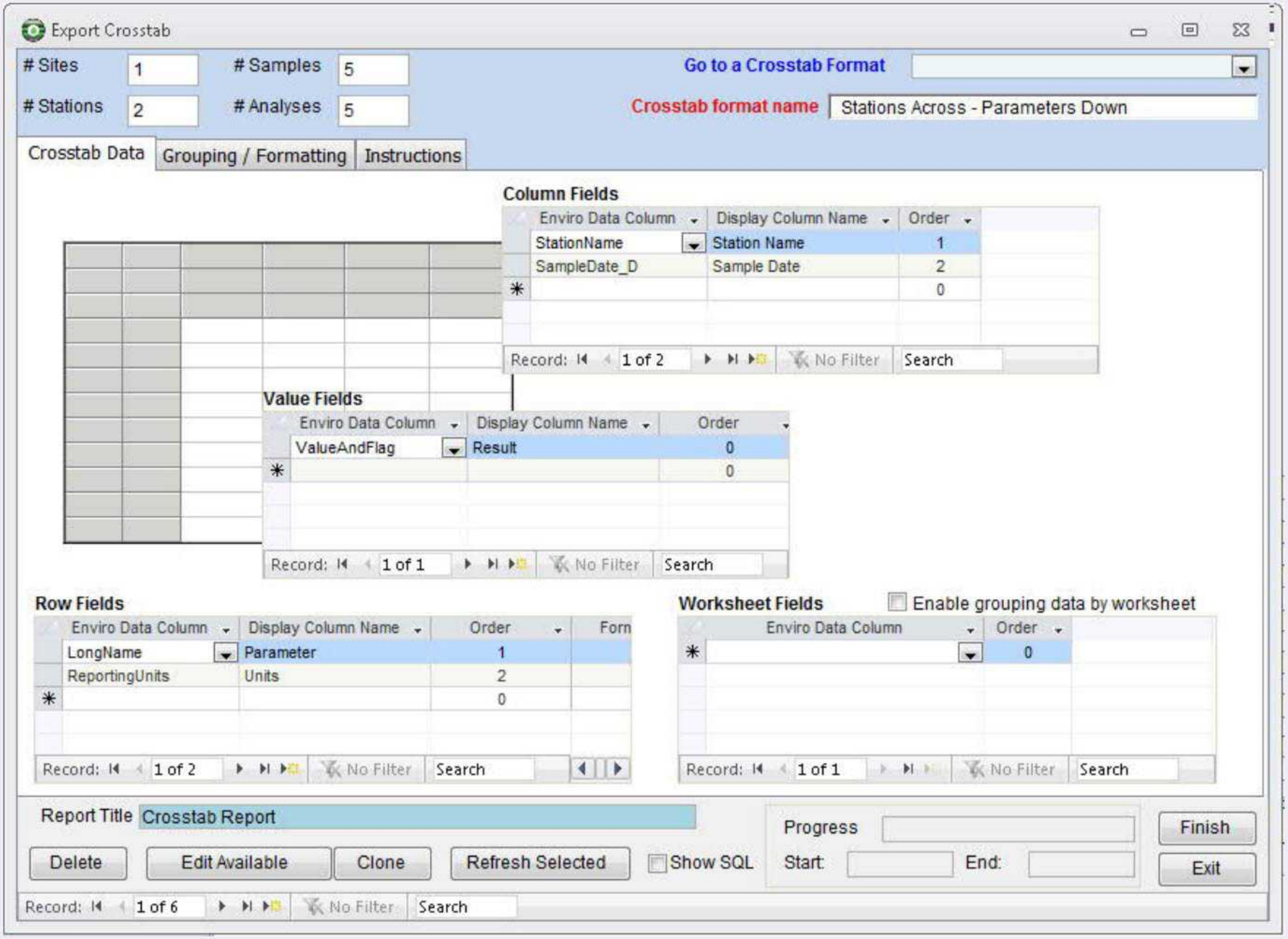
Example options:

- Regulatory limits
- Values and flags
- Unit conversion
- Date display
- Calculated parameters
- Non-detects
- Significant figures
- Graph display options
- Custom queries



Report examples





Geotech Computer Systems, Inc. **Crosstab Wizard setup** **www.geotech.com**

Book1

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	
1	**Crosstab Report**														
2	Station Name	Reporting Units	Federal MCL	Primary	Safe Drinking Water Standards	State Drinking Water Levels	MW-1	MW-1	MW-1	MW-1	Summary Statistics				
3	Sample Date						2/8/1984	5/10/1984	9/14/1984	11/13/1984					
4	QC Code						0	0	0	0	Results	Non-Detects	Minimum	Maximum	Mean**
5	**Field Param**														
6	Field pH	s.u.				7.1-8.4	7.70	7.10	7.10	7.20	4	0	7.1	7.7	7.2
7	**Inorganics**														
8	Bicarbonate	mg/l					520	550	470	560	4	0	470	560	525
9	Chloride	mg/l					250	260	230	190	4	0	190	260	232.5
10	Fluoride	mg/l					<1.00	<1.00	<1.00	<1.00	4	4	<1	<1	<1
11	Nitrate	mg/l		2			<1.00	2.00	2.00	<1.00	4	2	<1	2	1.2
12	Sulfate	mg/l	725	800	350	1000	1040	900	880	800	4	0	800	1040	905
13	**Metals**														
14	Arsenic (As)	mg/l	0.025	0.1	0.002	0.03	<0.11	<0.11	<0.11	<0.06	4	4	<0.06	<0.11	<0.11
15	Calcium	mg/l					180	170	203	180	4	0	170	203	183.2
16	Iron (Ferrous)	mg/l		0.1			0.2	3.2	3.7	4.8	4	0	0.2	4.8	2.9
17	Lead (Pb)	mg/l	0.001	0.004	0.005	0.0025	<0.068	<0.068	0.14	<0.08	4	3	<0.068	0.14	0.06
18	Magnesium	mg/l					94	100	107	100	4	0	94	107	100.2
19	Manganese	mg/l	0.0105	0.015	0.02	0.00225	0.077	0.066	0.076	0.086	4	0	0.066	0.086	0.07
20	Molybdenum	mg/l					0.02	<0.018	0.034	0.008	4	1	<0.018	0.034	0.01
21	Potassium	mg/l					5.20	6.20	5.61	20	4	0	5.2	20	9.2
22	Selenium	mg/l					<0.10	<0.10	<0.10	<0.08	4	4	<0.08	<0.1	<0.1
23	Sodium	mg/l					390	430	390	460	4	0	390	460	417.5
24	UTotal - sol	mg/l					0.003	0.01	0.003	0.003	4	0	0.003	0.01	0.004
25	**Other**														
26	Total Dissolved Solids	mg/l					2220	2230	2220	2200	4	0	2200	2230	2217.5
27	**Radiologic**														
28	Gross Alpha	pCi/l	1				<10.00	<10.00	<10.00	<10.00	4	4	<10	<10	<10
29	Ra-226 - soluble	mg/l			0.4375		0.32		0.035	0.0525	3	0	0.035	0.32375	0.1
30	Ra-228 - soluble	mg/l					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0.27125	0.595	0.3
31	Th-230 - soluble	mg/l										0	0.025375	0.35175	0.1
32															
33	** 1/2 RL used to calculate the mean wherer non-detect data occurred.														

