Hutchinson

Environmental Sciences Ltd.

Peninsula Lake Algae Bloom Causation Study

Prepared for: The District of Muskoka
Job #: J190080

August 11, 2020

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The District Municipality of Muskoka
70 Pine Street, Bracebridge, ON
P1L 1N3

Re: Peninsula Lake Causation Study - Final Report

We are pleased to offer this final report of our investigations into the potential cause(s) of the 2017 cyanobacterial bloom in Peninsula Lake to the District Municipality of Muskoka. This final report builds on comments on earlier drafts from District staff and from our meeting of June 16, 2020.

Our research included a detailed examination of the factors promoting algal blooms, with particular focus on *Gloeotrichia echinulata*, the bloom-forming species of concern in Peninsula Lake, followed by an assessment of causative factors that may have influenced bloom formation in Peninsula Lake. We note that it is very difficult to determine causation based on occasional bloom events, especially in lakes that are nutrient poor. Most literature and case studies of blooms addresses eutrophic lakes with repeated and consistent blooms.

Peninsula Lake is an oligotrophic lake with no evidence of long-term changes over time in nutrients or dissolved oxygen. Furthermore, *Gloeotrichia echinulata*, the algal species of concern, draws its nutrients from lake sediments and not from the water column and so waterborne nutrient levels provide little insight into bloom causation. Evidence gathered suggests that the bloom experienced in 2017 was likely triggered by climate conditions - specifically a period of hot and calm weather which created conditions that favour the proliferation of cyanobacterial species. There is some evidence that runoff of sediments into the lake may have pre-disposed it to blooms in 1993 and we note that the lake has a disproportionate potential input of nutrients from runoff from developed lands. Although there is no evidence that this was a direct factor in 2017, sediment enrichment by runoff over the long term could favour *Gloeotrichia echinulata* blooms.

Peninsula Lake has been well studied since the 1990s when the first cyanobacterial blooms occurred in 1993 and 1994. We have developed recommendations for future causation studies and for the ongoing monitoring of Peninsula Lake.

Please do not hesitate to contact myself (519-576-1711 ext. 304) or Neil Hutchinson (705-645-0021 ext. 100) if you have any questions or concerns.

Sincerely,
Hutchinson Environmental Sciences Ltd.
Kris Hadley, Ph.D.
kris.hadley@environmentalsciences.ca

Signatures

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Executive Summary

Hutchinson Environmental Sciences Ltd. (HESL) was retained by The District Municipality of Muskoka (the District) to prepare a causation study report for Peninsula Lake in response to a recent (2017) cyanobacterial bloom. The "Peninsula Lake Pilot Causation Study" was designed to assess long-term data collected on water quality, climate and algal history in the lake, incorporating data collected by the District, stakeholders and Ministry of the Environment, Conservation and Parks (MECP), to interpret the available data and to determine, if possible, the cause of the bloom and the potential that shoreline or watershed development contributed to the bloom and what additional studies might be warranted. Should development be a contributing cause to the bloom, policy recommendations could be explored.

Causation studies are part of a new approach to the protection of water quality recommended in the Revised Water Quality Model and Lake System Health Program report dated April 2016 undertaken by HESL (HESL, 2016) and implemented through recent updates to the Muskoka Official Plan (MOP, 2019) approved by the Province in June of 2019. Under the revised policies, all lakes are afforded a high level of protection by ensuring development occurs in a manner that does not negatively impact water quality. A subset of lakes is identified as potentially more vulnerable based on a set of indicators derived from the District's long-standing annual water sampling program. Lakes are considered vulnerable and listed on Schedule E2 of the MOP, 2019 if indicators are met for three consecutive years or if an algae bloom is confirmed in any year. A waterbody-wide causation study is then undertaken to determine the cause(s) of and/or relative contributing factors to the water quality indicator for waterbodies listed in Schedule E2

Previous algal blooms on Peninsula Lake, consisting of *Gloeotrichia* and *Anabaena* species of cyanobacteria, were observed in the 1990's and more recently in 2017 and a causation study initiated in 2019

. The general causation study process consisted of:

- Assessing the existing water quality conditions in the lake;
- Quantifying annual and seasonal trends in water quality and/or algal communities;
- Where possible, providing a historical perspective on water quality and/or algal abundances;
- Modelling and quantifying the relative contributions of sources of nutrients to the lake, including phosphorus from natural sources, human sources and internal loading from sediments;
- Determining if water quality is deteriorating and/or algal composition/communities are changing relative to previous years; and
- Attributing a specific cause or contributing factors to the water quality indicator, where possible..

This Causation Study was considered as a Pilot Study by the District of Muskoka and was intended to a) determine relative contributing causes for the observed blooms in Peninsula Lake and b) develop a procedure to guide future causation studies. The study included development of a weight of evidence approach for Peninsula Lake which was based on the factors known to lead to the proliferation of algae and cyanobacteria and which can be compared to the specific evidence for any lake to determine potential causation. It is submitted to guide future causation studies for vulnerable lakes.

The algal species *Gloeotrichia echinulata* was the dominant bloom forming algae in 2017, as it was in previous blooms in 1993 and 1994 and information from those blooms was used where it was available. It has a complex life cycle which allows it to thrive in low nutrient systems such as Peninsula Lake. Causal factors believed to control the germination and recruitment of *Gloeotrichia echinulata* include sediment phosphorus, water clarity (i.e. light), water temperature, and the size of the akinete seed bank in lake sediments. Many of these drivers are still being actively researched as the specific mechanisms are not necessarily well understood, particularly in oligotrophic lakes; however, a literature review presented some important conclusions for the ongoing management effort in Peninsula Lake. Most importantly, the existing scientific body of literature suggests that conventional efforts to limit blooms by controlling nutrient concentrations in the water column are unlikely to significantly impact *Gloeotrichia* blooms.

Multiple lines of evidence were considered based on the data provided by the MECP, DMM, stakeholders and our own field collections under three broad categories:

1. Climate History

    a. There was a period of marked increase in air temperature at the Harp Lake Meteorological Station in September of 2017 prior to the cyanobacterial bloom. Elevated air temperature (above the long-term average) was apparent in August and September of 1993 and 1994 as well. However, the durations and magnitude were not as striking as in 2017;

    b. Local climate data showed a substantial, sustained decline in wind speed which pre-dated the algae bloom in 2017 and below-average wind speed in 1993 and 1994, coupled with a general trend of reduced wind speed in Muskoka;

    c. Periods of sustained low wind speed and high air temperature were documented in all three known bloom years, from September 13-27th in 2017, from August 11-20 and 25-27th in 1993 and from September 12-16, 20-21 and 23-26th in 1994; and

    d. The potential for overland runoff is increased in more severe rainfall events, such as is predicted for a changing climate. Overland runoff from developed areas represents a significant contribution to the phosphorus budget of Peninsula Lake, and particularly of particulate sediment phosphorus and may help to predispose the lake to *Gloeotrichia echinulata* blooms by increasing the availability of sediment phosphorus.

2. Water Chemistry History

    a. There have been no significant long-term changes in total phosphorus concentrations in the lake over time, any increase specific to 2017, nor any abnormalities in water quality that could explain the blooms;

    b. There is a potential for periodic hypolimnetic anoxia in the East Basin of the lake but only minor increases in total phosphorus in the deep water of the East Basin (7 to 15 μg/L) were observed in August 2019 which did not suggest internal phosphorus loading as a factor; and

c. Low concentrations of deep-water oxygen (<2.0 mg/L) were noted in 11 years from 1990 to 2019 but low oxygen did not correlate with the occurrences of algae blooms in the lake.

3. Algae/Cyanobacteria Bloom History

a. Three blooms have been documented in Peninsula Lake, 1993, 1994 and 2017. The blooms in 1993 and 1994 were preceded by several years in which substantial amounts of sediment were added to the lake.

b. The location, extent and duration of the 1993 and 1994 blooms was difficult to reliably ascertain, but evidence was more complete from the 2017 bloom;

c. Information available in 2017 did not suggest a localized bloom but rather that the bloom occurred lake-wide, beginning in the nearshore as would be expected of *Gloeotrichia echinulata,*

d. Timing of the 2017 algal bloom was found to coincide with several key climate parameters (e.g., high temperatures, and low winds) known to a) trigger the germination of *Gloeotrichia* resting akinetes, and/or b) sustain or enhance cyanobacterial growth and dominance These conditions were consistent with those observed during previous blooms.

Conclusions for Peninsula Lake

Based on the lines of evidence considered and our analysis of the available data, we concluded that the most likely cause of the 2017 bloom in Peninsula Lake was a combination of climate factors including a period of prolonged high air temperature and low wind speed, which created ideal conditions for cyanobacterial dominance and proliferation. Periods of sustained low wind and high temperature were noted in all three bloom years in either August or September. The lake may also be predisposed to *Gloeotrichia* blooms by inputs of sediments in runoff from developed lands, but the link was not conclusive.

Increased sediment phosphorus levels could predispose a lake to blooms such that management to reduce runoff and stormwater is an increasingly important activity. This is also true, however, in the absence of algal blooms, as runoff adds nutrients and other pollutants to receiving waters and should, as a general principle, be minimized. The DMM supports and encourages, and should therefore continue to support and encourage:

- stewardship and educational programs to improve shoreline buffers, reduce disturbance and use of fertilizers and products containing phosphorus, planting of native vegetation, etc.
- improved storm water management to reduce run-off from developed or disturbed areas,
- Continued annual sampling through the District's existing program, the Lake Partner Program, or other standardized systems.

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Appendices

1. Project Background

Hutchinson Environmental Sciences Ltd. (HESL), was retained by the District Municipality of Muskoka to prepare a causation study report for Peninsula Lake in response to a recent (2017) cyanobacterial bloom and the related Muskoka Official Plan policies adopted in June 2019. The "Peninsula Lake Pilot Causation Study" was designed to assess long-term data collected on water quality, climate and algal history in the lake, incorporating data collected by the District, stakeholders and Ministry of the Environment, Conservation and Parks (MECP) and to determine if clear causation of algal blooms could be confirmed in order to assist potential approaches for managing the recreational water quality of Peninsula Lake. It was also intended as a broad scale pilot study that could inform future causation studies.

Peninsula Lake is a large (8.7 km^2), deep (Z_{max} = 37 m), oligotrophic lake which receives inflow from several other waterbodies including Harp Lake, Jerry Lake and Walker Lake within the 62.4 km^2 watershed area. Previous algal blooms on the lake, consisting of *Gloeotrichia* and *Anabaena* species of cyanobacteria, were noted in the 1990's (Cornelisse and Evans 1999) and the 2017 bloom resulted in the listing of the lake as Schedule E2 under the Muskoka Official Plan (MOP, 2019). The MOP identifies a lake as vulnerable based on the following water quality indicators:

1. A long-term statistically significant ($p<0.1$) increasing trend in total phosphorus concentration demonstrated by at least five (5) spring overturn phosphorus measurements obtained through the District of Muskoka water quality sampling program since 2001;
2. A long-term total phosphorus concentration of greater than 20 µg/L demonstrated by the average of five (5) most recent spring overturn phosphorus measurements obtained through the District of Muskoka water quality sampling program within the last ten (10) years; and/or
3. A blue-green algal (cyanobacteria) bloom confirmed and documented by the Province and/or Health Unit.

Lakes are considered vulnerable and listed on Schedule E2 if indicators 1 or 2 are met for three consecutive years or if indicator 3 is confirmed in any year. The latter is the case for Peninsula Lake, which experienced a documented blue-green algal bloom in 2017. Peninsula Lake was selected by the District as the pilot study because:

- It experienced a recent algal bloom (2017),
- of the lakes listed on Schedule E2 of the MOP, 2019, it has the second highest development potential of lakes that have experienced algae blooms,
- there has been modest investment in water quality initiatives to date,
- the lake association is highly engaged, and
- the lake is large and located in two Area Municipalities with the potential to impact a wide variety of stakeholders.

A waterbody-wide causation study is undertaken to determine the cause(s) of and/or relative contributing factors to the water quality indicator for waterbodies listed in Schedule E2. The general causation study process consists of:

- Assessing the existing water quality conditions in the lake;
- Quantifying annual and seasonal trends in water quality and/or algal communities;

- Where possible, providing a historical perspective on water quality and/or algal abundances;
- Estimating the relative contributions of sources of nutrients to the lake, including phosphorus from sediments;
- Determining if water quality is deteriorating and/or algal composition/communities are changing relative to previous years; and
- Attributing a specific cause or contributing factors to the water quality indicator where possible.

Substantial data collection has already taken place to quantify lake health and inform ongoing management on Peninsula Lake. The District Municipality of Muskoka maintains two water quality sampling stations on the lake (east and west basin). In addition, samples are collected annually in Wolf Bay by volunteers as a part of the Lake Partner Program coordinated by the Ministry of the Environment, Conservation and Parks (MECP). In 2012, data collection was undertaken by the University of Waterloo at seven unique locations to assess phosphorus concentrations spatially across the lake (Figure 1).

There have been three documented cyanobacterial blooms in Peninsula Lake, in 1993, 1994 and in 2017. The location, extent and duration of the 1993 and 1994 blooms were difficult to reliably ascertain, but evidence was more complete from the 2017 bloom including aerial photos (from helicopter) of the lake surface during the bloom.

2. Methods

2.1 Overview

Our approach to the pilot causation study began with an understanding of the potential causes of blooms, including a review of the ecology of *Gloeotrichia* and how that may relate to Peninsula Lake and a review of information from a survey of lake residents to better understand the timing and spatial distribution of the 2017 bloom among other matters. This was followed by water sampling and interpretation of water quality data and assessment of our findings against a “weight of evidence” approach. The latter is considered particularly useful to a pilot causation study, as we documented the potential causes of cyanobacterial blooms in general and compared that to any evidence that specific causes applied to Peninsula Lake. The weight of evidence approach provides for a structured and repeatable approach to causation that can be usefully applied for future causation studies.

HESL gathered historical water quality data from a number of sources, including the District of Muskoka, Lake Partner Program, University of Waterloo, and MECP, and analyzed this data to characterize the water quality in the East and West Basins of Peninsula Lake and evaluate the presence of any trends. HESL sampled the lake on October 10, 2019 to characterise the late-summer algae community, hypolimnetic oxygen status, and deep lake water quality at representative locations shown in Figure 1. Results are detailed in Section 5.2.

Summary statistics included minimum (Min), arithmetic mean, percentiles (25th, 50th, and 75th), and maximum (Max). The focus of our data analysis was total phosphorus (TP) and dissolved oxygen concentrations, as TP is the limiting nutrient in the lake and cyanobacteria are capable of fixing atmospheric nitrogen (N) in the absence of waterborne N.

The significance of differences in water quality between sites in the lake were tested using the non-parametric Mann-Whitney U test performed in R using the core "kruskal.test" function. Mann Kendall Trend analysis was performed using the "mk.test" and "sens.slope" functions of the "Trend" package in R (Pohlert, 2017) to assess any long-term changes in total phosphorus concentrations and climate variables. The significance of all statistical relationships was assessed at a Type I error rate of $\alpha = 0.05$.

2.2 Specific Tasks Undertaken

Our work plan was elaborated in seven specific tasks. A summary of each task is provided below.

Task 1: Start-up Meeting – HESL scientists provided detailed answers to questions from District staff in our work plan via a letter (September 30, 2019) and follow up teleconference of October 2, 2019. The specific questions addressed were:

- Sampling of Peninsula Lake in the summer of 2020 was not warranted based on information at hand and could not be completed within the available budget,
- Details of public engagement including commitments to –
    - a public meeting in Huntsville (which was completed on November 8 2019) to explain the study plan, receive feedback on it from the public and to collect observations from residents that could inform our analysis
    - development of a survey to receive public input, which the District would host on a web site (see Appendix A),
    - presentation of the study findings in a public forum
- Clarification that HESL would work with the District to obtain available data and that HESL's report would address the relative importance of ecology, climate and development on the re-emergence of cyanobacteria blooms in Peninsula Lake and that the results of this assessment would inform the need for additional analysis by means oif HESLs proposed "weight of evidence" approach to causation (see Section 7),
- Clarification that the timelines available allowed initial data review and sampling Peninsula Lake prior to fall turnover,
- Costs for seasonal sampling of algal communities in the summer of 2020, if that were to be required,
- Cost estimates to complete additional studies (e.g. septic inspections, mapping of land use changes and estimating point and non point source nutrient inputs to assess the role of development on land use change, should that be identified as the causative factor. HESL suggested that these could add tens of thousands of dollars to the budget but recommended against trying to cost any additional work until we have a better understanding of what we have and what it tells us and the need for additional information. That will give a better idea of what we need and allow any additional work to be correctly justified, scoped and budgeted,

- HESL clarified that GIS mapping of point and non-point source nutrient sources was not included in our scope of work,

- HESL clarified that documenting trends in concentrations of iron, nitrogen and boron was a) not possible in the absence of existing data, b) not justified based on current understanding and c) would not be useful unless it could be done over the long term in relationship to the presence and absence of blooms. HESL committed to sampling these parameters during the one field visit included in our work plan and data are presented in Section 5 and Appendix D.

- HESL clarified that any modelling of Peninsula Lake would not include measurement of flow or specific nutrient inputs as these would be very costly and would require one year or more of detailed monitoring to establish. Regional estimates of runoff and nutrient export could be obtained from MECP Dorset if such information was needed.

Task 2: Compile and Review Existing Data - This task included identification and documentation of data on water quality, climate and nutrient sources to the lake from existing sources and stakeholder engagement that could inform the causation study. These sources and resultant information are presented in Sections 3, 4, 5 and 6 of this report.

Task 3: Gap Analysis – Our approach was focused on determining if development on Peninsula Lake was expected to be a significant factor in causing the recent algal blooms or if other factors were suspected. We used the available historical water quality data, land use data, modelling tools and our own water quality and algae sampling in October of 2019 to inform our analysis. A Gap Analysis was included as an interim step in our proposal but was not necessary as our information review (Sections 3-6) did not identify gaps that needed to be filled to inform causation or which could be completed within the project budget and time lines. Instead formal documentation of data gaps and recommendations was provided in the final report (Section 8).

Task 4: 2019 Field Program – Our work plan included a limited field sampling program to gain information on the algal community composition and the potential for internal loading of phosphorus in Peninsula Lake, while limiting the cost of the data collection Field sampling to measure current water quality in Peninsula Lake was completed at 2 locations on October of 2019 ,to capture late-summer water quality when the water column was stratified and the potential for hypolimnetic anoxia and internal phosphorus loading was greatest (Section 5.2). Additional recommendations on sampling are provided in Section 9.

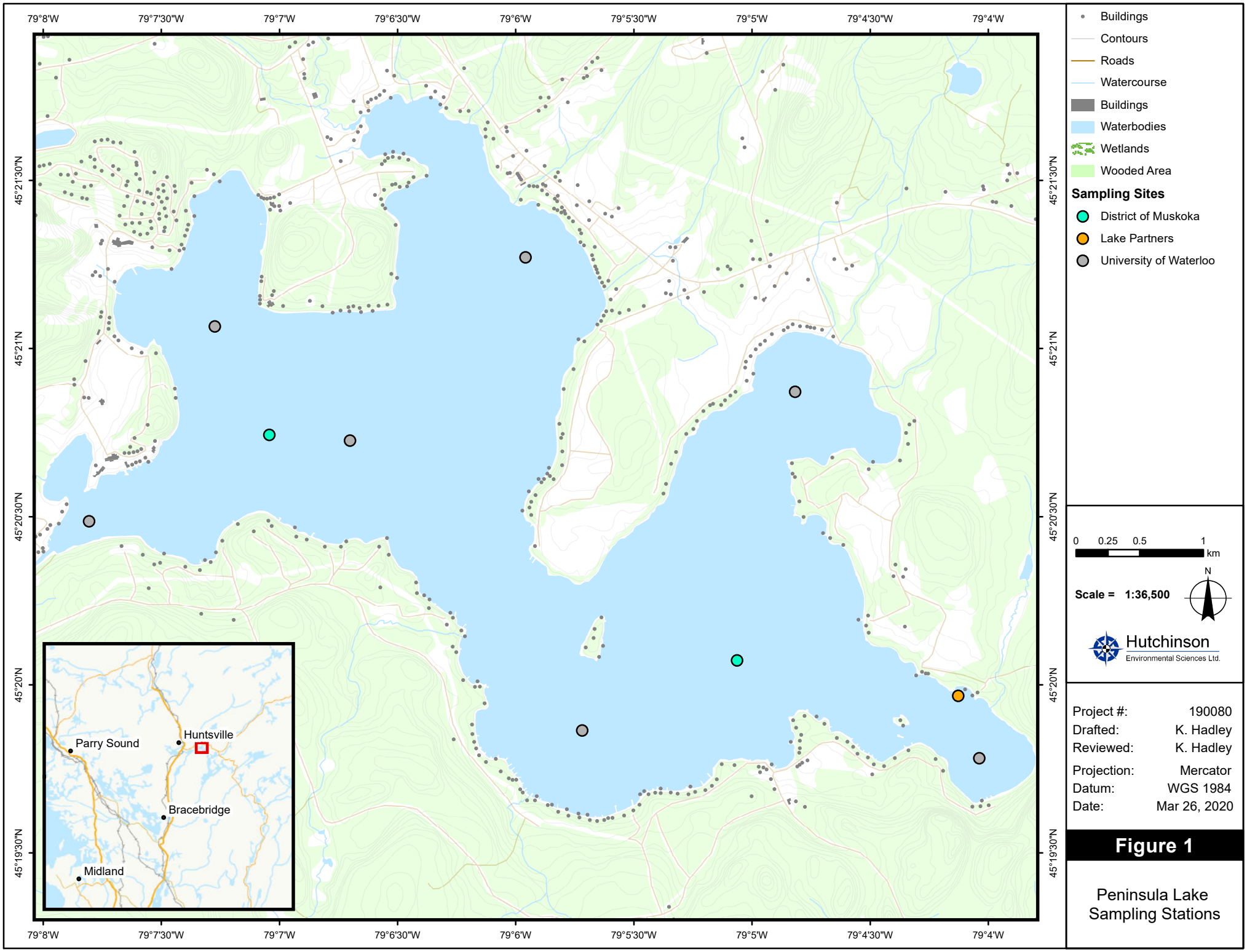
Task 5: Phosphorus Budget - The relative contributions of different sources of phosphorus to Peninsula Lake was addressed in Section 6 of this report using the DMM Water Quality Model (HESL, 2016, which was derived using MECP methods[1]) and discussions on the potential for internal phosphorus loading. was addressed in Section 5.2.2.3.

[1] Ontario Ministry of the Environment. 2010. Lakeshore Capacity Assessment Handbook. Protecting Water Quality in Inland Lakes on Ontario's Precambrian Shield. PIBS 7642e. Queens Printer for Ontario. 106pp.

Task 6: Stakeholder Engagement and Meetings – The details on stakeholder engagement were developed with District staff at the startup meeting (see Task 1 above) and are fully elaborated in Section 4 of this report.

Task 7: Reporting and Deliverables -Our work plan included submission of the draft and final reports which addressed the required elements:

- A summary of background (e.g. MECP) and current water quality information, including assessment of long term trends in nutrients and algae where possible;
- Identification of significant data gaps
- Results of the fall field sampling program
- Identification of the point and non-point sources discharges to Peninsula Lake (from the water quality model), including those from agricultural runoff and discharges, septic systems and internal loading;
- A Causation Study Framework to inform future studies which included
    - Lessons Learned
    - Detailed Statistical and Sampling Methodology
    - Recommendations for Additional Monitoring and/or special studies
    - Recommendations on waterbody-specific policies that should be implemented, if applicable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Sampling Sites
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Hutchinson
Environmental Sciences Ltd.
Project #: 190080
Drafted: K. Hadley
Reviewed: K. Hadley
Projection: Mercator
Datum: WGS 1984
Date: Mar 26, 2020
Figure 1
Peninsula Lake
Sampling Stations

3. Review – Ecology of Gloeotrichia echinulata

All three recorded bloom events in Peninsula Lake were dominated by *Gloeotrichia echinulata.* An understanding of its ecology is therefore a necessary first step in the assessment of causation.

3.1 Factors Contributing to *Gloeotrichia echinulata* Blooms

Gloeotrichia echinulata is a species of nitrogen-fixing, toxin producing cyanobacteria, which forms spiked colonies that are large enough to be visible to the naked eye in the water (between 1-3 mm in diameter) (Carey et al., 2007; Carey et al., 2008; Carey et al., 2012a). Like many species of cyanobacteria, *G. echinulata* contain gas vesicles which allow them to control their buoyancy in the water column. These gas vacuoles allow *G. echinulata* to migrate quickly, for example, moving from the sediment to the surface through 2 m of water in ~10 minutes. This vertical migration can allow *Gloeotrichia* colonies to out-compete other species by maximizing temperature, CO_2, nutrient and light conditions, as well as avoiding and minimizing grazing pressure (Hansson, 1996; Carey et al., 2008). Furthermore, while *Gloeotrichia* are edible to some zooplankters, Fey et al. (2010) showed that they are a “maintenance” food source not a preferred food source for zooplankton, thus abundance can remain high in the water column. Although *Gloeotrichia* is a toxin producing species, research suggests that microcystin-LR production in *Gloeotrichia* is lower than in other toxin producing species of cyanobacteria (Carey et al., 2007).

Gloeotrichia echinulata has a complex life cycle which consists of multiple phases, summarized briefly as: 1) germination on the sediment, 2) growth on the sediment, 3) gas vesicle formation and migration into the water column, 4) growth and division in the water column, 5) formation of resting stages, called akinetes, 6) sinking of akinetes out of the water column to the sediment, and 7) resting and maturation of the akinetes on the sediment. Together, the first three of these phases (germination to migration) are commonly referred to as recruitment. Recruitment from sediment resting stages is a vital component of *Gloeotrichia* dominance in oligotrophic lakes and is therefore reviewed here and in Section 3.2, below.

Prior to germination, *G. echinulata* occurs as dormant resting stages, called akinetes, on the surface of lake sediments. When conditions allow, they begin to grow and divide while simultaneously absorbing phosphorus from the sediment (Carey et al., 2008). Therefore, unlike many other phytoplankton species, including other cyanobacteria, which draw phosphorus from the water column, *G. echinulata* draws most of its P from the sediments (Tymowski and Duthie, 2000; Karlsson, 2003). By storing phosphorus early in its life cycle, *G. echinulata* may survive for up to 3 weeks in the water column (Karlsson-Elfgren et al., 2003), dividing multiple times with negligible P from lake water (Istvanovics et al., 1993). As a result, their abundance is frequently linked to P available in the sediment and not to water column P concentrations (Barbiero and Welch, 1992; Carey et al., 2008; Carey et al., 2014a).

Gloeotrichia echinulata therefore presents a serious management challenge as a) it is unlikely to respond to common Harmful Algal Bloom (HAB) management practices which address conditions in the water column and b) it can have an immediate and significant impact on its surrounding ecosystem, progressing from low relative abundance in the plankton community to complete dominance the following year (Jacobson, 1994). *G. echinulata* does not rely on water column P uptake (Istvanovics et al., 1993; Tymowski and Duthie, 2000), instead absorbing sedimentary P early in its life cycle, thus complicating conventional efforts (such as existing District policies) to limit blooms by controlling nutrient concentrations

in the water column (Cooke et al., 2005; Carey et al., 2008). Once established in low-nutrient lakes, *Gloeotrichia* may become a consistent part of the phytoplankton assemblage as seed banks of its akinetes can continue to draw phosphorus from sediments providing them with considerable advantages over other algal groups when lake conditions trigger a bloom. Nutrients such as nitrogen, iron, and boron, in addition to phosphorus, are also important to the life cycle and blooms of *Gloeotrichia echinulata* Section 3.3 outlines the importance of these nutrients to *Gloeotrichia echinulata* in detail.

3.2 Factors Affecting *G. echinulata* Recruitment – Literature Review

Population dynamics of many cyanobacterial species can depend critically on recruitment from sediment resting stages (e.g., Trimbee and Harris, 1984; Barbiero and Welch, 1992), particularly in ice-covered, north temperate lakes (Carey et al., 2014a). Amongst these species, the recruitment-dependency of *Gloeotrichia* from sediments has been noted as considerably higher than that of *Anabaena*, *Gomphosphaeria*, *Lyngbya*, or *Oscillatoria* (Trimbee and Harris, 1984; Barbiero and Welch, 1992; Hansson, 1996; Head et al., 1999; Karlsson-Elfgren and Brunberg, 2004; Carey et al., 2008; Carey et al., 2014a). Research suggests that up to 50% of *G. echinulata* populations in the water column are comprised of cells recruited from the sediments and thus factors which affect its life cycle at various stages will facilitate bloom events in both eutrophic and oligotrophic lake environments (Barbiero and Welch, 1992; Karlsson-Elfgren et al., 2005; Carey et al., 2008).

Recruitment has been shown to be variable both temporally (over a summer) and spatially (at different sites) within the same lake (Barbiero and Welch, 1992; Barbiero 1993; Forsell and Pettersson, 1995; Karlsson-Elfgren et al., 2005; Carey et al., 2008). In spite of this variability, akinete germination appears to be regulated by one or more lake-wide variables (e.g., increasing light, temperatures, nutrients, dissolved oxygen or a combination of these factors; Kaplan-Levy et al., 2010). For example, in Lake Sunapee, an oligotrophic lake in New Hampshire, Carey et al. (2008; 2009) found that a pulse of sediment phosphorus occurred prior to a significant increase in recruitment rate of *Gloeotrichia echinulata* in 2005 and 2006. The cause of the pulse could not be ascertained, however, and it is not known if *G. echinulata* germination was accelerated by a discrete pulse of P, or because P exceeded a certain threshold concentration.

Three blooms of *Gloeotrichia* have been documented in the recent history of Peninsula Lake - in 1993, 1994 and 2017. The blooms in 1993 and 1994 occurred several years after major siltation events introduced sediments into Peninsula Lake. Cornellise and Evans (1999) reported siltation events resulting from:

- Construction of the Deerhurst Resort Golf Course in 1990,
- Several hundred tonnes of unstabilized material on the Hidden Valley ski slopes in 1989-90,
- Erosion during construction of Muskoka Road 8 along Tally Ho Creek in 1991.

These events introduced several pulses of sediment into the lake that could have predisposed the lake to a bloom when other conditions were favourable (Carey et al., 2008, 2009).

Carey et al. (2014a) suggest that the rate and timing of recruitment is also modified by local, microhabitat characteristics including water depth (Karlsson-Elfgren et al., 2004), sediment chemistry and substrate type (Carey et al., 2008, 2009), the size of the akinete bank (Forsell, 1998), bioturbation (Pierson et al., 1992; Karlsson-Elfgren et al., 2004), and grazing (Rengefors et al., 1998).

With a changing climate, lake ecosystems are predicted to experience a myriad of limnological changes including increases in the strength and duration of thermal stratification, increased water temperatures, modified hydrology, and altered nutrient loading. In many cases, the impacts of these changes are hypothesized to favour cyanobacterial species over other eukaryotic phytoplankton. Carey et al (2012b) provide a comprehensive review outlining the expected impacts of climate change on limnological conditions and the consequences of those changes on cyanobacterial species. Akinete resting stage production may be beneficial in increasingly variable conditions including intermittent nutrient availability, while the ability to store phosphorus, fix nitrogen and regulate its position in the water column could be particularly advantageous for *Gloeotrichia,* as climate change brings stronger thermal stratification, sequestering nutrients outside the epilimnion. Furthermore, increased water temperature may also lead to earlier recruitment and a lengthened optimal growing season for *Gloeotrichia*. The decrease in wind speeds in Muskoka documented by MECP (Yao et al., 2013) will also favour cyanobacterial plumes - promoting a more stable water column.

Lake level fluctuations resulting from extreme climate patterns may also play an important role in cyanobacterial blooms in oligotrophic lakes. For example, recent research has linked phosphorus pulses resulting from lake level fluctuations in an oligotrophic lake to the summer appearance of a *Dolichospermum lemmermannii* bloom (Callieri et al., 2014), suggesting that both climate change and/or excessive water withdrawals resulting in lake level fluctuations could increase the threat of harmful algal blooms. The Water Survey of Canada maintains a water level gauge (02EB016) in Fairy Lake at the inflow from Peninsula Lake. Records start in 2002 and so there is no information on water levels during the 1993-1994 blooms. The data show that water was at average levels in 2017 and so climate change is more likely to have been an influence than low water levels.

3.3 Other Nutrients

Phosphorus in the water column and lake sediment is the most commonly studied nutrient trigger for *Gloeotrichia* blooms in both eutrophic and oligotrophic lakes. Phytoplankton competition for finite resources requires more than just phosphorus, and so other key nutrients may contribute to the success of *Gloeotrichia* in oligotrophic lakes. *G. echinulata* is a nitrogen fixing organism (i.e., it can use molecular nitrogen, available from the atmosphere, to meet its nitrogen demands if nitrogen (N) in the water is limiting) and previous research indicates that it preferentially uses nitrate, nitrite, or ammonium from the water column when they are available, leaving little for other phytoplankton (Szasz and Pettersson, 2000; King and Laliberte, 2005). Once these biological available nitrogen sources have been depleted, other non-nitrogen fixing phytoplankton often die out, while *Gloeotrichia* can continue to meet its nitrogen demands by fixing atmospheric N_2. Nitrogen fixation, however, only confers a competitive advantage at phosphorus concentrations far in excess of those in Peninsula Lake, when phosphorus is no longer a limiting nutrient.

Models dealing with phytoplankton competition are often based on macronutrient use efficiency and the consequences of adding more phosphorus (P) and nitrogen (N) into a lake ecosystem. Phytoplankton, however, require other micronutrients in order to compete. For example, cyanobacteria require ferric iron (Fe3+) for N-fixation (Murphy et al., 1976) and N-assimilation (Lin and Stewart, 1998). Iron is required for chlorophyll synthesis, the production of photosynthetic electron transport proteins and during the photosynthetic production of organic compounds. Iron and boron have also been shown to affect the *Gloeotrichia echinulata* growth rate (Hyenstrand et al., 2001; Karlsson-Elfgren et al., 2005) although the boron effect was confined to one laboratory study and was only observed in the presence of iron, nitrogen

and phosphorus. Cyanobacteria are the only group of phytoplankton that possess a specialized iron uptake system providing a competitive advantage over eukaryotic phytoplankton in iron-limited conditions (Wilhelm and Trick, 1994). Cyanobacteria can use siderophores (i.e., Fe-binding compounds) to scavenge iron thus facilitating their uptake and dictating the relative bioavailability of ferric Fe to other phytoplankton. Recent research has found that, in oligotrophic Ontario lakes, cyanobacterial biomass was highest at low iron concentration and suggests that the rise in cyanobacteria in oligotrophic lakes necessitates a better understanding of the mobilization of iron to lakes and/or lake controls on the fate of iron (Sorichetti et al., 2015). This specialized research involves highly detailed investigations at the time of bloom occurrence to determine if micronutrients were a factor and is not advanced enough to inform management of cyanobacterial blooms after the fact.

3.4 Potential Ecological Consequences of *Gloeotrichia echinulata* Blooms

Beyond the obvious concerns of surface scums and harmful toxin production, *Gloeotrichia* blooms may pose several other lake management challenges. Even at low concentrations of *G. echinulata*, there is evidence of health consequences (i.e., swimmers developing rashes; Backer, 2002; Serediak and Huynh, 2011; Carey et al., 2012a). Furthermore, blooms of *Gloeotrichia* in low nutrient lakes can have negative consequences on water quality, beyond the immediate health concerns of the bloom. For example, *Gloeotrichia echinulata* can lead to increased biomass, richness and diversity of other phytoplankton following a bloom (Carey et al., 2014b). *Gloeotrichia* blooms have been shown to increase the growth rates of some phytoplankton species by up to 620% in the laboratory (Carey and Rengefors, 2010). Mechanistically, this is believed to be the result of nutrients (stored P and fixed N) recycled from *Gloeotrichia* colonies during and after blooms. However, other factors could also contribute. Seasonal recruitment of cyanobacteria can contribute significantly to internal P loading by moving it from the sediments to the water column, accounting for as much as 66% of the total internal P loading in Green Lake, Washington, USA (Barbiero and Welch, 1992) and Lake Erken, Sweden (Istvanovics et al., 1993) and have also been shown to lead to increased Total N in mesocosm experiments (Carey et al., 2014b).

In addition to nutrient loading, bioactive secondary metabolites produced by cyanobacteria (Gross, 2003; Legrand et al., 2003) may be used by other phytoplankton for their own metabolism (Suikkanen et al., 2004), while antibacterial and antifungal compounds produced by *Gloeotrichia* colonies may also benefit other phytoplankton (Legrand et al., 2003; Carey and Rengefors, 2010). The impact of *Gloeotrichia* blooms on phytoplankton in lakes is only beginning to be understood. For example, phytoplankton respond differently to *Gloeotrichia* blooms in lakes of differing trophic status (Carey et al., 2014c). These types of ecosystem effects are particularly concerning given their potential to mediate the transition from a low-nutrient, clearwater regime to a high-nutrient, turbid-water regime (Cottingham et al., 2015).

3.5 Major Conclusions from the Literature Review

Causal factors believed to control the germination and recruitment of *Gloeotrichia echinulata* include increases in sediment phosphorus, water clarity (i.e., light), water temperature, and the size of the akinete seed bank. Many of these drivers are still being actively studied as the specific mechanisms are not necessarily well understood, particularly in oligotrophic lakes.Although research suggests that other nutrients, such as iron, nitrogen and boron may play a role in *Gloeotrichia* growth, the results are not conclusive, and there is insufficient data available for Peninsula Lake to relate them to the presence or absence of algal blooms.

The literature review, however, does present some important conclusions for the ongoing management effort in Peninsula Lake. Most importantly, the existing scientific body of literature suggests that the conventional understanding and management of algal blooms that is based on controlling phosphorus concentrations in the water column, especially in nutrient-enriched lakes, is not likely to explain the development of *Gloeotrichia* blooms in nutrient-poor Peninsula Lake because *Gloeotrichia* draws nutrients from the sediments.

4. Consultation

4.1 Survey

In cooperation with HESL, the District developed a survey to residents and stakeholders via their "Engage Muskoka" online platform in order to better understand the incidence and impact of algal blooms in the lake and whether the observations of lake residents provided any insights into potential causative factors. The public survey was designed to solicit input and local knowledge from lake residents and others who are familiar with Peninsula Lake. The survey was administered from October 21, 2019 to December 2, 2019 and was advertised on the District website and over social media. Submissions were received from 81 participants, however not every question was answered by every participant. The complete results are presented by the District in Appendix A, and the results are summarized by HESL below.

4.1.1 Timing of Blooms

Of the 81 survey participants, 68 provided an answer to the question "Have you observed algal blooms on Peninsula Lake?". Of those:

- 72% (or 49 of 68) said yes, they had observed algal blooms on Peninsula Lake in the past.
- 48 of 70 respondents described at least occasional impairment of recreational activities due to proliferation of algae or cyanobacteria in the lake, with swimming and wading in the nearshore being the most frequently impaired activity.

Amongst the survey replies, 22 indicated a specific year(s) of blooms in Peninsula Lake (Table 1). The year of the most recent documented algal bloom, 2017, was the most frequent answer. Blooms were also indicated, however, in 2018, 2019 as well as 1995 and 1996 when no blooms were formally documented. We also note that despite recorded blooms in 1993 and 1994 (Cornelisse and Evans, 1999), only a few (1 in 1993 and 3 in 1994) respondents indicated blooms in those years.

One respondent provided anecdotal background of conditions prior to the 2017 bloom, *stating "the 2017 bloom was in early September following a long hot spell with warm water and no wave action. Two weeks earlier it was preceded by a severe storm with very rough water, lots of run off and then hot weather with no wind".* This detailed observation was very useful and was later confirmed by analysis of meteorological records (Section 5.3).

Table 1. Survey Results Assessing the Timing of Algae/Cyanobacterial Blooms in Peninsula Lake.

	1993	1994	1995	1996	2017	2018	2019
Number of respondents	1	3	2	4	13	10	4

4.1.2 Location and Extent of Blooms

Survey participants were also asked:

- On what parts of the lake have you observed an algal bloom? (e.g. the whole lake, a specific basin (east or west), within specific bays, only in the nearshore, etc.)

Of the 81 surveys that were submitted, 39 provided an answer on the location and extent of blooms (Table 2). Enumeration of the responses suggests that the location of the homeowner was a substantial factor in determining the response to this question - residents would respond based on their particular location in the lake and the answers cannot be considered to be as representative as a whole-lake survey Photographs taken from a helicopter during the 2017 bloom (Figure 2; Appendix B) provided a more complete record of bloom location and extent. These photos and the information gathered in the survey suggest that it is unlikely that the bloom originated from a single source location as it was observed in various parts of the lake. Recruitment of Gloeotrichia in the nearshore areas is common, followed by the formation of a surface scum and distribution of the bloom by wind and wave action as documented in Section 3 and shown in Figure 2.

Table 2. Survey Results Assessing the Location and Extent of Algae/Cyanobacterial Blooms in Peninsula Lake.

