RiverStone
ENVIRONMENTAL SOLUTIONS INC.

Causation Study
Leonard Lake
District Municipality of Muskoka
November 2022

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The District Municipality of Muskoka
70 Pine Street
Bracebridge, ON

SUBJECT: Causation Study, Leonard Lake

RiverStone Environmental Solutions Inc. is pleased to submit our Causation Study Report summarizing our investigations into the potential cause(s) of historical cyanobacterial blooms on Leonard Lake in the District Municipality of Muskoka (DMM).

RiverStone conducted a detailed examination of the potential factors which may be contributing to the occurrence of algal blooms on Leonard Lake, including data collection in the field, analyses of the results, and an assessment of potential causative factors through historical data. As previously stated by Hutchinson Environmental Sciences Ltd. in their pilot Causation Study on Peninsula Lake, it is difficult to determine causation based on occasional bloom events in nutrient poor lakes, particularly without extensive baseline monitoring data which can be used as a control in statistical analyses to identify changes in the environment which may be correlated with or contributing to an increase in observed algal blooms. Although there has been historical monitoring of several potential contributing factors by a variety of agencies and organizations, our investigations of the potential causes or contributing factors to algal blooms on Leonard Lake where hindered by variability in the collection methods and laboratory analysis that have occurred both across time and between organizations. As part of the discussion, RiverStone has included recommendations for a sampling program moving forward that will work to focus on key variables, consistent sampling sites (and times) and consistency in laboratory analysis that will facilitate the analysis of future studies of this nature and will help to equip the DMM and members of the Leonard Lake Stakeholders Association (LLSA) to make informed decisions regarding the contributing factors of algal blooms on the lake.

Leonard Lake is an oligotrophic lake with no evidence of change in nutrients or dissolved oxygen prior to the onset of the frequent bloom events which, based on LLSA observations, began to occur in 2017. There are seasonal fluctuations in phosphorus and brief periods of high phosphorus concentrations in the water column, particularly during the summer months of 2017, in the southern basin, but water chemistry data suggests that consistent water quality has been documented in Leonard Lake for several decades prior to the onset of bloom events that have occurred in recent years. Nutrient levels therefore provide little insight into the shift in frequency and severity of bloom formation on Leonard

Lake. Without credible statistical links to changes in water quality, wind, or other physio-chemical data, the evidence collected during the completion of this report suggest that the blooms reported by the LLSA between 2017- 2022, and those observed by RiverStone during the study period, were likely triggered by climatic conditions that created a warm period with little mixing of the water column which created favourable conditions for the proliferation of harmful algal bloom forming species. Additionally, shifts in food web structure and interactions and the competitive advantage of *Dolichospermum* species, which is a primary species of concern in Leonard Lake, over other less harmful species existing in the water column, suggest that biotic factors may also be an important component in the causation of algal blooms in Leonard Lake. Finally, the physical characteristics of Leonard Lake in the southern portion contributes to the susceptibility of this area to bloom formation.

Given our review of data pertaining to Leonard Lake and the results of our analyses, we have included recommendations for ongoing monitoring of Leonard Lake as well as for future studies that may offer refined resolution of the conclusions outlined in this report.

Please contact us if there are any questions regarding the report, or if further information is required.

Best regards,

RiverStone Environmental Solutions Inc.

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NON-TECHNICAL SUMMARY

Type of Study Causation Study – Leonard Lake	**Date** June 23, 2023

Report Summary

The purpose of this study was to complete a Causation Study to collect data pertaining to the documented algae blooms on Leonard Lake. As part of completing this assignment, RiverStone conducted a literature review exercise focused on causes of algal bloom and analyses of contributed data from The District Municipality of Muskoka, the Leonard Lake Stakeholders Association (LLSA), the Ministry of Environment, Conservation and Parks (MECP), the Lake Partner Program (LPP) in addition to data which RiverStone collected during 3 site visits conducted during September, October and November of 2021 following a MECP confirmed bloom in the southwest bay of Leonard Lake.