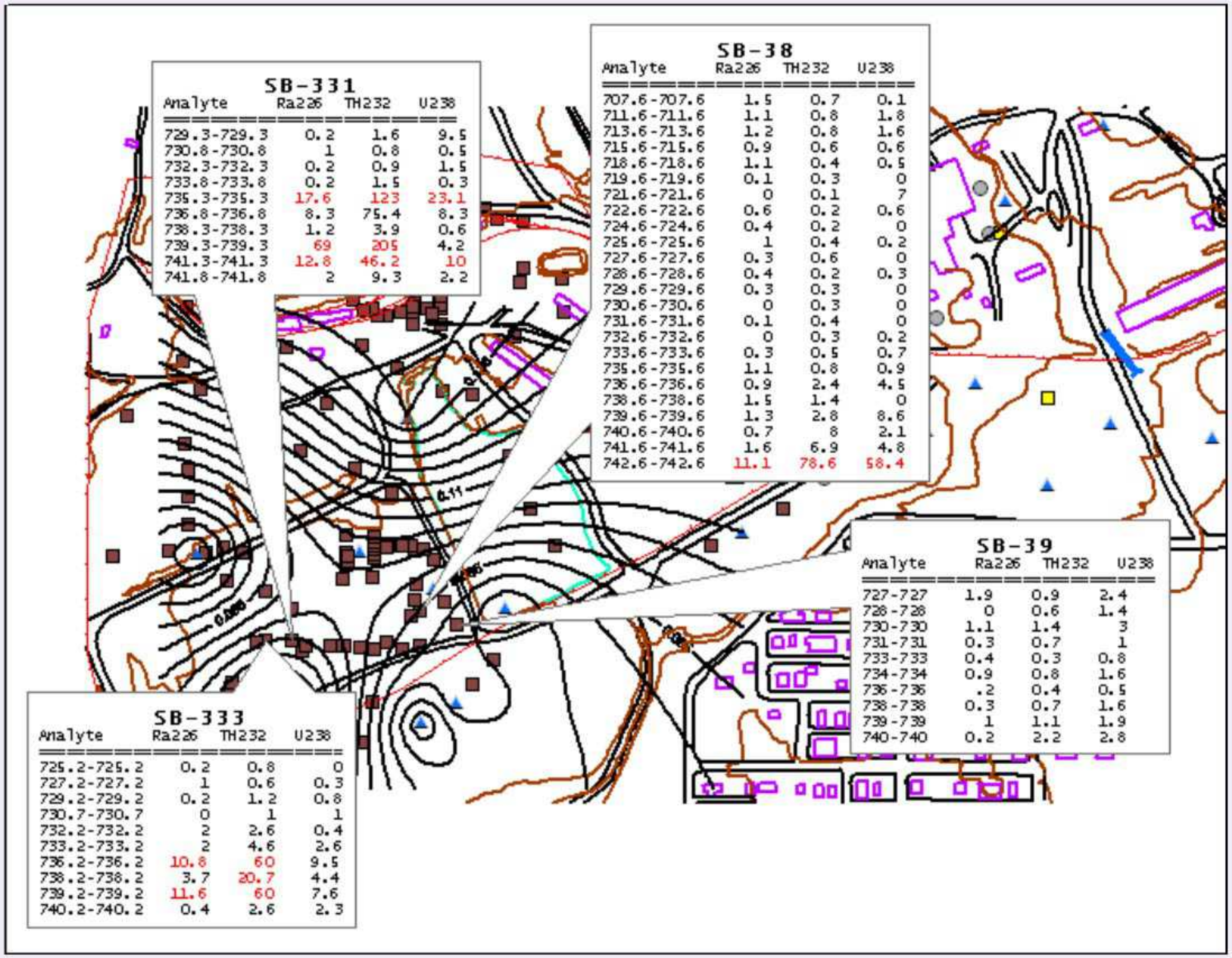
Crosstab Report | Sheet1 | Sheet2 | Sheet3

Crosstab Wizard output

Mapping and GIS

- You need a base map or image
- Sample locations must have coordinates
- And both have to match
- GIS software like ArcGIS makes the maps
- Specialized software can make environmental-specific displays
- Integration between the EDMS and the GIS can save time and improve quality

Crosstab Callouts From the Database



SB-331

Analyte	Ra226	TH232	U238
729.3-729.3	0.2	1.6	9.5
730.8-730.8	1	0.8	0.5
732.3-732.3	0.2	0.9	1.5
733.8-733.8	0.2	1.5	0.3
735.3-735.3	17.6	123	23.1
736.8-736.8	8.3	75.4	8.3
738.3-738.3	1.2	3.9	0.6
739.3-739.3	69	205	4.2
741.3-741.3	12.8	46.2	10
741.8-741.8	2	9.3	2.2

SB-38

Analyte	Ra226	TH232	U238
707.6-707.6	1.5	0.7	0.1
711.6-711.6	1.1	0.8	1.8
713.6-713.6	1.2	0.8	1.6
715.6-715.6	0.9	0.6	0.6
718.6-718.6	1.1	0.4	0.5
719.6-719.6	0.1	0.3	0
721.6-721.6	0	0.1	7
722.6-722.6	0.6	0.2	0.6
724.6-724.6	0.4	0.2	0
725.6-725.6	1	0.4	0.2
727.6-727.6	0.3	0.6	0
728.6-728.6	0.4	0.2	0.3
729.6-729.6	0.3	0.3	0
730.6-730.6	0	0.3	0
731.6-731.6	0.1	0.4	0
732.6-732.6	0	0.3	0.2
733.6-733.6	0.3	0.5	0.7
735.6-735.6	1.1	0.8	0.9
736.6-736.6	0.9	2.4	4.5
738.6-738.6	1.5	1.4	0
739.6-739.6	1.3	2.8	8.6
740.6-740.6	0.7	8	2.1
741.6-741.6	1.6	6.9	4.8
742.6-742.6	11.1	78.6	58.4

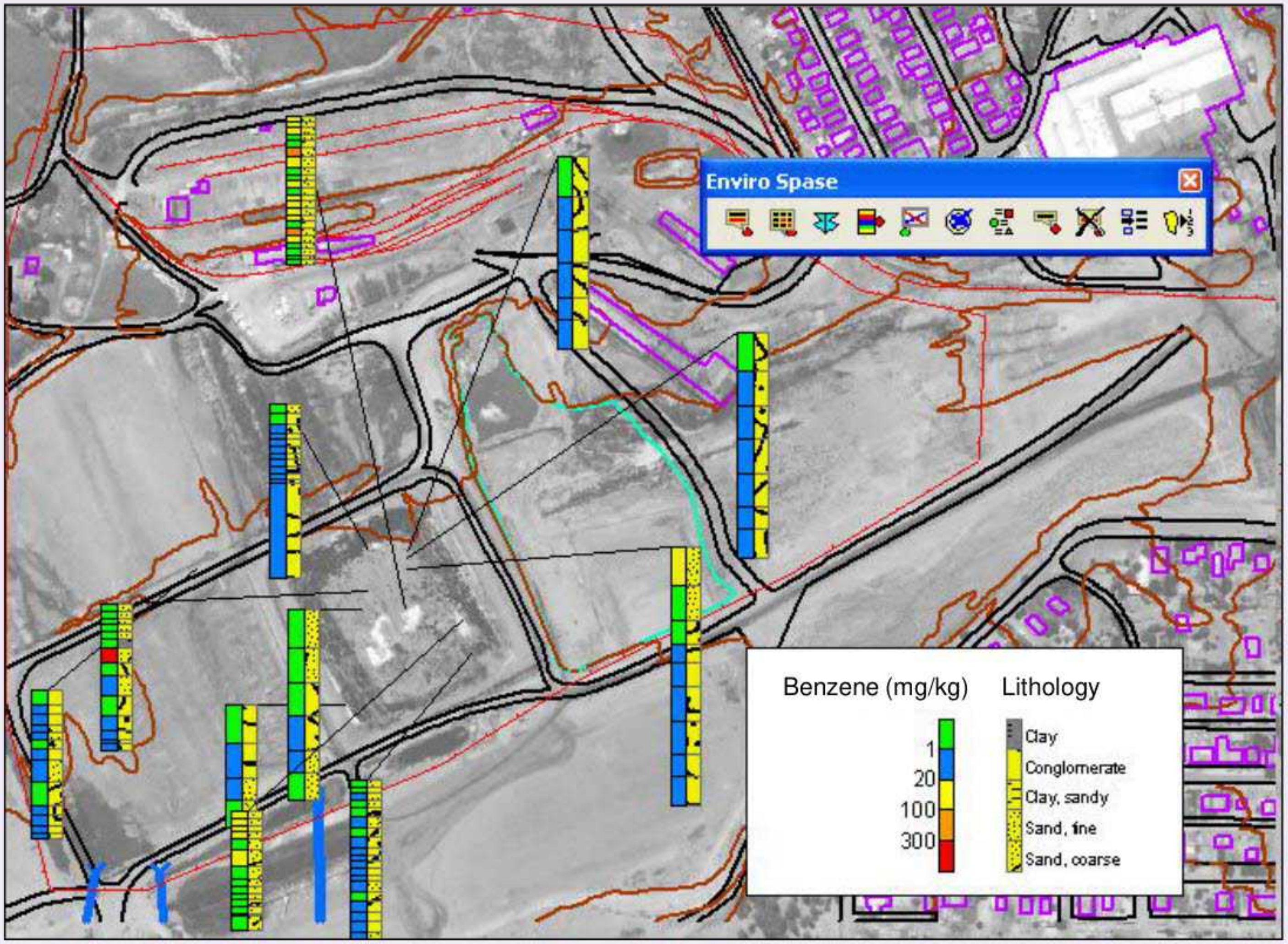
SB-39

Analyte	Ra226	TH232	U238
727-727	1.9	0.9	2.4
728-728	0	0.6	1.4
730-730	1.1	1.4	3
731-731	0.3	0.7	1
733-733	0.4	0.3	0.8
734-734	0.9	0.8	1.6
736-736	.2	0.4	0.5
738-738	0.3	0.7	1.6
739-739	1	1.1	1.9
740-740	0.2	2.2	2.8