	East	West	Whole Lake	Nearshore
Number of respondents	17	11	8	11

Results of the survey of residents showed variable recall of bloom history in Peninsula Lake and may have captured some small-scale or short-duration blooms that were not sampled or recorded. Cornelisse and Evans (1999) documented the occurrence of the 1993 and 1994 blooms but the specific details on location and extent were not recorded at the time.

Detailed bloom information is a key component of understanding causation - recording and maintaining detailed and accurate records of bloom history and spatial coverage at the time of occurrence is helpful to inform studies of causation.

Figure 2. Aerial Photos of Peninsula Lake Cyanobacterial Bloom – September 24th, 2017 looking west from east end of lake (top) and south at lake's western outflow (bottom) (Photos by Brian Tapley)

4.2 Stakeholder Engagement Meeting

A stakeholder engagement meeting was held on November 8, 2019 at the Huntsville Council Chambers and included approximately 30 participants including permanent and seasonal residents and business owners on Peninsula Lake, Area Municipal and District staff, as well as members of the general public. HESL provided a presentation outlining the proposal for the project terms of reference (Appendix C). Attendees were encouraged to complete the survey and provide any additional information to the consultant that may assist in informing the causation study.

Stakeholders posed a number of questions which were answered by HESL and District staff as follows:

1. The science involved in causation studies,

    - HESL provided scientific information regarding the causes of algal blooms (i.e. sedimentation, nutrient concentrations, climatic conditions, phosphorus triggers, changes in light regime), information specific to the life cycle and behaviour of *Gloeotrichia*, and the different parameters (e.g. phosphorus, nitrogen iron) sampled in the field program (phosphorus, nitrogen, iron).

2. The reasoning behind selecting Peninsula Lake as the pilot study,

    - District staff explained that Peninsula Lake was selected for several reasons: Peninsula Lake experienced a recent algal bloom (2017),
    - of the lakes listed on Schedule E2 of the MOP, 2019, it has the second highest development potential of lakes that have experienced algae blooms,
    - there has been modest investment in water quality initiatives to date,
    - the lake association is highly engaged, and
    - the lake is large and located in two Area Municipalities with the potential to impact a wide variety of stakeholders.

3. How stakeholders can be involved,

    - Many stakeholders in attendance wanted to know what they could do to help HESL throughout this process. HESL advised that providing as much information as possible from the individuals who are familiar with the lake's history. This would include observed land use changes over time, observations, dates and times of algal blooms, and any other information individuals think would be beneficial to the consultant. The District advised that stakeholders can provide this information and more by completing the survey on the "Engage Muskoka" webpage.

4. The effectiveness of conducting a sole causation study and the results it will produce,

    - Some stakeholders questioned why the pilot causation study was not being run in conjunction with other lakes such as Leonard Lake. The consultant explained that Leonard Lake did not experience the same type of bloom as Peninsula Lake and would therefore not be easily comparable. Additionally, the intent of the District was to conduct a pilot study and to learn from that to inform future studies. Stakeholders

also questioned whether HESL has enough information to produce clear results and recommendations. HESL explained that the study will explore several avenues, with the goal of producing recommendations for the future but that they were limited to working with the information available, and

5. Personal information and observations:

    - Personal observations were shared from several stakeholders in attendance. The District advised that following the meeting individuals could send their observations and pictures to the District who would then pass them along to the consultant. The "Engage Muskoka" survey was also promoted as the main point of data collection from stakeholders as it is designed to obtain information that the consultant deemed would be most beneficial.

4.3 Indigenous Engagement[2]

On November 14, 2019, a "Muskoka Area Indigenous Leadership Table" (MAILT) was held to discuss several upcoming and ongoing projects within Muskoka, including the Peninsula Lake Causation Study. Representatives from Chippewas of Rama First Nation, Moon River Metis Council, Moose Deer Point First Nation, Wahta Mohawks First Nation, Wasauksing First Nation, District Municipality of Muskoka, Town of Bracebridge, Town of Gravenhurst, Town of Huntsville, and Township of Georgian Bay were in attendance. District staff provided an overview of the Muskoka Official Plan (2019), which includes policies focused on monitoring lake system health, protecting water quality, and the implementation of causation studies with a pilot study being carried out on Peninsula Lake. District staff expressed that the District is engaging the community as a means to gather information pertinent to the study and to shape the processes involved in the pilot study and future studies. In this regard, staff stated that they would be grateful for Indigenous perspectives, advice and knowledge throughout this pilot study and as they move onto future lake studies. District staff also noted that informational materials regarding this study could be found on the "Engage Muskoka" website, included that there was an online feedback survey available on this website until the end of November and welcomed comments and feedback from Indigenous communities on this forum. No feedback from Indigenous stakeholders was received in regards to the Peninsula Lake Causation Study.

4.4 Other Data Collected

Additional information received through the public consultation process included data on total phosphorus in Wolf Bay collected by the Peninsula Lake Association through with the MECP Lake Partner Program and photos of the bloom provided by some residents (Appendix C).

4.5 Summary of Consultation and Impact on Study

Results from the consultation portions of the study were presented in Sections 4.1 to 4.4. Overall, the most useful contributions were:

[2] *Indigenous engagement was not part of HESL's contribution to the Peninsula Lake Causation Study but was undertaken by the District of Muskoka as a separate exercise. District staff provided the material on Indigenous Engagement for this report.*

- An awareness of the significance of cyanobacterial blooms and confirmation of public concern and use impairment,
- The opportunity for residents to question District and consulting staff directly, receive information first hand and guage the level of public interest,
- awareness of the importance of documenting the specific locations where blooms were observed in order to track spatial coverage of the blooms. It is important that managers understand spatial coverage to distinguish blooms in isolated areas with low coverage of the lake surface from significant blooms covering a large lake surface. The photographs taken from the helicopter were very useful documentations of the bloom coverage but we respect that such coverage is not generally available.
    - It would be useful if independent observations could be coordinated into lake wide surveys over several days to understand the onset and extent of future blooms,
- Recall of the 2017 bloom was greater than that of the blooms in the 1990s.
    - Stakeholder surveys should therefore be undertaken during and immediately after bloom occurrences to provide the most useful information,
- Detailed anecdotal information on background conditions during the 2017 bloom were a useful; contribution to understanding causation, for example, the observation that *"the 2017 bloom was in early September following a long hot spell with warm water and no wave action. Two weeks earlier it was preceded by a severe storm with very rough water, lots of run off and then hot weather with no wind".* This detailed observation was very useful and was later confirmed by analysis of meteorological records (Section 5.3).

5. Causation Study Lines of Evidence

5.1 Algal Bloom History

Published reports (Cornelisse and Evans, 1999) and District records indicate three known algal bloom events in Peninsula Lake: in 1993, 1994 and 2017. The 2017 bloom was confirmed by the Ministry of Environment, Conservation and Parks (MECP) and the Simcoe Muskoka District Health Unit (SMDHU). Three bloom incidents were also reflected in the survey of lake stakeholders but the dates were imprecise. Tymowski et al. (1998) observed that the *Gloeotrichia* blooms observed in Peninsula Lake in 1993 and 1994 coincided with a period of very calm weather which allowed unusually large planktonic populations to accumulate at the surface. Those authors also documented the potential role of sediment phosphorus in the planktonic phase of the life cycle.

5.2 Water Quality Analysis

5.2.1 Historical Water Quality Reporting

Deerhurst Village Centre Water Quality Study – 2013

In 2013, Azimuth Environmental Consulting was retained by Skyline Executive Acquisitions Inc. to perform a ground and surface water Preliminary Site Assessment for a proposed expansion to their existing development on the North shore of Peninsula Lake near the outflow to Fairy Lake.

The surface water quality sampling program was performed in August – November 2012 at 7 locations on Peninsula and Fairy Lakes and samples were generally collected from 1m below surface following periods of intense rainfall. Total phosphorus concentrations were analyzed at a detection limit of 0.02 mg/L (20 µg/L), limiting their usefulness in informing water quality in Peninsula Lake, as all but 2 of the DMMs measurements since 1990 (n=81) have fallen below this detection limit.

Sunset Bay exhibited the highest TP concentrations (0.04 mg/L) but the detection limits of laboratory analysis limit the usefulness of these data.

Fairy/Peninsula Lake Report – Cornelisse and Evans (1999)

The Ontario Ministry of Natural Resources published a report on Fairy and Peninsula Lake in 1999, which included multiple investigations into water quality and lake history in the two waterbodies. The report notes two recorded blooms, in 1993 and 1994, which it suggests were caused by large planktonic populations coinciding with a period of very calm weather (Cornelisse and Evans, 1999). They showed links between low wind speeds and maximal *G. echinulata* populations and reported large sediment inputs from the watershed in the years preceding the blooms.

Clerk et al (1998, in Cornelisse and Evans (1999)) used paleolimnology (i.e., physical, chemical and biological markers preserved in lake sediments), to reconstruct past total phosphorus conditions in the lake. The results of this analysis showed that phosphorus concentrations in Peninsula Lake varied historically between 5 and 7 µg/L prior to settlement and early development of the region, that they increased to ~12 µg/L as the watershed was cleared, agriculture increased and urbanization added sewage to the lake but, starting in the mid-1900s, concentrations began dropping, coincident with reforestation and sewage treatment and are now within their historical range.

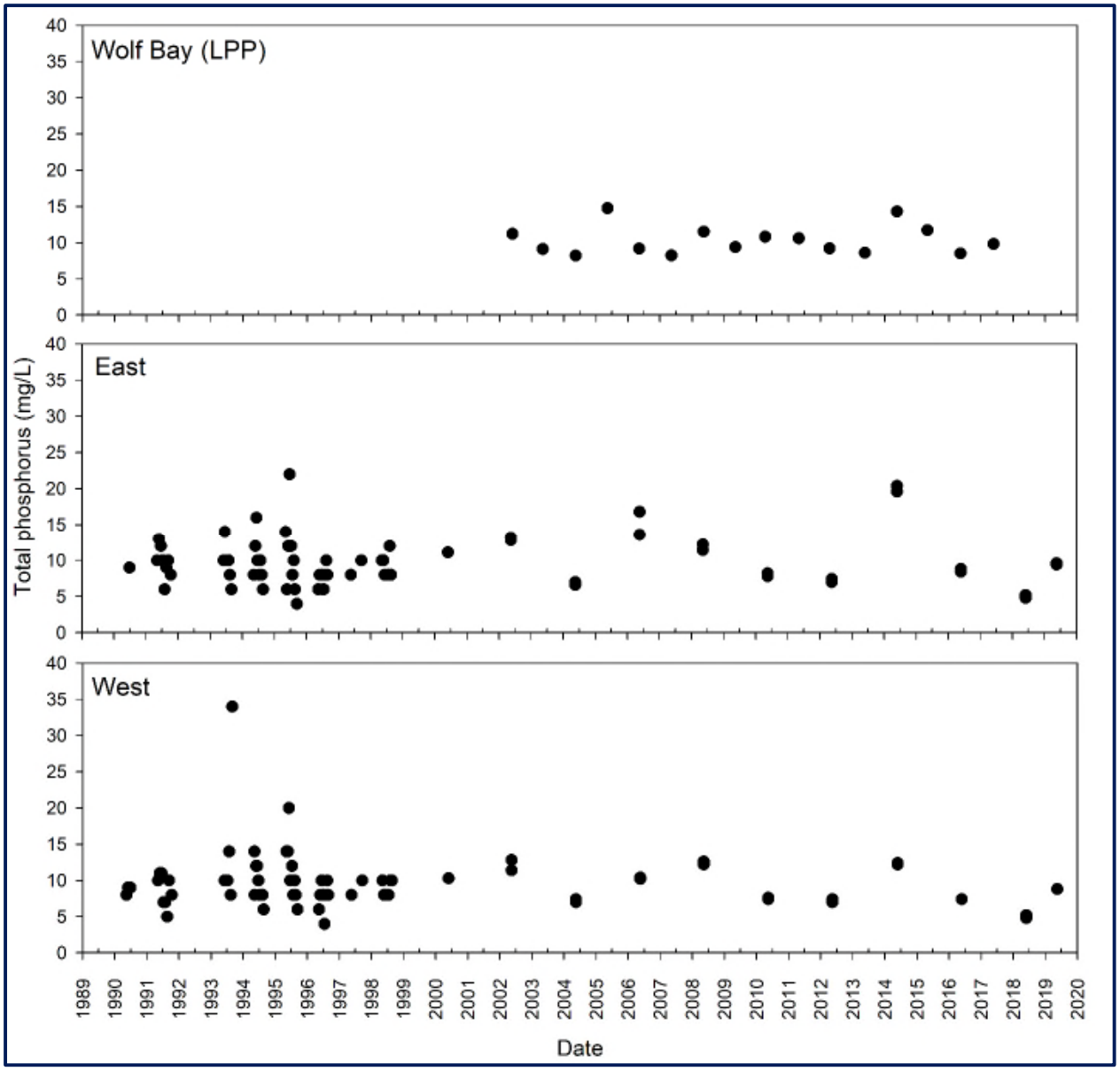
5.2.2 Current Water Quality Records

5.2.2.1 Total Phosphorus Concentrations

Total phosphorus has been sampled by the District of Muskoka in both the East and West Basin of Peninsula Lake since the early 1990's. Prior to the 2000 sampling season, monthly TP samples were collected, throughout the open water season, before switching to a consistent spring overturn sampling approach. In addition, spring overturn TP samples have been collected as a part of the MECP Lake Partner Program since 2002 in Wolf Bay and were collected at seven unique locations across the lake (See Figure 1) by the University of Waterloo Summit Centre for the Environment in 2012.

Total phosphorus concentrations in Peninsula Lake have ranged from 5 to 20 µg/L in the East basin and 5 to 14.3 µg/L in the West basin across all monitoring programs (Figure 3). The highest recorded total phosphorus concentration occurred in May 2014 (20.0 µg/L), a substantial step increase from the previous year (7.2 µg/L). TP concentrations returned to concentrations consistent with the long-term record (8.6 µg/L) by 2016 and have remained below 10 µg/L in all sampling events since.

Figure 3. Lake Partner Program and District of Muskoka data for Total Phosphorus.



No significant differences in total phosphorus concentrations ($p>0.05$) were noted between the East and West Basins. Linear trend assessment on both the East and West basin and Wolf Bay showed no significant trends in total phosphorus concentrations over time ($p>0.05$).

5.2.2.2 Other Water Quality Parameters

The DMM data set includes long-term monitoring of additional water quality parameters including total metals, general chemistry (e.g. cation and anions) and nutrients. No significant differences between the East and West basin were noted in any water quality parameters, and no increases over time were apparent. Summary statistics for all water quality data are provided in Appendix D.

Algal blooms were observed in August in 1993, 1994 and 2017. Surface water temperature in August varied between 19.5 and 24.8 ºC in the East basin and 19.8 to 25 ºC in the West basin from 1991 to 2018 with average surface water temperatures of 22.5 ºC and 22.4 ºC respectively. No changes over time or step increases in water temperature during bloom years (1993 and 1994) were noted, however 2017 was not a District of Muskoka monitoring year in Peninsula Lake and therefore no surface water temperatures were available. Furthermore, no data are generally collected beyond August, while long-term climate data suggest that important periods of calm wind may occur later into September and therefore the effect of these calm periods on water temperatures is not clear.

5.2.2.3 Dissolved Oxygen Profiles and Deep-Water Sampling

Historical records of deep-water oxygen in the 32m deep West basin of Peninsula Lake show that concentrations did not fall below 5 mg/L, except for 2 events (i.e., August 2008 and 2012) and were >2 mg/L in all profiles collected. This suggests that hypolimnetic anoxia and internal loading of phosphorus is unlikely. However, we note that the current DMM sampling program does not collect profile data beyond August and that dissolved oxygen may continue to decline into September or October depending on climate conditions.

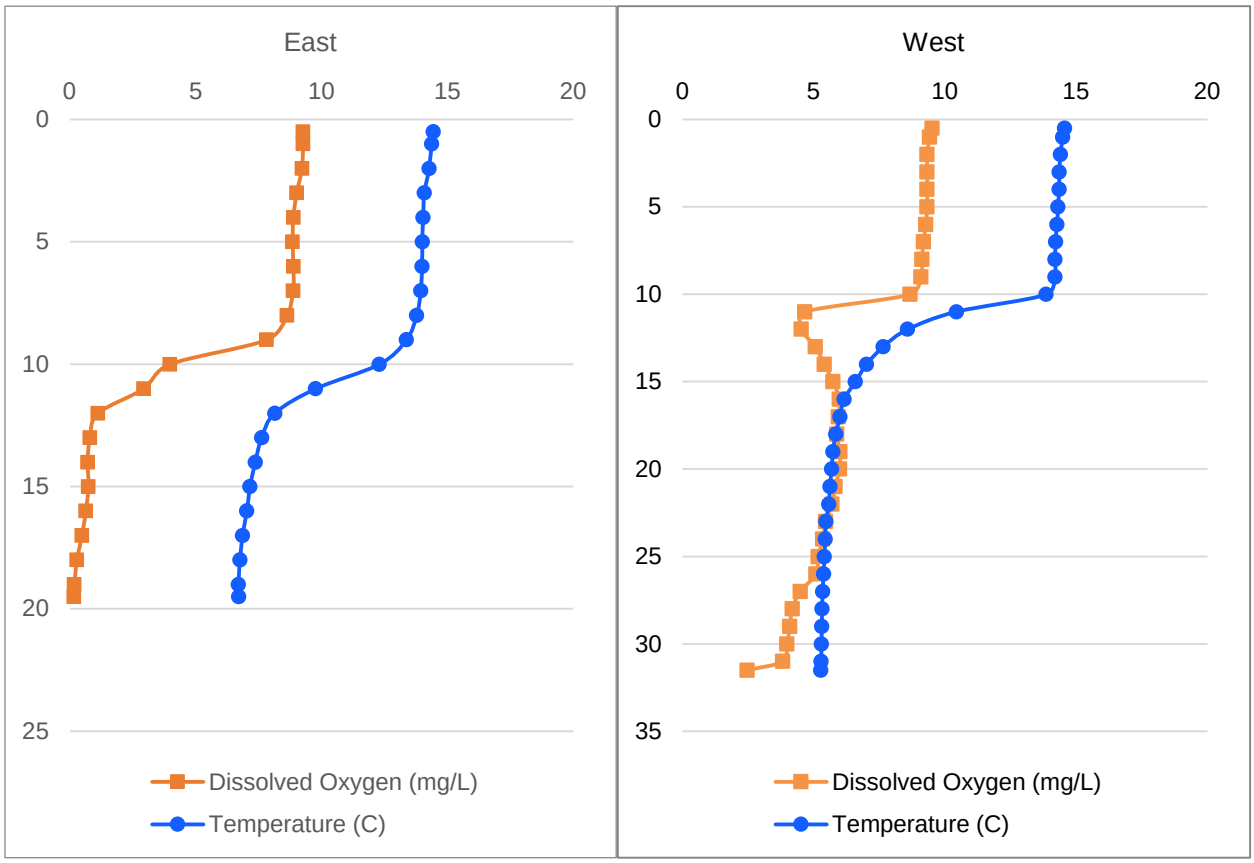
In the shallower (20m) East basin, historical records collected by the DMM showed that dissolved oxygen concentrations fell below 2.0 mg/L during late summer sampling in 1990, 1993, 1994, 1995, 1996, 1998, 2000, 2006, 2008, 2010, and 2012. These results suggest the potential for the development of hypolimnetic anoxia and the internal loading of phosphorus to the lake. Field data collected on October 10, 2019 by HESL showed the development of hypolimnetic anoxia in the East basin, with dissolved oxygen concentrations < 1 mg/L beginning at ~12 m depth and continuing to 19.5 m (Figure 4). The October 2019 sampling focused on characterising the late-summer algae community, hypolimnetic oxygen status, and deep lake water quality at representative locations shown in Figure 1. Results are presented in Figure 4, Figure 5 and Table 3.

Table 3. 2019 Fall Field Sampling Water Quality Data.

			Peninsula West	Peninsula East Top	Peninsula East Bottom
Date Sampled	**DL**	**Units**	**10-Oct-2019**	**10-Oct-2019**	**10-Oct-2019**
Physical Tests (Water)					
Hardness (as CaCO3)	1.3	mg/L	15.6	15.3	
pH	0.10	pH units	7.21	7.04	
Anions and Nutrients (Water)					
Alkalinity, Total (as CaCO3)	10	mg/L	12	11	
Ammonia, Total (as N)	0.010	mg/L	0.011	0.01	0.014
Chloride (Cl)	0.50	mg/L	13.7	13.7	
Total Kjeldahl Nitrogen	0.15	mg/L	0.15	0.15	0.17
Phosphorus, Total	0.0030	µg/L	10.3	7.7	15.0
Sulfate (SO4)	0.30	mg/L	3.55	3.52	
Organic / Inorganic Carbon (Water)					
Dissolved Organic Carbon	0.50	mg/L	4.06	4.23	
Bacteriological Tests (Water)					
Escherichia Coli		MPN/100mL	0	1	
Total Coliforms		MPN/100mL	25	53	
Total Metals (Water)					
Aluminum (Al)-Total	0.0050	mg/L			0.0272
Arsenic (As)-Total	0.00010	mg/L			0.00018
Barium (Ba)-Total	0.00010	mg/L			0.0162
Boron (B)-Total	0.010	mg/L			0.013
Cadmium (Cd)-Total	0.0000050	mg/L			0.0000289
Calcium (Ca)-Total	0.050	mg/L	4.13	4.10	4.84
Chromium (Cr)-Total	0.00050	mg/L			0.00141
Cobalt (Co)-Total	0.00010	mg/L			0.00030
Iron (Fe)-Total	0.010	mg/L			0.797
Lead (Pb)-Total	0.000050	mg/L			0.000104
Magnesium (Mg)-Total	0.0050	mg/L	1.28	1.22	2.84
Manganese (Mn)-Total	0.00050	mg/L			0.360
Molybdenum (Mo)-Total	0.000050	mg/L			0.000085
Nickel (Ni)-Total	0.00050	mg/L			0.00052
Potassium (K)-Total	0.050	mg/L			1.16
Rubidium (Rb)-Total	0.00020	mg/L			0.00153
Selenium (Se)-Total	0.000050	mg/L			0.000062
Silicon (Si)-Total	0.10	mg/L			2.99
Sodium (Na)-Total	0.050	mg/L			21.6
Strontium (Sr)-Total	0.0010	mg/L			0.0415
Sulfur (S)-Total	0.50	mg/L			2.26
Titanium (Ti)-Total	0.00030	mg/L			0.00055
Uranium (U)-Total	0.000010	mg/L			0.000013
Zinc (Zn)-Total	0.0030	mg/L			0.0103
Plant Pigments (Water)					
Chlorophyll a	0.010	ug/L	3.19	3.07	

Low deep-water oxygen concentrations recorded in the East basin of Peninsula Lake on October 10, 2019 prompted the sampling of deep-water phosphorus to determine if substantial internal loading could be detected. A single water sample was therefore collected at 1m off the bottom (mob) of the lake in the East basin. Total phosphorus concentrations 15.0 µg/L compared to 7.7 µg/L in the surface sample. Total iron concentrations (797 µg/L; Table 3) in the deep water were also elevated relative to long-term surface water concentrations recorded by the DMM (30-66 µg/L). Elevated concentrations of iron and total phosphorus in the deep waters suggest some internal loading of phosphorus but the enrichment of phosphorus was slight and could also be explained by settling of organic production from the surface waters to the hypolimnion. Significant internal loading would result in substantially higher phosphorus concentrations than those recorded here. For example, Nurnberg et al. (2009) found TP concentrations of 75-90 µg/L in samples collect 1 mob in oligotrophic Chub Lake (Lake of Bays Twp.) during a period of high internal loading. Although there is some evidence of internal loading in Peninsula Lake, historical records do not suggest a change over time in deep water oxygen concentrations or in phosphorus concentrations in the lake, nor have we noted any connections between phosphorus and cyanobacterial blooms in the Peninsula Lake data.

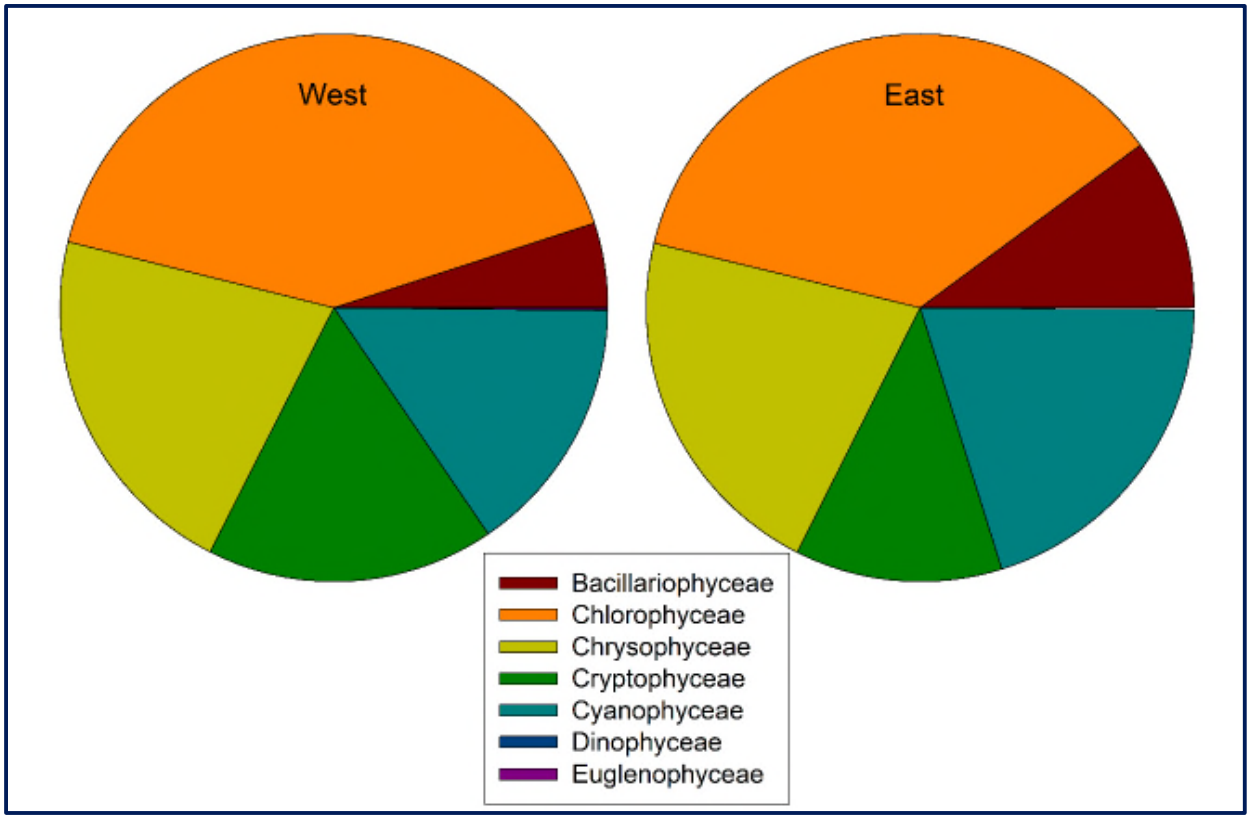
Figure 4. Dissolved Oxygen Profiles in the East and West Basin of Peninsula Lake – October 10, 2019.



5.2.2.4 Algae Communities

Algae communities in the East and West basins of Peninsula Lake in October 2019 were strikingly similar (Figure 5). Communities were dominated by green algal species which accounted for 36% and 41% of the algae enumerated in the East and West basins, respectively. Chrysophytes were the next most abundant algal group, accounting for 21% of the algal community at both sites. Cyanobacteria species (*Cyanophyceae*) comprised 15-20% relative abundance of the algal community, including taxa from the *Anabaena*, *Aphanocapsa*, *Chroococcus*, *Cyanodictyon* and *Planktolyngbya* genera. The presence of these cyanobacteria provides the opportunity for bloom formation under the right conditions – but the blooms of 1993, 1994 and 2017 were dominated by *Gloeotrichia*. No *Gloeotrichia echinulata* were identified as a part of the 2019 sampling event, which is not unexpected based on its tendency to remain dormant in resting stages on bottom sediments in isolated bays and near-shore environments prior to recruitment into the water column.

Figure 5. Relative Abundance of Phytoplankton Genera in Peninsula Lake – October 10, 2019.

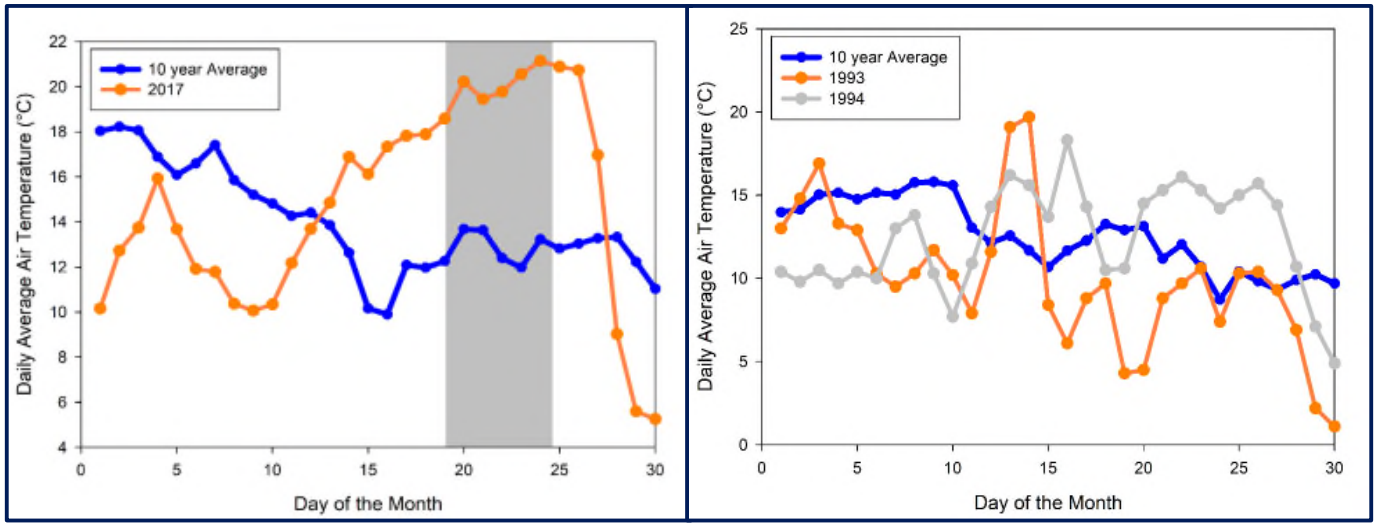


5.3 Climate History

5.3.1 Air Temperature

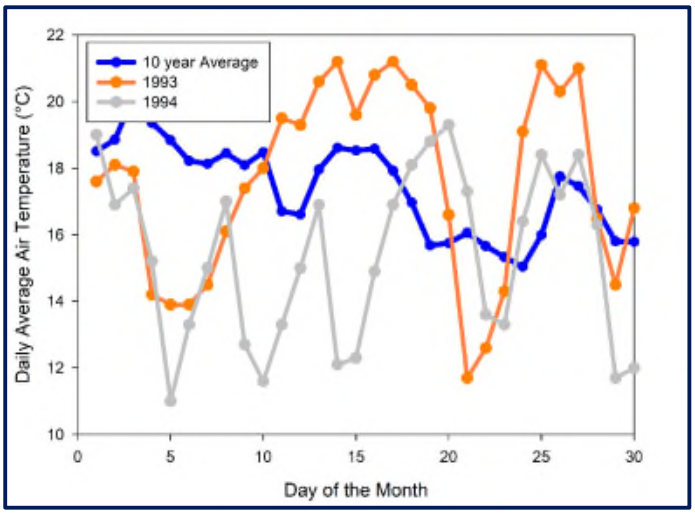
Elevated air temperatures were recorded at the MECP (Dorset Environmental Science Centre) Harp Lake Meteorological Station in September of 2017 prior to the cyanobacterial bloom (Figure 6) in early autumn, a period in which temperature is generally declining. Temperatures began to rise on the 10th of September and increased steadily and remained 5-10 ºC above the long-term average temperature until the 26th of the month. Similar patterns were observed in air temperature data from August and September of 1993 and 1994 but were not as marked as those noted in 2017 (Figure 6 and 7). Significant relationships between cyanobacterial blooms and climatic variables, including mean annual air temperature and total annual precipitation, have also been established elsewhere in Canada in the Lake of the Woods, suggesting that climate change may exacerbate or trigger algal blooms in moderately-enriched northern temperate lakes (Anderson et al., 2017).

Figure 6. Average Daily September Air Temperatures at the Harp Lake Meteorological Station.



Note: Grey box denotes the known period of the 2017 cyanobacterial bloom. 10-year averages are 2007-2016 and 1983-1992, respectively

Figure 7. Average Daily August Air Temperatures at the Harp Lake Meteorological Station.

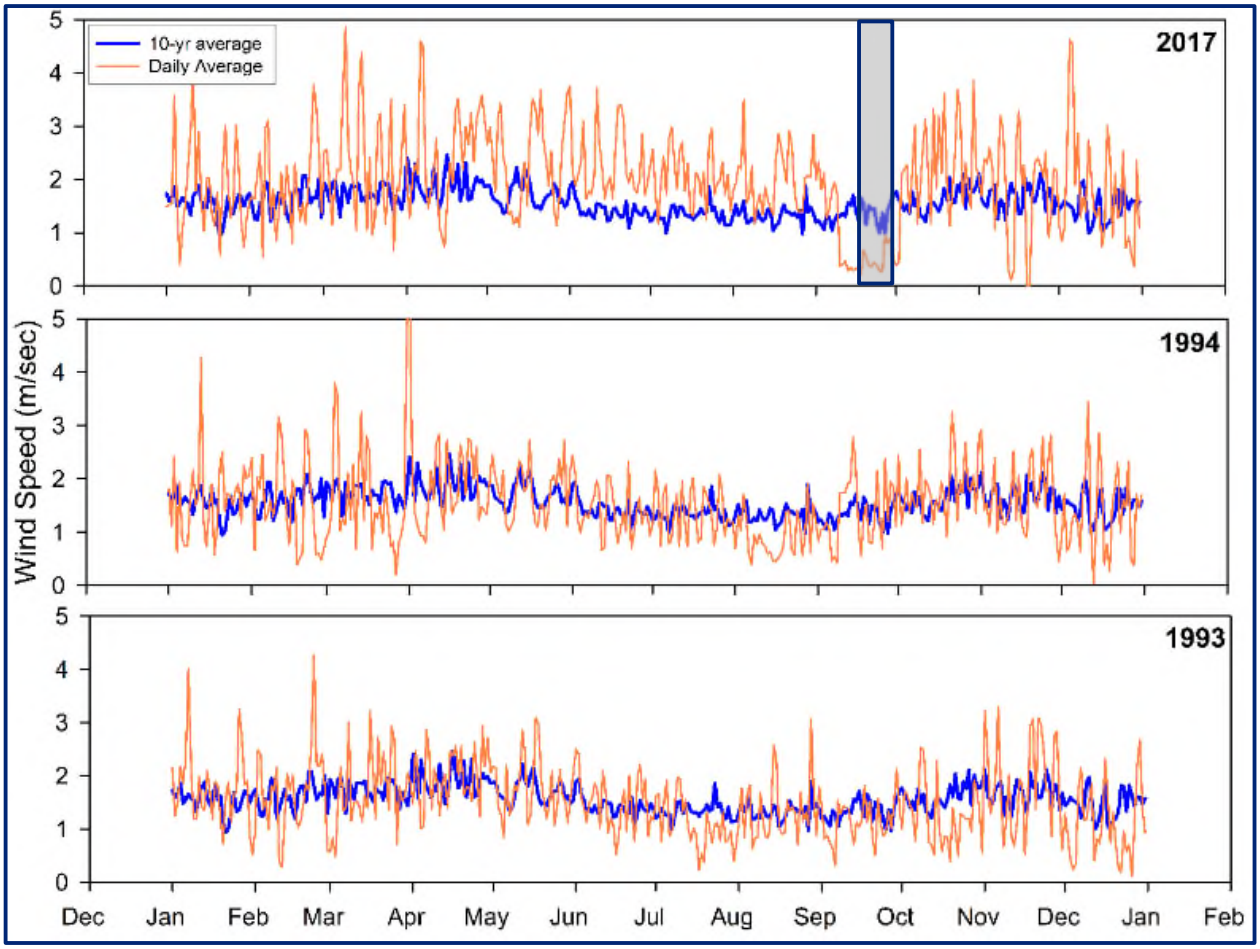


Note: 10-year average is 1983-1992.

5.3.2 Wind Speed

Local climate data showed a substantial decline in wind speed on September 10th 2017 which pre-dated the algae bloom (Figure 8) and these data are supported by anecdotal evidence provided during the DMM survey (Section 4.1.1 in which one observer stated that the 2017 bloom followed a sustained period of hot weather and calm winds). Wind records also show lower than average summer wind speeds during the bloom years of 1993 and 1994 (Figure 8). Population dynamics of *Gloeotrichia* depend critically on recruitment from sediment resting stages (e.g., Trimbee and Harris, 1984; Barbiero and Welch, 1992), particularly in north temperate lakes (Carey et al., 2014a) and literature evidence suggests akinete germination can be regulated by one or more lake-wide variables (e.g., increasing light, temperatures, nutrients, dissolved oxygen or a combination of these factors; Kaplan-Levy et al., 2010). A reduction in wind speed would be expected to increase light penetration and increase water temperature in a period of higher-than-average air temperature (Figure 6) and thus may have contributed to the germination of resting stages required to sustain a lake wide *Gloeotrichia* bloom. Furthermore, sustained periods of calm would provide a competitive advantage to cyanobacterial species which can regulate their buoyancy while diatoms and other algal groups would be expected to settle out of the water column. The importance of wind is heightened by trends to significant recent reductions in wind speed in Muskoka (Yao et. al., 2013).

Figure 8. Comparison of Wind Speed in Known Cyanobacterial Bloom Years to the Long-term Average.



Notes: Grey shaded area indicates the approximate period of the 2017 cyanobacterial bloom.

5.3.3 Summary

Periods of sustained low wind speed and high air temperature create conditions in the water column which support the dominance of cyanobacterial species. We documented periods of low wind speed coincident with high air temperature in all three known bloom years, from September 13-27th in 2017, from August 11-20 and 25-27th in 1993 and from September 12-16, 20-21 and 23-26th in 1994.

6. Phosphorus Budget

Monitoring data show no recent changes in TP concentrations or anoxic conditions in Peninsula Lake that could explain the blooms in 2017, 1993 or 1994 (Section 5.2) and the bloom species, *Gloeotrichia* is not dependent on waterborne phosphorus concentrations (Section 3.1). A phosphorus budget for Peninsula Lake, however, was reviewed to determine if there were potential sources that could influence cyanobacterial dynamics or contribute to sediment phosphorus concentrations that could be used by *Gloeotrichia.*

Gartner Lee Ltd. (2005) produced an updated phosphorus model for Muskoka's lakes which included an accounting of phosphorus sources to Peninsula Lake. Overland runoff represents a potential source of particulate and dissolved phosphorus form fertilizers, dust deposition and erosion. Runoff from large developed areas such as Hidden Valley and Deerhurst Resort contributed an estimated 12% of the total phosphorus load to Peninsula Lake (Table 4) while runoff from cottages around the lake contributed ~1.2%. Coverage by natural vegetation is reduced in large, developed areas and therefore, these areas are more susceptible to erosion and runoff during extreme storm events. Runoff increases the potential for mobilization of particulates and associated nutrients (i.e. soils) which are likely to be added to the sediment and made available to *Gloeotrichia*.

Table 4. Phosphorus Budget for Peninsula Lake.

Source	kg/yr	Percent
Natural (Watershed and Precipitation)	613	74
Overland Runoff – Cottage	9.70	1.2
Overland Runoff – Other	101.3	12.2
Septic Systems (After attenuation)	103	12.5
Total	827	100

7. Weight of Evidence Analysis

Lake systems are complex physical, chemical and biological systems whose individual components are interconnected through numerous mechanisms. In order to determine the causation of the recent and past Harmful Algal Blooms (HABs) in Peninsula Lake, and to inform causation studies on other lakes in the future, we developed a weight of evidence approach based on the many factors that may lead to the proliferation of algae and cyanobacteria in lakes in general, not just in Peninsula Lake (Figure 9 and Table 5). Each column in Table 5 represents a line of evidence which we considered based on the data presented in this report, while each row represents a potential cause of the algae or cyanobacterial blooms in Peninsula Lake based on literature reviews of causation in general. We assessed lines of evidence under three broad categories:

7.1 Climate

a. We observed a period of marked increase in air temperature at the Harp Lake Meteorological Station in September of 2017 prior to the cyanobacterial bloom. Elevated air temperature (above the long-term average) was apparent during the period of blooms in August and September of 1993 and 1994 as well but the durations and magnitude were not as striking as in 2017;

b. We analyzed local climate data and found a substantial, sustained decline in wind speed which pre-dated the algae blooms in 2017 and of below-average wind speed in 1993 and 1994, coupled with a general trend to reduced wind speed in Muskoka;

c. Periods of sustained low wind speed and high air temperature were documented in all three known bloom years, from September 13-27th in 2017, from August 11-20 and 25-27th in 1993 and from September 12-16, 20-21 and 23-26th in 1994; and

d. The potential for overland runoff is increased in more severe rainfall events, such as is predicted for a changing climate. Overland runoff from developed areas represents a significant contribution to the phosphorus budget of Peninsula Lake, and particularly of particulate sediment phosphorus and may help to predispose the lake to *Gloeotrichia echinulata* blooms by increasing the availability of sediment phosphorus.