The findings of this report suggest that climate is likely a primary contributing factor to the onset of algal blooms in Leonard Lake. Climatic changes and conditions are broader than simply changes in water and air temperature. Changes reported by residents of Leonard Lake such as changes in zooplankton and fish abundance can also be attributed to changes in abiotic factors that are driven by climate. Based on an extensive literature review, RiverStone additionally suggests that ecosystem interactions including interspecific competition between algal species, changes in available nutrients in the water column associated with changes in species assemblages, and the introduction of invasive species shifting plankton dynamics may also have contributed to the observed changes in water quality reported by Leonard Lake Residents. Finally, the physical structure of the southern areas of Leonard Lake make those areas more susceptible to bloom events due to past “priming of the water column” by bloom causing species, shallow waters that are easily stratified and higher levels of stagnation in these areas due to reduced fetch and consequently wind and wave action which is not able to mix the water to disperse or restore nutrients.

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1 PROJECT BACKGROUND

RiverStone Environmental Solutions Inc. (hereafter RiverStone) was retained by The District Municipality of Muskoka (hereafter DMM) to undertake a Causation Study for Leonard Lake in response to recent cyanobacteria blooms and in response to the updated water quality policies in the Muskoka Official Plan (June 2019). The Leonard Lake Causation Study is one of several studies being conducted on behalf of the DMM following the completion of the "Peninsula Lake Pilot Causation Study" by Hutchinson Environmental Sciences Ltd. (hereafter HESL) in 2020. The Leonard Lake Stakeholders Association (hereafter LLSA) has contributed their considerable data and recorded observations, as well as the expert reports that they have commissioned for Leonard Lake. RiverStone has incorporated these data into the report wherever possible. The Peninsula Lake Pilot Study (Pilot Study) attempted to determine if clear causation of algal blooms could be confirmed using long-term data on water quality, climate, and algal history, using statistical relationships. This study has used the Pilot Study as a guide to inform the work completed on Leonard Lake. Understanding the causes of cyanobacterial blooms in freshwater lakes is essential due to their ability to dominate summer phytoplankton assemblages, possible toxicity, negative impacts on aquatic food webs (Paerl et al. 1998) and recreational enjoyment of the lake waterfront.

Leonard Lake is a relatively small oligotrophic lake, with low nutrient levels, clear water, and a moderately steep shoreline. Leonard Lake has a surface area of 1.95 km^2, a maximum depth of 18.3m and a mean depth of 6.8m (Ministry of Natural Resources and Forestry (MNRF) 2015). It is also considered a headwater lake that drains a watershed approximately 4.29 km^2 in area, flowing downstream directly into Lake Muskoka. The Ontario Water Resources Commission (OWRC) describes the lake as "moderately enriched" dating back to 1971 and the MNRF has classified shoreline development as moderately dense, shoreline residential.

Ongoing sampling efforts by the Ministry of Environment, Conservation and Parks (MECP) between 1979 and 2016 did not detect any change in overall Total Phosphorus (TP) concentrations, however a gradual decline in water clarity and an increase in dissolved organic carbon were noted (Ingram and Patterson 2015, Watson and Kling 2017). Previous work by HESL (2016) suggested that Leonard Lake should be classified as a lake requiring normal protection from further lot development.

The MECP has confirmed a blue-green algal bloom (cyanobacteria) most recently in October 2022 on the western shore of Leonard Lake. The recent algal bloom is consistent with observations of lake residents who reported thick algal mats in the southwest area of the lake (Watson and Kling 2017) during previous bloom events. Previous blooms were also identified along the southeast shoreline in November of 2020. Samples collected and submitted to the MECP for analysis were identified as containing *Anabaena* (aka *Dolischospermum sp*.) as well as cryptophytes (*Cryptomonas sp*.) and diatoms (*Asterionella sp*.) in levels too low to contribute to a bloom. The

LLSA suggests that at least one bloom event has been occurring annually since 2017, some years with multiple blooms occurring (**Table 1**).

Table 1. Algae Bloom History, Leonard Lake

Date	Location	MECP Confirmed	Health Advisory	Primary Species
Sept 2017	Northwest Shore	Report not available		*Dolichospermum sp.* (few with akinetes)
Sept 2017	South Bay	Report not available		*Dolichospermum sp.*
Sept 2017	North End, West Bay	Report not available		*Dolichospermum sp.*
Aug 2018	Southern Bay	Remnants of bloom	No	Blue Green Algae, *Dolichospermum sp.*
Sept/Oct. 2018	Southwest Bay	**Yes**	**Yes**	*Dolichospermum sp.*
Aug 2019	South Bay	No	No	Test + coliform and E. coli, *Dolichosperm sp*
May 2020	Multiple locations	No	No	Diatoms, *Dinobryon*, *Dolichospermum* sp
Nov 2020	Southeast side	**Yes**	**Yes**	*Dolichospermum sp.*
Sept 2021	Southwest Bay	**Yes**		*Dolichospermum sp.*
Oct 2022	Western Shore	**Yes**	**Yes**	*Dolichospermum sp.*