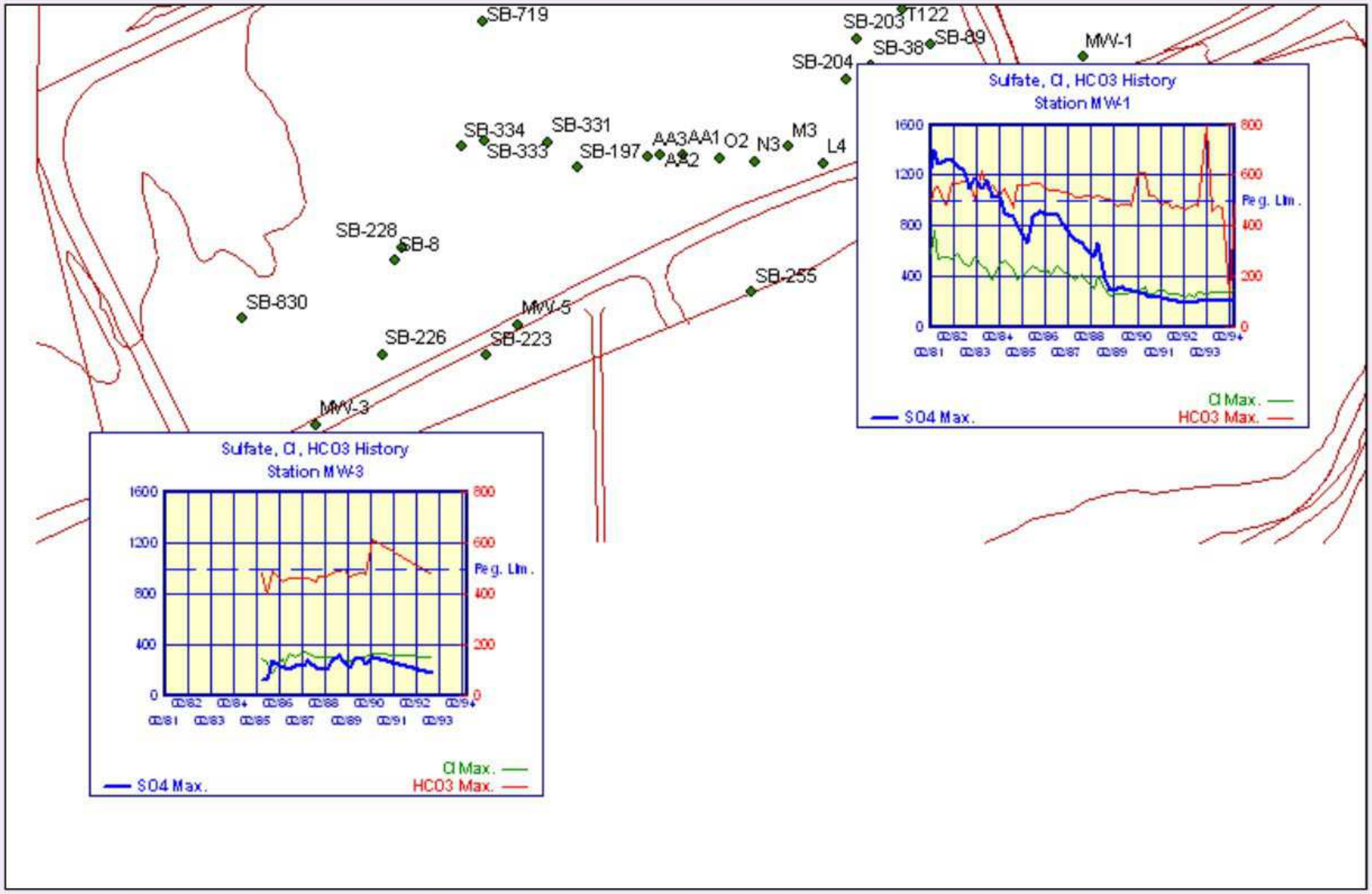
SB-333

Analyte	Ra226	TH232	U238
725.2-725.2	0.2	0.8	0
727.2-727.2	1	0.6	0.3
729.2-729.2	0.2	1.2	0.8
730.7-730.7	0	1	1
732.2-732.2	2	2.6	0.4
733.2-733.2	2	4.6	2.6
736.2-736.2	10.8	60	9.5
738.2-738.2	3.7	20.7	4.4
739.2-739.2	11.6	60	7.6
740.2-740.2	0.4	2.6	2.3

Soil borings with values from the database



Time sequence graphs on the map



Benefits of better data management

Decrease overhead - One industrial company was able to save $12,000 per year on just one project by moving the data management tasks to a much less expensive clerical person.

Lower operating cost - Another used data management to get their regulator to approve less-frequent sampling intervals for about two of their wells per year, resulting in a savings of $9,000 each year, cumulative from year to year.

Increase efficiency – For one organization, the time to process an electronic deliverable decreased from an average of 30 minutes to 5 minutes, resulting in an annual savings of $5,000 per year on each project.

An Indian tribe needed to make nine hundred graphs/year for their EPA PM. With Excel, it took 3 months. With a database with integrated graphing, it took 10 minutes.

Increase revenue - A consulting company client was able to use their Enviro Data software and expertise to land a $300,000 data management task from one of their clients.

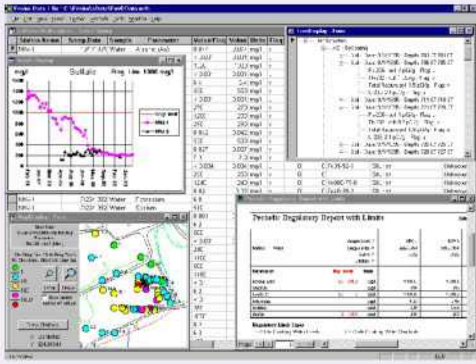
Conclusions

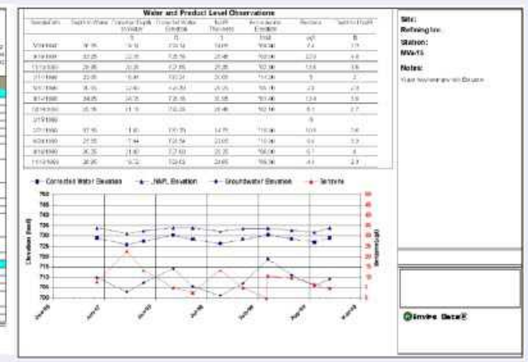
- Environmental investigation and remediation projects at DOD facilities are inherently complex
- Implementing a centralized data management system makes sense for most environmental projects
- Integrating validation with data management can greatly reduce cost and improve quality
- Is it time to retire your spreadsheet?

shades OF green on WALT DISNEY WORLD® Resort

Enviro Data®

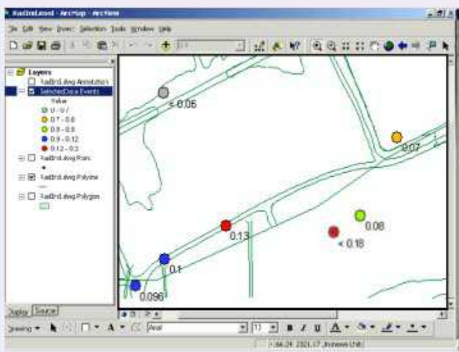
Relational Management of Site Environmental Data

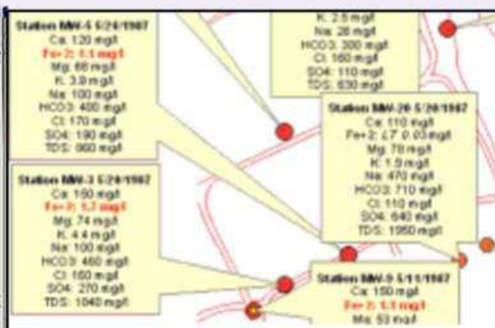


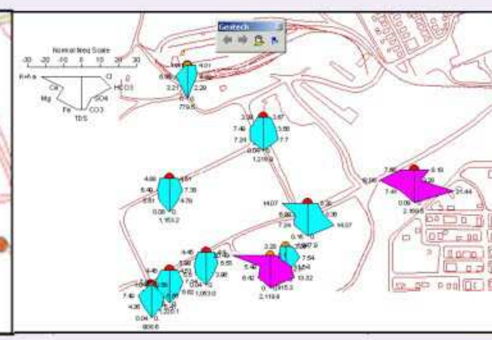


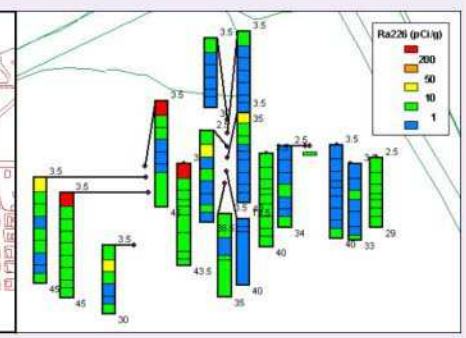
Enviro Spāse

Display and Analysis of Site Environmental Data









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May 15, 2019

Appendix F

Proposed Program Costing

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Table F-1: Framework 1 - Coordinated Regional and Community Focused Monitoring (once every 2 years)