7.2 Water Chemistry

a. We did not document any significant long-term changes in total phosphorus concentrations in the lake over time, any increase specific to 2017, nor any abnormalities in water quality that could explain the blooms;

b. We determined a potential for periodic hypolimnetic anoxia in the East basin of the lake but noted only minor increases in total phosphorus in the deep water of the East basin (7 to 15 μg/L) which did not suggest internal loading as a factor; and

c. Long-term data on potential anoxia showed low deep-water oxygen (<2.0 mg/L) in 11 years from 1990 to 2019 but this did not correlate with the occurrences of algae blooms in the lake.

7.3 Algae/Cyanobacteria Bloom History

a. The bloom species, *Gloeotrichia echinulata*, draws phosphorus from lake sediments and not from the water column,

b. Three blooms have been documented in Peninsula Lake: 1993, 1994 and 2017. The blooms in 1993 and 1994 were preceded by several years in which substantial amounts of sediment were added to the lake (Cornelisse and Evans, 1999);

c. The location, extent and duration of the 1993 and 1994 blooms was difficult to reliably ascertain, but evidence was more complete from the 2017 bloom;

d. Information available in 2017 did not suggest a localized bloom but rather that the bloom occurred lake-wide beginning in the nearshore as would be expected of *Gloeotrichia echinulata*; and

e. Timing of the 2017 algal bloom was found to coincide with several key climate parameters known to trigger either or both of a) the germination of *Gloeotrichia* resting akinetes, and b) sustain or enhance cyanobacterial growth and dominance (e.g., high temperatures, and low winds). These conditions were consistent with those observed during previous blooms.

We have tabulated these results in Table 4 below to summarize our findings and to support our conclusions and recommendations for Peninsula Lake.

7.4 Summary of Findings

Our investigation concludes that the 2017 cyanobacterial bloom was likely triggered by climate factors including air temperature and wind. The bloom was preceded by a prolonged period of high temperature and low wind, both of which are conditions which support the proliferation of cyanobacterial species. There was no evidence of changes in waterborne phosphorus concentrations in the lake over time, suggesting development and land use change have not significantly altered phosphorus in the lake based on the available data. The algal species, *Gloeotrichia*, draws its nutrients from lake sediments, storm events may therefore have acted as a factor predisposing the lake to blooms, through erosion and runoff of nutrient-rich sediments to the lake from developed areas, however there is no direct evidence to confirm this. Climate change is predicted to increase the severity of storm events and this should be considered when considering causative factors.

Figure 9. Interpretive Framework to Assess the Lines of Evidence for Cyanobacterial Blooms.

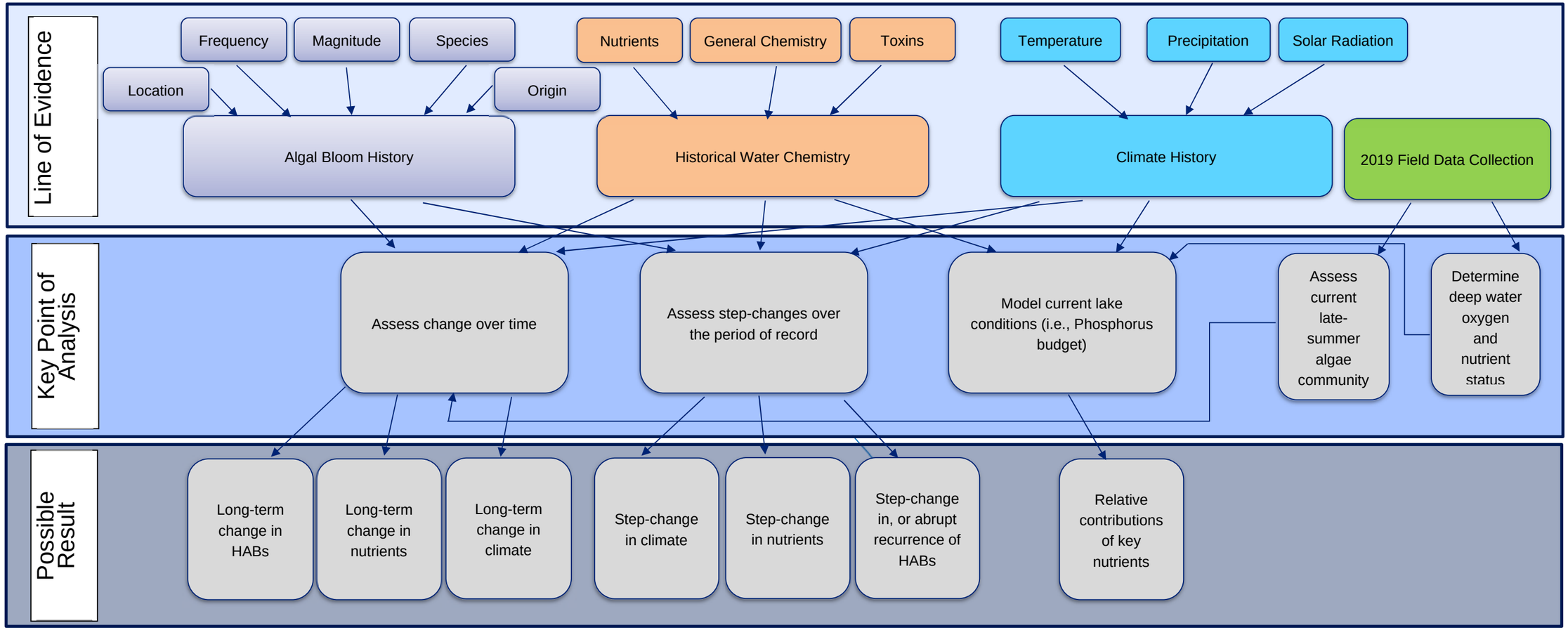


Table 5. Lines of Evidence to Inform the Potential Causes of Algal Blooms in Peninsula Lake*.

Potential Causes of Algal Blooms	Lines of Evidence											
	Increased Bloom Frequency	Documented Warmer Water	Documented Increase OR Step Change in Storm Intensity	Documented Warmer Air	Documented Increase or Step change in Low Wind Periods	Measured Internal Load	Periodic Anoxia	Documented Increase in Anoxia	Documented Increase in TP	Increased or Localized Watershed Disturbance	Location of Blooms	Extent of Blooms
Relevant Report Section	Not Applicable	Section 5.2.2.2		Section 5.3.1	Section 5.3.2	Section 5.2.2.3	Section 5.2.2.3	Section 5.2.2.3	Section 5.2.2.1	Section 4.5/5.2.1	Section 4.1/5.1	Section 4.1/5.1
Climate Conditions - Warmer/Calmer Water		X		X	X							
Climate Conditions - Enhanced Internal Loading		X		X		X	X	X	X			
Sediment Sources		X		X			X			X		
Local Landscape Disturbances			X						X	X	X	X
Internal Loading						X	X					
Increased TP Load - Septics								X	X		X	X
Increased TP load- Watershed			X						X	X	X	X
Increased TP Load - Specific Land Uses			X						X	X	X	X

Notes: * Not all lines of evidence will necessarily be relevant in all lake assessments. Green indicates a measured effect, red indicates no measured effect, yellow indicates that a measured effect could not be assessed, black indicates that the LoE was not relevant to this Causation Study (i.e. the frequency of algal blooms has not increased in Peninsula Lake).

8. Gap Analysis and Recommendations for Peninsula Lake

8.1 Gap Analysis

Substantial data collection has taken place to quantify lake health and inform ongoing management on Peninsula Lake, supplemented by a literature review and stakeholder observations. Our 2019 field data collection focused on characterising the late-summer algae community, hypolimnetic oxygen status, and deep lake water quality. Our intent was to determine the potential cause of the recent (2017) cyanobacterial bloom in Peninsula Lake and to establish if the additional investigations suggested as possible actions in the Request for Proposal from the District of Muskoka and the 2016 HESL report were required including:

- The assessment of point source or non-point source loads to inform the phosphorus budget of the lake
- A septic system survey
- Seasonal sampling of algae communities and water quality
- Hydrology and inflow assessment
- Sampling of additional parameters which may inform the causation study but are not currently a part of the DMM sampling program

Based on our findings, and particularly the ecology of the bloom species involved these additional surveys, while potentially informative, are not likely to contribute additional pertinent information to the causation of the cyanobacterial blooms in Peninsula Lake.

This study documented that blooms on Peninsula Lake are infrequent occurrences and that documentation of the timing and spatial extent of blooms is a key element in assessing causation. Cyanobacterial blooms in 1993 and 1994 were recorded by Cornelisse and Evans (1999), however we could not reliably determine the onset, extent and duration of those blooms, beyond their occurrence in later summer (N.J. Hutchinson, pers. comm.). Responses to the survey conducted as part of this study suggest that information from stakeholders may be valuable, however these records will generally reflect the observations made near locations of the respondent's residence and would be most informative if they were part of a coordinated lake-wide survey.

Water quality data on Peninsula Lake is currently collected by the DMM Lake System Health Program every other year and there is no indication that long-term changes in water quality have occurred. We agree with this sampling strategy in principle, as a cost effective means to track changes over time in a large set of lakes, but recognize that broad scale monitoring programs are not intended to provide all of the details required to address all specific concerns. They are not likely to inform specific blooms unless the blooms are caused by a long-term change in water quality that is detected in the routine program.

Peninsula Lake was not sampled in 2017 and water temperature and oxygen profile data from 2017 may have provided useful information when exploring the potential effects of calm winds on Peninsula Lake, however those data were not available. As Peninsula Lake is now listed as a vulnerable lake it will be sampled annually under the Official Plan policies until it is removed from Schedule E2. Climate factors which appear to be responsible for the 2017 bloom are monitored at Harp Lake (~6 km NE of Peninsula Lake) by the MECP and this information was very useful to this causation study.

Infrequent algal blooms, however, such as those recorded in Peninsula Lake, are best investigated by comparing conditions between bloom periods and non-bloom periods, at a focussed research level of investigation.

8.2 Lake-Specific Recommendations

Peninsula Lake has experienced periodic blooms over 25 years of a species, *Gloeotrichia echinulata*, that responds to phosphorus in lake sediments and not in the water column, and which appears to be triggered by periods of calm and warm weather that were preceded by intense rain events. As such, the presumed linkage between algal blooms, shoreline development and annual nutrient status that informed the concept of causation studies (HESL 2016) and the existing monitoring program does not hold for Peninsula Lake. The absence of any increasing trend in phosphorus in Peninsula Lake over the 24 year period in which the algal blooms were recorded, and the fact that phosphorus concentrations in the lake are at or near pre-development levels (Clerk et al. 2000) suggests that the link between algal blooms, waterborne phosphorus and shoreline development is weak in Peninsula Lake. We qualify this conclusion, however, as follows:

- Peninsula Lake has experienced three recorded blooms over the past 25 years and the recurring nature warrants a more serious management response than a single bloom in a single year would,

- The Causation Study for Peninsula Lake made a linkage between calm weather, increased intensity of rain events, the importance of runoff from developed areas to the Peninsula Lake phosphorus budget and the resultant potential that increased runoff could increase the loading of particulate phosphorus to lake sediments. Any increase in sedimentary load could increase the likelihood of a bloom in certain years when the climatic drivers favour cyanobacteria. This suggests that increased sediment phosphorus levels could predispose a lake to blooms and that management to reduce runoff and stormwater is an increasingly important activity. This is also true, however, in the absence of algal blooms, as runoff adds nutrients and other pollutants to receiving waters and should, as a general principle, be minimized.

The DMM supports and encourages, and should therefore continue to support and encourage:

- stewardship and educational programs to improve shoreline buffers, reduce disturbance and use of fertilizers and products containing phosphorus, planting of native vegetation, etc.
- improved storm water management to reduce run-off from developed or disturbed areas,
- Continued annual sampling through the District's existing program, the Lake Partner Program, or other standardized systems.

9. Pilot Causation Study Review – Lessons Learned, General Recommendations and Future Considerations

9.1 General Policy and Program Recommendations

Causation studies were originally proposed by HESL (2016) and were adopted by the District of Muskoka to support planning policy on individual lakes identified as vulnerable – to determine whether or not shoreline development practices were increasing the phosphorus concentrations in some lakes or resulting in algal blooms, so that appropriate planning responses could be implemented where warranted. We note that this rationale would be strongest where an algal bloom occurred repeatedly in a lake over several consecutive or near consecutive years. This would increase the likelihood that the cause was a long-term change in lake characteristics (such as increased nutrient loading from development) and not the result of variable weather or hydrologic conditions between years. This does not appear to be the case in Peninsula Lake – it has had periodic blooms which are not regular enough to suggest that a change in lake status is the cause. Phosphorus concentrations in the lake are stable and did not increase in years when a bloom occurred.

> **Recommendation –** Studies of algal bloom causation will be most informative when they are triggered by blooms which occur repeatedly in a lake over several consecutive or near consecutive years. This pattern is more likely to be traceable to a common and manageable cause which is manifest routinely, such as enriched nutrients or consistent internal loading. In contrast, blooms which are triggered by specific climatic events are less predictable and less likely to be traceable to causes that can be addressed through District policy.

Evidence presented in this Causation Study, for example, shows no evidence that phosphorus concentrations have increased in conjunction with the observed blooms, that the paleolimnological record shows substantial declines in phosphorus over the past 50 years (Clerk et al., 2000) and suggests that other factors, such as climate change, are more likely to be implicated in blooms in low nutrient lakes. In addition, recent research concluded that the presumed link between septic systems and lake phosphorus levels that helps inform District policy and the premise of causation studies, and which guides the Province's lake management approach (MOEE, 2010), is no longer supported. Robertson et al. (2019) concluded that the tile field of a typical septic system in Precambrian Shield retains, on average, 96% of the total phosphorus discharged to it. Other research has also shown the importance of factors unrelated to shoreline development in the recent proliferation of algae and cyanobacterial blooms in Ontario. Winter et al. (2011) documented increasing algal blooms across Ontario, even in undeveloped lakes, and phosphorus concentrations are, in general, stable or declining in South Central Ontario as shown in data from the MECP (Palmer et al., 2011) and in the District of Muskoka's own program (HESL, 2016). At the same time, the climate is warming with attendant changes in temperature, storm intensity, wind and ice cover.

> **Recommendation –** Climate change is an increasingly important trigger for algal blooms and prevention of climate -induced blooms is not addressed under current District policy. Additional causation studies may reveal different causes over time. The District should undertake periodic reviews of completed causation studies and revise policy, if and as warranted to reflect which aspects of policy are likely to address which specific causative factors in order that programs can focus on those conditions and cases that can be managed.

These observations challenge the link between algal blooms, development and nutrient status in oligotrophic lakes and the utility of using algal blooms on their own as a trigger for causation studies in Muskoka. Conventional sampling programs, including that of the DMM, monitor phosphorus concentrations in the water column, as this is the trigger for many algal blooms and is a good indicator of lake health. If shoreline development was the cause of a recent algal bloom, however, then we would expect that total phosphorus concentrations would also have increased over time. That rationale guides the MOP requirement for a causation study in response to a statistically significant ($p<0.1$) increase in TP concentrations since 2000, or a five-year mean TP concentration exceeding 20 µg/L (HESL, 2016).

Measurement of average phosphorus concentrations would not detect short term "spikes" in concentration but detection of such "spikes" is impractical[3] as part of a routine program. and not necessary. It is highly unlikely that these occur or to consider what could cause such a spike - the Muskoka Water Quality Model (HESL 2016) predicts that 80 kg of TP are required to raise concentrations by 1 µg/L in Peninsula Lake. Cornelisse and Evans (1999) and the user survey, however, did report episodes of sediment input to Peninsula Lake in the years preceding the 1993 and 1994 blooms and so could be useful here (Section 5.2.1).

> **Recommendation -** "Citizen Science" Programs, in which lake residents conducted organized whole lake surveys in response to a bloom event or conducted water quality sampling at finer spatial and temporal scales or which responded to storm events or specific interests do represent a practical means to investigate water quality and potential bloom causation at a more detailed scale[4]. Careful planning and coordinating of Citizen Science Programs through the DMM, including training and expert advise will ensure the usefulness and integrity of data collected.

The absence, however, of any measured increase in phosphorus in Peninsula Lake means that planning policy based on managing nutrient input from shoreline development, while still useful in its own right, may not be effective in controlling algal blooms, especially with the increasing impact of climate change and its role in algal blooms.

> **Recommendation -** We therefore recommend that the District reconsider the use of algal blooms as a criterion for a causation study or, if they choose to maintain this trigger, that the criteria by which an algal bloom triggers a causation study be strengthened, to consider repeated episodes and the extent and severity of blooms and be less responsive to individual bloom occurrences. Further work would be required to define "repeated episodes" or "bloom extent" to allow for meaningful policy implementation.

> **Recommendation -** Further, while increased monitoring frequency is not recommended for Peninsula Lake at this time, generally we recommend monitoring vulnerable lakes every year until the lake is a) no longer listed as vulnerable or b) causation is established and addressed, if feasible, for that lake. If feasible, this monitoring should include monthly sampling of water column profiles

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[3] *Such an investigation would require sampling at a very fine temporal resolution at many areas of a lake in anticipation that a bloom may occur. We submit that this would be impractical. An alternative may be an immediate response to any reported bloom, such that a lake could be sampled while the bloom was underway.*

[4] *https://www.mla.on.ca/History%20of%20the%20MLA%20Water%20Quality%20Program*
http://loba.ca/programs/environment/mandate/

(i.e. temperature and dissolved oxygen) into October and total phosphorus and 1 mob sampling in August and September if hypolimnetic anoxia is detected.

9.2 Considerations for Future Causation Studies

The conduct of the Peninsula Lake Causation Study as a pilot study has raised several recommendations that should be considered for future studies:

9.2.1 Nature of the Bloom

a. HESL (2016) proposed that algal blooms be included as an indicator based on the most common form of nutrient-triggered nuisance bloom– free floating cyanobacteria taking phosphorus from the water column. The Peninsula Lake bloom was known to be different – a species taking nutrients from lake sediments. As such, the findings of the Peninsula Lake study may not be applicable to causation studies for other lakes. However, elements of the methodology particularly the lines/weight of evidence framework should be adopted in future studies,

o The Request for Proposal was sent out with no information on the algal species that bloomed or details that would help consultants assess the severity of the bloom or scope their responses. We recommend that the District of Muskoka maintain records from sampling conducted by the Health Unit, MECP and/or lake association of future confirmed bloom events that include:

- the laboratory taxonomic results documenting the species and their relative abundances,
- the date when the bloom was first noted,
- location of the bloom (i.e., where was the bloom first observed),
- extent of the bloom (i.e., how much of the lake was affected) and photographic documentation,
- the duration of the bloom (i.e., how long did it last) and
- the results of any water quality measurements or biological samples collected by the District, the MECP or lake residents.
- And that these details be included in the Request for Proposal as this will help scope the proposal and more clearly identify the necessary effort.

We recommend that a strategy be put in place at the District to ensure the gathering and recording of systematic information on the identity of bloom – forming species and the extent, duration and onset of future cyanobacterial blooms through field sampling, cooperation with the Health Unit and MECP and engagement with the residents and stakeholders. Causation are hampered without knowing the details of the bloom.

9.2.2 Study Timing

If field sampling is necessary to supplement historical data, then the timing of project initiation is key. The current project began in early October making late summer sampling, when blooms tend to be an issue, difficult and the study was implemented two years after the bloom was reported. Where possible, the study timing should allow for up-front sampling in late summer and during or immediately after a bloom occurrence in order to capture the conditions present during the period in which the bloom occurred. As an alternative, the background information and assessment of historical data would be underway or completed prior to field investigation. As such, initial studies should be conducted over the winter so that any necessary follow up field can be recommended and approved prior to the summer season and the study completed in the fall.

9.2.3 Budget

f. HESL (2016) recommended budgets of $1,000 - $8,500 for causation studies, based primarily on desktop reviews of existing data and straightforward interpretations. Assuming limited desktop study of existing data ~$10,000 may still be sufficient to review existing material and analyze existing data, however the addition of field sampling components (annual, monthly or seasonal), public meetings and stakeholder surveys as well as other elements listed in the HESL (2016) report (i.e. septic system surveys, hydrology assessments, land use surveys, etc.) will require additional expense.

g. $20,000 was earmarked for this pilot program to include stakeholder engagement. Stakeholder engagement accounted for 25% of the total budgeted amount and travel time and costs could be substantial for consultants based outside Muskoka. Assessing Stakeholder survey responses was also a greater time investment than anticipated.

b. The original Request for Proposal for the Peninsula Lake study included stakeholder engagement (i.e. meetings and survey), background data analysis, seasonal field sampling, basic septic system inspections, assessment of point and non-point sources (including field data) and land use mapping as possible component of a causation study. Our experience advises that a causation study which includes these items would be budgeted between $80,000 - $100,000. We do not believe, however, that this level of study is necessary in every vulnerable lake to complete an assessment of causation.

9.2.4 Lines/Weight of Evidence Framework

a. The Lines/Weight of Evidence Framework developed for this assessment worked well in Peninsula Lake. Data were available in the majority of key categories. However, the framework may need to be tailored to each individual causation study depending on the circumstances surrounding the bloom. Nevertheless, we recommend that the framework, or a variant be used to inform all Causation Studies, to ensure that a consistent set of potential factors is considered to produce reproducible and defensible results.

9.2.5 Phased Approach

A phased approach to future Causation Studies is recommended where the need for the next phase is determined by the outcome of the previous. We recommend, as a general approach, that future Causation Studies proceed as follows:

a. Phase I – Desktop historical data review

   i. To be completed in accordance with the timing recommendations above,

   ii. Used to establish what data are available,

   iii. Provide an assessment of what those data show, and

   iv. Identify gaps in the available data and determine what is necessary to fill those gaps.

b. Phase II – Field Data collection

   i. As necessary to address issues with existing data identified in Phase I, and

   ii. Should be focussed on collecting data for a specific purpose (e.g., to inform point and non-point sources of pollution) or at a specific time of year (e.g. to measure late-summer oxygen conditions) rather than to collect seasonal samples which are unlike to greatly inform causation.

c. Phase III – Special Studies

   i. These would only be conducted if additional information is required to determine the cause of the identified water quality indicator and may include detailed land-use assessments or septic systems inspections to address water quality issues identified during earlier phases and guide management of water quality through planning policy or specific management actions.

9.2.6 Stakeholder Input

Input from stakeholders was a key focus of the District as a part of the Causation Study process to acquire information on the lake from residents and businesses that could provide background not available from standard lake monitoring. This information included:

a. Phosphorus data collected by the lake association in cooperation with the Lake Partner Program, which complemented and confirmed data from other sources ,

b. Photos of the bloom provided by some residents (Appendix B), and

c. A Stakeholder Survey which included responses to a series of questions on algal bloom and lake history.

Stakeholder input confirmed the weather conditions present prior to the 2017 bloom and assisted in interpretation of causation. Photos provided by some stakeholders contained some information of the cyanobacterial bloom but were limited to the nearshore environment around 1 or 2 properties and therefore did not provide the lake-wide scale of the bloom. The aerial photos provided were useful in documenting the spatial extent of the bloom.

Additional information collected in the survey included:

a. Property use (i.e., cottage or permanent residence, commercial enterprise, etc.),

b. Public perception of water quality, and

c. Impacts of the bloom on use of the lake.

We found that these data were of limited value in determining the causation of algal blooms on Peninsula Lake and added unnecessarily to the length of the survey. We would therefore recommend that future surveys be focussed on key questions about algal bloom history, timing and spatial extent. Additional information on the onset, duration and scale of any future blooms would be highly valuable information for stakeholders to document as these are the data that are difficult to capture with sporadic sampling.

Our review of the survey responses also indicated some degree of confusion on what constituted a bloom. Several responses, for example, described filamentous, attached algae as a “bloom”. While such attached algal masses are not aesthetically pleasing and a may be considered a nuisance, they are routine responses of algae to warm, slightly acidic waters and are conodred ot be a response to nutrient enrichment.

The District should consider some form of outreach program to better inform residents as to the characteristics of blooms. Useful materials are readily available[5] but awareness of and access to the may improve the reporting and understanding of causation.

[5] http://www.muskokawaterweb.ca/resources-by-topic#a

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1

Appendix A. Public Survey Results - DMM

Survey Report

21 October 2019 - 02 December 2019

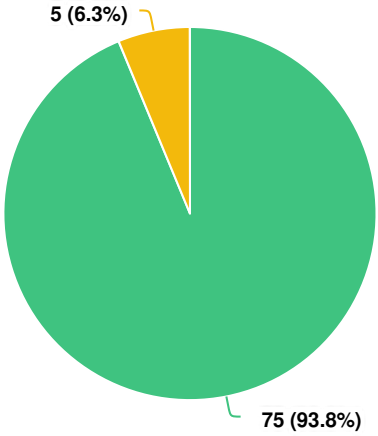
Peninsula Lake Causation Study

PROJECT: Protecting Muskoka's Vulnerable Lakes: Causation Studies

Engage Muskoka

engagement hq by Bang the Table

Q1 Whether you own property on Peninsula Lake or not, do you participate in recreational activities on Peninsula Lake? (e.g. s...

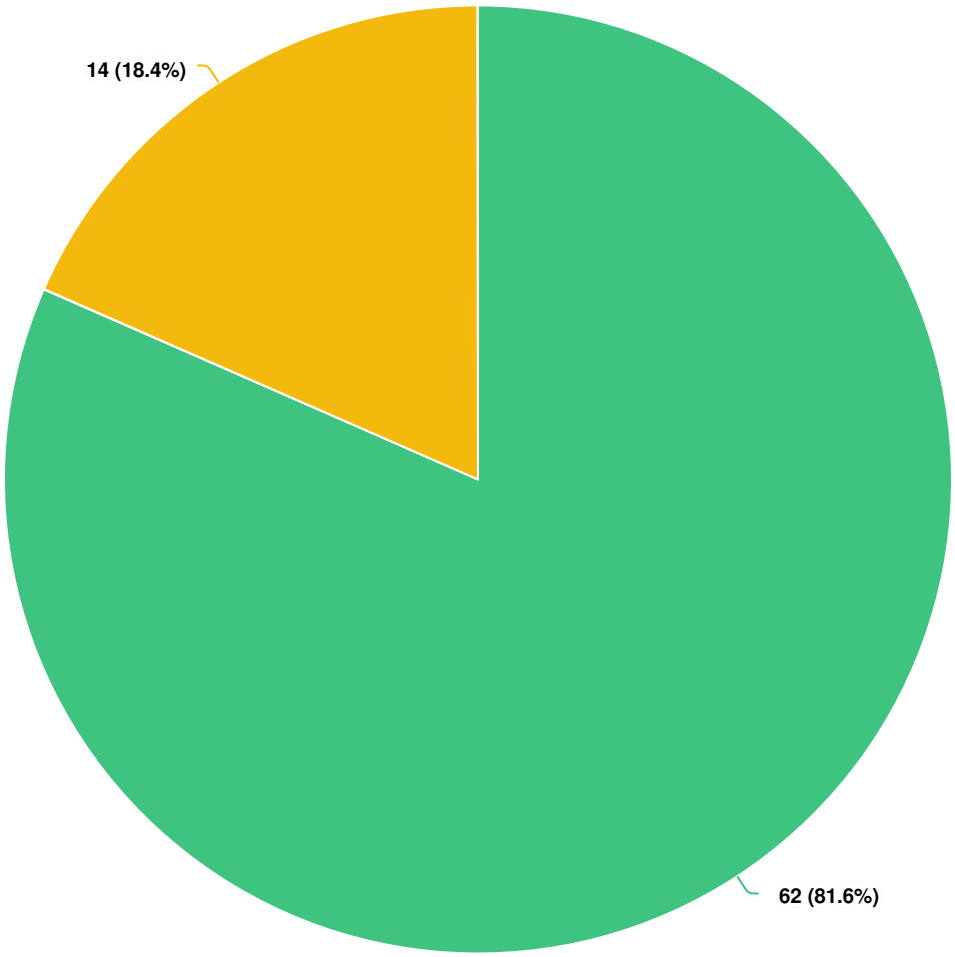


Question options

Yes No

Optional question (80 responses, 2 skipped)

Q2 Do you own property on Peninsula Lake?



Question options

- Yes
- No

Optional question (76 responses, 6 skipped)

Q3 How long have you owned your property on Peninsula Lake?

Anonymous 10/30/2019 10:24 AM	110 years
Anonymous 10/30/2019 02:04 PM	As cottager for 45 years and as resident for 18 years
Anonymous 11/01/2019 12:34 PM	10 years
Anonymous 11/01/2019 03:29 PM	Family cottage since 1929
Anonymous 11/01/2019 04:15 PM	In the family for over 100 years.
Anonymous 11/01/2019 04:45 PM	20 years
Anonymous 11/01/2019 05:47 PM	100 years
Anonymous 11/01/2019 06:47 PM	19 years
Anonymous 11/01/2019 07:38 PM	Has been in our family for 56 years.
Anonymous 11/01/2019 09:16 PM	1985
Anonymous 11/02/2019 05:09 AM	23 years
Anonymous 11/02/2019 07:08 AM	45 + years
Anonymous 11/02/2019 07:25 AM	55 years
Anonymous 11/02/2019 02:36 PM	24 years
Anonymous 11/03/2019 10:39 AM	32 years
Anonymous 11/04/2019 07:54 AM	4 years
Anonymous	97 years

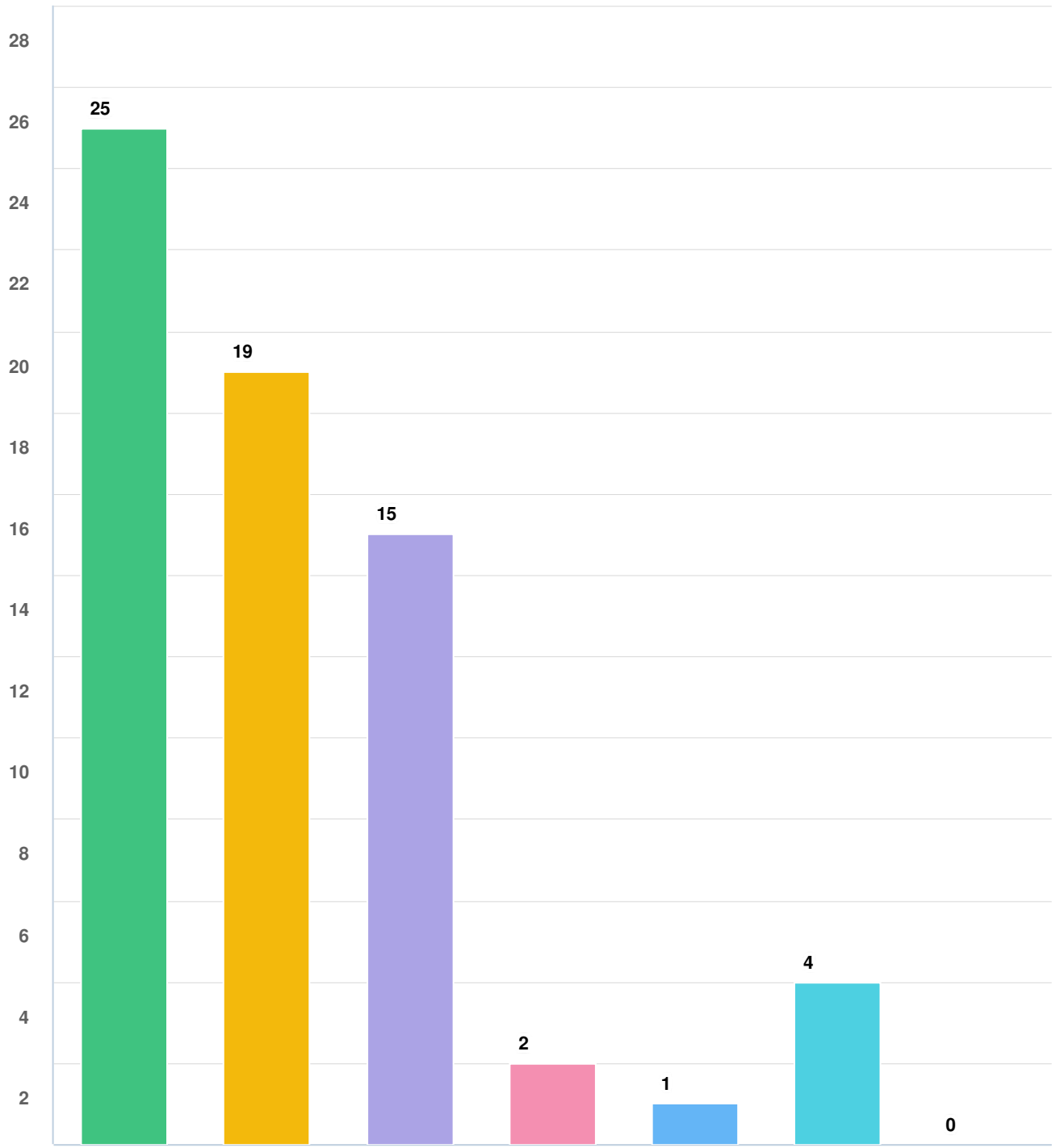
11/04/2019 08:45 AM	
Anonymous 11/04/2019 06:43 PM	25 years
Anonymous 11/06/2019 07:30 AM	3 yrs
Anonymous 11/06/2019 08:30 AM	50 years
Anonymous 11/06/2019 08:52 AM	My grandfather purchased our property in 1919, so we have been there for 100 years.
Anonymous 11/06/2019 08:55 AM	Over 60 years
Anonymous 11/06/2019 01:59 PM	6 years
Anonymous 11/06/2019 02:58 PM	10 years
Anonymous 11/06/2019 06:33 PM	100 years
Anonymous 11/06/2019 06:58 PM	~110 years
Anonymous 11/06/2019 07:58 PM	30 years
Anonymous 11/07/2019 01:12 AM	20 years
Anonymous 11/07/2019 05:14 AM	68 years
Anonymous 11/07/2019 08:17 AM	3 years
Anonymous 11/07/2019 08:28 AM	10 years
Anonymous 11/07/2019 08:45 AM	1 year
Anonymous 11/07/2019 08:46 AM	16 years
Anonymous 11/07/2019 08:51 AM	14 years

Anonymous 11/07/2019 09:14 AM	11 years
Anonymous 11/07/2019 09:29 AM	3+ years
Anonymous 11/07/2019 10:32 AM	Since 1990
Anonymous 11/07/2019 12:26 PM	10 years
Anonymous 11/07/2019 01:21 PM	12 years
Anonymous 11/07/2019 02:22 PM	1 year
Anonymous 11/07/2019 04:06 PM	26 years
Anonymous 11/07/2019 07:46 PM	3 years
Anonymous 11/08/2019 11:14 AM	9 years
Anonymous 11/08/2019 11:18 AM	27 years
Anonymous 11/08/2019 01:28 PM	Since 2001
Anonymous 11/08/2019 03:46 PM	6 years
Anonymous 11/09/2019 12:36 PM	3 years
Anonymous 11/10/2019 10:39 AM	30 years
Anonymous 11/11/2019 03:30 PM	5 years
Anonymous 11/11/2019 06:51 PM	3 years and vacationed by renting for the last 20 years
Anonymous 11/11/2019 09:28 PM	1 year
Anonymous 11/12/2019 01:19 PM	1929

Anonymous 11/13/2019 01:40 PM	100 years
Anonymous 11/13/2019 07:09 PM	9 years
Anonymous 11/14/2019 07:34 AM	70
Anonymous 11/14/2019 02:32 PM	1992
Anonymous 11/22/2019 01:37 PM	3 years
Anonymous 11/24/2019 04:13 PM	5 years
Anonymous 11/29/2019 09:17 PM	44 years
Anonymous 11/30/2019 09:42 AM	73 years
Anonymous 11/30/2019 09:48 AM	35 years

Optional question (61 responses, 21 skipped)

Q4 What type of property do you own?

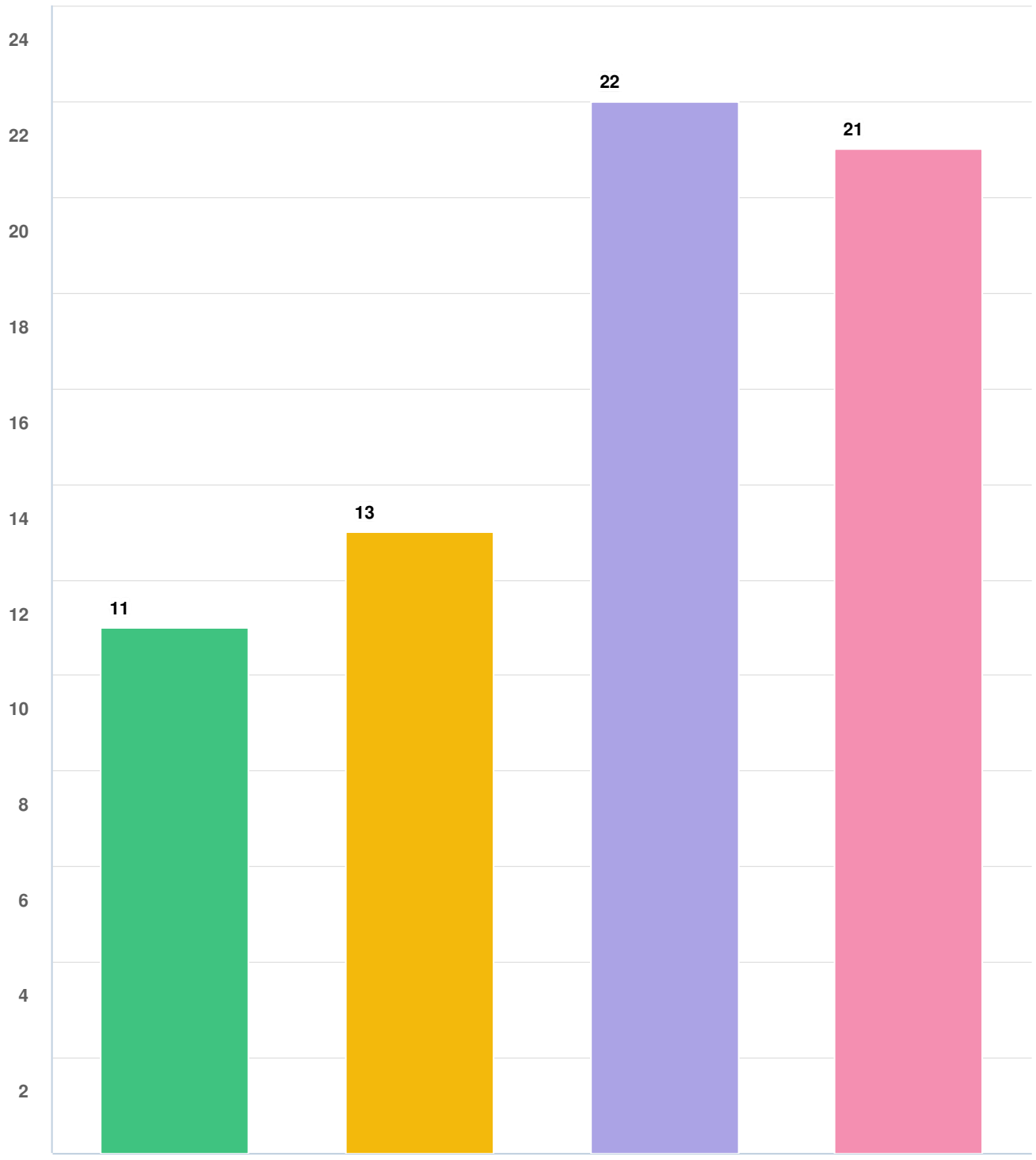


Question options

Cottage · Permanent Residence · Resort condominium unit · Vacant Land · Commercial · Other (please specify) · Marina

Optional question (62 responses, 20 skipped)

Q5 Do you use your property:

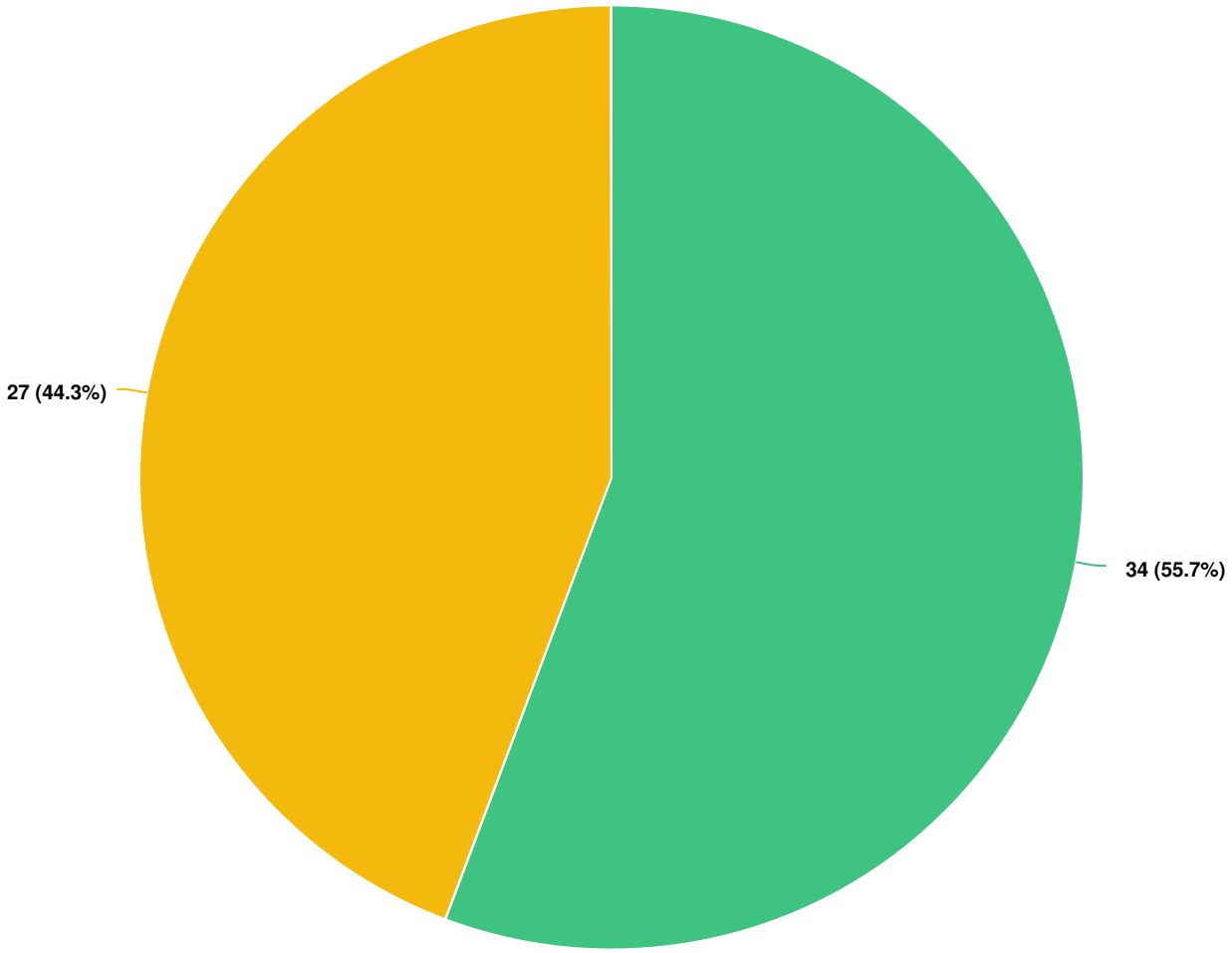


Question options

- Summer only
- Summer and occasionally in winter
- Regularly throughout the year
- I am a pemanent resident

Optional question (62 responses, 20 skipped)

Q6 Is your property located in the eastern or the western basin of the lake?