2 FIELD COLLECTIONS

2.1 Overview and Methods

As part of the Causation Study and because of an observed algae bloom, RiverStone conducted a monitoring program throughout the summer/fall of 2021. Sampling began in September and consisted of three sampling events occurring on September 9th, October 6th and November 26th. During each sampling event, water samples were collected at two sites (Station 1 and Station 2 – **Figure 1**), representing the main portion of the lake and the southern bay. Duplicate water samples were collected using a Van Dorn sampler at the surface and immediately above the lake bottom. Water samples were submitted to the Dorset Environmental Science Centre (MECP) laboratory for analysis of low-level total phosphorus (TP). A multi-meter (YSI) was used to collect temperature and dissolved oxygen measurements in one meter intervals from the lake surface to the bottom of the water column. Field collections were completed by A. Shaw (Senior Ecologist/ Principal), T. Robinson (Aquatic Ecologist), and J. Gauthier (Environmental Technician).

3 LITERATURE REVIEW

3.1 Ecology of Algal Blooms

Cyanobacteria (Blue-green algae) are widespread in aquatic environments globally. To date, toxic cyanobacteria have been reported in at least twenty-seven countries and have been documented on all continents globally, including Antarctica (Newcombe et al. 2010). Cyanobacteria species are varied in their size, shape and life history and can occur in free floating forms within the water column, as groups or colonies, can be found attached to rocks or within the substrate often in a dormant form that can survive for years in a variety of conditions (Whitton and Potts 2000). When conditions become favorable, cyanobacteria can accumulate causing floating surface scums and coloring of the water column (Newcombe et al. 2010). Cyanobacteria are also known to produce toxins which have been shown to be hazardous for humans, animals and aquatic ecosystems (Gunn et al. 1992; Mez et al. 1997, 1998; Baker et al. 2001; Izaguirre et al. 2007). The term harmful algal bloom (HAB) is used to describe any ecosystem-disrupting bloom (Mitra and Flynn 2006) although there can be some debate as to at what level a bloom can be considered ecosystem-disrupting.

The mechanisms through which algae blooms occur are variable and depend on a variety of factors related to lake specific biotic and abiotic factors. For many lakes, phosphorus has been reported as the primary limiting nutrient, particularly in oligotrophic lakes, where in some regions light can penetrate, and therefore algae can photosynthesize in depths up to 13 m (El-Serehy et al. 2018a), suggesting that blooms can occur throughout the water column in nutrient poor lakes as opposed to being more limited by light penetration in more nutrient rich lakes. The growth of cyanobacteria is thought to be favored by high nutrient levels, particularly phosphorus, in combination with other physical conditions which include high temperature, elevated levels of light and thermal stratification. The interactions of these factors however are not well documented (Newcombe et al. 2010). Generally, algal blooms tend to occur when the accumulation of biomass exceeds the capacity for dispersal through biological and/or physical processes (Mitra and Flynn 2006). Nuisance algal blooms are frequently reported in eutrophic and hypereutropic systems but have been considered relatively rare in oligotrophic systems which typically exhibit clear water, low productivity and no (or infrequent) algal blooms (Carey et al. 2008; El-Serehy et al. 2018b). In addition to specific nutrient and physiochemical parameters, recent paleolimnological analyses have linked climate change with the increase of harmful blue-green algal (cyanobacterial) blooms (HABs) even with no known addition of limiting nutrients (Smol 2019), which is consistent with increasing reports of cyanobacteria blooms occurring in oligotrophic lakes within Ontario, the northeastern region of the United States (Carey et al. 2008) and globally (Favot et al. 2019; Cocquyt et al. 2021).

Generally, population increases in cyanobacteria species occur either through recruitment from sediment resting stages or division in the water column (Wetzel 2001). Recruitment may encourage bloom formation and understanding recruitment dynamics may therefore be useful in predicting and managing cyanobacterial blooms (Carey et al. 2008). Research on the process of oligotrophic algal blooms suggest that, similar to eutrophic lakes, there is a seasonal peak in recruitment and surface abundance of cyanobacteria species in oligotrophic lakes with recruitment generally occurring from shallow (less than 5m) sediments (Carey et al. 2008). An important mechanism of algae blooms in both low and high nutrient lakes appears to be recruitment from sediments, which over time may allow for the important transfer of nutrients in oligotrophic lakes (Carey et al. 2008). As lakes recover from historical periods of acidification the pH will rise, which in turn will allow for increases in the amount of dissolved organic carbon (DOC). Elevated DOC will cause reductions in water clarity and contribute to more persistent lake thermoclines providing larger areas of refuge for cold-water species (Warren et al. 2017).