Class A Lakes (Spring and Summer)
Class B Lakes (Spring Only)
Reference Lakes

Total Highly Vulnerable "A" Lakes: 27
Total Moderately Vulnerable "B" Lakes: 48
Total lakes: 74

Both HRM and Community Focued Groups will complete the monitoring for Framework 1. Target lakes for sampling are divided equally between Year 1 and Year 2, as well as equal division of Class A and Class B lakes from across all watersheds. This results in the following sampling schedule:

Year 1 - SPRING:	Year 2 - SPRING:	Year 1 SUMMER:	Year 2 - SUMMER:
Total A Lakes: 13	Total A Lakes: 14	Total A Lakes: 13	Total A Lakes: 14
Total B Lakes: 24	Total B Lakes: 24	Total B Lakes: 0	Total B Lakes: 0

Number of Lakes HRM will sample:
Year 1 - Spring: 23
Year 1 - Summer: 7
Year 2 - Spring: 29
Year 2 - Summer: 8

Number of Lakes Community Groups will sample:
Year 1 - Spring: 13
Year 1 - Summer: 6
Year 2 - Spring: 9
Year 2 - Summer: 6

Overview of Estimated Costs - Framework 1

PROGRAM START UP		
Start Up Costs	$	21,750

TOTAL PROGRAM COST - YEAR 1		
Year 1 - Spring Sampling - Personnel, Expenses & Laboratory Costs	$	15,235
Year 1 - Summer Sampling - Personnel, Expenses & Laboratory Costs	$	9,296
Full Time Salary Costs[1]	$	133,000
Ongoing Costs	$	9,500
Grant Program	$	7,500
Consulting and Research	$	50,000
Total Cost	**$**	**224,531**

TOTAL PROGRAM COST - YEAR 2		
Year 2 - Spring Sampling - Personnel, Expenses & Laboratory Costs	$	15,361
Year 2 - Summer Sampling - Personnel, Expenses & Laboratory Costs	$	9,704
Full Time Salary Costs[1]	$	133,000
Ongoing Costs	$	9,500
Grant Program	$	7,500
Consulting and Research	$	75,000
Total Cost	**$**	**250,065**

Note: Salary costs does not include overhead burden

Detailed Breakdown - Framework 1 Costing

Operational Costs		
Start up Costs		
Boat, Trailer, Motor	$	7,500
Licensing & Registration	$	750
Data Management Software (Cloud based)	$	10,000
Equipment Kits for Community Groups ($250 * 14)	$	3,500
Start up Subtotal	**$**	**21,750**
Full Time Staff Salary (Annual)		
Program Manager	$	85,000
Program Assistant	$	48,000
Total Labour Costs	**$**	**133,000**
Ongoing Costs		
Boat Inspection and Maintenance	$	1,000
Data Management Licensing	$	2,500
Insurance	$	4,000
Equipment Kits and Supplies for Community Groups	$	1,000
Health and Safety Training - Staff	$	1,000
Ongoing Subtotal	**$**	**9,500**

AECOM

Other		
Limnological Consulting Services	$	30,000
Grant Program for Community Groups	$	7,500
Set-Aside for Collaborations with Academia	$	20,000
Other Subtotal	**$**	**50,000**

Seasonal Cost Estimate Summary

YEAR 1 - SPRING	
Will sample the following:	
Class A Lakes:	13
Class B Lakes:	23
Number of Priorty Eutrophication Lakes:	6
Number of Priorty Chloride Lakes:	4

Lab Analysis Budget

Parameter		Unit Cost	Jnit Quantit	Jnit Measure		Total Cost
Routine Analysis						
Total Phosphorus (euphotic zone)	$	29.15	36	each	$	1,049.40
Chlorophyll-A (euphotic zone)	$	60.50	36	each	$	2,178.00
Chloride (1m off bottom) - Priority Chloride Lakes (assumed)	$	17.60	4	each	$	70.40
QAQC Samples (assuming 10% of samples)	$	89.65	8	each	$	699.27
Supplemental Analysis (if triggered)						
Chloride (1m off bottom) - assuming 10% of Class A lakes get triggered	$	17.60	2	each	$	35.20
*Total phosphorus (1m off bottom - **end of summer only**)*	$	29.15	0	each	$	-
Total					**$**	**4,032.27**

Lake Type	Watersheds	Lakes	Lakes/Day	Working Days
Class A Lakes: HRM		7	2	3.5
Class B Lakes: HRM		16	2	8.0
Class A Lakes: Community Groups		6	1	6.0
Class B Lakes: Community Groups		7	1	7.0
Total		36	-	**25**

Personnel Costing		Daily Rate		Working Day		Personnel Costs
Seasonal Costs						
Sampling Technician (Half of salary costs of a 4 month term)	$	136.00		40	$	5,440.00
Total					**$**	**5,440.00**

Expenses		Unit Cost	Unit Quantity	Unit Measure		Cost
Sampling Related - HRM						
Truck Rental and Gas	$	100.00	12	days	$	1,150.00
Boat Operation Expenses (fuel, etc.)	$	50.00	12	days	$	575.00
YSI Rental (1 Unit)	$	75.00	12	days	$	862.50
Secchi Disk (purchased)	$	135.00	1	lump sum	$	135.00
Consumables (gloves, etc)	$	10.00	12	days	$	115.00
Variable Costs (per Community Groups involved)						
Mileage (HRM costs for sample pick up, etc)	$	50.00	13	Mileage per Group	$	650.00
Equipment for community groups, consumables	$	25.00	13	Costs per Group	$	325.00
YSI Rentals (2 Units)	$	150.00	13	Costs per Group	$	1,950.00
Total					**$**	**5,762.50**

TOTAL PROGRAM COST - YEAR 1 SPRING		
Lab Fees	$	4,032.27
Personnel Costing	$	5,440.00
Expenses	$	5,762.50
Total	**$**	**15,234.77**

YEAR 1 - SUMMER	
Will sample the following:	
Class A Lakes:	13
Class B Lakes:	0
Number of Priorty Eutrophication Lakes:	4
Number of Priorty Chloride Lakes:	3

AECOM

Lab Analysis Budget						
Parameter	Unit Cost		Jnit Quantit	Jnit Measur	Total Cost	
Routine Analysis						
Total Phosphorus (euphotic zone)	$	29.15	13	each	$	378.95
Chlorophyll-A (euphotic zone)	$	60.50	13	each	$	786.50
Chloride (1m off bottom) - Priority Chloride Lakes	$	17.60	3	each	$	52.80
QAQC Samples (assuming 10% of samples)	$	89.65	4	each	$	313.78
Supplemental Analysis (if triggered)						
Chloride (1m off bottom) - assuming 10% os Class A lakes get triggered	$	17.60	2	each	$	35.20
*Total phosphorus (1m off bottom - **end of summer only**)*	$	29.15	4	each	$	116.60
Total					**$**	**1,683.83**

Lake Type	Watersheds	Lakes	Lakes/Day	Working Days
Class A Lakes: HRM		7	2	3.5
Class B Lakes: HRM		0	-	-
Class A Lakes: Community Groups		6	1	6.0
Class B Lakes: Community Groups		0	-	-
Total		13	-	**10**

Personnel Costing	Daily Rate			Working Day	Personnel Costs	
Seasonal						
Sampling Technician (Half of salary costs of a 4 month term)	$	136.00		40	$	5,440.00
Total					**$**	**5,440.00**

Expenses	Unit Cost		Unit Quantity	Unit Measure	Cost	
Sampling Related - HRM						
Truck Rental and Gas	$	100.00	4	days	$	350.00
Boat Operation Expenses (fuel, etc.)	$	50.00	4	days	$	175.00
YSI Rental (1 Unit)	$	75.00	4	days	$	262.50
Consumables (gloves, etc)	$	10.00	4	days	$	35.00
Variable Costs (per Community Groups involved						
Mileage (HRM costs for sample pick up, etc)	$	50.00	6	Mileage per Group	$	300.00
Equipment for community groups, consumables	$	25.00	6	Costs per Group	$	150.00
YSI Rentals (2 Units)	$	150.00	6	Costs per Group	$	900.00
Total					**$**	**2,172.50**

YEAR 2 - SPRING	
Will sample the following:	
Class A Lakes:	14
Class B Lakes:	24
Number of Priorty Eutrophication Lakes:	8
Number of Priorty Chloride Lakes:	7