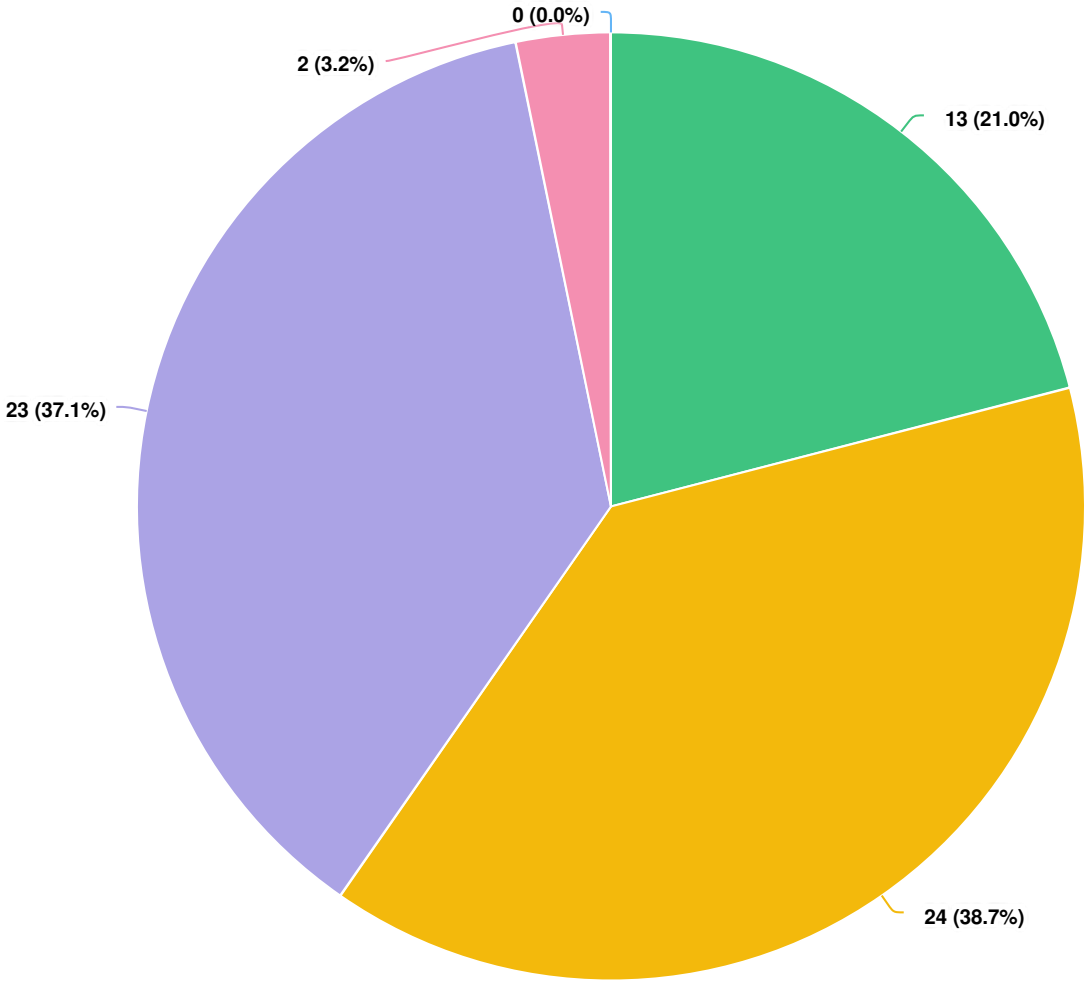


Question options

eastern western

Optional question (61 responses, 21 skipped)

Q7 Rate your overall satisfaction with water quality in your portion of the lake



Question options

Dissatisfied · Neutral · Satisifed · Very satisfied · Very dissatisfied

Optional question (62 responses, 20 skipped)

Q8 What characteristics or observations of the lake informed your satisfaction level?

Anonymous 10/30/2019 10:24 AM	We can swim in it, catch fish
Anonymous 10/30/2019 02:04 PM	Water clarity and temperature. Weed growth. Bacterial content.
Anonymous 11/01/2019 12:34 PM	We often see what looks like suds along the shore line and also some sort of green vegetation floating in the water. Also, because the hilly gravel road that leads to the lake near us is frequently washing into the lake, the shoreline around where our dock is, is often filling up with soil, gravel and debris and at some times, we have only a foot of water at the end of the 75 foot dock and the rest of the dock is sitting on dry land. When we put in the dock 5 years ago, LOB required we put it in exactly the same location as the former dock, but in the meantime the beach is becoming larger due to run off into the lake at the same location. Also, the sandy beach area next to our dock area is filled with gravel from runoff from the road. Once the road was so eroded that it was unpassable and looked like a bombed out basement. We were told that the gravel could not be removed because it was "natural". Of course it is not natural as it ran into the water from the man-made road.
Anonymous 11/01/2019 03:29 PM	Rocks at the shoreline are always covered with a thin (sometimes thicker) layer of some sort of unpleasant slimy stuff, which in decades past was never there. As well as occasional algal blooms.
Anonymous 11/01/2019 04:15 PM	Occasional murky impression and low visibility in the water.
Anonymous 11/01/2019 04:45 PM	large amount of traffic of jetskis on lake amount of green organic matter growing in lake misc garbage found in water
Anonymous 11/01/2019 05:47 PM	Significant Increased weed growth; decreased water clarity; erratic water levels
Anonymous 11/01/2019 07:38 PM	Cloudiness and changing clarity levels that seem to fluctuate over the summer.
Anonymous 11/01/2019 09:16 PM	Good number of fish and waterfowl. Relatively quiet bay re boat activity. No resorts in our end of the lake. Water usually clear of algae and bacterial level is low.
Anonymous 11/02/2019 05:09 AM	Lake water levels have become inconsistent within the season and season to season. Algal blooms occur later in the summer season on occasion with increased weed growth - this has occurred in the past however the frequency is up somewhat. Less rock bass around the deck edge in the last few summers. Still enjoy swimming
Anonymous 11/02/2019 07:08 AM	Algae bloom and more weed prominent growth in August. We are on an island, so the water is our life.
Anonymous	The benthic monitoring shows the lake is healthy and the MNRF fish study

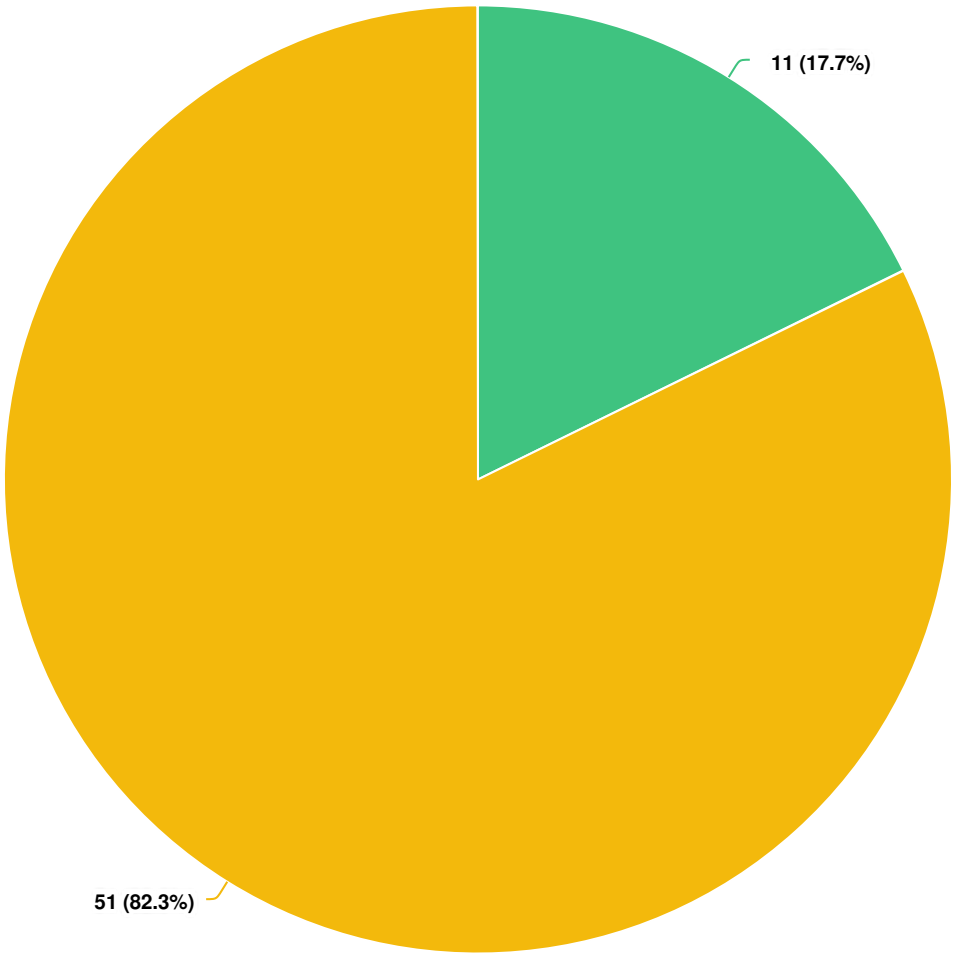
11/02/2019 07:25 AM	has shown we have a healthy population. The loons and duck population are also healthy. The only down side to this health is the invasive cormorant,s.
Anonymous 11/02/2019 02:36 PM	We didn't notice any algae blooms in our portion of the lake (Hillside Bay, Maplehurst Drive South) during the past summer (2019).
Anonymous 11/03/2019 10:39 AM	we have a relatively small, protected bay, Grassmere Bay at north end of the lake
Anonymous 11/04/2019 07:54 AM	being able to see clearly the bottom of lake
Anonymous 11/04/2019 08:45 AM	Watching the water quality for decades, it has been clean and clear for the most part. Only once in a blue moon - WHEN THE CONDITIONS JUST HAPPEN TO MATCH UP - there is an algae bloom. We have not seen an increase in these occurrences.
Anonymous 11/04/2019 06:43 PM	Water quality testing by district and lake association
Anonymous 11/06/2019 07:30 AM	weeds, gasoline
Anonymous 11/06/2019 08:30 AM	Regular inspections of beach and dock area water clarity.
Anonymous 11/06/2019 08:52 AM	It is usually good but can lose clarity with algae and or other particulates during the summer.
Anonymous 11/06/2019 08:55 AM	Clarity
Anonymous 11/06/2019 11:07 AM	There are too many geese fouling the water - the docks in September are covered in goose feces which I'm sure most residents & hotels simply clear off into the lake. Also with two golf courses on the lake (Grandview & Deerhurst) there may be a high level of fertilizer flowing into the lake during the summer.
Anonymous 11/06/2019 01:59 PM	Starting in late August for the past 3 years I have observed small suspended solids in the Hidden Valley bay area, not sure if this is goose droppings or algae (there is a large goose population in the area). The same water conditions were present before the blue-green algae bloom in 2017. During the spring and early summer the water has been clear.
Anonymous 11/06/2019 02:58 PM	Usually clear water, soft, tastes fine.
Anonymous 11/06/2019 06:33 PM	Algae blooms, pollution, water levels
Anonymous 11/06/2019 06:58 PM	Water is somewhat less clear than it was 50 years ago.
Anonymous 11/06/2019 07:58 PM	It looks pretty good to me most of the time. In very hot weather it gets cloudy.

Anonymous 11/07/2019 05:14 AM	Water is clear and fine for swimming, etc.
Anonymous 11/07/2019 08:17 AM	clear
Anonymous 11/07/2019 08:28 AM	generally clean
Anonymous 11/07/2019 08:45 AM	The generous usage of all water facilities throughout the recreation season.
Anonymous 11/07/2019 08:46 AM	algae blooms, marine fuel
Anonymous 11/07/2019 08:51 AM	algae bloom
Anonymous 11/07/2019 09:14 AM	Clear water, no colour distortion, foam, etc.
Anonymous 11/07/2019 09:29 AM	the water at times looks questionable. just not sure if I should be jumping into it
Anonymous 11/07/2019 01:21 PM	fresh and clear the only issue was a couple of years ago with the blue algae
Anonymous 11/07/2019 02:22 PM	Not as clean as other lakes.
Anonymous 11/07/2019 04:06 PM	Some silt
Anonymous 11/08/2019 11:14 AM	Water softness, clarity, wildlife and fish support.
Anonymous 11/08/2019 11:18 AM	Would be very satisfied except for the algae bloom we had a few years ago.
Anonymous 11/08/2019 01:28 PM	I see black dots in the water from time to time
Anonymous 11/08/2019 03:46 PM	visibility good, good fish and wildlife activity, able to drink it (after UV, particulate and organic filters)
Anonymous 11/09/2019 12:36 PM	Appears blue green algae like by late summer
Anonymous 11/10/2019 10:39 AM	Water clarity
Anonymous 11/11/2019 03:30 PM	Knowledge of number of golf courses on lake, number of boats, recent history of blue green algae, heavy smell of chlorine in drinking water which

	we assume indicates the presence of “something” requiring high level of disinfection/chlorine
Anonymous 11/11/2019 06:51 PM	Fish varieties and vegetation flourish.
Anonymous 11/12/2019 01:19 PM	The clarity of the water has gone down hill over the past 10 years. There is always a thick, slick slime on the rocks, and heavy sediment.
Anonymous 11/13/2019 07:09 PM	We are in likely the shallowest area of the lake just west of Tally Ho. At the shoreline we have generally hard packed sand but 200 feet from shore where our dock ends has been becoming much softer and weedier than prior. I was a child on the same property in the 60's early 70's and recently purchased the property back in 2010, so these are some of the differences I have experienced since then on the water front directly in front of me.
Anonymous 11/14/2019 07:34 AM	Ecoli and geese
Anonymous 11/14/2019 02:32 PM	very good unless we get an algae bloom then very dissatisfied. It has been happening more often in recent years.
Anonymous 11/24/2019 04:13 PM	The lake does have some algae, especially in the summer, but we would expect that. Our family has not experienced swimmers ear or any digestive issues that we know of that would have resulted from lake water. We are active swimmers.
Anonymous 11/30/2019 09:42 AM	Increased silt and sedimentation.
Anonymous 11/30/2019 09:48 AM	Periodic opacity and weed growth. Wake boats causing shoreline disturbance. Flooding and variable water levels.

Optional question (53 responses, 29 skipped)

Q9 Is Peninsula Lake your source for drinking water?

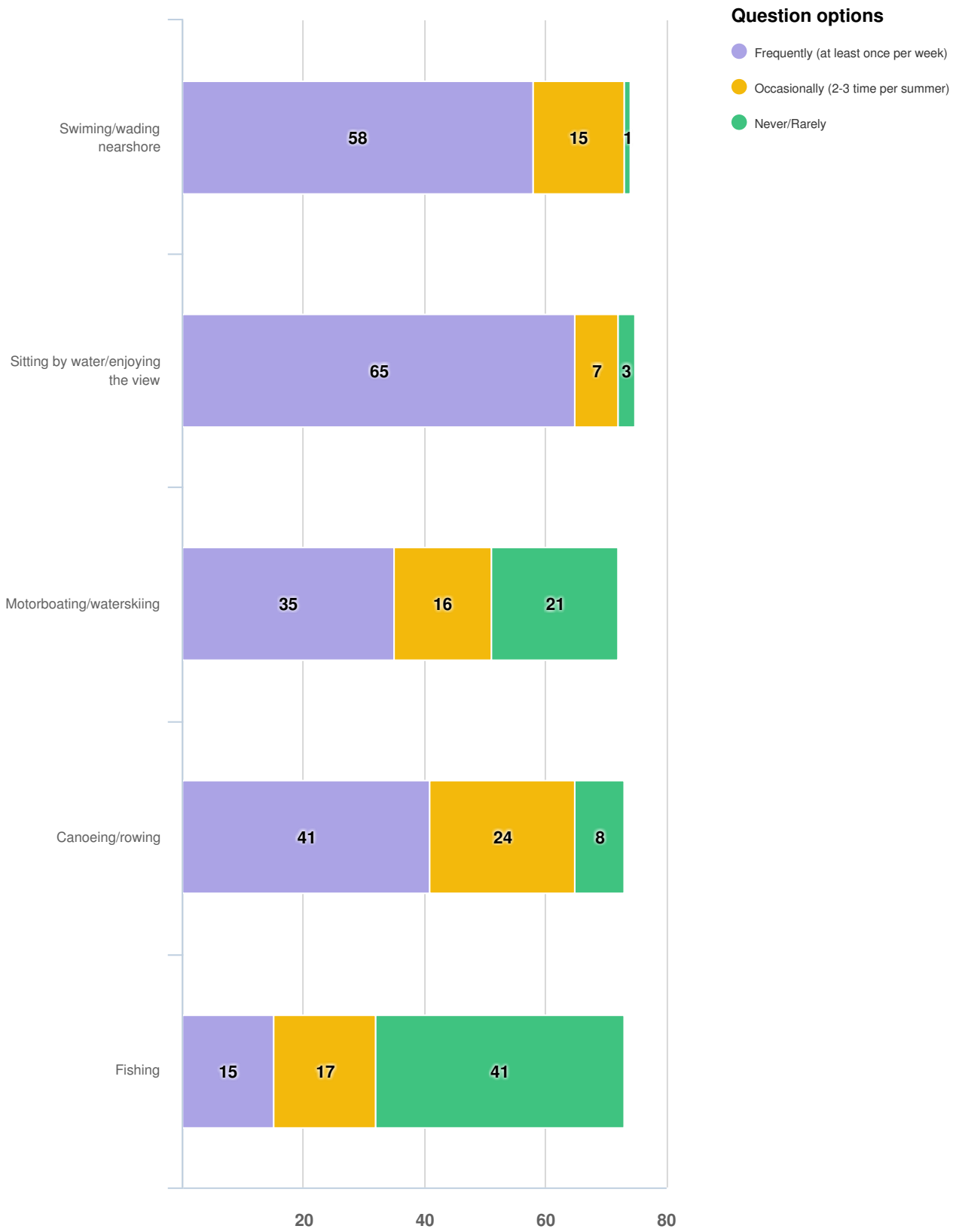


Question options

Yes No

Optional question (62 responses, 20 skipped)

Q10 How often do you/your family participate in the following activities on Peninsula Lake?



Optional question (76 responses, 6 skipped)

Q11 Have you observed algal blooms on Peninsula Lake?

Anonymous 10/30/2019 10:24 AM	Yes
Anonymous 10/30/2019 02:04 PM	Twice.
Anonymous 11/01/2019 12:34 PM	I don't know if they are algal blooms but there is green vegetation floating in the water.
Anonymous 11/01/2019 03:29 PM	Yes.
Anonymous 11/01/2019 04:15 PM	We missed the most recent one in Sept 2018, but I do recall the two that occurred in August of both 1993 and 1994 (approx. years), i.e. 2 years in succession, just when the Deerhurst golf-course expansion was being put in. Coincidence? I don't think so!
Anonymous 11/01/2019 04:45 PM	yes
Anonymous 11/01/2019 05:47 PM	Yes. Every 4 or 5 years there is an algae bloom generally in August.
Anonymous 11/01/2019 06:47 PM	No
Anonymous 11/01/2019 07:38 PM	Yes.
Anonymous 11/01/2019 09:16 PM	Yes in late 90s and 2017
Anonymous 11/02/2019 05:09 AM	Yes, they occur on the lee side of our dock where the water is shallower and with less wave action.
Anonymous 11/02/2019 07:08 AM	Yes
Anonymous 11/02/2019 07:25 AM	Yes 2017. Records show we had a bloom in 1995 and 1996.
Anonymous 11/02/2019 02:36 PM	Yes, I believe it was in 2018
Anonymous 11/03/2019 10:39 AM	occasionally, but not fully developed
Anonymous 11/04/2019 07:54 AM	No

Anonymous 11/04/2019 08:45 AM	Yes - as mentioned previously,they only occur once in a blue moon when all of the conditions align - in all of our time here we can recall only 2 algae blooms. We have not witnessed an increase in algae blooms in recent years.
Anonymous 11/04/2019 06:43 PM	Yes
Anonymous 11/05/2019 11:37 AM	yes for about 25 years
Anonymous 11/05/2019 10:00 PM	When there was a heavy rain in August 2018 the beach in Hidden Valley owned by the ski hill was completely washed out. I believe pollution from the property covered the beach property right down to the lake. We worked on the property in front of the beach raking all the dirt and gravel that covered quite a lot of the property right down to the beach. The smell as atrocious. It smelled like sewage I visited the beach about one week later and the water wasn't clear at all. I wondered at that time about the algal blooms.
Anonymous 11/06/2019 07:30 AM	no
Anonymous 11/06/2019 08:30 AM	Yes
Anonymous 11/06/2019 08:52 AM	Yes. A few times.
Anonymous 11/06/2019 08:55 AM	Yes
Anonymous 11/06/2019 10:36 AM	Yes and escaping down into Fairy Lake
Anonymous 11/06/2019 11:07 AM	Yes, fall of 2018 - excessive algae in Hidden Valley beach area
Anonymous 11/06/2019 01:59 PM	Yes, in September 2017.
Anonymous 11/06/2019 02:58 PM	Once very slight and didn’t know what it was
Anonymous 11/06/2019 06:33 PM	Yes, many over the years.
Anonymous 11/06/2019 06:58 PM	No, but I’m not sure what they would look like.
Anonymous 11/06/2019 07:58 PM	Occasionally.
Anonymous 11/07/2019 01:12 AM	yes

Anonymous 11/07/2019 05:14 AM	No
Anonymous 11/07/2019 06:41 AM	Have not observed personally, when I heard about it, I have avoided the lake entirely
Anonymous 11/07/2019 07:43 AM	Yes and importantly on adjoining lake...Fairy Lake...particularly on south side of lake by Springfield Farm
Anonymous 11/07/2019 08:17 AM	We believe so
Anonymous 11/07/2019 08:28 AM	no
Anonymous 11/07/2019 08:45 AM	No, but until now was unaware that may have been possible.
Anonymous 11/07/2019 08:46 AM	yes
Anonymous 11/07/2019 08:51 AM	yes
Anonymous 11/07/2019 09:14 AM	no
Anonymous 11/07/2019 09:29 AM	Not really sure
Anonymous 11/07/2019 10:32 AM	Occasionally
Anonymous 11/07/2019 12:26 PM	no
Anonymous 11/07/2019 01:21 PM	yes- a couple of years ago
Anonymous 11/07/2019 02:22 PM	Not really
Anonymous 11/07/2019 04:06 PM	Not sure
Anonymous 11/07/2019 05:03 PM	No
Anonymous 11/08/2019 11:14 AM	No but aware of one through the Lake Association email. I swam (inadvertently) throughout the “bloom period” with no ill effects.
Anonymous 11/08/2019 11:18 AM	Just once. A few years ago.

Anonymous 11/08/2019 01:28 PM	Yes, in 2017
Anonymous 11/08/2019 03:46 PM	I prefer to call it a cyanobacterial bloom because cyanobacteria are the causative agent not algae. Once in late summer of 2017
Anonymous 11/09/2019 12:36 PM	Yes
Anonymous 11/10/2019 10:39 AM	Yes 2/3 times
Anonymous 11/11/2019 07:45 AM	Yes
Anonymous 11/11/2019 09:18 AM	Yes
Anonymous 11/11/2019 03:30 PM	No
Anonymous 11/11/2019 04:40 PM	Yes, over the last few years Wolf bay and the narrrows by the canal near Deerhurst have had blooms. The summer of 2019 was I believe the third consecutive year of blue green algae blooms. This is what I have observed. I used to own property on three mile lake and witnessed that once there are consecutive years of blooms they grow in size and duration. No one, animal or human, could go in the lake or drink water from the lake or any well in the vicinity of the lake.
Anonymous 11/11/2019 06:51 PM	yes
Anonymous 11/12/2019 01:19 PM	yes.
Anonymous 11/13/2019 01:40 PM	Yes
Anonymous 11/13/2019 07:09 PM	Yes, during the year they were announced we saw them.
Anonymous 11/14/2019 07:34 AM	Yes
Anonymous 11/14/2019 02:32 PM	Yes and more often in recent years.
Anonymous 11/14/2019 04:06 PM	No
Anonymous 11/16/2019 07:17 AM	No

Anonymous 11/18/2019 11:19 AM	Yes
Anonymous 11/18/2019 07:24 PM	No
Anonymous 11/22/2019 01:37 PM	No
Anonymous 11/24/2019 04:13 PM	We observe algae, i.e. green coating on our dock ladder and staining on the boat's hull on a regular basis, but last year or the year before that, the lake had blue-green algae. Our daughter was at the cottage at the time, we weren't. This was well publicized by our cottage association.
Anonymous 11/26/2019 05:16 AM	No
Anonymous 11/29/2019 09:17 PM	not this year
Anonymous 11/30/2019 09:42 AM	Yes, in the summer of 2018.
Anonymous 11/30/2019 09:48 AM	Yes 2018

Optional question (74 responses, 8 skipped)

Q12 How would you describe an algal bloom? (i.e. What does it look like, smell like, etc.)

Anonymous 10/30/2019 10:24 AM	Green gelatinous mass on surface, more noticeable near shore, gets concentrated by the wind
Anonymous 10/30/2019 02:04 PM	Mat of green sludge.
Anonymous 11/01/2019 12:34 PM	It looks like green mush.
Anonymous 11/01/2019 03:29 PM	Thick layer of something covering the water surface (not pollen), as well as more often clouds of small particles of, I assume, algae.
Anonymous 11/01/2019 04:15 PM	Blue-green filamentary veiling of the upper layers of the lake. Not bad enough to notice any bad smell during the events mentioned above.
Anonymous 11/01/2019 04:45 PM	no smell, visual - green flecks floating in water
Anonymous 11/01/2019 05:47 PM	Visible opaque water loaded with algae and floating algae. It smells like rotting vegetation.
Anonymous 11/01/2019 07:38 PM	Looks like a large Green floating mushroom. Smells like fish.
Anonymous 11/01/2019 09:16 PM	No smell, green dots in the water followed by classic green scum which increased and then moved about the lake. I have pictures and then reported to the MNRF.
Anonymous 11/02/2019 05:09 AM	Appears more like a bottom scum rather than floating on the surface. As the bloom progresses it coats the stalks of the stems of the aquatic plants.
Anonymous 11/02/2019 07:08 AM	Green or dark green scum.
Anonymous 11/02/2019 07:25 AM	I took pictures. Like pea soup or a golf green. It did not smell.
Anonymous 11/03/2019 10:39 AM	not fully developed, i.e., small green dots suspended in the water, and an unusual odour.
Anonymous 11/04/2019 07:54 AM	green and mossy looking
Anonymous 11/04/2019 08:45 AM	green/brown floating pea soup
Anonymous 11/04/2019 06:43 PM	Dense growth.
Anonymous	looks like a frogs nest with a musty smell

11/05/2019 11:37 AM	
Anonymous 11/06/2019 08:30 AM	Primarily describe blooms by surface biomass and by the colour of it.
Anonymous 11/06/2019 08:52 AM	The water loses clarity and is filled with bits of particulate.
Anonymous 11/06/2019 08:55 AM	Moss looking substance. Very flowery.
Anonymous 11/06/2019 10:36 AM	Swirls of water turned bright green as the day went on and it appeared in the bay at the east end of Fairy Lake during August and in a small scale in late October early November 2019
Anonymous 11/06/2019 11:07 AM	It appears as a greenish slime floating on the surface - did not notice any smell
Anonymous 11/06/2019 01:59 PM	Bright green floating scum close to the shoreline.
Anonymous 11/06/2019 02:58 PM	No smell but the water looked like there was pollen on the surface
Anonymous 11/06/2019 06:33 PM	Looks green/yellow, swirling film of flecks in the water, smells fishy, makes my skin itchy after swimming.
Anonymous 11/06/2019 06:58 PM	Don’t know, but I would think it would be relatively odorless, with thousands of tiny green organisms (maybe 1 or 2 mms in diameter) mixed in the water.
Anonymous 11/06/2019 07:58 PM	Water gets quite murky.
Anonymous 11/07/2019 01:12 AM	yellow film
Anonymous 11/07/2019 05:14 AM	Discoloured water - green, blue, yellow - and perhaps a moldy smell.
Anonymous 11/07/2019 07:43 AM	Thick, slimy, has mass and depth...breaks up and then sinks to bottom of lake where it forms a scummy surface. No smell of note.
Anonymous 11/07/2019 08:17 AM	Moss like substance
Anonymous 11/07/2019 08:28 AM	n/a
Anonymous 11/07/2019 08:45 AM	Patchy area on surface or just below?
Anonymous 11/07/2019 08:46 AM	pea soup green in various degrees of thickness

Anonymous 11/07/2019 08:51 AM	green particles in lake
Anonymous 11/07/2019 09:14 AM	discoloration, lime green colour
Anonymous 11/07/2019 09:29 AM	i know there is sometimes a smell from the lake water
Anonymous 11/07/2019 10:32 AM	Unsure
Anonymous 11/07/2019 12:26 PM	no
Anonymous 11/07/2019 01:21 PM	we were told not to go in the water
Anonymous 11/07/2019 02:22 PM	Green soft I believe
Anonymous 11/07/2019 04:06 PM	Green
Anonymous 11/08/2019 11:14 AM	Blue green water
Anonymous 11/08/2019 11:18 AM	Bright (neon-like) scum on surface of water.
Anonymous 11/08/2019 01:28 PM	Green grass on the surface of the water
Anonymous 11/08/2019 03:46 PM	cyan surface to the water due to high levels of bacteria near the surface. I did not detect any odour.
Anonymous 11/09/2019 12:36 PM	Small green dots
Anonymous 11/10/2019 10:39 AM	Scum on water surface
Anonymous 11/11/2019 07:45 AM	Dark yellow to green
Anonymous 11/11/2019 09:18 AM	Green sludge, yellowish tinge
Anonymous 11/11/2019 03:30 PM	A blue-green scum/slick trailing in water
Anonymous 11/11/2019 04:40 PM	A blue green algae bloom start in the shallower parts of a vulnerable lake after hot dry conditions. The lake water start to have a green tinge, as the

	bloom grows, it turns to a brighter almost emerald green and looks like pea soup. The water becomes opaque and clumps of green and blue algae form and wash on to the shoreline and make a stinking mess.
Anonymous 11/11/2019 06:51 PM	top of water has a film on it which is blue-green
Anonymous 11/12/2019 01:19 PM	What I think of as an algal bloom is two different events. One is the regular (now) happening when the water looks full of small yellow/green pinhead sized dots of algae. The water is very murky when this occurs. The other is more rare and is a neon yellow slime that forms on the top of the water and leaves marks on the rocks. It's quite pungent and we're told not to swim, wade, nor use the water in our cottage
Anonymous 11/13/2019 07:09 PM	Like a blue/green film or blob that changes in size and shape, moving across the water with the wind direction or boat traffic.
Anonymous 11/14/2019 02:32 PM	changes the colour of the water to yellowish green.
Anonymous 11/16/2019 07:17 AM	Not sure
Anonymous 11/18/2019 11:19 AM	Looks terrible, stinks
Anonymous 11/24/2019 04:13 PM	Smelly green scum on the surface.
Anonymous 11/26/2019 05:16 AM	N/a
Anonymous 11/29/2019 09:17 PM	green slime ?
Anonymous 11/30/2019 09:42 AM	Yellow/green- stagnant, swirl of scum. Slight smell.
Anonymous 11/30/2019 09:48 AM	Alarming sight especially near shore. Blue/yellow/green scum inert/stabilized with noxious odour.

Optional question (63 responses, 19 skipped)

Q13 How many algal blooms have you observed during the years you have been enjoying Peninsula Lake? If possible, list the years.

Anonymous 10/30/2019 10:24 AM	Maybe 1994/95 and 2017
Anonymous 10/30/2019 02:04 PM	1994 and 2017.
Anonymous 11/01/2019 12:34 PM	Don't know.
Anonymous 11/01/2019 03:29 PM	Several, one serious (blue-green) can't remember the years
Anonymous 11/01/2019 04:15 PM	1993, 1994, 2018 (approx.)
Anonymous 11/01/2019 04:45 PM	2018 , another one several years prior
Anonymous 11/01/2019 05:47 PM	It's a regular but intermittent experience. Unable to gauge but every 4 or 5 years.
Anonymous 11/01/2019 07:38 PM	2017 is the only year I can recal.
Anonymous 11/01/2019 09:16 PM	2
Anonymous 11/02/2019 05:09 AM	Can remember 4 - one a few years ago, and three recent (2 of then in the last two summers)
Anonymous 11/02/2019 07:08 AM	2 or 3. Once many years ago (15 years or more) and 2 more recently.
Anonymous 11/02/2019 07:25 AM	As above: August 2017 1995 and 1996
Anonymous 11/02/2019 02:36 PM	2018 only
Anonymous 11/03/2019 10:39 AM	unknown
Anonymous 11/04/2019 07:54 AM	None
Anonymous 11/04/2019 08:45 AM	In 70 years of memory, we have noticed it twice: Once about 20 years ago ie approx 1999 (which was the worst occurrence, in about August), and then

	again 2 years ago 1997(which was not as bad as the one 20 years ago).
Anonymous 11/04/2019 06:43 PM	2018
Anonymous 11/05/2019 11:37 AM	evry year for the past 25 years
Anonymous 11/05/2019 10:00 PM	Don't know
Anonymous 11/06/2019 08:30 AM	unknown. Numerous
Anonymous 11/06/2019 08:52 AM	Several. I cannot recall the years but there was a bad one in 2018.
Anonymous 11/06/2019 10:36 AM	2018 x2 2019x1
Anonymous 11/06/2019 11:07 AM	We have been on the lake for 6 years, last year was the first time noticing the algal bloom - did not notice any this year but the lake seemed to be "cloudy" this year in Aug-Sept - A lot of floating particles in the lake at Hidden Valley
Anonymous 11/06/2019 01:59 PM	I have observed one in September 2017.
Anonymous 11/06/2019 02:58 PM	Once, 2017
Anonymous 11/06/2019 06:33 PM	Every year that I can remember (more than 15).
Anonymous 11/06/2019 06:58 PM	Don’t know, but if it’s what I’ve described above I’ve seen them three or four times in the past 40 years.
Anonymous 11/06/2019 07:58 PM	Occasionally, but can’t remember the years.
Anonymous 11/07/2019 01:12 AM	1 year only
Anonymous 11/07/2019 05:14 AM	None
Anonymous 11/07/2019 07:43 AM	Have noticed several...typically happening when the lake warms up...around end of July and through to early October.
Anonymous 11/07/2019 08:17 AM	A few
Anonymous 11/07/2019 08:28 AM	0
Anonymous	None

11/07/2019 08:45 AM

Anonymous
11/07/2019 08:46 AM
two, heavy in 2017

Anonymous
11/07/2019 08:51 AM
2

Anonymous
11/07/2019 09:14 AM
none

Anonymous
11/07/2019 12:26 PM
no

Anonymous
11/07/2019 01:21 PM
one

Anonymous
11/07/2019 02:22 PM
Can’t tell

Anonymous
11/07/2019 04:06 PM
Not sure

Anonymous
11/08/2019 11:14 AM
Never seen one

Anonymous
11/08/2019 11:18 AM
One. Can’t remember year.

Anonymous
11/08/2019 01:28 PM
Just one

Anonymous
11/08/2019 03:46 PM
2017 1996 when I was staying at a resort on the lake

Anonymous
11/09/2019 12:36 PM
This and last summer

Anonymous
11/10/2019 10:39 AM
2/3

Anonymous
11/11/2019 07:45 AM
1 - 2017

Anonymous
11/11/2019 09:18 AM
Two - one in the 90's and one last year

Anonymous
11/11/2019 03:30 PM
None

Anonymous
11/11/2019 04:40 PM
Three in 2017, 2018 and summer of 2019.

Anonymous 11/11/2019 06:51 PM	two
Anonymous 11/12/2019 01:19 PM	The neon yellow - once - 2017 or 2018 The other, ever since 2000 or so.
Anonymous 11/13/2019 01:40 PM	Once September 2017
Anonymous 11/13/2019 07:09 PM	Just the one year.
Anonymous 11/14/2019 02:32 PM	2019 and 2018 several noted maybe about 6 per year seem to be getting more frequent. Do not remember seeing 5 years ago.
Anonymous 11/16/2019 07:17 AM	None
Anonymous 11/18/2019 11:19 AM	Frequent
Anonymous 11/24/2019 04:13 PM	Over the 5 years, just the occurrence described on no. 11, above.
Anonymous 11/26/2019 05:16 AM	None
Anonymous 11/29/2019 09:17 PM	a couple
Anonymous 11/30/2019 09:42 AM	One.
Anonymous 11/30/2019 09:48 AM	One only (2018)

Optional question (63 responses, 19 skipped)

Q14 On what parts of the lake have you observed an algal bloom? e.g. the whole lake, a specific basin (east or west), within specific bays, only in the nearshore, etc.