In many instances, algal bloom formation seems to occur as a result of the interaction(s) between several contributing factors. For example, a positive association between *Microcystis* blooms and cyanobacteria blooms has been documented in some areas, one making conditions more suitable for the other. Further research into potential causes of *Microcystis* blooms suggests that the abundance of plankton species varied with wet and dry conditions, suggesting that climate is a significant driver of trophic structure during blooms (Lehman et al. 2021). *Microcystis* abundance has been shown to vary with several cyanobacteria and phytoplankton genera including several potentially toxic species such as *Pseudoanabaena, Dolichospermum, Planktothri, Sphaerospermpsis*, and *Aphanizomenon* (Lehman et al. 2021). It is important to note that only certain algal species form blooms, and to date there is not a definitive explanation of the physiology for bloom success; however, it does appear that bloom forming species are intrinsically more capable of producing secondary metabolites such as toxins or other structural defenses that render them less attractive to grazers (Mitra and Flynn 2006) that would normally keep populations in check. In some instances, bloom forming algal species are thought to adversely affect the growth of competitor (non-bloom forming) species, furthering their dominance in the water column (Newcombe et al. 2010).

3.1.1 ***Dolichospermum sp*. (formerly *Anabaena*)**

Dolichospermum species are among the most toxic cyanobacterial genera and often succeed each other during a harmful bloom event. This genus has been identified in every potential algal bloom identified by either the MECP or the LLSA on Leonard Lake. The life cycle of this species includes a planktonic stage (free floating in the water column through the formation of gas vesicles) and a benthic or bottom dwelling stage in the form of akinetes which are the algal equivalent of seeds or spores (Baker 1999). When the environmental conditions are appropriate, the akinetes germinate allowing populations to persist throughout the seasons (Baker 1999). The filaments of this species grow through cell division, followed by akinete production and release, which is generally thought to be an overwintering mechanism of this species. This is followed by growth from the akinete which is triggered by abiotic factors such as temperature and/or light. Buoyancy within the water column is achieved by using gas chambers within the cells (Walsby 1978). Colonies located closer to the surface are exposed to higher levels of light and tend to have a higher rate of photosynthesis which results in the buildup of carbohydrates (sugars) within the cells. The carbohydrates make the cells heavy which causes them to sink out of the euphotic zone, where light penetrates, therefore the colonies stop producing carbohydrates and begin to consume them through respiration (Reynolds et al. 1987). This allows colonies to become buoyant again and return to the surface to begin photosynthesis. The daily migration cycle of *Dolichospermum* species positions colonies at the optimal depth for light penetration for photosynthesis limiting the impact of water clarity on bloom formation and may also provide a mechanism through which colonies are able to scavenge available nutrients from the water column (Newcombe et al. 2010). The vertical migration observed in several *Dolichospermum* species likely provides an adaptive advantage over other planktonic algal species, particularly in stratified lakes where turbulence is low. The characteristic scums observed on the surface of the lake when the water is calm can likely be attributed to the vertical migration of this species when they become buoyant at night and rise to the surface (Newcombe et al. 2010).

3.1.2 Gloetrichia echinulata

Gloeotrichia echinulata is a nitrogen-fixing cyanobacteria that has been associated with blooms in eutrophic lakes across a broad geographic range. Some species of cyanobacteria such as *G. echinulata* use recruitment from substates to subsidize its bloom formation. This species is a nitrogen-fixer that typically produces large (~2mm) colonies (Carey et al. 2008). This species is not thought to be primarily responsible for the blooms observed in Leonard Lake (**see Table 1** for the primary list of species associated with each bloom event) but it does likely exist in the environment and may interact with other bloom-causing species, contributing to harmful bloom events in the future.