Lab Analysis Budget						
Parameter	Unit Cost		Jnit Quantit	Jnit Measur	Total Cost	
Routine Analysis						
Total Phosphorus (euphotic zone)	$	29.15	38	each	$	1,107.70
Chlorophyll-A (euphotic zone)	$	60.50	38	each	$	2,299.00
Chloride (1m off bottom) - Priority Chloride Lakes	$	17.60	7	each	$	123.20
QAQC Samples (assuming 10% of samples)	$	89.65	9	each	$	770.99
Supplemental Analysis (if triggered)						
Chloride (1m off bottom) - assuming 10% of Class A lakes get triggered	$	17.60	2	each	$	35.20
Total phosphorus (1m off bottom - end of summer only)	$	89.65	1	each	$	89.65
Total					**$**	**4,425.74**

Lake Type	Watersheds	Lakes	Lakes/Day	Working Days
Class A Lakes: HRM		8	2	4
Class B Lakes: HRM		21	2	11
Class A Lakes: Community Groups		6	1	6
Class B Lakes: Community Groups		3	1	3
Total		38	-	**24**

AECOM

Personnel Costing	Daily Rate		Working Day	Personnel Costs
Seasonal Costs				
Sampling Technician (Half of salary costs of a 4 month term)	$ 136.00		40	$ 5,440.00
Total				**$ 5,440.00**

Expenses	Unit Cost	Unit Quantity	Unit Measure	Cost
Sampling Related - HRM				
Truck Rental and Gas	$ 100.00	15	days	$ 1,450.00
Boat Operation Expenses (fuel, etc.)	$ 50.00	15	days	$ 750.00
YSI Rental (1 Unit)	$ 75.00	15	days	$ 1,125.00
Consumables (gloves, etc)	$ 10.00	15	days	$ 145.00
Variable Costs (per Community Groups involved				
Mileage	$ 50.00	9	Mileage per Group	$ 450.00
Equipment Kit - Per Group (secchi disc, gloves, sample cooler)	$ 25.00	9	Costs per Group	$ 225.00
YSI Rentals (2 Units)	$ 150.00	9	Costs per Group	$ 1,350.00
Total				**$ 5,495.00**

YEAR 2 - SUMMER	
Will sample the following:	
Class A Lakes:	14
Class B Lakes:	0
Number of Priorty Eutrophication Lakes:	6
Number of Priorty Chloride Lakes:	7

Lab Analysis Budget				
Parameter	**Unit Cost**	**Jnit Quantit**	**Jnit Measur**	**Total Cost**
Routine Analysis				
Total Phosphorus (euphotic zone)	$ 29.15	14	each	$ 408.10
Chlorophyll-A (euphotic zone)	$ 60.50	14	each	$ 847.00
Chloride (1m off bottom) - Priority Chloride Lakes	$ 17.60	7	each	$ 123.20
QAQC Samples (assuming 10% of samples)	$ 89.65	4	each	$ 385.50
Supplemental Analysis (if triggered)				
Chloride (1m off bottom) - assuming 10% os Class A lakes get triggered	$ 17.60	2	each	$ 35.20
*Total phosphorus (1m off bottom - **end of summer only**)*	$ 29.15	6	each	$ 174.90
Total				**$ 1,973.90**

Lake Type	Watersheds	Lakes	Lakes/Day	Working Days
Class A Lakes: HRM		8	2	4
Class B Lakes: HRM		0	-	-
Class A Lakes: Community Groups		6	1	6
Class B Lakes: Community Groups		0	-	-
Total		14	-	**10**

Personnel Costing	Daily Rate		Working Day	Personnel Costs
Seasonal Costs				
Sampling Technician (Half of salary costs of a 4 month term)	$ 136.00		40	$ 5,440.00
Total				**$ 5,440.00**

Expenses	Unit Cost	Unit Quantity	Unit Measure	Cost
Sampling Related - HRM				
Truck Rental and Gas	$ 100.00	4	days	$ 400.00
Boat Operation Expenses (fuel, etc.)	$ 50.00	4	days	$ 200.00
YSI Rental (1 Unit)	$ 75.00	4	days	$ 300.00
Consumables (gloves, etc)	$ 10.00	4	days	$ 40.00
Variable Costs (per Community Groups involved				
Mileage	$ 50.00	6	Mileage per Group	$ 300.00
Equipment Kit - Per Group (secchi disc, gloves, sample cooler)	$ 25.00	6	Costs per Group	$ 150.00
YSI Rentals (2 Units)	$ 150.00	6	Costs per Group	$ 900.00
Total				**$ 2,290.00**

Table F-2: Framework 1 - Class A & B Lakes to be Sampled (once every 2 years)

Note: each watershed is represented by a different coloured cell

Framework 1 - YEAR 1					
List of "A Lakes" to be sampled: SPRING + SUMMER					
Watershed	**Lake Name**	**Priority Eutrophication Lake**	**Priority Chloride Lake**	**Sampled by: Community Group**	**Sampled by: HRM**
1EJ-5	Ash				✓
1EJ-5	Kearney			✓	
1EJ-2	Banook	✓	✓	✓	
1EJ-2	Maynard				✓
1EJ-1	Bell	✓			✓
LC-2	Charles	✓		✓	
1EJ-P	Chocolate		✓		✓
1EJ-6	Kidston				✓
1EJ-13	Five Island			✓	
1EK-2	McQuade				✓
GL-1	Springfield			✓	
1EJ-AL	Albro	✓	✓		✓
FL-1	Fletchers			✓	
TOTAL "A LAKES" (SPRING+SUMMER)		**4**	**3**	**6**	**7**
List of "B Lakes" to be sampled: SPRING ONLY					
Watershed	**Lake Name**	**Priority Eutrophication Lake**	**Priority Chloride Lake**	**Sampled by: Community Group**	**Sampled by: HRM**
1EJ-5	Quarry (Birch Cove)			✓	
1EJ-5	Susies (Birch Cove)			✓	
1EJ-1	Bissett	✓	✓		✓
1EJ-1	Lamont				✓
1EJ-6	Bayers				✓
1EJ-13	Albert Bridge Lake				✓
1EK-2	Scots				✓
1EJ-4	Little Springfield Lake	✓		✓	
GL-1	Barrett				✓
1EH-1	Big Cranberry				✓
1EH-2	McCabe				✓
1EK-4	Porters (North)				✓
1EK-4	Porters (Middle)				✓
1EK-4	Porters (South)				✓
LT-1	Miller			✓	
LW-1	First				✓
1EJ-10	Whites				✓
1EJ-3	Anderson				✓
1EJ-8	Moody				✓
1EJ-9	Hatchet				✓
1EK-3	Petpeswick			✓	
1EK-5	Echo			✓	
1EL-5	Charlotte			✓	
TOTAL "B LAKES" (SPRING ONLY)		**2**	**1**	**7**	**16**
TOTAL "A & B LAKES" (SPRING+SUMMER)		**6**	**4**	**13**	**23**

Note: Tables are organized and shaded by watershed grouping. Where possible, the schedule for sampling is spread out such that each watershed is sampled each year.

Framework 1 - YEAR 2					
List of "A Lakes" to be sampled: SPRING + SUMMER					
Watershed	**Lake Name**	**Priority Eutrophication Lake**	**Priority Chloride Lake**	**Sampled by: Community Group**	**Sampled by: HRM**
1EJ-5	Paper Mill	✓			✓
1EJ-2	Oathill		✓	✓	
1EJ-2	Penhorn		✓		✓
1EJ-2	MicMac	✓	✓	✓	
1EJ-1	Morris		✓	✓	
1EJ-1	Russell	✓		✓	
1EJ-1	Settle		✓		✓

Table F-2: Framework 1 - Class A B Lakes to be Sampled (once every 2 years)

Watershed	Lake Name	Priority Eutrophication Lake	Priority Chloride Lake	Sampled by: Community Group	Sampled by: HRM
1EJ-1	Topsail				✓
LC-2	Cranberry	✓	✓		✓
LC-2	Loon				✓
1EJ-P	Governors	✓	✓		✓
1EJ-P	Williams (Spryfield)			✓	
1EJ-6	Long Pond				✓
1EJ-4	Sandy (Bedford)	✓		✓	
	TOTAL "A LAKES" (SPRING+SUMMER)	6	7	6	8
	List of "B Lakes" to be sampled: SPRING ONLY				
Watershed	Lake Name	Priority Eutrophication Lake	Priority Chloride Lake	Sampled by: Community Group	Sampled by: HRM
1EJ-6	First Chain				✓
1EJ-6	Long				✓
1EJ-13	Black Point				✓
1EJ-13	Hubley Big			✓	
1EJ-13	Sheldrake				✓
1EJ-4	Sandy (Glen Arbour)	✓			✓
GL-1	Beaver Bank				✓
GL-1	Beaver Pond				✓
GL-1	Brand				✓
GL-1	Fenerty	✓			✓
GL-1	Kinsac				✓
GL-1	Shubenacadie Grand			✓	
GL-1	Tucker				✓
1EH-1	Elbow				✓
1EH-1	Stillwater				✓
1EH-2	Mill				✓
1EH-2	Wrights			✓	
LT-1	Thomas (North Basin)				✓
LT-1	Thomas (South Basin)				✓
LW-1	Powder Mill				✓
LW-1	Second				✓
LW-1	William				✓
LW-1	Rocky (North East Basin)				✓
LW-1	Third				✓
	TOTAL "B LAKES" (SPRING ONLY)	2	0	3	21
	TOTAL "A & B LAKES" (SPRING+SUMMER)	8	7	9	29

Note: Tables are organized and shaded by watershed grouping. Where possible, the schedule for sampling is spread out such that each watershed is sampled each year.