Anonymous 10/30/2019 10:24 AM	Eastern basin , Wolf Bay
Anonymous 10/30/2019 02:04 PM	The whole lake.
Anonymous 11/01/2019 12:34 PM	Have not had the opportunity to study other parts of the lake. Have seen the floating green mushy vegetation in the bay in front of the Portage Inn (east end, before Wolf Bay--called All Saints Bay we believe. On Wolf Bay Road right where it turns to run along the lake.
Anonymous 11/01/2019 03:29 PM	Near the shore on both sides.
Anonymous 11/01/2019 04:15 PM	I didn't check anywhere else besides in front of my cottage.
Anonymous 11/01/2019 04:45 PM	right in front of dock on east shore
Anonymous 11/01/2019 05:47 PM	From the canal area through to the eastern shore and also towards Hill's Bay and Hill's island
Anonymous 11/01/2019 07:38 PM	In our basin(east) and in the west basin near Deerhurst.
Anonymous 11/01/2019 09:16 PM	Only near shores but moving in the quiet waters. Tally Ho Bay, Hills Bay, Mainly in the quiet shallow warm bays but it moved around over the 7 days it was visible depending upon the current and the breeze.
Anonymous 11/02/2019 05:09 AM	only near our shoreline on Springsyde
Anonymous 11/02/2019 07:08 AM	Around Hills Island / Dunelg Island where we live, and at the junction of Maplehurst Drive and Shaw's Rd where we moor our boat.
Anonymous 11/02/2019 07:25 AM	East shore along Maplehurst but it moved to the Wolf bay area when the wind changed.
Anonymous 11/02/2019 02:36 PM	In the eastern part of the lake, near Shaws Road, NOT close to our cottage
Anonymous 11/04/2019 08:45 AM	In 1999 the whole middle of the lake. The one 2 years ago seemed to be in various bays, somewhat in Grace's Bay but seemed to be worse in the eastern part.
Anonymous 11/04/2019 06:43 PM	East basin

Anonymous 11/05/2019 11:37 AM	the whole lake as you can look down in the water adn see them in the middle of the lake
Anonymous 11/06/2019 08:30 AM	Only noted blooms that happen in the bay in which our property is located.
Anonymous 11/06/2019 08:52 AM	Near the shore and around our dock. We are at the East end.
Anonymous 11/06/2019 10:36 AM	East end of Fairy Lake
Anonymous 11/06/2019 11:07 AM	In the Hidden Valley hotel beach area - Specifically where the dock meets the beach next to the our condo.
Anonymous 11/06/2019 01:59 PM	At the Hidden Valley Resort beach shoreline and surrounding the dock.
Anonymous 11/06/2019 02:58 PM	Near north shore across from Hills Island
Anonymous 11/06/2019 06:33 PM	I can only speak for our shore (Eastern), more so in the bays.
Anonymous 11/06/2019 06:58 PM	East end of wolf bay.
Anonymous 11/06/2019 07:58 PM	Really on,y around our property on Grassmere. Don’t notice it when I’m rowing.
Anonymous 11/07/2019 01:12 AM	near shore
Anonymous 11/07/2019 05:14 AM	n/a
Anonymous 11/07/2019 07:43 AM	South part of basin
Anonymous 11/07/2019 08:17 AM	Nearshore
Anonymous 11/07/2019 08:28 AM	?
Anonymous 11/07/2019 08:45 AM	N/ a
Anonymous 11/07/2019 08:46 AM	west basin, morgan's bay, along shore to deerhurst
Anonymous 11/07/2019 08:51 AM	all over

Anonymous 11/07/2019 09:14 AM	none
Anonymous 11/07/2019 01:21 PM	west basin near hidden valley
Anonymous 11/07/2019 02:22 PM	Not applicable
Anonymous 11/08/2019 11:14 AM	N/a
Anonymous 11/08/2019 11:18 AM	By Hidden Valley
Anonymous 11/08/2019 01:28 PM	East basin on the west shore
Anonymous 11/08/2019 03:46 PM	2017 east 1996 west
Anonymous 11/09/2019 12:36 PM	West side near hidden valley resort
Anonymous 11/10/2019 10:39 AM	Once whole lake others near shore
Anonymous 11/11/2019 07:45 AM	Hidden Valley Beach area
Anonymous 11/11/2019 09:18 AM	East and west, near the public access docks (off Maplehurst Drive and at Tally Ho Resort), and in the nearshore
Anonymous 11/11/2019 03:30 PM	None
Anonymous 11/11/2019 04:40 PM	Wolf bay and the canal entrance near Deerhurst
Anonymous 11/11/2019 06:51 PM	East section near Hidden Valley
Anonymous 11/12/2019 01:19 PM	Near the shore in our area (mid point, northern shore) and in the middle on calm days
Anonymous 11/13/2019 07:09 PM	Once in front of our property. Out of curiosity prior to seeing it in front of us, but having heard of it, we took our boat out to find locations where it was present.
Anonymous 11/14/2019 02:32 PM	Only noticed them on the west where we live near shore.
Anonymous	N/a

11/16/2019 07:17 AM	
Anonymous 11/18/2019 11:19 AM	Nearshore
Anonymous 11/24/2019 04:13 PM	We are in Grassmere Bay, at the north end of the lake, and it was in our bay.
Anonymous 11/26/2019 05:16 AM	N/a
Anonymous 11/29/2019 09:17 PM	west. Haven't paid attention to rest
Anonymous 11/30/2019 09:42 AM	East basin, near shore. Brian Tapley (Bondi Resort) has excellent aerial photos of the bloom.
Anonymous 11/30/2019 09:48 AM	East basin although the warning and public health notices limiting swimming and water use applied to entire lake

Optional question (57 responses, 25 skipped)

Q15 What time of year have you typically first observed algal blooms and how long have those blooms persisted?

Anonymous 10/30/2019 10:24 AM	Usually late August , maybe less than a week
Anonymous 10/30/2019 02:04 PM	Late summer for several days.
Anonymous 11/01/2019 12:34 PM	So sorry but did not note this.
Anonymous 11/01/2019 03:29 PM	Summer, weeks.
Anonymous 11/01/2019 04:15 PM	Late summer, lasting about a month.
Anonymous 11/01/2019 04:45 PM	late summer
Anonymous 11/01/2019 05:47 PM	Last week of July until mid-August probably about 10 days
Anonymous 11/01/2019 07:38 PM	Summer months, observed In the hot month of August.
Anonymous 11/01/2019 09:16 PM	Early September following a long hot spell with warm water and no wave action. 2 weeks earlier it was preceded by a severe storm with very rough water, lots of run off and then hot weather with no wind.
Anonymous 11/02/2019 05:09 AM	The month of August - and go into September - when the water is warmest
Anonymous 11/02/2019 07:08 AM	Maybe as early as late July to show. Can't comment on the end bacause we close up in early fall.
Anonymous 11/02/2019 07:25 AM	August and was visible for about 10 days
Anonymous 11/02/2019 02:36 PM	In the summer
Anonymous 11/03/2019 10:39 AM	July or August of a hot summer
Anonymous 11/04/2019 08:45 AM	The first one was in August (20 years ago). The most recent one was in September.
Anonymous 11/04/2019 06:43 PM	Fall

Anonymous 11/05/2019 11:37 AM	end of July to the end of August
Anonymous 11/06/2019 08:30 AM	fall 2 weeks
Anonymous 11/06/2019 08:52 AM	Mid to late summer. A few weeks.
Anonymous 11/06/2019 10:36 AM	August to early November east end of Fairy Lake where Penn flows into Fairy Lake
Anonymous 11/06/2019 11:07 AM	Seems to be late summer (Sept) - last year was also warmer than normal so lake temp may be contributing to this.
Anonymous 11/06/2019 01:59 PM	September, for the week staying there. Not sure how long it persisted since I stayed there for just that week.
Anonymous 11/06/2019 02:58 PM	Fall. One or two days
Anonymous 11/06/2019 06:33 PM	Generally nearing the middle/end of summer.
Anonymous 11/06/2019 06:58 PM	Late July or early august
Anonymous 11/06/2019 07:58 PM	July/August.
Anonymous 11/07/2019 01:12 AM	summer
Anonymous 11/07/2019 05:14 AM	n/a
Anonymous 11/07/2019 07:43 AM	See response to 6. above
Anonymous 11/07/2019 08:17 AM	Summer
Anonymous 11/07/2019 08:28 AM	0
Anonymous 11/07/2019 08:45 AM	N/A
Anonymous 11/07/2019 08:46 AM	late summer, early fall during lower water levels lasting a few weeks
Anonymous 11/07/2019 08:51 AM	Auguast September

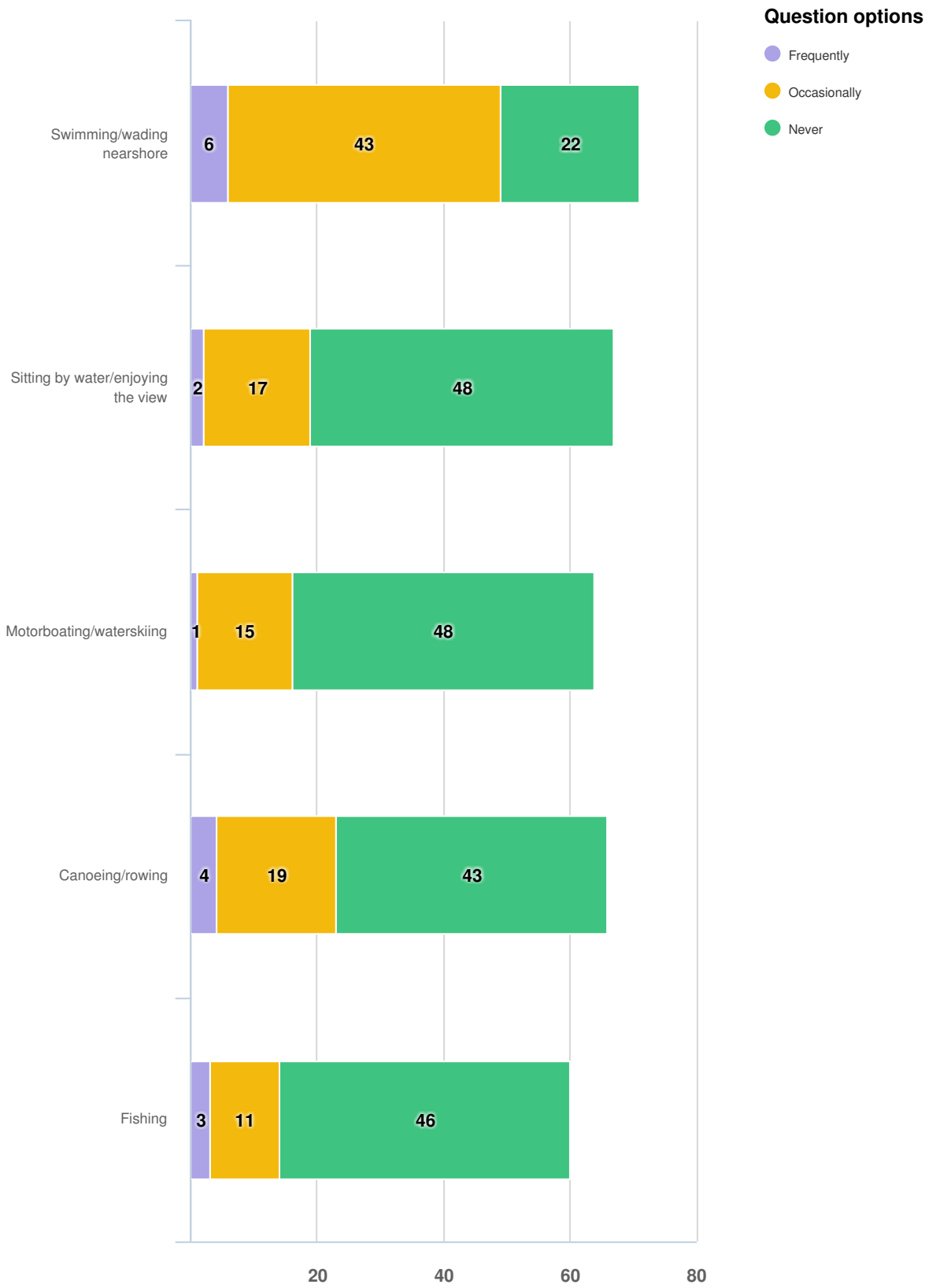
Anonymous 11/07/2019 09:14 AM	none
Anonymous 11/07/2019 01:21 PM	fall
Anonymous 11/07/2019 02:22 PM	Not applicable
Anonymous 11/08/2019 11:14 AM	N/a
Anonymous 11/08/2019 11:18 AM	August September
Anonymous 11/08/2019 01:28 PM	August, only a few days
Anonymous 11/08/2019 03:46 PM	late summer
Anonymous 11/09/2019 12:36 PM	Late summer , August to October
Anonymous 11/10/2019 10:39 AM	Mid august
Anonymous 11/11/2019 07:45 AM	Mid August
Anonymous 11/11/2019 09:18 AM	summertime.
Anonymous 11/11/2019 03:30 PM	NA
Anonymous 11/11/2019 04:40 PM	August and late summer and have lasted 6 to 10 weeks
Anonymous 11/11/2019 06:51 PM	I think it was late spring, early summer
Anonymous 11/12/2019 01:19 PM	July to August
Anonymous 11/13/2019 07:09 PM	Late summer and only the one year.
Anonymous 11/14/2019 02:32 PM	They seem to move with the wind. Here one day gone the next then back again.
Anonymous	None

11/16/2019 07:17 AM

Anonymous 11/18/2019 11:19 AM	July August
Anonymous 11/24/2019 04:13 PM	Late summer, early fall and lasted 2 to 4 weeks.
Anonymous 11/26/2019 05:16 AM	N/a
Anonymous 11/30/2019 09:42 AM	Algal bloom was in August and stayed well over a week.
Anonymous 11/30/2019 09:48 AM	Late summer lasting for days (more than a week but less than two).

Optional question (57 responses, 25 skipped)

Q16 Has your/your family's ability to participate in the following activities on Peninsula Lake been impeded by algal blooms?



Optional question (71 responses, 11 skipped)

Q17 What factors do you think are affecting the water quality of the lake?

Anonymous 10/30/2019 10:24 AM	Development, water level adjustments,
Anonymous 10/30/2019 02:04 PM	major developments
Anonymous 11/01/2019 12:34 PM	In our bay, definitely the runoff from the gravel road. Not sure about the rest of the lake. For the most part, the lake is very quiet and we do not see in our end an excess of any particular activity. Not sure where the suds originate.
Anonymous 11/01/2019 03:29 PM	Too much nutrient and silt runoff, as well as probably some invasive species.
Anonymous 11/01/2019 04:15 PM	Overloading of nutrients combined with warm conditions, allowing the algae (which are always present but not visible normally) to rapidly multiply.
Anonymous 11/01/2019 04:45 PM	Failing septics Fertilizer / organic run off Intense rain "flushing" matter into lake causing a immediate overload High degree of development (overdevelopment in some areas)
Anonymous 11/01/2019 05:47 PM	Stream-fed lake so all the streams can carry contaminants from farms, wild animals, septic issues, likely the fertilizer required for cottage waterfront lawns and golf course maintenance, increased population density (individual houses and resorts/condo) combined with widespread practice of urinating in the lake
Anonymous 11/01/2019 06:47 PM	Fertilizing and weed control on the golf course. Possibly, run off of E coli from the Deerhurst stables.
Anonymous 11/01/2019 07:38 PM	Increased pressure from lower water levels and hot weather.
Anonymous 11/01/2019 09:16 PM	Climate change, ie hot weather. Increase in pollution by greatly increased numbers of waterfowl, ie geese. Increase in grassy areas going to the shore which increase in run off and nesting areas or grazing areas for geese such as resort development. No control over old septic beds such as Hidden Valley.
Anonymous 11/02/2019 05:09 AM	The atypical weather patterns - snow melt and rain have kept the creeks and springs that flow into the lake, active longer throughout the season. Water temperature has been rising and warms earlier then previously noted
Anonymous 11/02/2019 07:08 AM	The golf courses on the water system and poor sewage treatment, compounded by warmer water temperatures.
Anonymous 11/02/2019 07:25 AM	The 2017 bloom happened just after a torrential rain brought run off into the water shed and stored up the whole hills bays area with brown silt.
Anonymous 11/02/2019 02:36 PM	Hotter summers; chemicals from soaps, etc finding their way into the lake

Anonymous 11/03/2019 10:39 AM	fertilizer use likely
Anonymous 11/04/2019 07:54 AM	Spring floods, lack of sunshine
Anonymous 11/04/2019 08:45 AM	Increased average air temperature, stillness of the water? We are on the lake almost daily from May-Oct, especially in Grace's Bay, Hidden Valley Bay, Deerhurst area, the shoreline along Pow Wow Point all around Grassmere to Tally Ho, and in the middle of the lake, and we see no septic runoff. In theory it is possible that overly packed air bnb's would have the potential to overload a cottage's single family septic system, though we have seen no evidence of this.
Anonymous 11/04/2019 06:43 PM	Unknown
Anonymous 11/05/2019 11:37 AM	2 golf courses
Anonymous 11/05/2019 10:00 PM	The pollution from motorized boats etc., Deerhurst Golf courses. I believe that Pen Lake will get much worse in the future with the abundance of motorized water craft on the lake. Same for Deerhurst using chemicals on their golf courses. Sadly, in Muskoka it is all about the Tourists. Deerhurst should never have been approved for their recent expansion.
Anonymous 11/06/2019 07:30 AM	motorboats, jet skis
Anonymous 11/06/2019 08:30 AM	run-off from numerous septic systems around the lake.
Anonymous 11/06/2019 08:52 AM	Extensive run off from torrential rainstorms, fertilizer that should not be used, a lack of a riparian zone at certain properties, over development, increased motor boat traffic, the arrival of geese and cormorants.
Anonymous 11/06/2019 08:55 AM	Run off , water temperature
Anonymous 11/06/2019 10:36 AM	Septic tank overflow and or leaching? Golf course fertilizer
Anonymous 11/06/2019 11:07 AM	One again the Canada Goose population and Golf course fertilizer.
Anonymous 11/06/2019 01:59 PM	Droppings from the large goose population, fertilizer use by nearby golf courses, lawn fertilizer use by cottagers, motor boat use.
Anonymous 11/06/2019 02:58 PM	Fast motor boats and sea-doos
Anonymous 11/06/2019 06:33 PM	Climate change/temperature, pollution

Anonymous 11/06/2019 06:58 PM	Deerhurst, run off of fertilizer from cottages with lawns
Anonymous 11/06/2019 07:58 PM	Don’t know.
Anonymous 11/07/2019 01:12 AM	chemical and waste run off, air pollution, use of motorised craft, currents, temperature change
Anonymous 11/07/2019 05:14 AM	Excessive number of people at the resorts esp. Deerhurst.
Anonymous 11/07/2019 06:41 AM	Rumour was the liquid de-icer used by Carillon when they had the contarct had much to do with it, not sure if that is true though
Anonymous 11/07/2019 07:43 AM	Am not sure....didn't notice the blooms though until Canada Geese started appearing on lake nor until large wake boats appeared, eroding shoreline
Anonymous 11/07/2019 08:17 AM	motorized boats
Anonymous 11/07/2019 08:28 AM	?
Anonymous 11/07/2019 08:45 AM	Untreated runoff, biological contaminants garbage etc.
Anonymous 11/07/2019 08:46 AM	deerhurst construction, runoff from multiple cottage sites clearing trees + vegetation from lakeside land, heavy use of rental jetskis, enlargement of Hidden Valley association dock marina.
Anonymous 11/07/2019 08:51 AM	Development
Anonymous 11/07/2019 09:14 AM	I am only beginning to understand algae blooms and do not know the factors
Anonymous 11/07/2019 01:21 PM	number of people using. weather geese
Anonymous 11/07/2019 02:22 PM	Not sure
Anonymous 11/08/2019 11:14 AM	Climate change and fertilizer run off (from Deerhurst golf course on lake, cottage owners with lawns to the shoreline?),Canada Geese excretions and old septic systems.
Anonymous 11/08/2019 11:18 AM	Fertilizer run-off
Anonymous 11/08/2019 01:28 PM	Run off from cow farm. Hot weather. Water level
Anonymous	usege, storms and the run off water coming into the lake, goose defecation,

11/08/2019 03:46 PM	temperature and weather conditions.
Anonymous 11/09/2019 12:36 PM	Septics and farmland in canal
Anonymous 11/10/2019 10:39 AM	Septic tanks not being maintained
Anonymous 11/11/2019 07:45 AM	Human pressure Geese
Anonymous 11/11/2019 09:18 AM	Over development, uncontrolled/unmonitiored Deehurst development, faulty septic systems
Anonymous 11/11/2019 03:30 PM	Population growth, climate-warmer lake water
Anonymous 11/11/2019 04:40 PM	Over development, especially close to the canal, too much damage to the natural shoreline due to lawn cutting and landscaping, too much use of phosphate heavy detergents and shampoos around the lake, historical factors such as dumping sewage into lakes and poorly maintained septic beds. Although this last point has changed since the 1980's
Anonymous 11/11/2019 06:51 PM	Not familiar with the cause
Anonymous 11/12/2019 01:19 PM	Fertilized lawns being on or near the waterfront Construction along waterfront properties - mainly the large resorts Wake boarders washing the shoreline into the water
Anonymous 11/13/2019 01:40 PM	Golf course Golf course mechanical shop on Canal.
Anonymous 11/13/2019 07:09 PM	The year we had the agal bloom we had experienced particularly heavy rain falls in a short period of time. Roads were washed out, flooding and I suspect anything on the ground such as fertilizers, chemicals, gas from driveways were washed into the lakes. Septic beds may have leached into the water. Contaminants on the surface or just below would have washed into the lake.
Anonymous 11/14/2019 07:34 AM	Heat, fertilizer
Anonymous 11/14/2019 02:32 PM	This I can not say.
Anonymous 11/14/2019 04:06 PM	Properties developed right to the lake edge. Use of fertilizers and pesticides, including those from golf courses.
Anonymous 11/16/2019 07:17 AM	Pollution, dumping
Anonymous 11/18/2019 11:19 AM	Don't know

Anonymous 11/18/2019 07:24 PM	Massice developmennt
Anonymous 11/24/2019 04:13 PM	The canal between Fairy and Pen Lakes is man-made. Flow is quite often from Fairy to Penn since most water into Vernon, Fairy and Penn lake system (all the same water level) comes from the Big East River, via Lake Vernon, and then flows down Muskoka River to Mary Lake. Some of the water that flows into Penn comes from Ballantine Creek but a lot of it could be just backwater flowing up the canal. Maybe there is not enough freshet for the lake from it's natural watershed??
Anonymous 11/26/2019 05:16 AM	Too many cottages
Anonymous 11/30/2019 09:42 AM	Poorly protected building sites, 2 - ‘100’ year rain storms, wetland fill in, east of Adventure Park off Hwy 60.
Anonymous 11/30/2019 09:48 AM	Increased powerboat and snowmobile use, plus growth in permanent residency, along with resort/condo development and golfing activity compounded by accelerating impacts of climate change.

Optional question (67 responses, 15 skipped)

Q18 Has the lake changed since you first started enjoying it – if so, in what ways?

Anonymous 10/30/2019 02:04 PM	Increase in skidoo seeds traffic. More kayak and paddle board use. Larger cottages/residences. Bigger resorts.
Anonymous 11/01/2019 12:34 PM	Yes, due to erosion of road into the lake. While we don't know for sure, the erosion going into the water would also include any salt/sand (is winter sand salted?) that is laid down over the winter to help folks get up and down the steep hill safely.
Anonymous 11/01/2019 03:29 PM	Drastically, I can remember pristine water. Remember I go back many decades, to the 1960's in my personal memory.
Anonymous 11/01/2019 04:15 PM	Before 1993 I never saw an algae bloom.
Anonymous 11/01/2019 04:45 PM	greater volume of development, not just near the lake but surrounding area Highland estates as an example. All streams & watersheds
Anonymous 11/01/2019 05:47 PM	Fish species have changed. 1970s and before lots of bass. 1980 to 2010 more pike. Presently return of bass and very few pike. Surge in commercial fishing activity.
Anonymous 11/01/2019 06:47 PM	We have noticed more weeds growing in it.
Anonymous 11/01/2019 07:38 PM	Yes. Water seems cloudier and no-see ‘ems seem more prevalent.
Anonymous 11/01/2019 09:16 PM	Increased resort development ie Deerhurst and Hidden Valley. With more to come. Town of Huntsville seems to support and encourage the expansion of this resort. Lack of control over lack of shoreline vegetation which causes increase in run off.
Anonymous 11/02/2019 05:09 AM	Mother nature has maintained the lake fairly well, aside from fish loss by the shore - have noticed a small increase in boat activity - also have noted that the night time shoreline lights have increased indicating more human interaction by the lake
Anonymous 11/02/2019 07:08 AM	Fewer sail boats / canoes more jet skis / motor boats towing "tubers", crazy water level fluctuations REGULARLY, "dirty" lake water ... we used to drink later water up to about 15 years ago.
Anonymous 11/02/2019 07:25 AM	The depletion of calcium has put a strain on the lake as we do not see a lot of crayfish that need it. The water is more tainted than it use to be. secci depth.
Anonymous 11/02/2019 02:36 PM	Not that we have noticed
Anonymous 11/03/2019 10:39 AM	no
Anonymous	No not really

11/04/2019 07:54 AM

Anonymous
11/04/2019 08:45 AM

There was a peak in recreational use in the 60's-90's, but activities such as jet skiing, waterskiing, boating, etc. have actually decreased in the last 10 years or so. Although there are more dwellings/people living on the lake than 50 years ago, it has actually become quieter out on the water. Less people are actively using their cottages on a regular basis. We see people at their cottage perhaps once or twice during the summer, whereas years ago these cottages were utilized more often/all summer. Even year round residents seem to boat/waterski, etc. less. Building density has increased, but actual activity on the water has decreased.

Anonymous
11/04/2019 06:43 PM

More boat traffic. Hidden Valley Deerhurst recreation and resort development density increase. Golf courses. Extended lake use, ice out till November

Anonymous
11/05/2019 11:37 AM

yes, it used to be cool and clear but it's not anymore

Anonymous
11/05/2019 10:00 PM

Yes it isn't the same anymore with so much motorized watercraft. You can smell the gas when people are starting and idling their boats by the docks. It is terrible.

Anonymous
11/06/2019 08:30 AM

It has gotten busier but all of Muskoka has gotten busier

Anonymous
11/06/2019 08:52 AM

Yes. More geese and cormorants and increased motor boat and Seadoo traffic.

Anonymous
11/06/2019 11:07 AM

Yes, there are now more residents on the lake and that will get much worse with new developments at Grandview and Deerhurst - I now see more garbage floating near the shore (We always try to clean this up)

Anonymous
11/06/2019 01:59 PM

Yes, in the last few years noticeable particulate in the water and first algae bloom in 2017.

Anonymous
11/06/2019 02:58 PM

There are more sea-doos

Anonymous
11/06/2019 06:33 PM

Generally, it's the water levels that I find have changed the most over the years.

Anonymous
11/06/2019 06:58 PM

There’s a lot more noise pollution and light pollution. More motor boats.

Anonymous
11/06/2019 07:58 PM

No.

Anonymous
11/07/2019 01:12 AM

not significantly

Anonymous
11/07/2019 05:14 AM

More traffic from jet skis.

Anonymous

Much busier

11/07/2019 06:41 AM	
Anonymous 11/07/2019 07:43 AM	Algae and erosion of shoreline and spring flooding of lake
Anonymous 11/07/2019 08:17 AM	na as only been there for 3 years
Anonymous 11/07/2019 08:28 AM	no
Anonymous 11/07/2019 08:45 AM	Not that I have noticed.
Anonymous 11/07/2019 08:46 AM	Much more use of motorized boats and rental jetski by resorts, more density, lots being split to build more cottages
Anonymous 11/07/2019 08:51 AM	development
Anonymous 11/07/2019 09:14 AM	no
Anonymous 11/07/2019 09:29 AM	smell
Anonymous 11/07/2019 10:32 AM	Some years have more throat allergies
Anonymous 11/07/2019 01:21 PM	not that I've noticed
Anonymous 11/07/2019 02:22 PM	Not really
Anonymous 11/08/2019 11:14 AM	No
Anonymous 11/08/2019 11:18 AM	Don’t think so
Anonymous 11/08/2019 03:46 PM	Not that I have noticed
Anonymous 11/09/2019 12:36 PM	We didn't notice it the first year 2016 but now look for it
Anonymous 11/10/2019 10:39 AM	Water quality has deteriorated
Anonymous 11/11/2019 07:45 AM	Increased geese feces on beach has stopped us using this beach area.

Anonymous 11/11/2019 09:18 AM	many more boats, more development, more noise
Anonymous 11/11/2019 03:30 PM	Increased boat traffic
Anonymous 11/11/2019 04:40 PM	Yes, I first enjoyed Pen Lake in the late 1970's. First the loppet cross country ski race used to go across the ice in Pen Lake: this happened in January. Now the ice is never reliable on own lake in January. A good record if Thai is when snowmobile trials open each year as the water needs to be frozen for snowmobiles to run the ice. As a child I swam and hosted in Penisula Lake, fairy and Vernon. All three were free of blue green algae. It is only in the last decade that blue green algae has appeared on penisula lake but I won't swim in it anymore. I also will never consider purchasing a property on Penisula lake
Anonymous 11/11/2019 06:51 PM	While there are a lot of fish, I thought that there were more in the past
Anonymous 11/12/2019 01:19 PM	The population density increases annually thanks to the rentals & growing resorts The non-resident fishing has increased (annoyingly, because they don't follow the Lake Rules and their typically rude) There are more motorized boats on the lake and visiting the lake There are more motorized water sports - Wake boarding, seadoos, etc.
Anonymous 11/13/2019 07:09 PM	Weedier and not as clear.
Anonymous 11/14/2019 07:34 AM	Very few frogs now.
Anonymous 11/14/2019 02:32 PM	Yes but only in recent years with the blooms.
Anonymous 11/14/2019 04:06 PM	The properties are much larger and built/developed much closer to shore. I have been here 30 years.
Anonymous 11/16/2019 07:17 AM	More concerns of algae blooms
Anonymous 11/18/2019 11:19 AM	Yes. Water used to be clean and clear
Anonymous 11/18/2019 07:24 PM	Deerhurst expa sion soon has ruined the lake
Anonymous 11/24/2019 04:13 PM	No. We've just been there for 5 years.
Anonymous 11/26/2019 05:16 AM	Yes way too many boats both large and small. No quite time on the lake in the summer months
Anonymous	large resort got much larger

11/29/2019 09:17 PM

Anonymous
11/30/2019 09:42 AM

We are now more concerned with the water quality and how it is changing.

Anonymous
11/30/2019 09:48 AM

Increasing awareness of human impacts and the need to protect/preserve the natural setting through planning restrictions. Pen Lake created one of the first “lake plans” which has proven beneficial to lake protection (eg. rejection of industrial rock quarry adjacent to eastern basin)

Optional question (64 responses, 18 skipped)

Q19 Have there been any changes to shoreline uses since you first started enjoying Peninsula Lake - if so in what ways?

Anonymous 10/30/2019 10:24 AM	More docks, more boats, more people, new animal species (geese, cormorants), lawns
Anonymous 10/30/2019 02:04 PM	More clearing of shoreline vegetation, but not in Wolf Bay near oir residence.
Anonymous 11/01/2019 12:34 PM	Yes, the water close to shore is getting shallower due to erosion into the lake.
Anonymous 11/01/2019 03:29 PM	A continuous and still ongoing intensification of development.
Anonymous 11/01/2019 04:15 PM	There are now over 300 properties around the lake (more than ever before), fairly often with little respect for a healthy shoreline, e.g. groomed lawn down to the water line. My guess is that about 1/3 of property owners have inappropriate shorelines. This is unfortunately worst for the resorts, especially Deerhurst. All this despite our Lake Plan, first published and now available in complete form on the Pen Lake website.
Anonymous 11/01/2019 04:45 PM	more clear cutting of land as peope redevelop their properties with year round homes. resort development intensification at deerhurst etc.
Anonymous 11/01/2019 05:47 PM	Shift of docks from trestle and cedar to pole aluminum docks; more all year round cottages; more people using drilled wells. Motor boats larger and more powerful
Anonymous 11/01/2019 07:38 PM	Increase usage by resort, specifically Deerhurst. Golf courses add pressure to shoreline use.
Anonymous 11/01/2019 09:16 PM	Huntsville and Lake of Bays seem to have no control of shoreline for new builds or rebuilds. Residents are increasingly mowing grass to the shore and then complaining about geese or erosion. There is a new tendency to pave driveways which doesn’t seem to require a permit and causes increased run off into the lake.
Anonymous 11/02/2019 05:09 AM	Cannot speak to other properties - however our property has a vegetation strip at the water's edge - this zone is very active with small songbirds. This was implemented 6-7 years ago.
Anonymous 11/02/2019 07:08 AM	More cottages, the golf courses, more permanent residents.
Anonymous 11/02/2019 07:25 AM	Property owners taking out vegetation and putting in grass invites geese to graze adding pollutants to the water.
Anonymous 11/03/2019 10:39 AM	more and larger docks built
Anonymous	No

11/04/2019 07:54 AM

Anonymous
11/04/2019 08:45 AM
Numerous - cottages built, resorts built, lot sizes increased, trees felled for views. We have been here for 97 years.

Anonymous
11/04/2019 06:43 PM
Deerhurst shoreline development,

Anonymous
11/05/2019 11:37 AM
All the building along the shoreline, houses and cottages with the increase of septic systems and then every few years Deerhurst has an accident and releases sewage into the lake

Anonymous
11/06/2019 07:30 AM
more and longer docks, more activity at shoreline for resorts

Anonymous
11/06/2019 08:30 AM
numerous more cottages and homes

Anonymous
11/06/2019 08:52 AM
Yes. Some properties have cleared natural trees and brush from their shoreline allowing run off to flow into the lake.

Anonymous
11/06/2019 10:36 AM
More condo style development close to water.

Anonymous
11/06/2019 11:07 AM
Too many "Bouncy Islands" at the big resort - it takes from the natural beauty of te shoreline. I'm glad that there is no longer Jet Ski flyboarding - this activity produces a lot of exhaust into the air at the shore.

Anonymous
11/06/2019 01:59 PM
Yes, not being able to swim during late summer.

Anonymous
11/06/2019 02:58 PM
Have not noticed

Anonymous
11/06/2019 06:33 PM
No.

Anonymous
11/06/2019 06:58 PM
Cottage density along the shore is higher. More year-round cottages have been built. There are some cottages with lawns. The golf course has been replaced with more cottages.

Anonymous
11/06/2019 07:58 PM
Not round Grassmere the rapper Ian zone is fairly intact.

Anonymous
11/07/2019 01:12 AM
no

Anonymous
11/07/2019 05:14 AM
No

Anonymous
11/07/2019 07:43 AM
Large docks and boathouses...in abundance

Anonymous
11/07/2019 08:17 AM
na

Anonymous 11/07/2019 08:28 AM	yes- busier
Anonymous 11/07/2019 08:45 AM	Much more cottages, marinas and recreational.
Anonymous 11/07/2019 08:46 AM	Cottage owners clear cutting lakeside trees for view leaving sloped land to create runoff into lake. Much more manicured lawns and propensity of goose waste. Enlargement of marine docks at resorts
Anonymous 11/07/2019 08:51 AM	not really
Anonymous 11/07/2019 09:14 AM	only the high levels of water in the spring of 2019 after being on the lake for approx. 11 years
Anonymous 11/07/2019 01:21 PM	more geese making mess
Anonymous 11/07/2019 02:22 PM	Not really
Anonymous 11/08/2019 11:14 AM	We have been returning our shoreline to its natural state by adding to the shoreline buffer zone on our property and letting native vegetation grow.
Anonymous 11/08/2019 11:18 AM	Not by Hidden Valleyno
Anonymous 11/08/2019 03:46 PM	many more permanent residences
Anonymous 11/10/2019 10:39 AM	More grass to shore line
Anonymous 11/11/2019 07:45 AM	Higher water level
Anonymous 11/11/2019 09:18 AM	Deerhurst is so much bigger than the family-run resort it once was, and the capacity of that property seems overtaxed (relatively small waterfront for so many guests, in a small bay)
Anonymous 11/11/2019 03:30 PM	No
Anonymous 11/11/2019 04:40 PM	Massive development at Deerhurst and more residences and tourist use
Anonymous 11/11/2019 06:51 PM	not aware of the changes
Anonymous 11/12/2019 01:19 PM	More people are enjoying their shorelines now, which means an increase in water activities.
Anonymous	Many changes since the 60's with the dramatic change in Deerhurst and

11/13/2019 07:09 PM	Hidden Valley most notably. Golf Course road properties were also new, but thankfully on large lots and better standards than some of the older properties. More boats being launched for day use that was seldom done previously. 99% more winter fishing. Never saw an ice hut on the lake that I recall back in the 60's early 70's. Often wonder what washroom facilities are available at that time of year. The portable ones at the Hillside launch where so many of the huts are located isn't available.
Anonymous 11/14/2019 07:34 AM	Higher spring floods
Anonymous 11/14/2019 02:32 PM	Yes but only in recent years with the blooms.
Anonymous 11/14/2019 04:06 PM	Much more motorboats.
Anonymous 11/16/2019 07:17 AM	Much more shoreline development
Anonymous 11/18/2019 11:19 AM	Water level is higher . Pathways along lake have disappeared in places
Anonymous 11/18/2019 07:24 PM	Development destroying natural shorelines
Anonymous 11/24/2019 04:13 PM	Other than the flood last spring, no. See answer to above.
Anonymous 11/26/2019 05:16 AM	A lot of natural shore lost due to cottage landscaping
Anonymous 11/30/2019 09:42 AM	More hard scape along shore, tree/shrub removal and mowing lawns to lake edge.
Anonymous 11/30/2019 09:48 AM	Large scale resort/condo development has meant increased year round lake use (snowmobiles and seadoos). Lawns abound with mowing to waters edge, reducing or eliminating the natural shoreline, especially near resorts and golf courses. Canada goose population has exploded to detriment of lake generally and water quality in particular. Newer style wake boats designed to create large waves cause major shore disturbance even when operating far offshore due to small surface area of the lake.

Optional question (59 responses, 23 skipped)

Q20 **Point source pollution is the discharge of substances from specific locations directly into waterways (e.g. drain pipes, sewer outlets, chemical spills). They can typically be traced back to the source and dealt with. Are you aware of any point sources of nutrients which could flow into Peninsula Lake? **

Anonymous 10/30/2019 10:24 AM	Disturbed shorelines affect run off
Anonymous 10/30/2019 02:04 PM	Late building of protective dams during redevelopment, Discharge of garbage on streams by short term renters.
Anonymous 11/01/2019 12:34 PM	None that we know of.
Anonymous 11/01/2019 03:29 PM	No.
Anonymous 11/01/2019 04:15 PM	Not as mentioned above, but I have witnessed occasional rushing of water off shoreline sites where erosion has taken place or with insufficient vegetation, especially trees with elaborate retaining root systems.
Anonymous 11/01/2019 04:45 PM	Aging septics - Older properties near ski area.
Anonymous 11/01/2019 05:47 PM	No
Anonymous 11/01/2019 06:47 PM	We back onto the golf course by the canal. Near our cottage there is a culvert. When it rains or the snow melts, the water comes through the culvert and down the side of our property and drains into the lake.
Anonymous 11/01/2019 07:38 PM	No.
Anonymous 11/01/2019 09:16 PM	A stream goes through a pasture at Maplehurst and hwy 60. Cows and horses are kept in the pasture and heavy rain takes the manure into Hills Bay.
Anonymous 11/02/2019 05:09 AM	No
Anonymous 11/02/2019 07:08 AM	Not specifically.
Anonymous 11/02/2019 07:25 AM	There is a natural water flow from a farm where cows are allowed to graze. The run off flows into the lake by Shaw's road.
Anonymous 11/02/2019 02:36 PM	Not aware of any
Anonymous 11/03/2019 10:39 AM	no, except perhaps Deerhurst golf course.