3.2 <u>Light</u>

The euphotic zone, by definition, “extends from the surface to the depth at which 1% of the surface light intensity is measured”. The euphotic zone can be estimated by multiplying the Secchi depth values by a factor of approximately 2-3. Cyanobacteria such as *Dolichospermum* sp. have the capacity for buoyancy regulation and can overcome the limitation of the euphotic zone by floating to depths with optimal light conditions. The depth of light penetration is important for the growth of benthic cyanobacteria species, with greater light penetration increasing the depths at which the benthic species can grow (as reviewed in Newcombe et al. 2010).

Cyanobacteria contain chlorophyll a as well as other light harvesting pigments called phycobiliproteins which can capture light in the yellow, orange, and green part of the spectrum, enabling cyanobacteria species to efficiently use light energy from across the spectrum. In conditions where light is limiting, growth rates of Cyanobacteria tend to be higher than that of other green algae species, which in combination with the buoyancy regulation capacity of *Dolichospermum* sp. allows them to outcompete less harmful algal species such as green algae (Newcombe et al. 2010).

3.3 <u>Water Temperature</u>

The growth rates of Cyanobacteria and algal species are temperature dependent. While some growth can occur at lower temperatures, there is significant potential for growth when water temperatures are above 15ºC with optimal growth temperatures for most species occurring about 25ºC (Robarts and Zohary 1987). Temperature is also an important contributing factor to the other physical characteristics of the lake such as stratification, which is based on temperature associated differences in water densities creating stable, non-mixing layers in the water column during particular times of the year (Heinze et al. 2013; Verschoor et al. 2017; Dadi et al. 2020). It has been well documented that increased stratification is a contributing factor to the increased onset of reported algal blooms (Newcombe et al. 2010).

3.4 <u>Nutrients</u>

Elevated nutrient concentrations, including phosphorus, have typically been associated with algal blooms. A well accepted relationship between spring (total) phosphorus loading and summer biomass of all algal phytoplankton has been established in the literature (Paerl et al. 1998; Carey et al. 2008; Newcombe et al. 2010) for some time. The conventional understanding is that HABs are, at least initially, driven by catchment processes that contribute excess nutrients to the waterbody (Newcombe et al. 2010). Since, historically, many of the blooms recorded have occurred in eutrophic lakes, it was thought that high phosphorus and nitrogen concentrations were required. Generally, it is thought that phosphorus levels below 10ug/L are associated with a low risk of algal blooms, 10-25ug/L present a moderate risk and over 25ug/L present high algal growth potential and risk of bloom formation (Newcombe et al. 2010). Cyanobacterial blooms, however, have been documented in aquatic environments with relatively low phosphorus levels, such as a few micrograms per liter. Experimental data have demonstrated that the affinity of many cyanobacteria species for phosphorus or nitrogen are higher than other photosynthetic microalgae, suggesting that if phosphorus or nitrogen is limiting, that cyanobacteria species can out compete other algal species (as reviewed in Newcombe et al. 2010) suggesting that if the physical conditions are ideal, algal blooms can occur even with low levels of phosphorus and/or nitrogen (Weyhenmeyer and Broberg 2014). Additionally, some cyanobacterial species have been shown to have the capacity to store enough phosphorus to complete between two and four (2-4) cell divisions which represents a four to thirty-two (4-32) fold increase in biomass with no additional phosphorus input (Newcombe et al. 2010).

The ratio of Total Nitrogen to Total Phosphorus (TN:TP) may also be a contributing factor to the tendency of cyanobacteria to dominate over other plankton species in a lake (Smith 1983), although this relationship is not as well established as the role of spring phosphorus loading and algal blooms. Other publications suggest that it is not the relationship between TN and TP, but rather whether either nutrient is limiting, which may be limiting for either cyanobacterial growth or the growth of other algal species (Smith 1983, Newcombe et al. 2010).

3.5 Stratification

The thermal stratification of a waterbody influences many physical conditions such as depth of light penetration, concentrations of nutrients within the waterbody and the depth at which cyanobacteria species are likely to be located (Newcombe et al. 2010). The latitude, shape, structure and characteristics of the waterbody and the climatic conditions all influence thermal stratification. Generally, if stratification occurs, the water is separated into two non-mixing layers known as the epilimnion and the hypolimnion with a transition layer known as the thermocline. The upper epilimnion layer tends to be warmer and can be mixed by wind and wave action resulting in an exchange of dissolved gases such as oxygen with the atmosphere. The lower hypolimnion is isolated from the upper layer by the thermocline and is not able to mix or exchange gases with the upper layers. Stratification, and associated anoxia can result in a sizeable release of phosphorus from the sediments resulting in an increase in internal nutrient loading in the lake (Newcombe et al. 2010) which may promote bloom formation.