Community Groups Considered for Community Participation

Banook Area Residents' Association
Eastern Shore Group
Five Island Lake Estates Homeowners' Association
Friends of Blue Mountain - Birch Cove Lakes
Hubley Area Community Group
Lake Charles Community Group
Lake MicMac Residents Association
Oathill Lake Conservation Society
Portland Hills and Estates Residents Association
Sandy Lake Conservation Association
Springfield Lake Group
Shubenacadie Watershed Enviromental
Westwood Hills Residents Association
Williams Lake Conservation Company

Table F-3: Framework 2 - Coordinated Regional and Community Focused Monitoring (Annual)

Priority Eutrophication Lakes
Priority Chloride Enrichment Lakes

Total Priority Eutrophication Lakes: 14
Total Priority Chloride Lakes: 11
Total lakes: 19

Both HRM and Community Focued Groups will complete the monitoring for Framework 2. Priority lakes are sampled annually, with an equal division of Eutrophication and Chloride lakes from across all watersheds. This results in the following sampling schedule:

SPRING:	SUMMER:
Total Priority Eutrophication Lakes: 14	Total Priority Eutrophication Lakes: 10
Total Priority Chloride Lakes: 11	Total Priority Chloride Lakes: 10

Number of Lakes HRM will sample:	Number of Lakes Community Groups will sample:
Year 1 - Spring: 11	Year 1 - Spring: 8
Year 1 - Summer: 8	Year 1 - Summer: 7

Overview of Estimated Costs - Framework 2

PROGRAM START UP		
Start Up Costs	$	21,750

TOTAL PROGRAM COST - ANNUAL		
Spring Sampling - Personnel, Expenses & Laboratory Costs	$	11,044
Summer Sampling - Personnel, Expenses & Laboratory Costs	$	9,908
Full Time Salary Costs[1]	$	85,000
Ongoing Costs	$	9,500
Grant Program	$	5,000
Consulting and Research	$	30,000
Total Cost	**$**	**150,452**

Note: Salary costs does not include overhead burden

Detailed Breakdown - Framework 2 Costing

Operational Costs		
Start up Costs		
Boat, Trailer, Motor	$	7,500
Licensing & Registration	$	750
Data Management Software (Cloud based)	$	10,000
Equipment Kits for Community Groups ($250 * 14)	$	3,500
Start up Subtotal	**$**	**21,750**
Full Time Staff Salary (Annual)		
Program Manager	$	85,000
Total Labour Costs	**$**	**85,000**

Ongoing Costs		
Boat Inspection and Maintenance	$	1,000
Data Management Licensing	$	2,500
Insurance	$	4,000
Equipment Kits and Supplies for Community Groups	$	1,000
Health and Safety Training - Staff	$	1,000
Ongoing Subtotal	**$**	**9,500**
Other		
Limnological Consulting Services	$	20,000
Grant Program for Community Groups	$	5,000
Set-Aside for Collaborations with Academia	$	10,000
Other Subtotal	**$**	**30,000**

Seasonal Cost Estimate Summary	
SPRING	
Will sample the following:	
Class A Lakes:	15
Class B Lakes:	4
Number of Priorty Eutrophication Lakes:	14
Number of Priorty Chloride Lakes:	11

Lab Analysis Budget						
Parameter		**Unit Cost**	**Unit Quantity**	**Jnit Measur**		**Total Cost**
Routine Analysis						
Total Phosphorus (euphotic zone)	$	29.15	19	each	$	553.85
Chlorophyll-A (euphotic zone)	$	60.50	19	each	$	1,149.50
Chloride (1m off bottom) - Priority Chloride Lakes	$	17.60	11	each	$	193.60
QAQC Samples (assuming 10% of samples)	$	89.65	5	each	$	452.73
Supplemental Analysis (if triggered)						
Chloride (1m off bottom) - assuming 10% of Class A	$	17.60	2	each	$	26.40
*Total phosphorus (1m off bottom - **end of summer***	$	29.15	0	each	$	-
Total					**$**	**2,376.08**

Lake Type	Watersheds	Lakes	Lakes/Day	Working Days
Total Priority Lakes: HRM		11	2	6
Total Priority Lakes: Community Groups		8	1	8
Total		19	-	**14**

Personnel Costing		Daily Rate		Working Day		Personnel Costs
Seasonal Costs						
Sampling Technician (Half of salary costs of a 4 mo	$	136.00		40	$	5,440.00
Total					**$**	**5,440.00**

Expenses		Unit Cost	Unit Quantity	Unit Measure		Cost
Sampling Related - HRM						
Truck Rental and Gas	$	100.00	6	days	$	550.00
Boat Operation Expenses (fuel, etc.)	$	50.00	6	days	$	275.00
YSI Rental (1 Unit)	$	75.00	6	days	$	412.50
Secchi Disk (purchased)	$	135.00	1	lump sum	$	135.00
Consumables (gloves, etc)	$	10.00	6	days	$	55.00

Variable Costs (per Community Groups involved)						
Mileage (HRM costs for sample pick up, etc)	$	50.00	8	Mileage per Group	$	400.00
Equipment for community groups, consumables	$	25.00	8	Costs per Group	$	200.00
YSI Rentals (2 Units)	$	150.00	8	Costs per Group	$	1,200.00
Total						**$3,227.50**
SUMMER						
Will sample the following:						
Class A Lakes:	15					
Class B Lakes:	0					
Number of Priorty Eutrophication Lakes:	10					
Number of Priorty Chloride Lakes:	10					

	Lab Analysis Budget					
Parameter		**Unit Cost**	**Unit Quantity**	**Jnit Measur**		**Total Cost**
	Routine Analysis					
Total Phosphorus (euphotic zone)	$	29.15	15	each	$	437.25
Chlorophyll-A (euphotic zone)	$	60.50	10	each	$	605.00
Chloride (1m off bottom) - Priority Chloride Lakes	$	17.60	10	each	$	176.00
QAQC Samples (assuming 10% of samples)	$	89.65	5	each	$	416.87
	Supplemental Analysis (if triggered)					
Chloride (1m off bottom) - assuming 10% of Class A	$	17.60	2	each	$	26.40
*Total phosphorus (1m off bottom - **end of summer***	$	29.15	10	each	$	291.50
Total					**$**	**1,953.02**

Lake Type	**Watersheds**	**Lakes**	**Lakes/Day**	**Working Days**
Total Priority Lakes: HRM		8	2	4
Total Priority Lakes: Community Groups		7	1	7
Total		15	-	**11**

Personnel Costing		**Daily Rate**		**Working Day**		**Personnel Costs**
Seasonal Costs						
Sampling Technician (Half of salary costs of a 4 mo	$	136.00		40	$	5,440.00
Total					**$**	**5,440.00**

Expenses		**Unit Cost**	**Unit Quantity**	**Unit**		**Cost**
Sampling Related - HRM						
Truck Rental and Gas	$	100.00	4	days	$	400.00
Boat Operation Expenses (fuel, etc.)	$	50.00	4	days	$	200.00
YSI Rental (1 Unit)	$	75.00	4	days	$	300.00
Consumables (gloves, etc)	$	10.00	4	days	$	40.00
Variable Costs (per Community Groups involved)						
Mileage (HRM costs for sample pick up, etc)	$	50.00	7	Mileage per Group	$	350.00
Equipment for community groups, consumables	$	25.00	7	Costs per Group	$	175.00
YSI Rentals (2 Units)	$	150.00	7	Costs per Group	$	1,050.00
Total						**$2,515.00**

Table F-4: Framework 2 - Priority Lakes to be Sampled (annually)