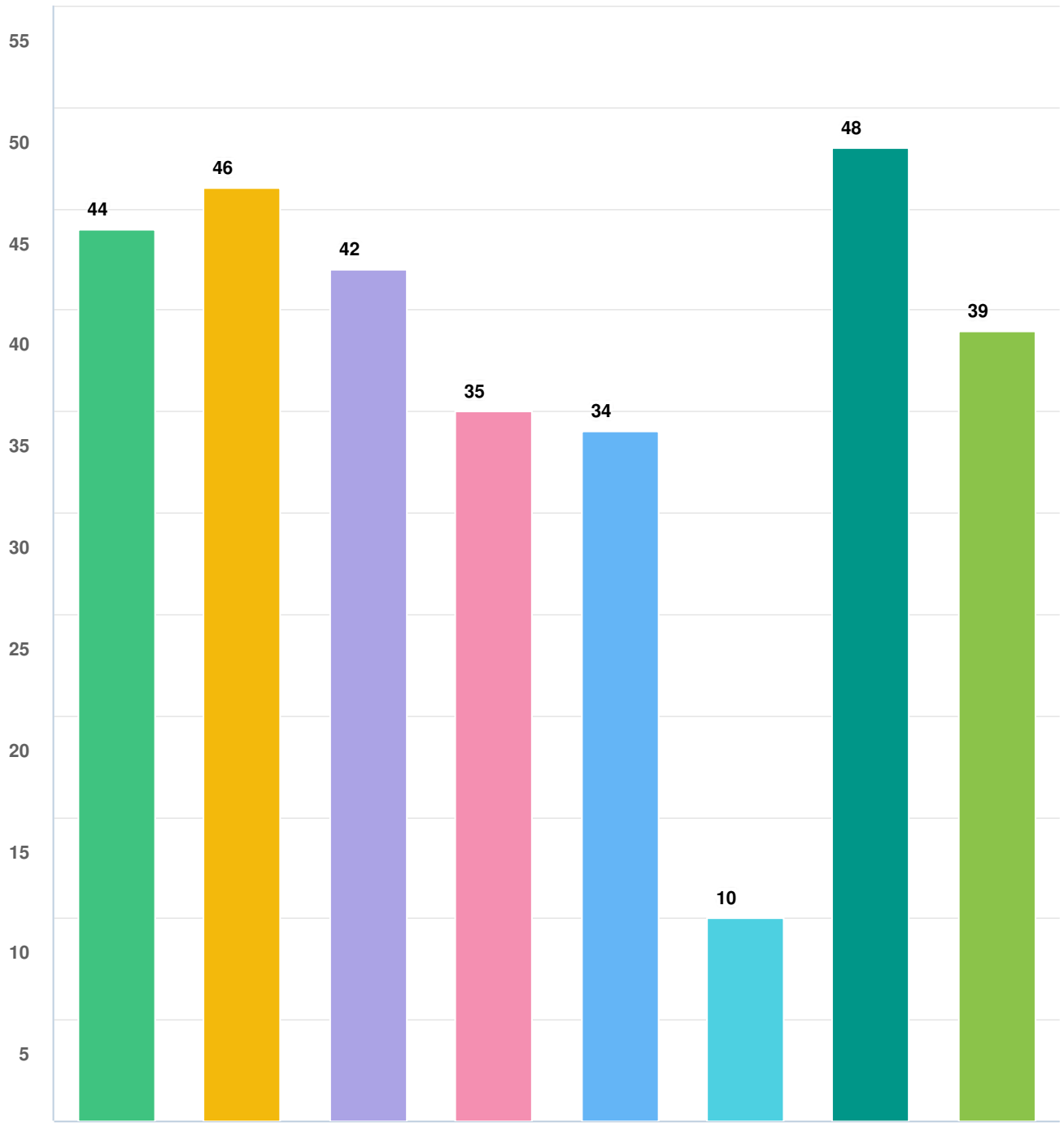
Anonymous 11/04/2019 07:54 AM	No
Anonymous 11/04/2019 08:45 AM	None that we are aware of.
Anonymous 11/04/2019 06:43 PM	No
Anonymous 11/05/2019 11:37 AM	2 golf courses and lots of resorts
Anonymous 11/06/2019 07:30 AM	Deerhurst golf course
Anonymous 11/06/2019 08:30 AM	No specific locations but water quality after significant rain events can be poor. This happens all around the lake.
Anonymous 11/06/2019 08:52 AM	I suspect the increased developments at the west end of the lake are a factor.
Anonymous 11/06/2019 11:07 AM	There is a small drainage culvert off Ski Club road (in between Hidden Valley Resort and the Ski Club Park. I believe mostly rain water runoff but could be a source of pollution too.
Anonymous 11/06/2019 01:59 PM	Have observed gasoline floating on the water surface in the Deerhurst resort area.
Anonymous 11/06/2019 02:58 PM	No
Anonymous 11/06/2019 06:33 PM	No.
Anonymous 11/06/2019 06:58 PM	Not that I'm aware of on the east side.
Anonymous 11/06/2019 07:58 PM	No
Anonymous 11/07/2019 01:12 AM	not specifically
Anonymous 11/07/2019 05:14 AM	No
Anonymous 11/07/2019 07:43 AM	No but wonder if part of the problem is not caused by old septic systems; boaters dumping raw sewage into the lake; expanding Canada Geese populations and their poop; and lake sediment being disturbed by ever more powerful motor boats
Anonymous 11/07/2019 08:17 AM	not aware

Anonymous 11/07/2019 08:28 AM	no
Anonymous 11/07/2019 08:45 AM	There are many drains and pipes directed to the lake but I have not studied the contents with enough awareness to comment.
Anonymous 11/07/2019 08:46 AM	no
Anonymous 11/07/2019 08:51 AM	no
Anonymous 11/07/2019 09:14 AM	no but would be interested in knowing
Anonymous 11/07/2019 01:21 PM	no
Anonymous 11/07/2019 02:22 PM	No
Anonymous 11/08/2019 11:14 AM	Yes see # 17
Anonymous 11/08/2019 11:18 AM	No
Anonymous 11/08/2019 01:28 PM	Flood near cattle farm.
Anonymous 11/08/2019 03:46 PM	No
Anonymous 11/10/2019 10:39 AM	No
Anonymous 11/11/2019 03:30 PM	Construction of new lakeside building at Deerhurst which levelled and decimated a tree filled knoll/green space that helped slow storm water seepage into the lake
Anonymous 11/11/2019 06:51 PM	Not aware of any other than if farmers pesticides and fertilizers are go into the lakes.
Anonymous 11/12/2019 01:19 PM	Deerhurst Golf Course is not exactly a "point source" as described, however the golf course runs toward the lake and canal and in heavy rains all the fertilizer must run into the lake.
Anonymous 11/13/2019 07:09 PM	Often wonder about the golf courses that are on the lake and what chemicals they may or may not use and the geese that are on those courses and their excrement.
Anonymous 11/14/2019 07:34 AM	No
Anonymous	No but have had some significant storms in recent years that maybe causing

11/14/2019 02:32 PM	run off.
Anonymous 11/14/2019 04:06 PM	Golf courses.
Anonymous 11/16/2019 07:17 AM	No
Anonymous 11/18/2019 11:19 AM	Added building around Deerhurst
Anonymous 11/24/2019 04:13 PM	No
Anonymous 11/26/2019 05:16 AM	No
Anonymous 11/30/2019 09:42 AM	Perhaps pollution occurs from streams running through cattle farm,off Maplehurst and truck graveyard off Limberlost Road, Hillside.
Anonymous 11/30/2019 09:48 AM	No

Optional question (57 responses, 25 skipped)

Q22 What is your hope for the outcome of a causation study?



Question options

- learn what I can do to help
- increased understanding
- Other (please specify)
- controls on recreational use and boat traffic
- development of a lake plan
- stronger planning policies
- enhanced stewardship initiatives
- restrictions on future development

Optional question (73 responses, 9 skipped)

Q24 Other comments:

Anonymous 10/30/2019 02:04 PM	Algal blooms have occurred coincidently in remote lakes of Algonquin Park.
Anonymous 11/01/2019 12:34 PM	In your query about when we are at the property, you did not offer 3 seasons as an option. We are there spring, summer and fall.
Anonymous 11/01/2019 04:15 PM	Education is certainly a good way to go. However, we've been doing this for decades now with little to show for it. Few people (usually about 30 out of 250 PL members) show up at our annual ecology events during the summer. I really think it's time for our municipal councils to show some teeth and take strong initiatives to change things. Unfortunately, PL was divided a few decades ago into about 1/3 under Huntsville, 2/3 Lake-of-Bays. The former has been very slow to mitigate climate change and encourage good environmental practices; the latter definitely better, but still not enough. environmental loading capacity needs to be understood along with the biggest factors causing excessive load on environment getting addressed.
Anonymous 11/01/2019 04:45 PM	Lipstick style actions are only skin deep and while may look good, does not solve real problems.
Anonymous 11/02/2019 05:09 AM	We love the lake - for its beauty and peace - we wish others would enjoy the lake quietly, with less night-time lights and respect for the water.
Anonymous 11/04/2019 08:45 AM	Thank you!
Anonymous 11/05/2019 11:37 AM	it would nice if our kids had a nice clean lake to swim in in years to come. can we do this study on other lakes as well 3 Mile Lake in Muskoka also had algea blooms this summer that wrecks havoc on drinking water, fishing and pleasure experiences. we need to smarten up
Anonymous 11/05/2019 10:00 PM	Please enforce all of the above for Peninsula Lake before it is loo late.
Anonymous 11/06/2019 08:52 AM	Thank you!
Anonymous 11/06/2019 08:55 AM	Thank you for doing this. It is important.
Anonymous 11/06/2019 11:07 AM	Peninsula Lake is a gem and needs protection.
Anonymous 11/07/2019 05:14 AM	I find the lake clean and am not concerned with algae
Anonymous	Wishing you success with this timely endevour.

11/07/2019 08:45 AM

Anonymous
11/07/2019 09:14 AM

thank you for this survey

Anonymous
11/08/2019 03:46 PM

I think there should be a attempt by professionals to educate the public about what the causative organism is. The constant use of the word algae which is only similar to cyanobacteria in that they both contain chloroplasts and are found in water only leads to more confusion about an organism that is already very poorly understood. I did not realize until the meeting today that Gleotrichia are mainly found in the material on the lake bottom. (make me wonder why we are not sampling the lake bottom). As I found as a veterinarian everyone always wants to know what the cause of a malady but all to frequently this eludes us and we can only speculate. Speculation without confirming date frequently leads to false conclusions which the lay population thinks is "fact" I must have heard many times in the last couple of years that the few head of cattle in the field near the east end of the lake are responsible for the "algae bloom". Of course there is no evidence to support it. In fact, give that the phosphorus levels in the lake tend to be steady would suggest other wise. I hope your knowledge and investigation help explain the occasional cyanobacteria outbreaks on Penn Lake and help understand not only why they have occurred but what we can do to prevent outbreaks. Personally, I believe there is not enough data available on the parameters that we suspect are involved to come to anything but an educated guess. I hope that this will be your conclusion too. I would look forward however to hearing what we can do so that we have the data and doing the right samples so if another bloom occurs we might have something to turn to. Thank You I found it interesting that you mentioned today that Gleotrichia are present in Penn Lake and therefore most likely present in Fairy Lake, yet Fairy Lake does not experience outbreaks. Given that Fairly Lake tends to be much deeper than Penn Lake I would expect there is less light and colder temperature at the bottom of the lake. Perhaps these differences could be factor as to why that lake does not experience cyanobactrial blooms

Anonymous
11/10/2019 10:39 AM

Good luck

Anonymous
11/11/2019 04:40 PM

Water quality is massively important to me and I care about the development of our lakes. I do hope visitors and condo owners will be aware of natural shorelines and the care it takes to keep our lakes beautiful, clean and safe.

Anonymous
11/12/2019 01:19 PM

We hope it's not too late for our lake.

Anonymous
11/13/2019 07:09 PM

I would like to be kept informed on the study and involved if allowed. Thank you for this opportunity.

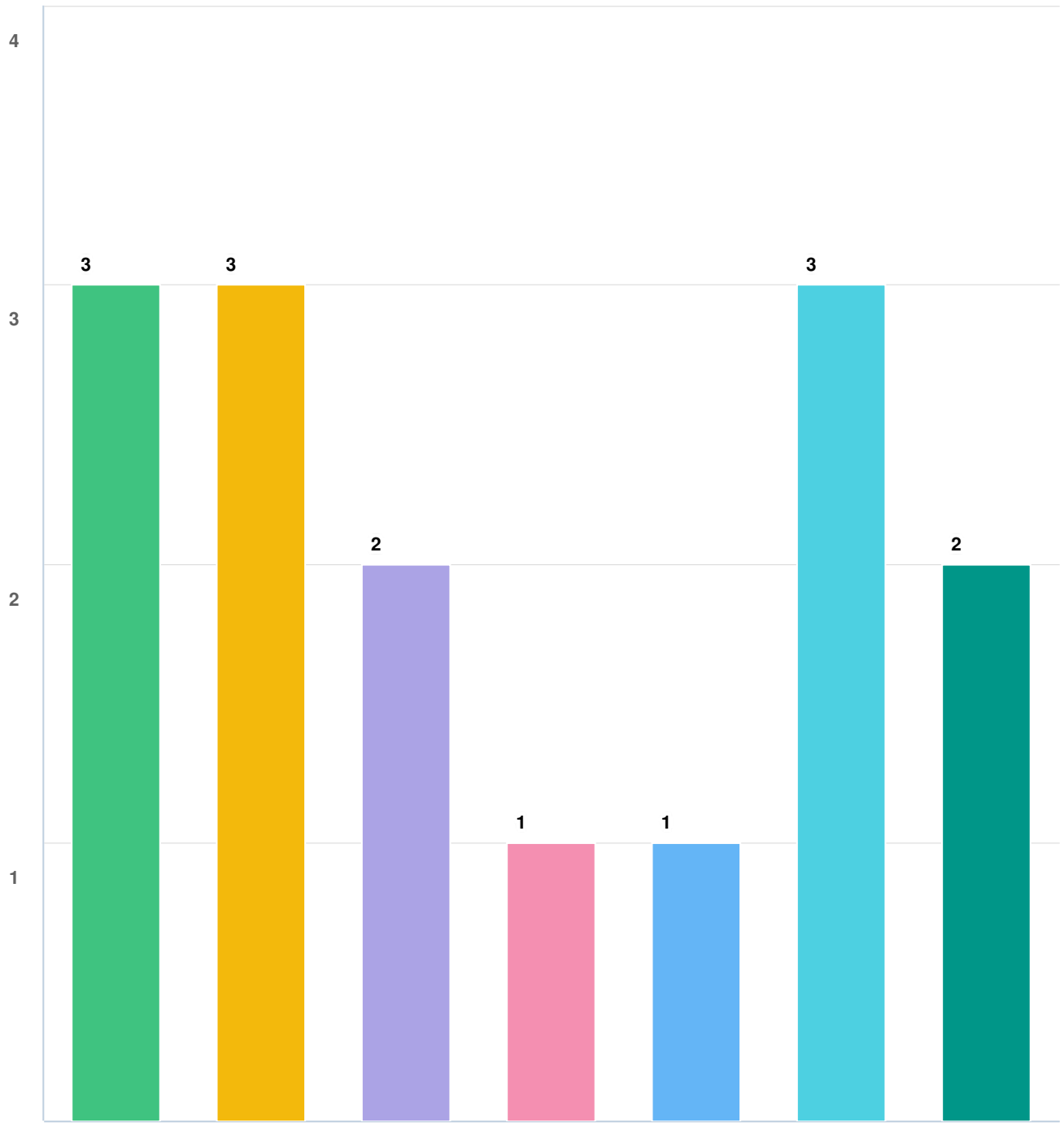
Anonymous
11/24/2019 04:13 PM

I am a water resources professional engineer of 40+ years working experience and currently a candidate for a Masters of Applied Science in civil engineering (water resources) at York University. I have also had some past minor dealings with Dr. Neil Hutchinson through work.

Anonymous 11/30/2019 09:48 AM	Wishing you good results from your analysis, and future benefits for Pen Lake.

Optional question (22 responses, 60 skipped)

Q25 What is your interest in the pilot causation study on Peninsula Lake?



Question options

- Learning what I can do to help
- Increased understanding
- Other (please specify)
- I have information to share with the consultant about Peninsula Lake
- My lake is also listed as vulnerable
- I'm generally interested in the science or the process
- I live/own property on a nearby lake, but not on Peninsula Lake

Optional question (5 responses, 77 skipped)

Q26 **Do you have any knowledge, documentation, studies, sampling data or materials that you wish to share with the consultant? If yes, please include the title or nature of the document and be sure to leave your contact information below.**

Anonymous
11/05/2019 07:27 PM

NO - just LOB

Anonymous
11/10/2019 09:39 AM

Optional question (2 responses, 80 skipped)

Appendix B. Stakeholder Photographs.

Figure A1. Hills Island – East Basin

Figure A2. Fairy Lake – Inlet from Peninsula Lake

Figure A3. Northern Bay near Public Launch

Figure A4. Wolf Bay – East Basin

Figure A5. Deerhurst Resort

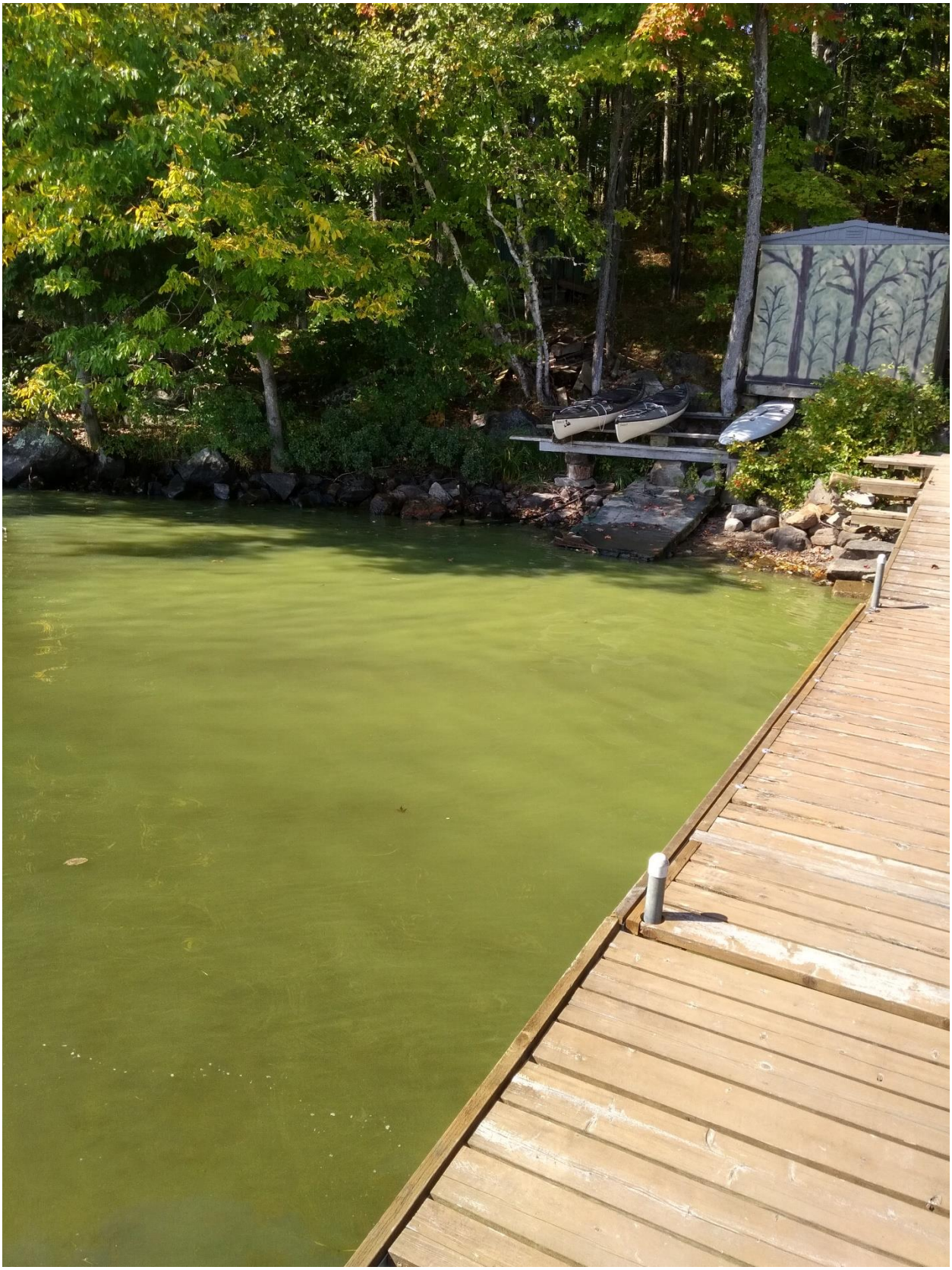
Figure A6. Outlet to Fairy Lake

Figure A7. Deerhurst Resort

Figure A8. Local Stakeholder A1

Figure A9. Local Stakeholder A2

Figure A10. Local Stakeholder A3



Appendix C. November 8, 2019 Public Meeting Presentation

Hutchinson
Environmental Sciences Ltd.

Peninsula Lake Causation Study

Stakeholder Meeting
November 8, 2019

Kris Hadley, Neil Hutchinson (Hutchinson Environmental Sciences Ltd.)
In collaboration with the District Municipality of Muskoka

Schedule

- Presentation
  - Background to study and study scope
  - What do we know already ?
  - What do we want to learn?
- Formal Question and Answer

Background

- Request for Proposal issued by the District Municipality of Muskoka on August 13, 2019
  - Goal is to develop an evidence-based, defensible approach to determine the cause(s) and contributing factors that are impacting water quality focused on Peninsula Lake but adaptable to other lakes listed as vulnerable under the Muskoka Official Plan
  - Hutchinson Environmental Sciences Ltd. awarded the project

HESL

Project Team

- Hutchinson Environmental Sciences Ltd. (HESL) is a team of 9 experienced scientists specializing in aquatic environmental science for over a decade and head office in Bracebridge
- HESL's areas of expertise:
  - Lake and Watershed Management,
  - Algal and Nutrient Dynamics
  - Water Quality Assessment and Modelling,
  - Receiving Water and Assimilative Capacity Studies, and
  - Peer Review, Public Engagement/Facilitation and Scientific Synthesis.

Workplan

1. Start-up meeting ✓
2. Compile and review existing data – Ongoing
   a) Background Review
3. Field program ✓
   a) Water quality sampling (October 2019) ✓
4. Gap analysis and establish parameters of interest
5. Phosphorus budget
6. Development of Causation Study Pilot Program – Weight of Evidence

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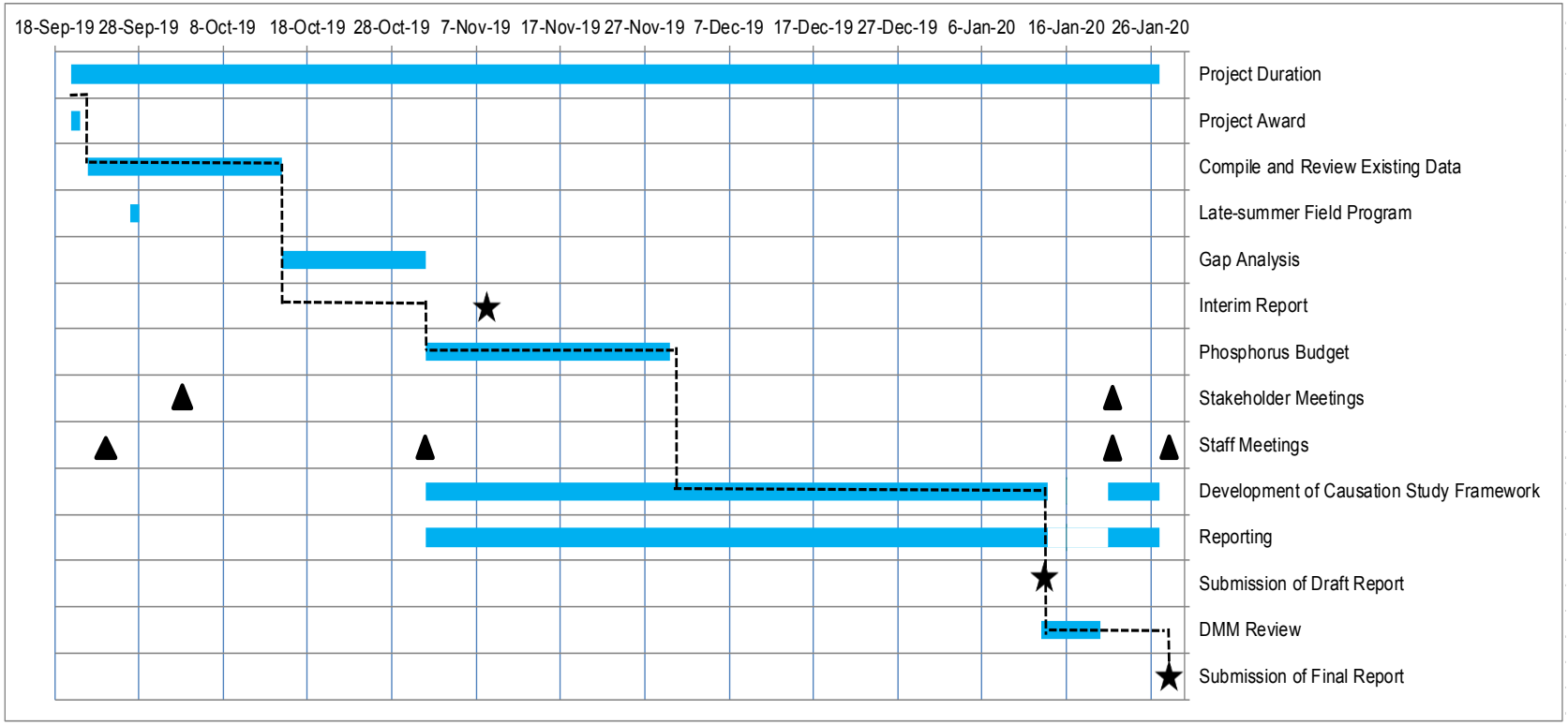
Scheduling



Notes

★ Deliverable

▲ Meeting

--- Critical Path

HESL

What Might Cause an Algal Bloom?

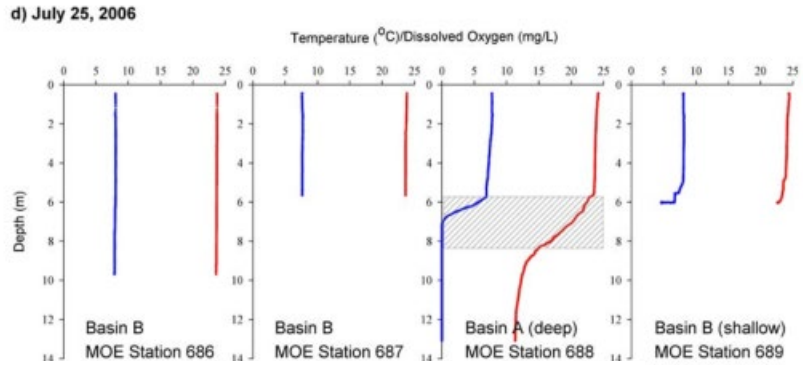
No definitive cause – they are favoured in nutrient rich waters –but not in low nutrient waters like Peninsula Lake.

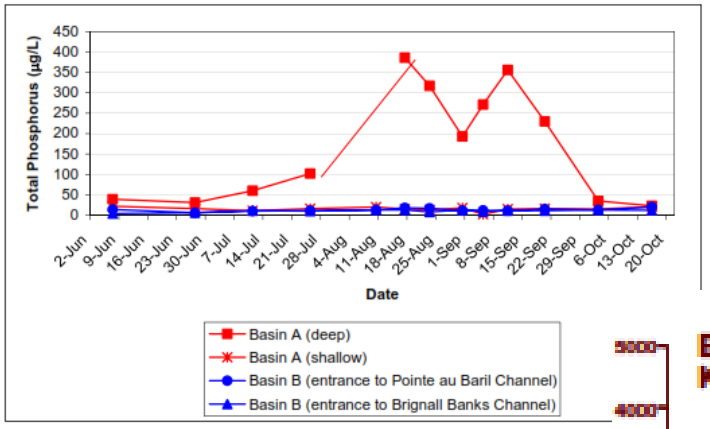
- Increase in total phosphorus in surface water
  - Land use changes, point sources
- Warmer, more stable water column favours cyanobacteria
- Algal species that take phosphorus from enriched sediments
- Other ions in water (iron)
- Loss of oxygen in deep water
  - Some lakes have deep water anoxia
    - Warming climate promotes anoxia (earlier stratification)
  - Anoxia promotes phosphorus release from bottom sediments (internal load)
  - Some algal forms (cyanobacteria) can migrate to deep water to take up this phosphorus then bloom on surface

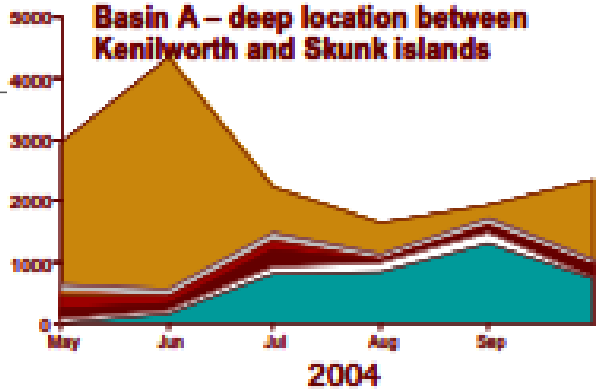
HESL

What Might Cause an Algal Bloom?

- Loss of oxygen in deep water – Sturgeon Bay Example
- Deep basin loses oxygen in July
- Deep Basin shows internal load in August and September
- Deep Basin shows cyanobacterial dominance in August and September







Background Review

- Water quality data
  - Lake Partner Program Phosphorus Data (2002-2017)
  - Citizen Science Data – Pending
  - Ministry of Environment, Conservation and Parks (MECP)
  - District Municipality of Muskoka (DMM) data
- GIS data
  - DMM in-house data
  - Ontario Flow Assessment Tool (OFAT) data
- Historical Data
  - Information on Past Algal Blooms (Engage Muskoka)
  - Public Survey Posted at: https://www.engagemuskoka.ca/protecting-muskokas-vulnerable-lakes-causation-studies

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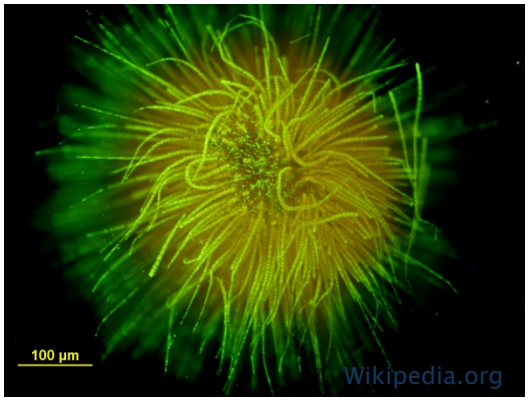
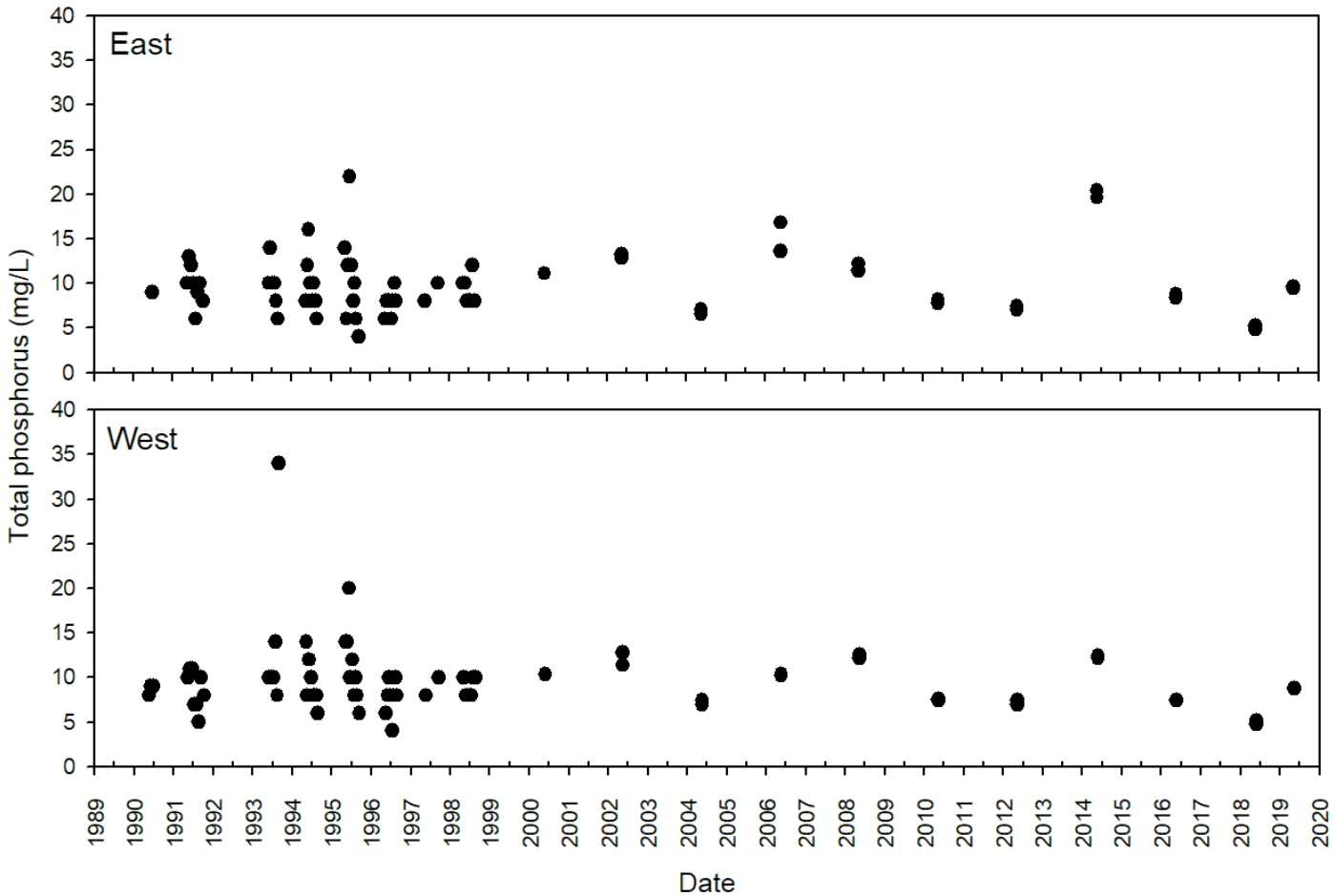
Peninsula Lake Algal Bloom

- Species is *Gloeotrichia echinulata*
  - Also bloomed on Peninsula Lake in mid-1990s
- Complex life cycle summarized briefly as:
  - 1) germination on the sediment,
  - 2) growth on the sediment,
  - 3) gas vesicles formation and migration into the water column,
  - 4) growth and division in the water column,
  - 5) formation of resting stages, called akinetes,
  - 6) sinking of akinetes out of the water column to the sediment, and
  - 7) resting and maturation of the akinetes on the sediment



Historical Total Phosphorus



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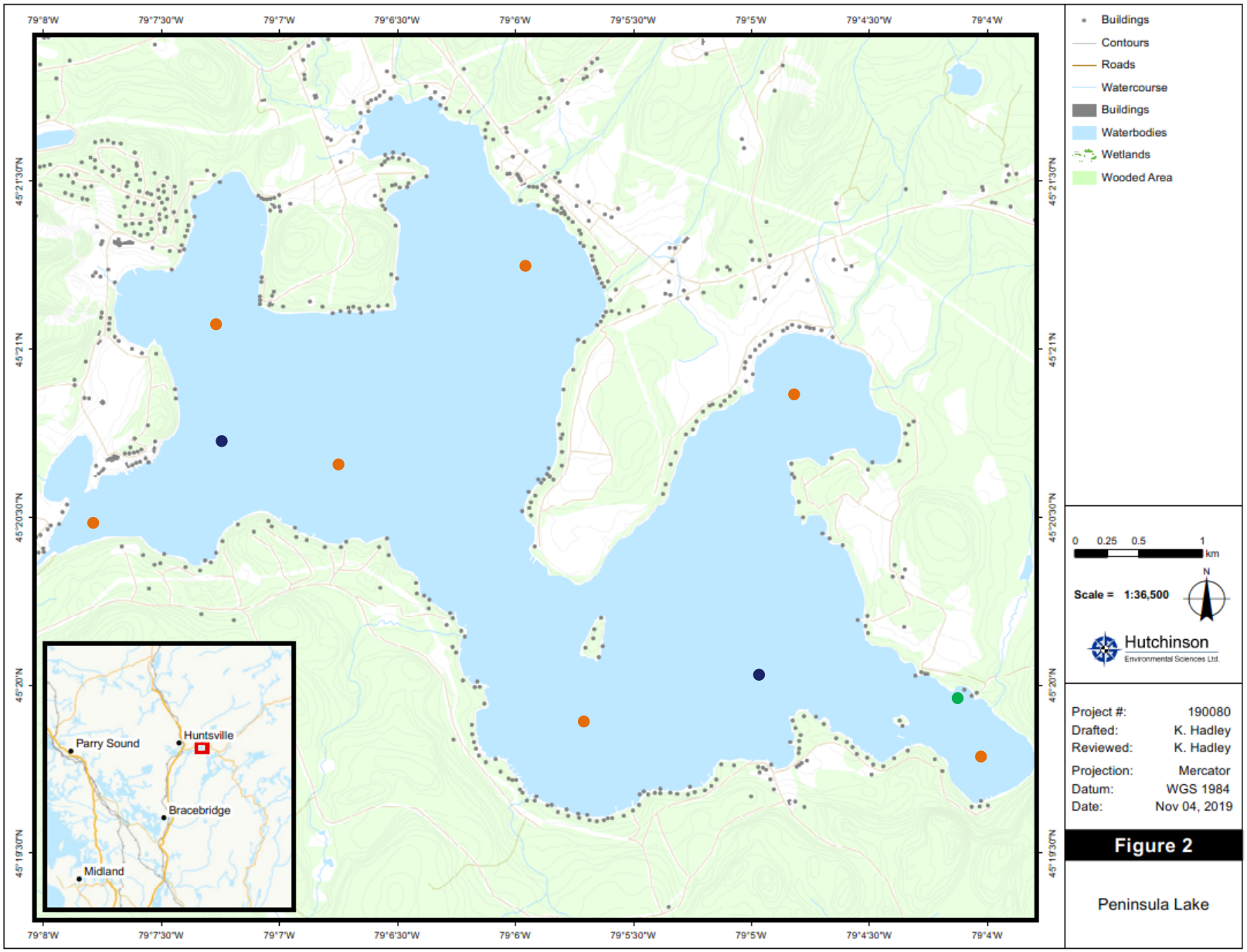
Monitoring Plan

- Goal: Establish oxygen status of the deep water and determine if internal loading is a factor in Peninsula Lake
- Water Quality Sampling
  - Sampling Locations
    - 2 sampling locations on Peninsula Lake, deep spot in each basin
- Sampling frequency
  - 1 event: October 2019

HESL



● DMM and HESL Sites ● U Waterloo (2012) ● LPP

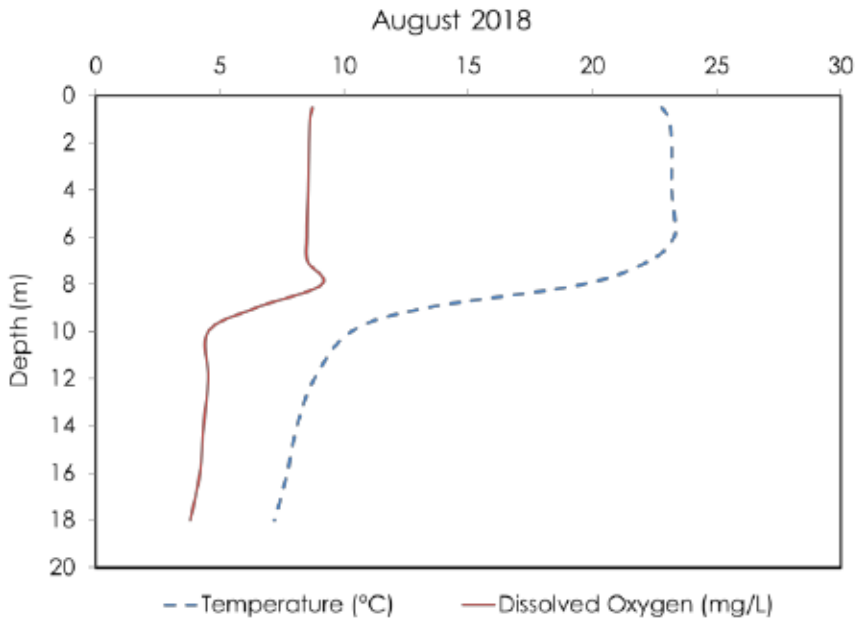
HESL

Monitoring Plan

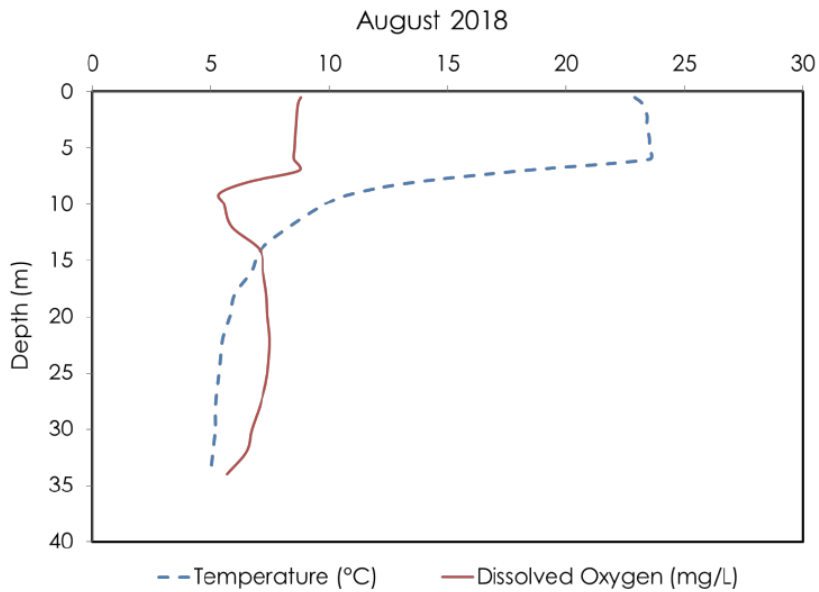
- Water Quality Parameters
  - General chemistry, nutrients and metals
  - Phosphorus and iron from bottom waters if dissolved oxygen is low
  - Field measurements of pH, conductivity, temperature and dissolved oxygen

Dissolved Oxygen Profiles – DMM

Peninsula Lake – East



Peninsula Lake – West



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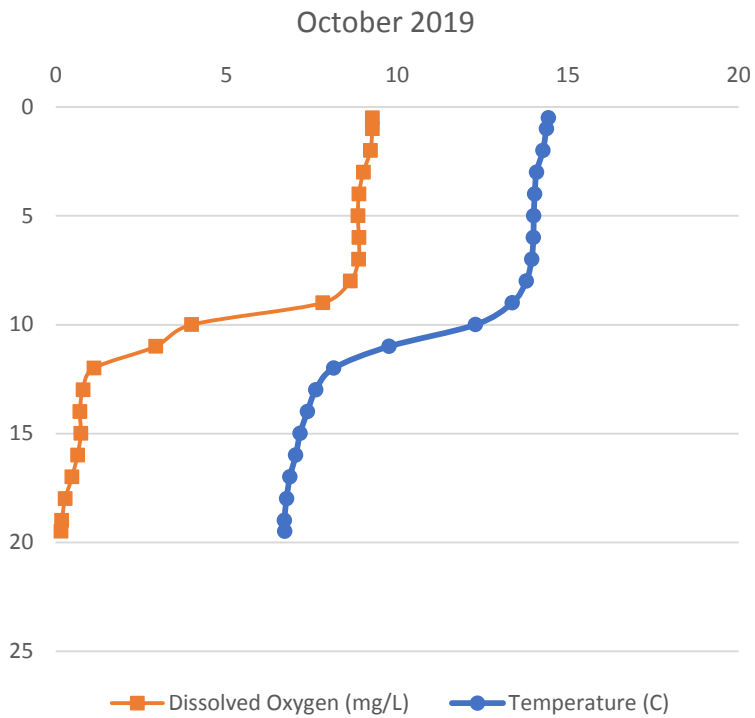
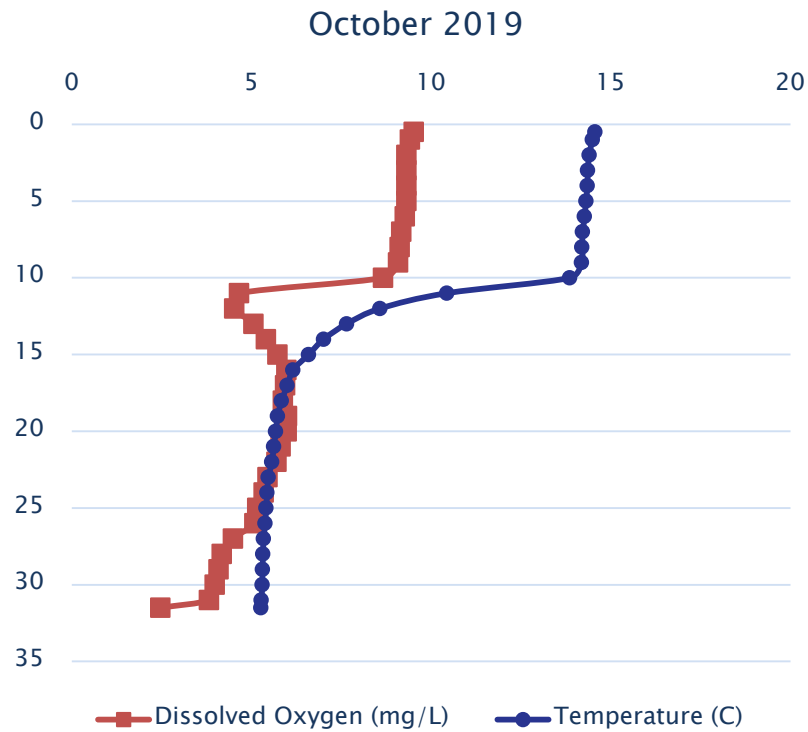
Dissolved Oxygen – Fall 2019

Peninsula Lake – East



Peninsula Lake – West



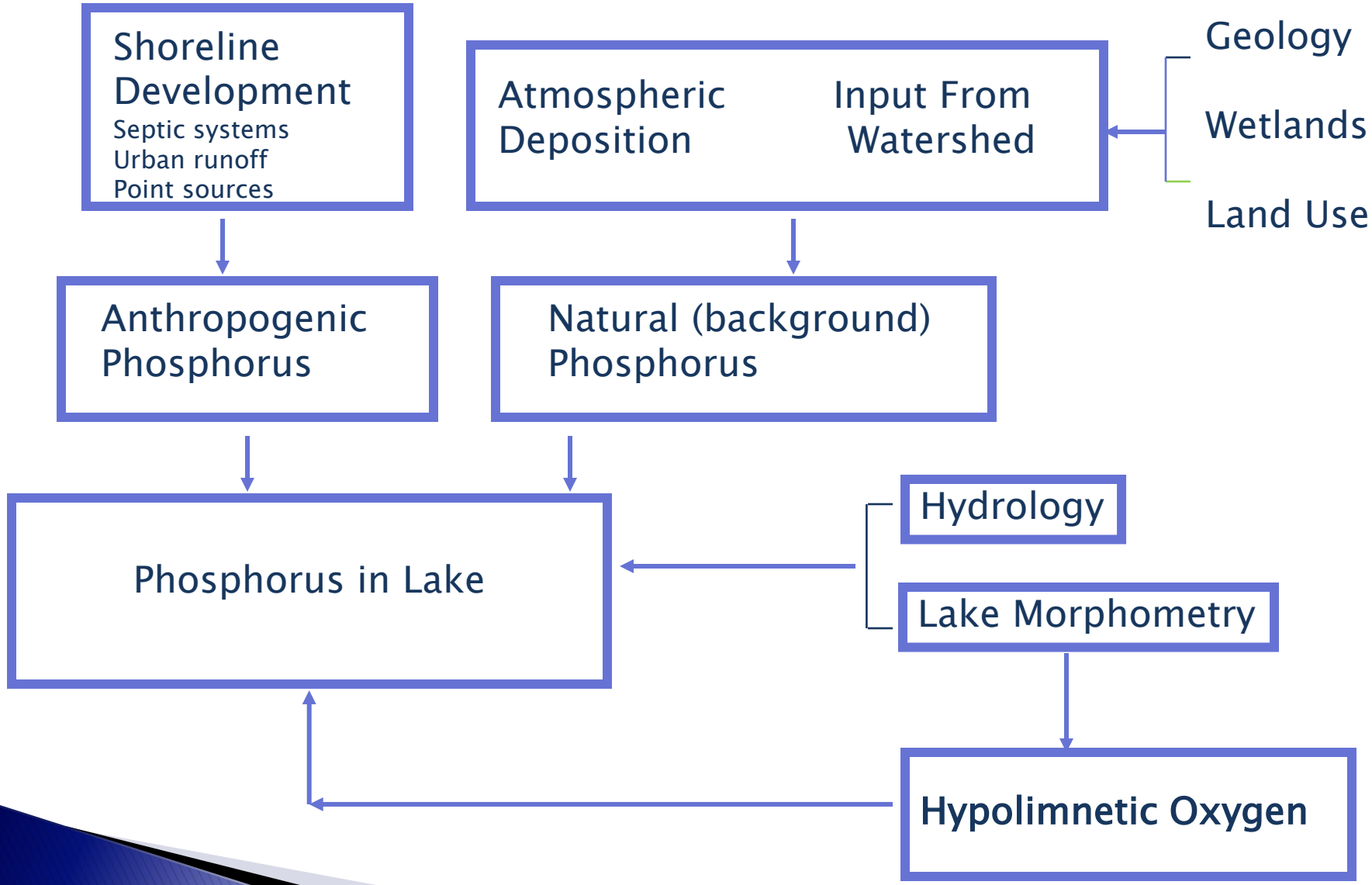
Phosphorus Budget

- Export coefficient modelling
- Quantify nutrient loading from internal (sediments) and external sources (overland runoff, septic systems, precipitation)

Phosphorus Budget

- DMM Water Quality Model
  - Mass balance model that estimates natural and human sources to predict phosphorus concentrations
- Allows for management to focus on greatest potential sources of nutrients and to define conditions according to water quality guidelines

Muskoka Water Quality Model



Causation Study

- Focused on estimating the relative importance of ecology, climate and development on the re-emergence of cyanobacteria blooms in Peninsula Lake, to inform on the need for the development of additional monitoring programs, septic surveys or other special studies

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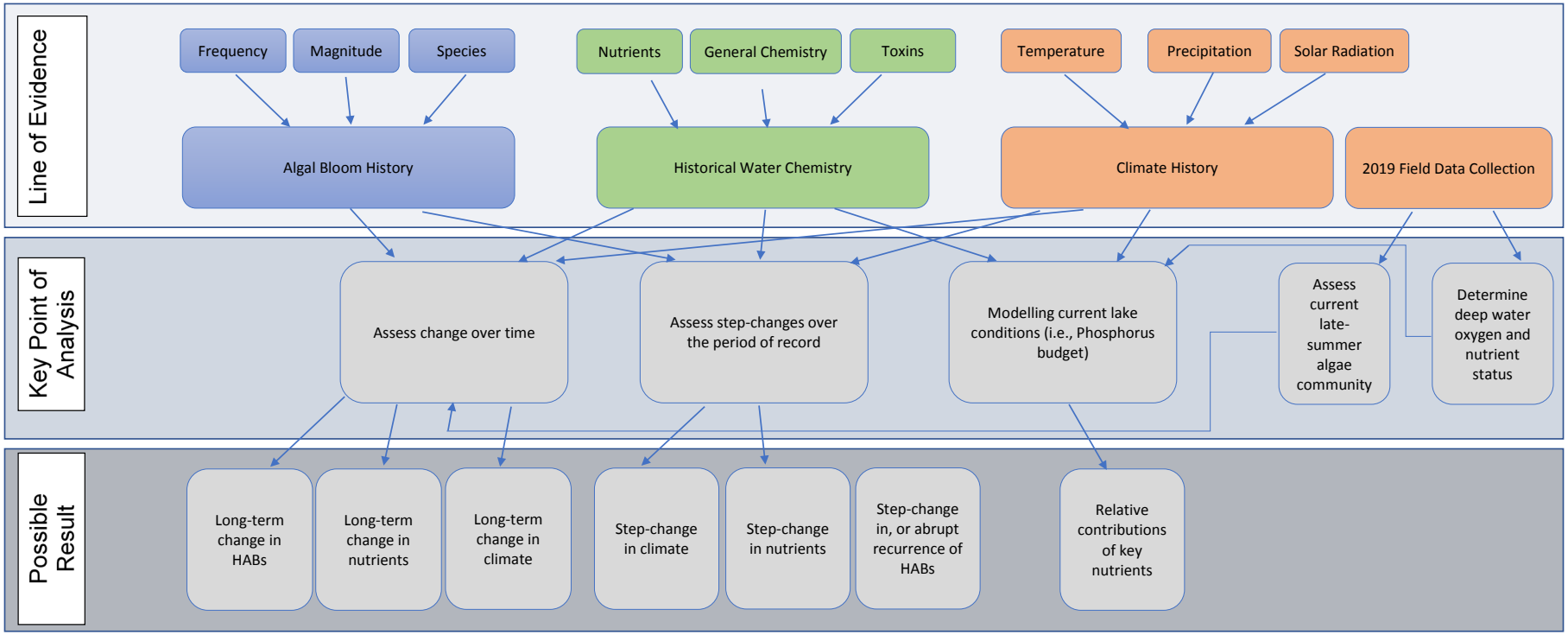
How Can you Help?

- Engage Muskoka Survey
  - Provide information on the history of Peninsula Lake, specifically on the history of algal blooms in the lake
- Citizen Science Data
  - Data on water quality or climate that could be incorporated into the Causation Study

How Will Your Input Be Used?

- To inform our Weight of Evidence approach to connect changes in climate, water quality and development to recent algal blooms in Peninsula Lake

Weight of Evidence Approach



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Weight of Evidence Approach

	Lines of Evidence												
Potential Causes of Algal Blooms	Increased Bloom Frequency	Benthic vs Planktonic Species	Documented Warmer Water	Documented Increase in Storm Intensity	Documented Warmer Air	Documented Increase in Low Wind Periods	Measured Internal Load	Periodic Anoxia	Documented Increase in Anoxia	Documented Increase in TP	Increased Watershed Disturbance	Location of Blooms	Extent of Blooms
Climate Change – Warmer/Calmer Water	X	P	X		X	X							
Climate Change – Enhanced Internal Loading	X	P	X		X		X	X	X	X			
Sediment Sources		B	X		X		X	X			X		
Local Landscape Disturbances		P		X						X	X	X	X
Natural Internal Loading		P					X	X					
Increased TP Load – Septics	X	P							X	X		X	X
Increasd TP load– Watershed	X	P		X						X	X	X	X
Increased TP Load – Specific Land Uses		P		X						X	X	X	X
Benthic = Gloeotrichia													

HESL

Thank you

- Emily Crowder
  - District Municipality of Muskoka
  - Phone: (705) 645-6764 x4313
  - Emily.Crowder@muskoka.on.ca

- Engage Muskoka Survey
  - https://www.engagemuskoka.ca/protecting-muskokas-vulnerable-lakes-causation-studies

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Appendix D. Water Quality Summary Statistics

Table 1. DMM Data

Station	Parameter	Units	Date	Result
East	Alkalinity	milligrams/litre	18-05-2004	8.51
East	Alkalinity	milligrams/litre	19-05-2006	8.56
East	Alkalinity	milligrams/litre	09-05-2008	8.38
East	Alkalinity	milligrams/litre	14-05-2010	9.77
East	Alkalinity	milligrams/litre	14-05-2012	9.92
East	Alkalinity	milligrams/litre	26-05-2014	10.78
East	Alkalinity	milligrams/litre	24-05-2016	9.18
East	Alkalinity	milligrams/litre	30-05-2018	10
East	Alkalinity	milligrams/litre	17-05-2019	11
East	Alkalinity; Total Fixed Endpt	milligrams/litre	14-05-2010	11.6
East	Alkalinity; Total Fixed Endpt	milligrams/litre	14-05-2012	10.8
East	Alkalinity; Total Fixed Endpt	milligrams/litre	26-05-2014	12.12
East	Alkalinity; Total Fixed Endpt	milligrams/litre	24-05-2016	10.6
East	Alkalinity; Total Fixed Endpt	milligrams/litre	30-05-2018	11.9
East	Alkalinity; Total Fixed Endpt	milligrams/litre	17-05-2019	9
East	Aluminum	micrograms/litre	19-05-2006	18.3
East	Aluminum	micrograms/litre	09-05-2008	33
East	Aluminum	micrograms/litre	14-05-2010	11.1
East	Aluminum	micrograms/litre	14-05-2012	10.2
East	Aluminum	micrograms/litre	26-05-2014	25
East	Aluminum	micrograms/litre	24-05-2016	21.8
East	Aluminum	micrograms/litre	30-05-2018	14.2
East	Aluminum	micrograms/litre	17-05-2019	28
East	Ammonium Nitrate	micrograms/litre	18-05-2004	14
East	Ammonium Nitrate	micrograms/litre	19-05-2006	42
East	Ammonium Nitrate	micrograms/litre	09-05-2008	16
East	Ammonium Nitrate	micrograms/litre	14-05-2010	8
East	Ammonium Nitrate	micrograms/litre	14-05-2012	18
East	Ammonium Nitrate	micrograms/litre	26-05-2014	54
East	Ammonium Nitrate	micrograms/litre	24-05-2016	8
East	Ammonium Nitrate	micrograms/litre	30-05-2018	12
East	Ammonium Nitrate	micrograms/litre	17-05-2019	38
East	Anions	milliequiv/litre	19-05-2006	0.5
East	Anions	milliequiv/litre	09-05-2008	0.55
East	Anions	milliequiv/litre	14-05-2010	0.56
East	Anions	milliequiv/litre	14-05-2012	0.536
East	Anions	milliequiv/litre	26-05-2014	0.569

East	Anions	milliequiv/litre	24-05-2016	0.519
East	Anions	milliequiv/litre	30-05-2018	0.585
East	Anions	milliequiv/litre	17-05-2019	1
East	Antimony	micrograms/litre	14-05-2012	0
East	Antimony	micrograms/litre	26-05-2014	0
East	Antimony	micrograms/litre	24-05-2016	0
East	Antimony	micrograms/litre	30-05-2018	0
East	Antimony	micrograms/litre	17-05-2019	0
East	Arsenic	micrograms/litre	14-05-2012	0.2
East	Arsenic	micrograms/litre	26-05-2014	0.2
East	Arsenic	micrograms/litre	24-05-2016	0.2
East	Arsenic	micrograms/litre	30-05-2018	0.1
East	Arsenic	micrograms/litre	17-05-2019	0
East	Barium	micrograms/litre	19-05-2006	12.9
East	Barium	micrograms/litre	09-05-2008	13.4
East	Barium	micrograms/litre	14-05-2010	12
East	Barium	micrograms/litre	14-05-2012	11.1
East	Barium	micrograms/litre	26-05-2014	11.9
East	Barium	micrograms/litre	24-05-2016	10.9
East	Barium	micrograms/litre	30-05-2018	11.3
East	Barium	micrograms/litre	17-05-2019	12
East	Beryllium	micrograms/litre	19-05-2006	0
East	Beryllium	micrograms/litre	09-05-2008	-0.03
East	Beryllium	micrograms/litre	14-05-2010	0.006
East	Beryllium	micrograms/litre	14-05-2012	0
East	Beryllium	micrograms/litre	26-05-2014	0
East	Beryllium	micrograms/litre	24-05-2016	0
East	Beryllium	micrograms/litre	30-05-2018	0
East	Beryllium	micrograms/litre	17-05-2019	0
East	Boron	micrograms/litre	14-05-2012	3
East	Boron	micrograms/litre	26-05-2014	6
East	Boron	micrograms/litre	24-05-2016	4
East	Boron	micrograms/litre	30-05-2018	5
East	Boron	micrograms/litre	17-05-2019	5
East	Cadmium	micrograms/litre	19-05-2006	0.2
East	Cadmium	micrograms/litre	09-05-2008	0.99
East	Cadmium	micrograms/litre	14-05-2010	0.096
East	Cadmium	micrograms/litre	14-05-2012	0
East	Cadmium	micrograms/litre	26-05-2014	0
East	Cadmium	micrograms/litre	24-05-2016	0
East	Cadmium	micrograms/litre	30-05-2018	0
East	Cadmium	micrograms/litre	17-05-2019	0
East	Calcium	milligrams/litre	18-05-2004	4.2

East	Calcium	milligrams/litre	19-05-2006	4.16
East	Calcium	milligrams/litre	09-05-2008	3.96
East	Calcium	milligrams/litre	14-05-2010	4.9
East	Calcium	milligrams/litre	14-05-2012	3.86
East	Calcium	milligrams/litre	26-05-2014	4
East	Calcium	milligrams/litre	24-05-2016	3.62
East	Calcium	milligrams/litre	30-05-2018	4.02
East	Calcium	milligrams/litre	17-05-2019	4
East	Cations	milliequiv/litre	19-05-2006	0.59
East	Cations	milliequiv/litre	09-05-2008	0.57
East	Cations	milliequiv/litre	14-05-2010	0.622
East	Cations	milliequiv/litre	14-05-2012	0.572
East	Cations	milliequiv/litre	26-05-2014	0.593
East	Cations	milliequiv/litre	24-05-2016	0.554
East	Cations	milliequiv/litre	30-05-2018	0.651
East	Cations	milliequiv/litre	17-05-2019	1
East	Chloride	milligrams/litre	18-05-2004	8.29
East	Chloride	milligrams/litre	19-05-2006	7.67
East	Chloride	milligrams/litre	09-05-2008	8.98
East	Chloride	milligrams/litre	14-05-2010	9.04
East	Chloride	milligrams/litre	14-05-2012	8.4
East	Chloride	milligrams/litre	26-05-2014	9.26
East	Chloride	milligrams/litre	24-05-2016	9.11
East	Chloride	milligrams/litre	30-05-2018	11
East	Chloride	milligrams/litre	17-05-2019	12
East	Chromium	micrograms/litre	19-05-2006	-0.09
East	Chromium	micrograms/litre	09-05-2008	0.23
East	Chromium	micrograms/litre	14-05-2010	0.036
East	Chromium	micrograms/litre	14-05-2012	0.2
East	Chromium	micrograms/litre	26-05-2014	0.3
East	Chromium	micrograms/litre	24-05-2016	0.1
East	Chromium	micrograms/litre	30-05-2018	0.2
East	Chromium	micrograms/litre	17-05-2019	0
East	Cobalt	micrograms/litre	19-05-2006	-0.45
East	Cobalt	micrograms/litre	09-05-2008	1.18
East	Cobalt	micrograms/litre	14-05-2010	0.045
East	Cobalt	micrograms/litre	14-05-2012	0
East	Cobalt	micrograms/litre	26-05-2014	0
East	Cobalt	micrograms/litre	24-05-2016	0
East	Cobalt	micrograms/litre	30-05-2018	0
East	Cobalt	micrograms/litre	17-05-2019	0
East	Conductivity	microSiemens/cm	18-05-2004	64
East	Conductivity	microSiemens/cm	19-05-2006	67.6

East	Conductivity	microSiemens/cm	09-05-2008	66
East	Conductivity	microSiemens/cm	14-05-2010	62.8
East	Conductivity	microSiemens/cm	14-05-2012	68.4
East	Conductivity	microSiemens/cm	26-05-2014	67
East	Conductivity	microSiemens/cm	24-05-2016	66.2
East	Conductivity	microSiemens/cm	30-05-2018	72
East	Conductivity	microSiemens/cm	17-05-2019	74
East	Conductivity Estimated	microSiemens/cm	14-05-2010	70
East	Conductivity Estimated	microSiemens/cm	14-05-2012	65.1
East	Conductivity Estimated	microSiemens/cm	26-05-2014	68.1
East	Conductivity Estimated	microSiemens/cm	24-05-2016	63.2
East	Conductivity Estimated	microSiemens/cm	30-05-2018	72.5
East	Conductivity Estimated	microSiemens/cm	17-05-2019	76
East	Copper	micrograms/litre	19-05-2006	0.48
East	Copper	micrograms/litre	09-05-2008	1.04
East	Copper	micrograms/litre	14-05-2010	-0.357
East	Copper	micrograms/litre	14-05-2012	1.1
East	Copper	micrograms/litre	26-05-2014	0.7
East	Copper	micrograms/litre	24-05-2016	0.7
East	Copper	micrograms/litre	30-05-2018	0.6
East	Copper	micrograms/litre	17-05-2019	1
East	Dissolved Inorganic Carbon	milligrams/litre	24-05-2016	2.48
East	Dissolved Inorganic Carbon	milligrams/litre	30-05-2018	2.4
East	Dissolved Inorganic Carbon	milligrams/litre	17-05-2019	3
East	Dissolved Organic Carbon	milligrams/litre	18-05-2004	3.9
East	Dissolved Organic Carbon	milligrams/litre	19-05-2006	3.7
East	Dissolved Organic Carbon	milligrams/litre	09-05-2008	3.8
East	Dissolved Organic Carbon	milligrams/litre	14-05-2010	3.8
East	Dissolved Organic Carbon	milligrams/litre	14-05-2012	3.8
East	Dissolved Organic Carbon	milligrams/litre	26-05-2014	2.46
East	Dissolved Organic Carbon	milligrams/litre	26-05-2014	4.1
East	Dissolved Organic Carbon	milligrams/litre	24-05-2016	4
East	Dissolved Organic Carbon	milligrams/litre	30-05-2018	3.4
East	Dissolved Organic Carbon	milligrams/litre	17-05-2019	3
East	Hardness	milligrams/litre	14-05-2010	16.2
East	Ion Balance Calculation	percent	14-05-2010	11
East	Ion Balance Calculation	percent	14-05-2012	6.7
East	Ion Balance Calculation	percent	26-05-2014	4.3
East	Ion Balance Calculation	percent	24-05-2016	6.8
East	Ion Balance Calculation	percent	30-05-2018	11
East	Ion Balance Calculation	percent	17-05-2019	17

East	Iron	micrograms/litre	19-05-2006	30.3
East	Iron	micrograms/litre	09-05-2008	65.8
East	Iron	micrograms/litre	14-05-2010	28.1
East	Iron	micrograms/litre	14-05-2012	30
East	Iron	micrograms/litre	26-05-2014	50
East	Iron	micrograms/litre	24-05-2016	30
East	Iron	micrograms/litre	30-05-2018	30
East	Iron	micrograms/litre	17-05-2019	70
East	Langeliers Index Calculation	N/A	14-05-2010	-2
East	Langeliers Index Calculation	N/A	14-05-2012	-2
East	Langeliers Index Calculation	N/A	24-05-2016	-1
East	Langeliers Index Calculation	N/A	30-05-2018	-1
East	Langeliers Index Calculation		17-05-2019	-1
East	Lead	micrograms/litre	19-05-2006	-1.41
East	Lead	micrograms/litre	09-05-2008	-4.11
East	Lead	micrograms/litre	14-05-2010	-2.03
East	Lead	micrograms/litre	14-05-2012	0
East	Lead	micrograms/litre	26-05-2014	0
East	Lead	micrograms/litre	24-05-2016	0
East	Lead	micrograms/litre	30-05-2018	0
East	Lead	micrograms/litre	17-05-2019	0
East	Magnesium	milligrams/litre	18-05-2004	1.32
East	Magnesium	milligrams/litre	19-05-2006	1.32
East	Magnesium	milligrams/litre	09-05-2008	1.28
East	Magnesium	milligrams/litre	14-05-2010	1.35
East	Magnesium	milligrams/litre	14-05-2012	1.29
East	Magnesium	milligrams/litre	26-05-2014	1.21
East	Magnesium	milligrams/litre	24-05-2016	1.12
East	Magnesium	milligrams/litre	30-05-2018	1.25
East	Magnesium	milligrams/litre	17-05-2019	1
East	Manganese	micrograms/litre	19-05-2006	11.2
East	Manganese	micrograms/litre	09-05-2008	20.3
East	Manganese	micrograms/litre	14-05-2010	7.96
East	Manganese	micrograms/litre	14-05-2012	8.4
East	Manganese	micrograms/litre	26-05-2014	10.1
East	Manganese	micrograms/litre	24-05-2016	6.8
East	Manganese	micrograms/litre	30-05-2018	6
East	Manganese	micrograms/litre	17-05-2019	14
East	Molybdenum	micrograms/litre	19-05-2006	-0.84
East	Molybdenum	micrograms/litre	09-05-2008	0.32

East	Molybdenum	micrograms/litre	14-05-2010	0.554
East	Molybdenum	micrograms/litre	14-05-2012	0
East	Molybdenum	micrograms/litre	26-05-2014	0.1
East	Molybdenum	micrograms/litre	24-05-2016	0
East	Molybdenum	micrograms/litre	30-05-2018	0
East	Molybdenum	micrograms/litre	17-05-2019	0
East	Nickel	micrograms/litre	19-05-2006	0.74
East	Nickel	micrograms/litre	09-05-2008	-0.04
East	Nickel	micrograms/litre	14-05-2010	0.358
East	Nickel	micrograms/litre	14-05-2012	0.2
East	Nickel	micrograms/litre	26-05-2014	0.4
East	Nickel	micrograms/litre	24-05-2016	0.3
East	Nickel	micrograms/litre	30-05-2018	0.3
East	Nickel	micrograms/litre	17-05-2019	0
East	Nitrate	micrograms/litre	18-05-2004	64
East	Nitrate	micrograms/litre	19-05-2006	10
East	Nitrate	micrograms/litre	09-05-2008	60
East	Nitrate	micrograms/litre	14-05-2010	2
East	Nitrate	micrograms/litre	14-05-2012	4
East	Nitrate	micrograms/litre	26-05-2014	2
East	Nitrate	micrograms/litre	24-05-2016	2
East	Nitrate	micrograms/litre	30-05-2018	12
East	Nitrate	micrograms/litre	17-05-2019	76
East	Nitrogen; Total	milligrams/litre	24-05-2016	0.3
East	Nitrogen; Total	milligrams/litre	30-05-2018	0.24
East	Nitrogen; Total	milligrams/litre	17-05-2019	0
West	Phosphorus (1)	micrograms/litre	14-05-1990	8
West	Phosphorus (1)	micrograms/litre	31-05-1990	9
East	Phosphorus (1)	micrograms/litre	27-06-1990	9
West	Phosphorus (1)	micrograms/litre	27-06-1990	9
East	Phosphorus (1)	micrograms/litre	08-05-1991	10
West	Phosphorus (1)	micrograms/litre	08-05-1991	10
East	Phosphorus (1)	micrograms/litre	29-05-1991	13
West	Phosphorus (1)	micrograms/litre	29-05-1991	11
East	Phosphorus (1)	micrograms/litre	19-06-1991	12
West	Phosphorus (1)	micrograms/litre	19-06-1991	11
East	Phosphorus (1)	micrograms/litre	10-07-1991	10
West	Phosphorus (1)	micrograms/litre	10-07-1991	7
East	Phosphorus (1)	micrograms/litre	31-07-1991	6
West	Phosphorus (1)	micrograms/litre	31-07-1991	7
East	Phosphorus (1)	micrograms/litre	21-08-1991	9
West	Phosphorus (1)	micrograms/litre	21-08-1991	5
East	Phosphorus (1)	micrograms/litre	11-09-1991	10

West	Phosphorus (1)	micrograms/litre	11-09-1991	10
East	Phosphorus (1)	micrograms/litre	10-10-1991	8
West	Phosphorus (1)	micrograms/litre	10-10-1991	8
East	Phosphorus (1)	micrograms/litre	03-06-1993	10
West	Phosphorus (1)	micrograms/litre	03-06-1993	10
East	Phosphorus (1)	micrograms/litre	17-06-1993	14
West	Phosphorus (1)	micrograms/litre	17-06-1993	10
East	Phosphorus (1)	micrograms/litre	08-07-1993	10
West	Phosphorus (1)	micrograms/litre	08-07-1993	10
East	Phosphorus (1)	micrograms/litre	27-07-1993	10
West	Phosphorus (1)	micrograms/litre	27-07-1993	14
East	Phosphorus (1)	micrograms/litre	12-08-1993	8
West	Phosphorus (1)	micrograms/litre	12-08-1993	8
East	Phosphorus (1)	micrograms/litre	30-08-1993	6
West	Phosphorus (1)	micrograms/litre	30-08-1993	34
West	Phosphorus (1)	micrograms/litre	11-05-1994	14
East	Phosphorus (1)	micrograms/litre	12-05-1994	8
West	Phosphorus (1)	micrograms/litre	12-05-1994	8
East	Phosphorus (1)	micrograms/litre	30-05-1994	12
West	Phosphorus (1)	micrograms/litre	30-05-1994	12
East	Phosphorus (1)	micrograms/litre	09-06-1994	16
West	Phosphorus (1)	micrograms/litre	09-06-1994	12
East	Phosphorus (1)	micrograms/litre	23-06-1994	10
West	Phosphorus (1)	micrograms/litre	23-06-1994	10
East	Phosphorus (1)	micrograms/litre	11-07-1994	8
West	Phosphorus (1)	micrograms/litre	11-07-1994	8
East	Phosphorus (1)	micrograms/litre	26-07-1994	10
West	Phosphorus (1)	micrograms/litre	26-07-1994	8
East	Phosphorus (1)	micrograms/litre	10-08-1994	8
West	Phosphorus (1)	micrograms/litre	10-08-1994	8
East	Phosphorus (1)	micrograms/litre	24-08-1994	6
West	Phosphorus (1)	micrograms/litre	24-08-1994	6
East	Phosphorus (1)	micrograms/litre	10-05-1995	14
West	Phosphorus (1)	micrograms/litre	10-05-1995	14
East	Phosphorus (1)	micrograms/litre	25-05-1995	6
West	Phosphorus (1)	micrograms/litre	25-05-1995	14
East	Phosphorus (1)	micrograms/litre	08-06-1995	12
West	Phosphorus (1)	micrograms/litre	08-06-1995	20
East	Phosphorus (1)	micrograms/litre	22-06-1995	22
West	Phosphorus (1)	micrograms/litre	22-06-1995	10
East	Phosphorus (1)	micrograms/litre	10-07-1995	12
West	Phosphorus (1)	micrograms/litre	10-07-1995	12
East	Phosphorus (1)	micrograms/litre	25-07-1995	8

West	Phosphorus (1)	micrograms/litre	25-07-1995	8
East	Phosphorus (1)	micrograms/litre	09-08-1995	10
West	Phosphorus (1)	micrograms/litre	09-08-1995	10
East	Phosphorus (1)	micrograms/litre	23-08-1995	6
West	Phosphorus (1)	micrograms/litre	23-08-1995	8
East	Phosphorus (1)	micrograms/litre	13-09-1995	4
West	Phosphorus (1)	micrograms/litre	13-09-1995	6
East	Phosphorus (1)	micrograms/litre	15-05-1996	6
West	Phosphorus (1)	micrograms/litre	15-05-1996	6
East	Phosphorus (1)	micrograms/litre	30-05-1996	8
East	Potassium	milligrams/litre	18-05-2004	0.87
East	Potassium	milligrams/litre	19-05-2006	1.14
East	Potassium	milligrams/litre	09-05-2008	0.41
East	Potassium	milligrams/litre	14-05-2010	0.779
East	Potassium	milligrams/litre	14-05-2010	0.76
East	Potassium	milligrams/litre	14-05-2012	0.735
East	Potassium	milligrams/litre	26-05-2014	0.74
East	Potassium	milligrams/litre	24-05-2016	0.7
East	Potassium	milligrams/litre	30-05-2018	0.75
East	Potassium	milligrams/litre	17-05-2019	1
East	Potential of Hydrogen (pH)	N/A	18-05-2004	7.14
East	Potential of Hydrogen (pH)	N/A	19-05-2006	6.85
East	Potential of Hydrogen (pH)	N/A	09-05-2008	6.66
East	Potential of Hydrogen (pH)	N/A	14-05-2010	7.17
East	Potential of Hydrogen (pH)	N/A	14-05-2012	7.23
East	Potential of Hydrogen (pH)	N/A	26-05-2014	7.21
East	Potential of Hydrogen (pH)	N/A	24-05-2016	6.76
East	Potential of Hydrogen (pH)	N/A	30-05-2018	6.79
East	Potential of Hydrogen (pH)		17-05-2019	7
East	Saturation pH Estimated	N/A	14-05-2010	9.52
East	Saturation pH Estimated	N/A	14-05-2012	9.65
East	Saturation pH Estimated	N/A	24-05-2016	9.69
East	Saturation pH Estimated	N/A	30-05-2018	9.6
East	Saturation pH Estimated		17-05-2019	10
East	Secchi Depth	metre	27-06-1990	2
East	Secchi Depth	metre	25-07-1990	4.5
East	Secchi Depth	metre	08-05-1991	2
East	Secchi Depth	metre	29-05-1991	2.5
East	Secchi Depth	metre	19-06-1991	4
East	Secchi Depth	metre	31-07-1991	4
East	Secchi Depth	metre	21-08-1991	4
East	Secchi Depth	metre	11-09-1991	4
East	Secchi Depth	metre	12-05-1993	2.5

East	Secchi Depth	metre	03-06-1993	2.5
East	Secchi Depth	metre	17-06-1993	2
East	Secchi Depth	metre	08-07-1993	2
East	Secchi Depth	metre	27-07-1993	1.5
East	Secchi Depth	metre	12-08-1993	2.5
East	Secchi Depth	metre	30-08-1993	3.5
East	Secchi Depth	metre	12-05-1994	2.5
East	Secchi Depth	metre	30-05-1994	3.3
East	Secchi Depth	metre	09-06-1994	3.5
East	Secchi Depth	metre	23-06-1994	3.9
East	Secchi Depth	metre	11-07-1994	3.4
East	Secchi Depth	metre	26-07-1994	4.2
East	Secchi Depth	metre	10-08-1994	3
East	Secchi Depth	metre	24-08-1994	4
East	Secchi Depth	metre	10-05-1995	2.8
East	Secchi Depth	metre	25-05-1995	2.4
East	Secchi Depth	metre	08-06-1995	4
East	Secchi Depth	metre	22-06-1995	4.3
East	Secchi Depth	metre	10-07-1995	4
East	Secchi Depth	metre	25-07-1995	3.2
East	Secchi Depth	metre	09-08-1995	3.5
East	Secchi Depth	metre	23-08-1995	4.4
East	Secchi Depth	metre	13-09-1995	6.5
East	Secchi Depth	metre	15-05-1996	2.8
East	Secchi Depth	metre	30-05-1996	2.5
East	Secchi Depth	metre	14-06-1996	3.1
East	Secchi Depth	metre	28-06-1996	3.7
East	Secchi Depth	metre	15-07-1996	4.3
East	Secchi Depth	metre	29-07-1996	4.7
East	Secchi Depth	metre	14-08-1996	6
East	Secchi Depth	metre	26-08-1996	5.4
East	Secchi Depth	metre	20-05-1997	4.5
East	Secchi Depth	metre	18-09-1997	5
East	Secchi Depth	metre	07-05-1998	2
East	Secchi Depth	metre	25-05-1998	3
East	Secchi Depth	metre	10-06-1998	3
East	Secchi Depth	metre	02-07-1998	4
East	Secchi Depth	metre	17-07-1998	4.75
East	Secchi Depth	metre	05-08-1998	5
East	Secchi Depth	metre	21-08-1998	5
East	Secchi Depth	metre	29-05-2000	4.1
East	Secchi Depth	metre	15-06-2000	3.6
East	Secchi Depth	metre	05-07-2000	6.3

East	Secchi Depth	metre	26-07-2000	6.4
East	Secchi Depth	metre	17-08-2000	6.2
East	Secchi Depth	metre	28-08-2000	6.2
East	Secchi Depth	metre	15-05-2002	2.5
East	Secchi Depth	metre	28-08-2002	5
East	Secchi Depth	metre	19-05-2004	3.6
East	Secchi Depth	metre	04-08-2004	4.6
East	Secchi Depth	metre	19-05-2006	2.5
East	Secchi Depth	metre	31-08-2006	5.4
East	Secchi Depth	metre	09-05-2008	3.1
East	Secchi Depth	metre	28-08-2008	3.2
East	Secchi Depth	metre	14-05-2010	2.25
East	Secchi Depth	metre	17-08-2010	4
East	Secchi Depth	metre	14-05-2012	3.5
East	Secchi Depth	metre	28-08-2012	4.75
East	Secchi Depth	metre	26-05-2014	1.5
East	Secchi Depth	metre	18-08-2014	4.00
East	Secchi Depth	metre	24-05-2016	2.25
East	Secchi Depth	metre	17-08-2016	4.25
East	Secchi Depth	metre	30-05-2018	4.25
East	Secchi Depth	metre	22-08-2018	4.25
East	Selenium	micrograms/litre	14-05-2012	0.1
East	Selenium	micrograms/litre	26-05-2014	0.1
East	Selenium	micrograms/litre	24-05-2016	0.4
East	Selenium	micrograms/litre	30-05-2018	0.1
East	Selenium	micrograms/litre	17-05-2019	0
East	Silicon	milligrams/litre	18-05-2004	1.72
East	Silicon	milligrams/litre	19-05-2006	1.44
East	Silicon	milligrams/litre	09-05-2008	1.74
East	Silicon	milligrams/litre	14-05-2010	1.76
East	Silicon	milligrams/litre	14-05-2012	1.72
East	Silicon	milligrams/litre	26-05-2014	2.04
East	Silicon	milligrams/litre	24-05-2016	2.06
East	Silicon	milligrams/litre	30-05-2018	2.2
East	Silicon	milligrams/litre	17-05-2019	3
East	Silver	micrograms/litre	14-05-2012	0
East	Silver	micrograms/litre	26-05-2014	0
East	Silver	micrograms/litre	24-05-2016	0
East	Silver	micrograms/litre	30-05-2018	0
East	Silver	micrograms/litre	17-05-2019	0
East	Sodium	milligrams/litre	18-05-2004	5.55
East	Sodium	milligrams/litre	19-05-2006	5.56
East	Sodium	milligrams/litre	09-05-2008	5.82

East	Sodium	milligrams/litre	14-05-2010	5.67
East	Sodium	milligrams/litre	14-05-2010	5.72
East	Sodium	milligrams/litre	14-05-2012	5.81
East	Sodium	milligrams/litre	26-05-2014	6.22
East	Sodium	milligrams/litre	24-05-2016	6.04
East	Sodium	milligrams/litre	30-05-2018	7.53
East	Sodium	milligrams/litre	17-05-2019	8
East	Solids; Dissolved Estimated	milligrams/litre	14-05-2010	33
East	Solids; Dissolved Estimated	milligrams/litre	14-05-2012	31
East	Solids; Dissolved Estimated	milligrams/litre	26-05-2014	32.5
East	Solids; Dissolved Estimated	milligrams/litre	24-05-2016	30
East	Solids; Dissolved Estimated	milligrams/litre	30-05-2018	34.2
East	Solids; Dissolved Estimated	milligrams/litre	17-05-2019	36
East	Strontium	micrograms/litre	19-05-2006	33
East	Strontium	micrograms/litre	09-05-2008	31.7
East	Strontium	micrograms/litre	14-05-2010	31.3
East	Strontium	micrograms/litre	14-05-2012	32.1
East	Strontium	micrograms/litre	26-05-2014	31.8
East	Strontium	micrograms/litre	24-05-2016	28.5
East	Strontium	micrograms/litre	30-05-2018	28.7
East	Strontium	micrograms/litre	17-05-2019	28
East	Sulphate	milligrams/litre	18-05-2004	6.1
East	Sulphate	milligrams/litre	19-05-2006	5.2
East	Sulphate	milligrams/litre	09-05-2008	5.95
East	Sulphate	milligrams/litre	14-05-2010	5.25
East	Sulphate	milligrams/litre	14-05-2012	4.8
East	Sulphate	milligrams/litre	26-05-2014	4.4
East	Sulphate	milligrams/litre	24-05-2016	3.75
East	Sulphate	milligrams/litre	30-05-2018	3.5
East	Sulphate	milligrams/litre	17-05-2019	3
East	Thallium	micrograms/litre	14-05-2012	0
East	Thallium	micrograms/litre	26-05-2014	0
East	Thallium	micrograms/litre	24-05-2016	0
East	Thallium	micrograms/litre	30-05-2018	0
East	Thallium	micrograms/litre	17-05-2019	0
East	Titanium	micrograms/litre	19-05-2006	0.37
East	Titanium	micrograms/litre	09-05-2008	1.65
East	Titanium	micrograms/litre	14-05-2010	0.536
East	Titanium	micrograms/litre	14-05-2012	0.5
East	Titanium	micrograms/litre	26-05-2014	1