Note: each watershed is represented by a different coloured cell

Framework 2					
List of "A Lakes" to be sampled: SPRING + SUMMER					
Watershed	**Lake Name**	**Priority Eutrophication Lake**	**Priority Chloride Lake**	**Sampled by: Community Group**	**Sampled by: HRM**
1EJ-5	Paper Mill	✓			✓
1EJ-2	Banook	✓	✓	✓	
1EJ-2	Oathill		✓	✓	
1EJ-2	Penhorn		✓		✓
1EJ-2	MicMac	✓	✓	✓	
1EJ-1	Bell	✓			✓
1EJ-1	Morris		✓	✓	
1EJ-1	Russell	✓		✓	
1EJ-1	Settle		✓		✓
LC-2	Charles	✓		✓	
LC-2	Cranberry	✓	✓		✓
1EJ-P	Chocolate		✓		✓
1EJ-P	Governors	✓	✓		✓
1EJ-AL	Albro	✓	✓		✓
1EJ-4	Sandy (Bedford)	✓		✓	
TOTAL "A LAKES" (SPRING+SUMMER)		**10**	**10**	**7**	**8**
List of "B Lakes" to be sampled: SPRING ONLY					
Watershed	**Lake Name**	**Priority Eutrophication Lake**	**Priority Chloride Lake**	**Sampled by: Community Group**	**Sampled by: HRM**
1EJ-1	Bissett	✓	✓		✓
1EJ-4	Little Springfield Lake	✓		✓	
1EJ-4	Sandy (Glen Arbour)	✓			✓
GL-1	Fenerty	✓			✓
TOTAL "B LAKES" (SPRING ONLY)		**4**	**1**	**1**	**3**
TOTAL "A & B LAKES" (SPRING+SUMMER)		**14**	**11**	**8**	**11**

Note: Tables are organized and shaded by watershed grouping. Where possible, the schedule for sampling is spread out such that each watershed is sampled each year.

Community Groups Considered for Community Participation

Banook Area Residents' Association
Friends of Blue Mountain - Birch Cove Lakes
Lake Charles Community Group
Lake MicMac Residents Association
Oathill Lake Conservation Society
Portland Hills and Estates Residents Association
Sandy Lake Conservation Association
Springfield Lake Group
Shubenacadie Watershed Enviromental

Table F-5: Framework 3 - HRM Focused Monitoring

Class A Lakes (Spring and Summer)
Class B Lakes (Spring Only)
Reference Lakes

Total Highly Vulnerable "A" Lakes: 27
Total Moderately Vulnerable "B" Lakes: 48
Total lakes: 74

HRM will be completing the sampling for Framework 3. Sampling approach involves dividing the total number of lakes equally between Year 1 and Year 2, as well as equal division of Class A and Class B lakes from across all watersheds. This results in the following sampling schedule:

Year 1 - SPRING:	Year 2 - SPRING:	Year 1 SUMMER:	Year 2 - SUMMER:
Total A Lakes: 13	Total A Lakes: 14	Total A Lakes: 13	Total A Lakes: 14
Total B Lakes: 24	Total B Lakes: 24	Total B Lakes: 0	Total B Lakes: 0

Overview of Estimated Costs - Framework 3

PROGRAM START UP		
Start Up Costs	$	18,250

TOTAL PROGRAM COST - YEAR 1		
Year 1 - Spring Sampling - Personnel, Expenses & Laboratory Costs	$	13,837
Year 1 - Summer Sampling - Personnel, Expenses & Laboratory Costs	$	8,651
Full Time Salary Costs[1]	$	133,000
Ongoing Costs	$	8,500
Grant Program	$	7,500
Consulting and Research	$	50,000
Total Cost	**$**	**221,489**

TOTAL PROGRAM COST - YEAR 2		
Year 2 - Spring Sampling - Personnel, Expenses & Laboratory Costs		#REF!
Year 2 - Summer Sampling - Personnel, Expenses & Laboratory Costs	$	9,059
Full Time Salary Costs[1]	$	133,000
Ongoing Costs	$	8,500
Grant Program	$	7,500
Consulting and Research	$	75,000
Total Cost		**#REF!**

Note: Salary costs does not include overhead burden

Details for Framework 3 Costing

Operational Costs		
Start up Costs		
Boat, Trailer, Motor	$	7,500
Licensing & Registration	$	750
Data Management Software (Cloud based)	$	10,000
Start up Subtotal	**$**	**18,250**
Full Time Staff Salary (Annual)		
Program Manager	$	85,000
Program Assistant	$	48,000
Total Labour Costs	**$**	**133,000**

Ongoing Costs		
Boat Inspection and Maintenance	$	1,000
Data Management Licensing	$	2,500
Insurance	$	4,000
Health and Safety Training - Staff	$	1,000
Ongoing Subtotal	**$**	**8,500**

Other		
Limnological Consulting Services	$	30,000
Grant Program for Community Groups	$	7,500
Set-Aside for Collaborations with Academia	$	20,000
Other Subtotal	**$**	**50,000**

Seasonal Cost Estimate Summary	
YEAR 1 - SPRING	
Will sample the following:	
Class A Lakes:	13
Class B Lakes:	23
Number of Priorty Eutrophication Lakes:	6
Number of Priorty Chloride Lakes:	4

Lab Analysis Budget						
Parameter		**Unit Cost**	**Unit Quantity**	**Jnit Measur**		**Total Cost**
Routine Analysis						
Total Phosphorus (euphotic zone)	$	29.15	36	each	$	1,049.40
Chlorophyll-A (euphotic zone)	$	60.50	36	each	$	2,178.00
Chloride (1m off bottom) - Priority Chloride Lakes (assumed)	$	17.60	4	each	$	70.40
QAQC Samples (assuming 10% of samples)	$	89.65	8	each	$	699.27
Supplemental Analysis (if triggered)						
Chloride (1m off bottom) - assuming 10% of Class A lakes get	$	17.60	2	each	$	35.20
*Total phosphorus (1m off bottom - **end of summer only**)*	$	29.15	0	each	$	-
Total					**$**	**4,032.27**

Lake Type	Watersheds	Lakes	Lakes/Day	Working Days
Class A Lakes		13	2	6.5
Class B Lakes		23	2	11.5
Total		36	2	**18**

Personnel Costing		Daily Rate		Working Day		Personnel Costs
Seasonal Costs						
Sampling Technician (Half of salary costs of a 4 month term)	$	136.00		40	$	5,440.00
Total					**$**	**5,440.00**

Expenses		**Unit Cost**	**Unit Quantity**	**Unit Measure**		**Cost**
Sampling Related - HRM						
Truck Rental and Gas	$	100.00	18	days	$	1,800.00
Boat Operation Expenses (fuel, etc.)	$	50.00	18	days	$	900.00
YSI Rental	$	75.00	18	days	$	1,350.00
Secchi Disk (purchased)	$	135.00	1	lump sum	$	135.00
Consumables (gloves, etc)	$	10.00	18	days	$	180.00
Total					**$**	**4,365.00**

YEAR 1 - SUMMER	
Will sample the following:	
Class A Lakes:	13
Class B Lakes:	0
Number of Priorty Eutrophication Lakes:	4
Number of Priorty Chloride Lakes:	3

Lab Analysis Budget				
Parameter	**Unit Cost**	**Unit Quantity**	**Jnit Measur**	**Total Cost**
Routine Analysis				
Total Phosphorus (euphotic zone)	$ 29.15	13	each	$ 378.95
Chlorophyll-A (euphotic zone)	$ 60.50	13	each	$ 786.50
Chloride (1m off bottom) - Priority Chloride Lakes	$ 17.60	3	each	$ 52.80
QAQC Samples (assuming 10% of samples)	$ 89.65	4	each	$ 313.78
Supplemental Analysis (if triggered)				
Chloride (1m off bottom) - assuming 10% os Class A lakes get	$ 17.60	2	each	$ 35.20
*Total phosphorus (1m off bottom - **end of summer only**)*	$ 29.15	4	each	$ 116.60
Total				**$ 1,683.83**

Lake Type	Watersheds	Lakes	Lakes/Day	Working Days
Class A Lakes		13	2	6.5
Class B Lakes		0	0	0
Total		13	2	**7**

Personnel Costing	Daily Rate		Working Day	Personnel Costs
Seasonal				
Sampling Technician (Half of salary costs of a 4 month term)	$ 136.00		40	$ 5,440.00
Total				**$ 5,440.00**

Expenses	Unit Cost	Unit Quantity	Unit Measure	Cost
Sampling Related - HRM				
Truck Rental and Gas	$ 100.00	7	days	$ 650.00
Boat Operation Expenses (fuel, etc.)	$ 50.00	7	days	$ 325.00
YSI Rental	$ 75.00	7	days	$ 487.50
Consumables (gloves, etc)	$ 10.00	7	days	$ 65.00
Total				**$ 1,527.50**