East	Titanium	micrograms/litre	24-05-2016	0.8
East	Titanium	micrograms/litre	30-05-2018	0.6
East	Titanium	micrograms/litre	17-05-2019	1
East	Total Kjeldahl Nitrogen	micrograms/litre	18-05-2004	239
East	Total Kjeldahl Nitrogen	micrograms/litre	19-05-2006	282
East	Total Kjeldahl Nitrogen	micrograms/litre	09-05-2008	283
East	Total Kjeldahl Nitrogen	micrograms/litre	14-05-2010	233
East	Total Kjeldahl Nitrogen	micrograms/litre	14-05-2012	240
East	Total Kjeldahl Nitrogen	micrograms/litre	26-05-2014	368
East	Total Kjeldahl Nitrogen	micrograms/litre	24-05-2016	313
East	Total Kjeldahl Nitrogen	micrograms/litre	30-05-2018	251
East	Total Kjeldahl Nitrogen	micrograms/litre	17-05-2019	212
East	True Colour	TCU	18-05-2004	12.6
East	True Colour	TCU	18-05-2004	12.6
East	True Colour	TCU	19-05-2006	14.4
East	True Colour	TCU	19-05-2006	14.4
East	True Colour	TCU	09-05-2008	14.8
East	True Colour	TCU	09-05-2008	14.8
East	True Colour	TCU	14-05-2010	14.4
East	True Colour	TCU	14-05-2012	14.8
East	True Colour	TCU	26-05-2014	29.82
East	True Colour	TCU	24-05-2016	22.8
East	True Colour	TCU	30-05-2018	17.2
East	True Colour	TCU	17-05-2019	18
East	Uranium	micrograms/litre	14-05-2012	0
East	Uranium	micrograms/litre	26-05-2014	0
East	Uranium	micrograms/litre	24-05-2016	0
East	Uranium	micrograms/litre	30-05-2018	0
East	Uranium	micrograms/litre	17-05-2019	0
East	Vanadium	micrograms/litre	19-05-2006	0.77
East	Vanadium	micrograms/litre	09-05-2008	1.25
East	Vanadium	micrograms/litre	14-05-2010	-0.534
East	Vanadium	micrograms/litre	14-05-2012	0.1
East	Vanadium	micrograms/litre	26-05-2014	0.1
East	Vanadium	micrograms/litre	24-05-2016	0.1
East	Vanadium	micrograms/litre	30-05-2018	0.1
East	Vanadium	micrograms/litre	17-05-2019	0
East	Zinc	micrograms/litre	19-05-2006	2.71
East	Zinc	micrograms/litre	09-05-2008	3.82
East	Zinc	micrograms/litre	14-05-2010	1.22
East	Zinc	micrograms/litre	14-05-2012	1.5
East	Zinc	micrograms/litre	26-05-2014	3.8
East	Zinc	micrograms/litre	24-05-2016	2.2

East	Zinc	micrograms/litre	30-05-2018	1.5
East	Zinc	micrograms/litre	17-05-2019	3
West	Alkalinity	milligrams/litre	18-05-2004	8.59
West	Alkalinity	milligrams/litre	19-05-2006	8.86
West	Alkalinity	milligrams/litre	09-05-2008	8.59
West	Alkalinity	milligrams/litre	14-05-2010	9.59
West	Alkalinity	milligrams/litre	14-05-2012	10.6
West	Alkalinity	milligrams/litre	26-05-2014	9.7
West	Alkalinity	milligrams/litre	24-05-2016	9.37
West	Alkalinity	milligrams/litre	30-05-2018	9.76
West	Alkalinity	milligrams/litre	17-05-2019	11.10
West	Alkalinity; Total Fixed Endpt	milligrams/litre	14-05-2010	11.5
West	Alkalinity; Total Fixed Endpt	milligrams/litre	14-05-2012	11.4
West	Alkalinity; Total Fixed Endpt	milligrams/litre	26-05-2014	11.55
West	Alkalinity; Total Fixed Endpt	milligrams/litre	24-05-2016	11.2
West	Alkalinity; Total Fixed Endpt	milligrams/litre	30-05-2018	11.4
West	Alkalinity; Total Fixed Endpt	milligrams/litre	17-05-2019	9.24
West	Aluminum	micrograms/litre	19-05-2006	15.5
West	Aluminum	micrograms/litre	09-05-2008	44.8
West	Aluminum	micrograms/litre	14-05-2010	10
West	Aluminum	micrograms/litre	14-05-2012	10.1
West	Aluminum	micrograms/litre	26-05-2014	26.1
West	Aluminum	micrograms/litre	24-05-2016	20.3
West	Aluminum	micrograms/litre	30-05-2018	14.2
West	Aluminum	micrograms/litre	17-05-2019	28.80
West	Ammonium Nitrate	micrograms/litre	18-05-2004	16
West	Ammonium Nitrate	micrograms/litre	19-05-2006	34
West	Ammonium Nitrate	micrograms/litre	09-05-2008	16
West	Ammonium Nitrate	micrograms/litre	14-05-2010	10
West	Ammonium Nitrate	micrograms/litre	14-05-2012	18
West	Ammonium Nitrate	micrograms/litre	26-05-2014	36
West	Ammonium Nitrate	micrograms/litre	24-05-2016	8
West	Ammonium Nitrate	micrograms/litre	30-05-2018	12
West	Ammonium Nitrate	micrograms/litre	17-05-2019	38.00
West	Anions	milliequiv/litre	19-05-2006	0.59
West	Anions	milliequiv/litre	09-05-2008	0.57
West	Anions	milliequiv/litre	14-05-2010	0.557
West	Anions	milliequiv/litre	14-05-2012	0.555
West	Anions	milliequiv/litre	26-05-2014	0.545
West	Anions	milliequiv/litre	24-05-2016	0.523

West	Anions	milliequiv/litre	30-05-2018	0.58
West	Anions	milliequiv/litre	17-05-2019	0.60
West	Antimony	micrograms/litre	14-05-2012	0
West	Antimony	micrograms/litre	26-05-2014	0
West	Antimony	micrograms/litre	24-05-2016	0
West	Antimony	micrograms/litre	30-05-2018	0
West	Antimony	micrograms/litre	17-05-2019	0.00
West	Arsenic	micrograms/litre	14-05-2012	0.1
West	Arsenic	micrograms/litre	26-05-2014	0.2
West	Arsenic	micrograms/litre	24-05-2016	0.2
West	Arsenic	micrograms/litre	30-05-2018	0.1
West	Arsenic	micrograms/litre	17-05-2019	0.10
West	Barium	micrograms/litre	19-05-2006	13.1
West	Barium	micrograms/litre	09-05-2008	13.6
West	Barium	micrograms/litre	14-05-2010	11.8
West	Barium	micrograms/litre	14-05-2012	11.2
West	Barium	micrograms/litre	26-05-2014	12.3
West	Barium	micrograms/litre	24-05-2016	11
West	Barium	micrograms/litre	30-05-2018	11.2
West	Barium	micrograms/litre	17-05-2019	12.10
West	Beryllium	micrograms/litre	19-05-2006	0
West	Beryllium	micrograms/litre	09-05-2008	-0.04
West	Beryllium	micrograms/litre	14-05-2010	0.018
West	Beryllium	micrograms/litre	14-05-2012	0
West	Beryllium	micrograms/litre	26-05-2014	0
West	Beryllium	micrograms/litre	24-05-2016	0
West	Beryllium	micrograms/litre	30-05-2018	0
West	Beryllium	micrograms/litre	17-05-2019	0.00
West	Boron	micrograms/litre	14-05-2012	3
West	Boron	micrograms/litre	26-05-2014	6
West	Boron	micrograms/litre	24-05-2016	4
West	Boron	micrograms/litre	30-05-2018	5
West	Boron	micrograms/litre	17-05-2019	5.00
West	Cadmium	micrograms/litre	19-05-2006	-0.34
West	Cadmium	micrograms/litre	09-05-2008	0.23
West	Cadmium	micrograms/litre	14-05-2010	0.198
West	Cadmium	micrograms/litre	14-05-2012	0
West	Cadmium	micrograms/litre	26-05-2014	0
West	Cadmium	micrograms/litre	24-05-2016	0
West	Cadmium	micrograms/litre	30-05-2018	0
West	Cadmium	micrograms/litre	17-05-2019	0.00
West	Calcium	milligrams/litre	18-05-2004	4.2
West	Calcium	milligrams/litre	19-05-2006	4.16

West	Calcium	milligrams/litre	09-05-2008	4.04
West	Calcium	milligrams/litre	14-05-2010	4.9
West	Calcium	milligrams/litre	14-05-2012	3.8
West	Calcium	milligrams/litre	26-05-2014	3.96
West	Calcium	milligrams/litre	24-05-2016	3.6
West	Calcium	milligrams/litre	30-05-2018	4.02
West	Calcium	milligrams/litre	17-05-2019	4.26
West	Cations	milliequiv/litre	19-05-2006	0.58
West	Cations	milliequiv/litre	09-05-2008	0.59
West	Cations	milliequiv/litre	14-05-2010	0.625
West	Cations	milliequiv/litre	14-05-2012	0.571
West	Cations	milliequiv/litre	26-05-2014	0.587
West	Cations	milliequiv/litre	24-05-2016	0.551
West	Cations	milliequiv/litre	30-05-2018	0.661
West	Cations	milliequiv/litre	17-05-2019	0.71
West	Chloride	milligrams/litre	18-05-2004	8.54
West	Chloride	milligrams/litre	19-05-2006	9.83
West	Chloride	milligrams/litre	09-05-2008	9.5
West	Chloride	milligrams/litre	14-05-2010	9.1
West	Chloride	milligrams/litre	14-05-2012	8.63
West	Chloride	milligrams/litre	26-05-2014	9.19
West	Chloride	milligrams/litre	24-05-2016	9.16
West	Chloride	milligrams/litre	30-05-2018	11.1
West	Chloride	milligrams/litre	17-05-2019	11.90
West	Chromium	micrograms/litre	19-05-2006	0.5
West	Chromium	micrograms/litre	09-05-2008	-0.36
West	Chromium	micrograms/litre	14-05-2010	-0.142
West	Chromium	micrograms/litre	14-05-2012	0.2
West	Chromium	micrograms/litre	26-05-2014	0.3
West	Chromium	micrograms/litre	24-05-2016	0.1
West	Chromium	micrograms/litre	30-05-2018	0.2
West	Chromium	micrograms/litre	17-05-2019	0.00
West	Cobalt	micrograms/litre	19-05-2006	-0.77
West	Cobalt	micrograms/litre	09-05-2008	0.72
West	Cobalt	micrograms/litre	14-05-2010	0.021
West	Cobalt	micrograms/litre	14-05-2012	0
West	Cobalt	micrograms/litre	26-05-2014	0
West	Cobalt	micrograms/litre	24-05-2016	0
West	Cobalt	micrograms/litre	30-05-2018	0
West	Cobalt	micrograms/litre	17-05-2019	0.00
West	Conductivity	microSiemens/cm	18-05-2004	64.2
West	Conductivity	microSiemens/cm	19-05-2006	67.2
West	Conductivity	microSiemens/cm	09-05-2008	67.2

West	Conductivity	microSiemens/cm	14-05-2010	64
West	Conductivity	microSiemens/cm	14-05-2012	68.4
West	Conductivity	microSiemens/cm	26-05-2014	66.6
West	Conductivity	microSiemens/cm	24-05-2016	66.3
West	Conductivity	microSiemens/cm	30-05-2018	72.2
West	Conductivity	microSiemens/cm	17-05-2019	74.60
West	Conductivity Estimated	microSiemens/cm	14-05-2010	70
West	Conductivity Estimated	microSiemens/cm	14-05-2012	66
West	Conductivity Estimated	microSiemens/cm	26-05-2014	66.7
West	Conductivity Estimated	microSiemens/cm	24-05-2016	63.2
West	Conductivity Estimated	microSiemens/cm	30-05-2018	72.7
West	Conductivity Estimated	microSiemens/cm	17-05-2019	76.90
West	Copper	micrograms/litre	19-05-2006	1.39
West	Copper	micrograms/litre	09-05-2008	0.88
West	Copper	micrograms/litre	14-05-2010	-0.623
West	Copper	micrograms/litre	14-05-2012	0.6
West	Copper	micrograms/litre	26-05-2014	0.7
West	Copper	micrograms/litre	24-05-2016	0.7
West	Copper	micrograms/litre	30-05-2018	0.8
West	Copper	micrograms/litre	17-05-2019	1.00
West	Dissolved Inorganic Carbon	milligrams/litre	24-05-2016	2.46
West	Dissolved Inorganic Carbon	milligrams/litre	30-05-2018	2.36
West	Dissolved Inorganic Carbon	milligrams/litre	17-05-2019	2.66
West	Dissolved Organic Carbon	milligrams/litre	18-05-2004	3.7
West	Dissolved Organic Carbon	milligrams/litre	19-05-2006	3.6
West	Dissolved Organic Carbon	milligrams/litre	09-05-2008	3.5
West	Dissolved Organic Carbon	milligrams/litre	14-05-2010	3.5
West	Dissolved Organic Carbon	milligrams/litre	14-05-2012	3.7
West	Dissolved Organic Carbon	milligrams/litre	26-05-2014	2.44
West	Dissolved Organic Carbon	milligrams/litre	26-05-2014	3.8
West	Dissolved Organic Carbon	milligrams/litre	24-05-2016	4
West	Dissolved Organic Carbon	milligrams/litre	30-05-2018	3.4
West	Dissolved Organic Carbon	milligrams/litre	17-05-2019	3.20
West	Hardness	milligrams/litre	14-05-2010	16.6
West	Ion Balance Calculation	percent	14-05-2010	12
West	Ion Balance Calculation	percent	14-05-2012	3
West	Ion Balance Calculation	percent	26-05-2014	7.6
West	Ion Balance Calculation	percent	24-05-2016	5.3
West	Ion Balance Calculation	percent	30-05-2018	14
West	Ion Balance Calculation	percent	17-05-2019	18.00
West	Iron	micrograms/litre	19-05-2006	31.3

West	Iron	micrograms/litre	09-05-2008	79.9
West	Iron	micrograms/litre	14-05-2010	29
West	Iron	micrograms/litre	14-05-2012	30
West	Iron	micrograms/litre	26-05-2014	50
West	Iron	micrograms/litre	24-05-2016	30
West	Iron	micrograms/litre	30-05-2018	30
West	Iron	micrograms/litre	17-05-2019	60.00
West	Langeliers Index Calculation	N/A	14-05-2010	-2
West	Langeliers Index Calculation	N/A	14-05-2012	-2.4
West	Langeliers Index Calculation	N/A	24-05-2016	-2.9
West	Langeliers Index Calculation	N/A	30-05-2018	-1
West	Langeliers Index Calculation		17-05-2019	-2.70
West	Lead	micrograms/litre	19-05-2006	-3.26
West	Lead	micrograms/litre	09-05-2008	-2.67
West	Lead	micrograms/litre	14-05-2010	-1.01
West	Lead	micrograms/litre	14-05-2012	0
West	Lead	micrograms/litre	26-05-2014	0
West	Lead	micrograms/litre	24-05-2016	0
West	Lead	micrograms/litre	30-05-2018	0
West	Lead	micrograms/litre	17-05-2019	0.10
West	Magnesium	milligrams/litre	18-05-2004	1.31
West	Magnesium	milligrams/litre	19-05-2006	1.32
West	Magnesium	milligrams/litre	09-05-2008	1.29
West	Magnesium	milligrams/litre	14-05-2010	1.35
West	Magnesium	milligrams/litre	14-05-2012	1.27
West	Magnesium	milligrams/litre	26-05-2014	1.17
West	Magnesium	milligrams/litre	24-05-2016	1.11
West	Magnesium	milligrams/litre	30-05-2018	1.26
West	Magnesium	milligrams/litre	17-05-2019	1.27
West	Manganese	micrograms/litre	19-05-2006	11.4
West	Manganese	micrograms/litre	09-05-2008	28.9
West	Manganese	micrograms/litre	14-05-2010	7.52
West	Manganese	micrograms/litre	14-05-2012	8.9
West	Manganese	micrograms/litre	26-05-2014	9
West	Manganese	micrograms/litre	24-05-2016	6.6
West	Manganese	micrograms/litre	30-05-2018	6
West	Manganese	micrograms/litre	17-05-2019	15.70
West	Molybdenum	micrograms/litre	19-05-2006	0.7
West	Molybdenum	micrograms/litre	09-05-2008	-0.12
West	Molybdenum	micrograms/litre	14-05-2010	0.183

West	Molybdenum	micrograms/litre	14-05-2012	0
West	Molybdenum	micrograms/litre	26-05-2014	0.1
West	Molybdenum	micrograms/litre	24-05-2016	0
West	Molybdenum	micrograms/litre	30-05-2018	0
West	Molybdenum	micrograms/litre	17-05-2019	0.10
West	Nickel	micrograms/litre	19-05-2006	0.25
West	Nickel	micrograms/litre	09-05-2008	-0.8
West	Nickel	micrograms/litre	14-05-2010	0.227
West	Nickel	micrograms/litre	14-05-2012	0.2
West	Nickel	micrograms/litre	26-05-2014	0.3
West	Nickel	micrograms/litre	24-05-2016	0.3
West	Nickel	micrograms/litre	30-05-2018	0.3
West	Nickel	micrograms/litre	17-05-2019	0.30
West	Nitrate	micrograms/litre	18-05-2004	62
West	Nitrate	micrograms/litre	19-05-2006	14
West	Nitrate	micrograms/litre	09-05-2008	86
West	Nitrate	micrograms/litre	14-05-2010	2
West	Nitrate	micrograms/litre	14-05-2012	8
West	Nitrate	micrograms/litre	26-05-2014	6
West	Nitrate	micrograms/litre	24-05-2016	2
West	Nitrate	micrograms/litre	30-05-2018	12
West	Nitrate	micrograms/litre	17-05-2019	108.00
West	Nitrogen; Total	milligrams/litre	24-05-2016	0.28
West	Nitrogen; Total	milligrams/litre	30-05-2018	0.24
West	Nitrogen; Total	milligrams/litre	17-05-2019	0.30
West	Phosphorus (1)	micrograms/litre	30-05-1996	8
East	Phosphorus (1)	micrograms/litre	14-06-1996	8
West	Phosphorus (1)	micrograms/litre	14-06-1996	10
East	Phosphorus (1)	micrograms/litre	28-06-1996	8
West	Phosphorus (1)	micrograms/litre	28-06-1996	8
East	Phosphorus (1)	micrograms/litre	15-07-1996	6
West	Phosphorus (1)	micrograms/litre	15-07-1996	4
East	Phosphorus (1)	micrograms/litre	29-07-1996	8
West	Phosphorus (1)	micrograms/litre	29-07-1996	8
East	Phosphorus (1)	micrograms/litre	14-08-1996	10
West	Phosphorus (1)	micrograms/litre	14-08-1996	10
East	Phosphorus (1)	micrograms/litre	26-08-1996	8
West	Phosphorus (1)	micrograms/litre	26-08-1996	8
East	Phosphorus (1)	micrograms/litre	20-05-1997	8
West	Phosphorus (1)	micrograms/litre	20-05-1997	8
East	Phosphorus (1)	micrograms/litre	18-09-1997	10
West	Phosphorus (1)	micrograms/litre	18-09-1997	10
East	Phosphorus (1)	micrograms/litre	07-05-1998	10

West	Phosphorus (1)	micrograms/litre	07-05-1998	10
East	Phosphorus (1)	micrograms/litre	25-05-1998	10
West	Phosphorus (1)	micrograms/litre	25-05-1998	8
East	Phosphorus (1)	micrograms/litre	10-06-1998	8
West	Phosphorus (1)	micrograms/litre	10-06-1998	8
East	Phosphorus (1)	micrograms/litre	02-07-1998	8
West	Phosphorus (1)	micrograms/litre	02-07-1998	8
East	Phosphorus (1)	micrograms/litre	17-07-1998	8
West	Phosphorus (1)	micrograms/litre	17-07-1998	8
East	Phosphorus (1)	micrograms/litre	05-08-1998	12
West	Phosphorus (1)	micrograms/litre	05-08-1998	10
East	Phosphorus (1)	micrograms/litre	21-08-1998	8
West	Phosphorus (1)	micrograms/litre	21-08-1998	10
East	Phosphorus (1)	micrograms/litre	29-05-2000	11.1
West	Phosphorus (1)	micrograms/litre	29-05-2000	10.3
East	Phosphorus (1)	micrograms/litre	15-05-2002	12.8
East	Phosphorus (2)	micrograms/litre	15-05-2002	13.2
West	Phosphorus (1)	micrograms/litre	15-05-2002	12.8
West	Phosphorus (2)	micrograms/litre	15-05-2002	11.4
East	Phosphorus (1)	micrograms/litre	18-05-2004	7
East	Phosphorus (2)	micrograms/litre	18-05-2004	6.6
West	Phosphorus (1)	micrograms/litre	18-05-2004	7
West	Phosphorus (2)	micrograms/litre	18-05-2004	7.4
East	Phosphorus (1)	micrograms/litre	19-05-2006	16.8
East	Phosphorus (2)	micrograms/litre	19-05-2006	13.6
West	Phosphorus (1)	micrograms/litre	19-05-2006	10.2
West	Phosphorus (2)	micrograms/litre	19-05-2006	10.4
East	Phosphorus (1)	micrograms/litre	09-05-2008	12.2
East	Phosphorus (2)	micrograms/litre	09-05-2008	11.4
West	Phosphorus (1)	micrograms/litre	09-05-2008	12.2
West	Phosphorus (2)	micrograms/litre	09-05-2008	12.6
West	Phosphorus (1)	micrograms/litre	14-05-2010	7.6
West	Phosphorus (2)	micrograms/litre	14-05-2010	7.4
East	Phosphorus (1)	micrograms/litre	14-05-2010	7.8
East	Phosphorus (2)	micrograms/litre	14-05-2010	8.2
West	Phosphorus (1)	micrograms/litre	14-05-2012	7
West	Phosphorus (2)	micrograms/litre	14-05-2012	7.4
East	Phosphorus (1)	micrograms/litre	14-05-2012	7.4
East	Phosphorus (2)	micrograms/litre	14-05-2012	7
East	Phosphorus (1)	micrograms/litre	26-05-2014	19.6
East	Phosphorus (2)	micrograms/litre	26-05-2014	20.4
West	Phosphorus (1)	micrograms/litre	26-05-2014	12.2
West	Phosphorus (2)	micrograms/litre	26-05-2014	12.4

West	Phosphorus (1)	micrograms/litre	24-05-2016	7.4
West	Phosphorus (2)	micrograms/litre	24-05-2016	7.4
East	Phosphorus (1)	micrograms/litre	24-05-2016	8.8
East	Phosphorus (2)	micrograms/litre	24-05-2016	8.4
West	Phosphorus (1)	micrograms/litre	30-05-2018	4.8
West	Phosphorus (2)	micrograms/litre	30-05-2018	5.2
East	Phosphorus (1)	micrograms/litre	30-05-2018	5.2
East	Phosphorus (2)	micrograms/litre	30-05-2018	4.8
East	Phosphorus (1)	micrograms/litre	17-05-2019	9
East	Phosphorus (2)	micrograms/litre	17-05-2019	10
West	Phosphorus (1)	micrograms/litre	17-05-2019	8.80
West	Phosphorus (2)	micrograms/litre	17-05-2019	8.80
West	Potassium	milligrams/litre	18-05-2004	0.82
West	Potassium	milligrams/litre	19-05-2006	0.76
West	Potassium	milligrams/litre	09-05-2008	1.01
West	Potassium	milligrams/litre	14-05-2010	0.782
West	Potassium	milligrams/litre	14-05-2010	0.75
West	Potassium	milligrams/litre	14-05-2012	0.725
West	Potassium	milligrams/litre	26-05-2014	0.75
West	Potassium	milligrams/litre	24-05-2016	0.71
West	Potassium	milligrams/litre	30-05-2018	0.755
West	Potassium	milligrams/litre	17-05-2019	0.78
West	Potential of Hydrogen (pH)	N/A	18-05-2004	7.13
West	Potential of Hydrogen (pH)	N/A	19-05-2006	6.88
West	Potential of Hydrogen (pH)	N/A	09-05-2008	6.64
West	Potential of Hydrogen (pH)	N/A	14-05-2010	7.15
West	Potential of Hydrogen (pH)	N/A	14-05-2012	7.22
West	Potential of Hydrogen (pH)	N/A	26-05-2014	7.25
West	Potential of Hydrogen (pH)	N/A	24-05-2016	6.75
West	Potential of Hydrogen (pH)	N/A	30-05-2018	6.76
West	Potential of Hydrogen (pH)		17-05-2019	6.90
West	Saturation pH Estimated	N/A	14-05-2010	9.52
West	Saturation pH Estimated	N/A	14-05-2012	9.64
West	Saturation pH Estimated	N/A	24-05-2016	9.67
West	Saturation pH Estimated	N/A	30-05-2018	9.62
West	Saturation pH Estimated		17-05-2019	9.61
West	Secchi Depth	metre	14-05-1990	2
West	Secchi Depth	metre	31-05-1990	1.5
West	Secchi Depth	metre	27-06-1990	2.5
West	Secchi Depth	metre	25-07-1990	3.5
West	Secchi Depth	metre	08-05-1991	2.5
West	Secchi Depth	metre	29-05-1991	3
West	Secchi Depth	metre	19-06-1991	3.8

West	Secchi Depth	metre	10-07-1991	4
West	Secchi Depth	metre	31-07-1991	3
West	Secchi Depth	metre	21-08-1991	4
West	Secchi Depth	metre	11-09-1991	5
West	Secchi Depth	metre	12-05-1993	3
West	Secchi Depth	metre	03-06-1993	2.5
West	Secchi Depth	metre	17-06-1993	2.5
West	Secchi Depth	metre	08-07-1993	2
West	Secchi Depth	metre	27-07-1993	1.5
West	Secchi Depth	metre	12-08-1993	1.5
West	Secchi Depth	metre	30-08-1993	3.5
West	Secchi Depth	metre	11-05-1994	2.5
West	Secchi Depth	metre	12-05-1994	2.5
West	Secchi Depth	metre	30-05-1994	3.3
West	Secchi Depth	metre	09-06-1994	3.4
West	Secchi Depth	metre	23-06-1994	3.4
West	Secchi Depth	metre	11-07-1994	3.4
West	Secchi Depth	metre	26-07-1994	4
West	Secchi Depth	metre	10-08-1994	3
West	Secchi Depth	metre	24-08-1994	3.5
West	Secchi Depth	metre	10-05-1995	2.8
West	Secchi Depth	metre	25-05-1995	2.3
West	Secchi Depth	metre	08-06-1995	3.8
West	Secchi Depth	metre	22-06-1995	4
West	Secchi Depth	metre	10-07-1995	4.5
West	Secchi Depth	metre	25-07-1995	3.2
West	Secchi Depth	metre	09-08-1995	4.8
West	Secchi Depth	metre	23-08-1995	3.4
West	Secchi Depth	metre	13-09-1995	6
West	Secchi Depth	metre	15-05-1996	3
West	Secchi Depth	metre	30-05-1996	2.6
West	Secchi Depth	metre	14-06-1996	3.2
West	Secchi Depth	metre	28-06-1996	3.8
West	Secchi Depth	metre	15-07-1996	4.5
West	Secchi Depth	metre	29-07-1996	4.7
West	Secchi Depth	metre	14-08-1996	5.5
West	Secchi Depth	metre	26-08-1996	4.6
West	Secchi Depth	metre	20-05-1997	4.5
West	Secchi Depth	metre	18-09-1997	5
West	Secchi Depth	metre	07-05-1998	1.5
West	Secchi Depth	metre	25-05-1998	3
West	Secchi Depth	metre	10-06-1998	4.5
West	Secchi Depth	metre	02-07-1998	4

West	Secchi Depth	metre	17-07-1998	4.5
West	Secchi Depth	metre	05-08-1998	4
West	Secchi Depth	metre	21-08-1998	4
West	Secchi Depth	metre	29-05-2000	4.6
West	Secchi Depth	metre	15-06-2000	3.6
West	Secchi Depth	metre	05-07-2000	6.9
West	Secchi Depth	metre	26-07-2000	6.75
West	Secchi Depth	metre	17-08-2000	6.6
West	Secchi Depth	metre	28-08-2000	6.2
West	Secchi Depth	metre	15-05-2002	2.9
West	Secchi Depth	metre	28-08-2002	5.5
West	Secchi Depth	metre	19-05-2004	3.4
West	Secchi Depth	metre	04-08-2004	4.9
West	Secchi Depth	metre	19-05-2006	2.3
West	Secchi Depth	metre	15-08-2006	4.5
West	Secchi Depth	metre	09-05-2008	3.2
West	Secchi Depth	metre	28-08-2008	4
West	Secchi Depth	metre	14-05-2010	3.25
West	Secchi Depth	metre	17-08-2010	4.5
West	Secchi Depth	metre	14-05-2012	3.25
West	Secchi Depth	metre	28-08-2012	3.25
West	Secchi Depth	metre	26-05-2014	2
West	Secchi Depth	metre	18-08-2014	4.25
West	Secchi Depth	metre	24-05-2016	2.25
West	Secchi Depth	metre	17-08-2016	4.75
West	Secchi Depth	metre	30-05-2018	4.75
West	Secchi Depth	metre	22-08-2018	3.75
West	Selenium	micrograms/litre	14-05-2012	0.1
West	Selenium	micrograms/litre	26-05-2014	0.1
West	Selenium	micrograms/litre	24-05-2016	0.4
West	Selenium	micrograms/litre	30-05-2018	0.1
West	Selenium	micrograms/litre	17-05-2019	0.00
West	Silicon	milligrams/litre	18-05-2004	1.68
West	Silicon	milligrams/litre	19-05-2006	1.44
West	Silicon	milligrams/litre	09-05-2008	1.78
West	Silicon	milligrams/litre	14-05-2010	1.76
West	Silicon	milligrams/litre	14-05-2012	1.72
West	Silicon	milligrams/litre	26-05-2014	2.04
West	Silicon	milligrams/litre	24-05-2016	2.08
West	Silicon	milligrams/litre	30-05-2018	2.2
West	Silicon	milligrams/litre	17-05-2019	2.68
West	Silver	micrograms/litre	14-05-2012	0
West	Silver	micrograms/litre	26-05-2014	0

West	Silver	micrograms/litre	24-05-2016	0
West	Silver	micrograms/litre	30-05-2018	0
West	Silver	micrograms/litre	17-05-2019	0.00
West	Sodium	milligrams/litre	18-05-2004	5.43
West	Sodium	milligrams/litre	19-05-2006	5.46
West	Sodium	milligrams/litre	09-05-2008	5.75
West	Sodium	milligrams/litre	14-05-2010	5.74
West	Sodium	milligrams/litre	14-05-2010	5.68
West	Sodium	milligrams/litre	14-05-2012	5.94
West	Sodium	milligrams/litre	26-05-2014	6.23
West	Sodium	milligrams/litre	24-05-2016	6
West	Sodium	milligrams/litre	30-05-2018	7.75
West	Sodium	milligrams/litre	17-05-2019	8.44
West	Solids; Dissolved Estimated	milligrams/litre	14-05-2010	32.9
West	Solids; Dissolved Estimated	milligrams/litre	14-05-2012	31.6
West	Solids; Dissolved Estimated	milligrams/litre	26-05-2014	31.7
West	Solids; Dissolved Estimated	milligrams/litre	24-05-2016	30
West	Solids; Dissolved Estimated	milligrams/litre	30-05-2018	34.3
West	Solids; Dissolved Estimated	milligrams/litre	17-05-2019	36.20
West	Strontium	micrograms/litre	19-05-2006	33
West	Strontium	micrograms/litre	09-05-2008	32.1
West	Strontium	micrograms/litre	14-05-2010	31.5
West	Strontium	micrograms/litre	14-05-2012	31.9
West	Strontium	micrograms/litre	26-05-2014	31.7
West	Strontium	micrograms/litre	24-05-2016	28.2
West	Strontium	micrograms/litre	30-05-2018	28.6
West	Strontium	micrograms/litre	17-05-2019	28.80
West	Sulphate	milligrams/litre	18-05-2004	6.2
West	Sulphate	milligrams/litre	19-05-2006	6.6
West	Sulphate	milligrams/litre	09-05-2008	6.1
West	Sulphate	milligrams/litre	14-05-2010	5.2
West	Sulphate	milligrams/litre	14-05-2012	4.8
West	Sulphate	milligrams/litre	26-05-2014	4.4
West	Sulphate	milligrams/litre	24-05-2016	3.7
West	Sulphate	milligrams/litre	30-05-2018	3.45
West	Sulphate	milligrams/litre	17-05-2019	3.45
West	Thallium	micrograms/litre	14-05-2012	0
West	Thallium	micrograms/litre	26-05-2014	0
West	Thallium	micrograms/litre	24-05-2016	0
West	Thallium	micrograms/litre	30-05-2018	0

West	Thallium	micrograms/litre	17-05-2019	0.00
West	Titanium	micrograms/litre	19-05-2006	0.53
West	Titanium	micrograms/litre	09-05-2008	2.66
West	Titanium	micrograms/litre	14-05-2010	0.438
West	Titanium	micrograms/litre	14-05-2012	0.5
West	Titanium	micrograms/litre	26-05-2014	1.1
West	Titanium	micrograms/litre	24-05-2016	0.6
West	Titanium	micrograms/litre	30-05-2018	0.5
West	Titanium	micrograms/litre	17-05-2019	1.00
West	Total Kjeldahl Nitrogen	micrograms/litre	18-05-2004	249
West	Total Kjeldahl Nitrogen	micrograms/litre	19-05-2006	249
West	Total Kjeldahl Nitrogen	micrograms/litre	09-05-2008	277
West	Total Kjeldahl Nitrogen	micrograms/litre	14-05-2010	238
West	Total Kjeldahl Nitrogen	micrograms/litre	14-05-2012	237
West	Total Kjeldahl Nitrogen	micrograms/litre	26-05-2014	308
West	Total Kjeldahl Nitrogen	micrograms/litre	24-05-2016	297
West	Total Kjeldahl Nitrogen	micrograms/litre	30-05-2018	249
West	Total Kjeldahl Nitrogen	micrograms/litre	17-05-2019	209.00
West	True Colour	TCU	18-05-2004	13.2
West	True Colour	TCU	18-05-2004	12.6
West	True Colour	TCU	18-05-2004	13.2
West	True Colour	TCU	19-05-2006	14
West	True Colour	TCU	19-05-2006	14.4
West	True Colour	TCU	19-05-2006	14
West	True Colour	TCU	09-05-2008	14.8
West	True Colour	TCU	09-05-2008	14.8
West	True Colour	TCU	14-05-2010	12
West	True Colour	TCU	14-05-2012	15
West	True Colour	TCU	26-05-2014	23.38
West	True Colour	TCU	24-05-2016	22.6
West	True Colour	TCU	30-05-2018	16.5
West	True Colour	TCU	17-05-2019	17.90
West	Uranium	micrograms/litre	14-05-2012	0
West	Uranium	micrograms/litre	26-05-2014	0
West	Uranium	micrograms/litre	24-05-2016	0
West	Uranium	micrograms/litre	30-05-2018	0
West	Uranium	micrograms/litre	17-05-2019	0.00
West	Vanadium	micrograms/litre	19-05-2006	0.34
West	Vanadium	micrograms/litre	09-05-2008	0.87
West	Vanadium	micrograms/litre	14-05-2010	-0.447
West	Vanadium	micrograms/litre	14-05-2012	0.1
West	Vanadium	micrograms/litre	26-05-2014	0.1
West	Vanadium	micrograms/litre	24-05-2016	0.1

West	Vanadium	micrograms/litre	30-05-2018	0.1
West	Vanadium	micrograms/litre	17-05-2019	0.10
West	Zinc	micrograms/litre	19-05-2006	2.03
West	Zinc	micrograms/litre	09-05-2008	3.83
West	Zinc	micrograms/litre	14-05-2010	1.51
West	Zinc	micrograms/litre	14-05-2012	1.6
West	Zinc	micrograms/litre	26-05-2014	2.4
West	Zinc	micrograms/litre	24-05-2016	2.1
West	Zinc	micrograms/litre	30-05-2018	1.5
West	Zinc	micrograms/litre	17-05-2019	4.00

Table 2. Field Data

			Peninsula West	Peninsula East Top	Peninsula East Bottom
Date Sampled	DL	Units	10-Oct-2019	10-Oct-2019	10-Oct-2019
Physical Tests (Water)					
Hardness (as CaCO3)	1.3	mg/L	15.6	15.3	
pH	0.10	pH units	7.21	7.04	
Anions and Nutrients (Water)					
Alkalinity, Total (as CaCO3)	10	mg/L	12	11	
Ammonia, Total (as N)	0.010	mg/L	0.011	0.01	0.014
Chloride (Cl)	0.50	mg/L	13.7	13.7	
Total Kjeldahl Nitrogen	0.15	mg/L	0.15	0.15	0.17
Phosphorus, Total	0.0030	mg/L	0.0103	0.0077	0.0150
Sulfate (SO4)	0.30	mg/L	3.55	3.52	
Organic / Inorganic Carbon (Water)					
Dissolved Organic Carbon	0.50	mg/L	4.06	4.23	
Bacteriological Tests (Water)					
Escherichia Coli		MPN/100mL	0	1	
Total Coliforms		MPN/100mL	25	53	
Total Metals (Water)					
Aluminum (Al)-Total	0.0050	mg/L			0.0272
Arsenic (As)-Total	0.00010	mg/L			0.00018
Barium (Ba)-Total	0.00010	mg/L			0.0162
Boron (B)-Total	0.010	mg/L			0.013
Cadmium (Cd)-Total	0.0000050	mg/L			0.0000289
Calcium (Ca)-Total	0.050	mg/L	4.13	4.10	4.84
Chromium (Cr)-Total	0.00050	mg/L			0.00141
Cobalt (Co)-Total	0.00010	mg/L			0.00030
Iron (Fe)-Total	0.010	mg/L			0.797
Lead (Pb)-Total	0.000050	mg/L			0.000104

Magnesium (Mg)-Total	0.0050	mg/L	1.28	1.22	2.84
Manganese (Mn)-Total	0.00050	mg/L			0.360
Molybdenum (Mo)-Total	0.000050	mg/L			0.000085
Nickel (Ni)-Total	0.00050	mg/L			0.00052
Potassium (K)-Total	0.050	mg/L			1.16
Rubidium (Rb)-Total	0.00020	mg/L			0.00153
Selenium (Se)-Total	0.000050	mg/L			0.000062
Silicon (Si)-Total	0.10	mg/L			2.99
Sodium (Na)-Total	0.050	mg/L			21.6
Strontium (Sr)-Total	0.0010	mg/L			0.0415
Sulfur (S)-Total	0.50	mg/L			2.26
Titanium (Ti)-Total	0.00030	mg/L			0.00055
Uranium (U)-Total	0.000010	mg/L			0.000013
Zinc (Zn)-Total	0.0030	mg/L			0.0103
Plant Pigments (Water)					
Chlorophyll a	0.010	ug/L	3.19	3.07	
BDL					
Antimony (Sb)-Total	0.00010	mg/L			<0.00010
Beryllium (Be)-Total	0.00010	mg/L			<0.00010
Bismuth (Bi)-Total	0.000050	mg/L			<0.000050
Cesium (Cs)-Total	0.000010	mg/L			<0.000010
Copper (Cu)-Total	0.0010	mg/L			<0.0010
Lithium (Li)-Total	0.0010	mg/L			<0.0010
Phosphorus (P)-Total	0.050	mg/L			<0.050
Silver (Ag)-Total	0.000050	mg/L			<0.000050
Tellurium (Te)-Total	0.00020	mg/L			<0.00020
Thallium (Tl)-Total	0.000010	mg/L			<0.000010
Thorium (Th)-Total	0.00010	mg/L			<0.00010
Tin (Sn)-Total	0.00010	mg/L			<0.00010
Tungsten (W)-Total	0.00010	mg/L			<0.00010
Vanadium (V)-Total	0.00050	mg/L			<0.00050
Zirconium (Zr)-Total	0.00020	mg/L			<0.00020