YEAR 2 - SPRING	
Will sample the following:	
Class A Lakes:	14
Class B Lakes:	24
Number of Priorty Eutrophication Lakes:	8
Number of Priorty Chloride Lakes:	7

Lab Analysis Budget				
Parameter	**Unit Cost**	**Unit Quantity**	**Jnit Measur**	**Total Cost**
Routine Analysis				
Total Phosphorus (euphotic zone)	$ 29.15	38	each	$ 1,107.70
Chlorophyll-A (euphotic zone)	$ 60.50	38	each	$ 2,299.00
Chloride (1m off bottom) - Priority Chloride Lakes	$ 17.60	7	each	$ 123.20
QAQC Samples (assuming 10% of samples)	$ 89.65	9	each	$ 770.99

Supplemental Analysis (if triggered)							
Chloride (1m off bottom) - assuming 10% of Class A lakes get	$	17.60	2	each	$	35.20
Total phosphorus (1m off bottom - end of summer only)	$	89.65	1	each	$	89.65
Total					**$**	**4,425.74**

Lake Type	Watersheds	Lakes	Lakes/Day	Working Days
Class A Lakes		14	2	7
Class B Lakes		24	2	12
Total		38	2	**19**

Personnel Costing	Daily Rate		Working Day	Personnel Costs
Seasonal Costs				
Sampling Technician (Half of salary costs of a 4 month term)	$ 136.00		40	$ 5,440.00
Total				**$ 5,440.00**

Expenses	Unit Cost	Unit Quantity	Unit Measure	Cost
Sampling Related - HRM				
Truck Rental and Gas	$ 100.00	19	days	$ 1,900.00
Boat Operation Expenses (fuel, etc.)	$ 50.00	19	days	$ 950.00
YSI Rental	$ 75.00	19	days	$ 1,425.00
Consumables (gloves, etc)	$ 10.00	19	days	$ 190.00
Total				**$ 4,465.00**

YEAR 2 - SUMMER	
Will sample the following:	
Class A Lakes:	14
Class B Lakes:	0
Number of Priorty Eutrophication Lakes:	6
Number of Priorty Chloride Lakes:	7

Lab Analysis Budget				
Parameter	**Unit Cost**	**Unit Quantity**	**Jnit Measur**	**Total Cost**
Routine Analysis				
Total Phosphorus (euphotic zone)	$ 29.15	14	each	$ 408.10
Chlorophyll-A (euphotic zone)	$ 60.50	14	each	$ 847.00
Chloride (1m off bottom) - Priority Chloride Lakes	$ 17.60	7	each	$ 123.20
QAQC Samples (assuming 10% of samples)	$ 89.65	4	each	$ 385.50
Supplemental Analysis (if triggered)				
Chloride (1m off bottom) - assuming 10% os Class A lakes get	$ 17.60	2	each	$ 35.20
*Total phosphorus (1m off bottom - **end of summer only**)*	$ 29.15	6	each	$ 174.90
Total				**$ 1,973.90**

Lake Type	Watersheds	Lakes	Lakes/Day	Working Days
Class A Lakes		14	2	7
Class B Lakes		0	0	0
Total		14	2	**7**

Personnel Costing	Daily Rate		Working Day	Personnel Costs
Seasonal Costs				
Sampling Technician (Half of salary costs of a 4 month term)	$ 136.00		40	$ 5,440.00
Total				**$ 5,440.00**

Expenses	Unit Cost	Unit Quantity	Unit Measure	Cost
Sampling Related - HRM				
Truck Rental and Gas	$ 100.00	7	days	$ 700.00
Boat Operation Expenses (fuel, etc.)	$ 50.00	7	days	$ 350.00
YSI Rental	$ 75.00	7	days	$ 525.00
Consumables (gloves, etc)	$ 10.00	7	days	$ 70.00
Total				**$ 1,645.00**

Table F-6: Framework 3 - Class A & B Lakes to be Sampled (once every 2 years)

Note: each watershed is represented by a different coloured cell

Framework 3 - YEAR 1				
List of "A Lakes" to be sampled: SPRING + SUMMER				
Watershed	**Lake Name**	**Priority Eutrophication Lake**	**Priority Chloride Lake**	**Sampled by: HRM**
1EJ-5	Ash			✓
1EJ-5	Kearney			✓
1EJ-2	Banook	✓	✓	✓
1EJ-2	Maynard			✓
1EJ-1	Bell	✓		✓
LC-2	Charles	✓		✓
1EJ-P	Chocolate		✓	✓
1EJ-6	Kidston			✓
1EJ-13	Five Island			✓
1EK-2	McQuade			✓
GL-1	Springfield			✓
1EJ-AL	Albro	✓	✓	✓
FL-1	Fletchers			✓
	TOTAL "A LAKES" (SPRING+SUMMER)	**4**	**3**	**13**
List of "B Lakes" to be sampled: SPRING ONLY				
Watershed	**Lake Name**	**Priority Eutrophication Lake**	**Priority Chloride Lake**	**Sampled by: HRM**
1EJ-5	Quarry (Birch Cove)			✓
1EJ-5	Susies (Birch Cove)			✓
1EJ-1	Bissett	✓	✓	✓
1EJ-1	Lamont			✓
1EJ-6	Bayers			✓
1EJ-13	Albert Bridge Lake			✓
1EK-2	Scots			✓
1EJ-4	Little Springfield Lake	✓		✓
GL-1	Barrett			✓
1EH-1	Big Cranberry			✓
1EH-2	McCabe			✓
1EK-4	Porters (North)			✓
1EK-4	Porters (Middle)			✓
1EK-4	Porters (South)			✓
LT-1	Miller			✓
LW-1	First			✓

1EJ-10	Whites			✓
1EJ-3	Anderson			✓
1EJ-8	Moody			✓
1EJ-9	Hatchet			✓
1EK-3	Petpeswick			✓
1EK-5	Echo			✓
1EL-5	Charlotte			✓
	TOTAL "B LAKES" (SPRING ONLY)	**2**	**1**	**23**
	TOTAL "A & B LAKES" (SPRING+SUMMER)	**6**	**4**	**36**

Note: Tables are organized and shaded by watershed grouping. Where possible, the schedule for sampling is spread out such that each watershed is sampled each year.

Framework 3 - YEAR 2

List of "A Lakes" to be sampled: SPRING + SUMMER				
Watershed	**Lake Name**	**Priority Eutrophication Lake**	**Priority Chloride Lake**	**Sampled by: HRM**
1EJ-5	Paper Mill	✓		✓
1EJ-2	Oathill		✓	✓
1EJ-2	Penhorn		✓	✓
1EJ-2	MicMac	✓	✓	✓
1EJ-1	Morris		✓	✓
1EJ-1	Russell	✓		✓
1EJ-1	Settle		✓	✓
1EJ-1	Topsail			✓
LC-2	Cranberry	✓	✓	✓
LC-2	Loon			✓
1EJ-P	Governors	✓	✓	✓
1EJ-P	Williams (Spryfield)			✓
1EJ-6	Long Pond			✓
1EJ-4	Sandy (Bedford)	✓		✓
	TOTAL "A LAKES" (SPRING+SUMMER)	**6**	**7**	**14**

List of "B Lakes" to be sampled: SPRING ONLY				
Watershed	**Lake Name**	**Priority Eutrophication Lake**	**Priority Chloride Lake**	**Sampled by: HRM**
1EJ-6	First Chain			✓
1EJ-6	Long			✓
1EJ-13	Black Point			✓
1EJ-13	Hubley Big			✓
1EJ-13	Sheldrake			✓
1EJ-4	Sandy (Glen Arbour)	✓		✓
GL-1	Beaver Bank			✓
GL-1	Beaver Pond			✓

Table F-6: Framework 3 - Class A B Lakes to be Sampled (once every 2 years)

Watershed	Lake Name	Priority Eutrophication Lake	Priority Chloride Lake	Sampled by: HRM
GL-1	Brand			✓
GL-1	Fenerty	✓		✓
GL-1	Kinsac			✓
GL-1	Shubenacadie Grand			✓
GL-1	Tucker			✓
1EH-1	Elbow			✓
1EH-1	Stillwater			✓
1EH-2	Mill			✓
1EH-2	Wrights			✓
LT-1	Thomas (North Basin)			✓
LT-1	Thomas (South Basin)			✓
LW-1	Powder Mill			✓
LW-1	Second			✓
LW-1	William			✓
LW-1	Rocky (North East Basin)			✓
LW-1	Third			✓
TOTAL "B LAKES" (SPRING ONLY)		**2**	**0**	**24**
TOTAL "A & B LAKES" (SPRING+SUMMER)		**8**	**7**	**38**

Note: Tables are organized and shaded by watershed grouping. Where possible, the schedule for sampling is spread out such that each watershed is sampled each year.

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