3.6 Trophic Structure and Food Web Interactions

Many algal blooms invariably disrupt the flow of energy and elements through the trophic levels of aquatic ecosystems (Mitra and Flynn 2006). Aquatic ecosystems are likely to experience multi-trophic effects of changing resource quality associated with warming temperatures due to climate change, because macroalgae and phytoplankton quality are highly sensitive to temperature (Tseng et al. 2021). Additionally, algal nutrient status affects the likelihood of top-down control of these species through grazing, with any negative impact on predator growth decreasing nutrient regeneration which will further stress algal species, increasing their unpalatability to grazing species (Mitra and Flynn 2006). For example, during algae blooms, a decrease in large zooplankton and an increase in small zooplankton species has been reported (Lehman et al. 2021). These shifts, both in organism quality and quantity, can have cascading effects on higher trophic levels (Tseng et al. 2021) leading some to predict that warmer water temperatures will result in decreased secondary productivity in aquatic systems (Hixson and Arts 2016).

The MNRF (2015) has identified a fish community in Leonard Lake consisting of stocked Rainbow Trout (Oncorhynchus mykiss), Lake Whitefish (Coregonus clupeaformis), Burbot (Lota lota), Smallmouth Bass (Micropterus dolomieu), Walleye (Sander vitreous), Golden Shiner (Notemigonus crysoleucas), Pearl Dace (Margariscus margarita), Brown Bullhead (Ameiurus nebulosus), Pumpkinseed (Lepomis gibbosus) and Yellow Perch (Perca flavescens). Anglers on Leonard Lake reported a decrease in Rainbow Trout caught and are concerned about the diversity of the invertebrate community which is considered an indicator of ecosystem health. The MNRF reported that the invasive Spiny Water Flea (Bythotrephes longimanus) was introduced in 2001 and is a voracious predator of crustacean zooplankton species such as Daphnia and can alter the tropic structure of lakes. The invasion of the Spiny Water Flea is thought to be associated with reductions in species richness and abundance of cladoceran species although the full impacts of the Spiny Water Flea on ecosystems have not been established (Kelly et al. 2013). The Spiny Water Flea has been introduced to other lakes in the Muskoka region, including Peninsula Lake in 1991 according to the NDMNRF fact sheet. Further research is needed to fully understand the interactions of plankton dynamics and invasive species on ecosystem health and bloom formation, particularly in oligotrophic lakes that have begun to experience bloom events.

It is interesting to note that the features of Leonard Lake that contributed to historically poor habitat quality for fish species such as Walleye include small size, moderately high depth, lack of extensive shallow areas, and high water clarity. In recent years, residents of Leonard Lake have indicated that they have observed a decrease in lake clarity, which was initially thought to be associated with the increased occurrence of algal blooms. More recently, communication with a resident of Leonard Lake suggested that perhaps some of the change in clarity has occurred due to a recovery in Leonard Lake from the impacts of acid rain (Warren et al. 2017) and a reduction in water clarity that is associated with higher productivity and a higher pH.

3.7 <u>Ecological Consequences of Algae Blooms</u>

The formation of algal blooms requires the decoupling of grazing from phytoplankton growth which alters the dynamics of nutrient regeneration in the ecosystem. The dynamics between limiting nutrients as opposed to nutrient consumption by algal species is a mechanism through which trophic interactions and ecosystem composition can impact harmful algal bloom (HAB) formation in lakes. HAB events often follow blooms of non HAB species and over time can alter species diversity and abundance (Mitra and Flynn 2006) resulting in shifts in species assemblages throughout the ecosystem.

3.8 <u>General Conclusions from Literature Review</u>

Algal blooms tend to occur when a grouping of environmental conditions favoring blooms, including nutrient concentrations, temperature, light and thermal stratification, occur concurrently. Generally, high levels of phosphorus alone are not sufficient to trigger the formation of algae blooms including HABs, and in some cases phosphorus can be relatively low and a bloom can still occur if the other biotic and abiotic factors are present and HAB forming species are successfully able to out compete non HAB forming species in the water column. The development of algal blooms tends to occur in a series of phases including an initial seeding phase, a rapid growth phase, a plateau and a die off. Under calm water conditions, colonies which are excessively buoyant may accumulate together at the surface. While the term "algal bloom" does not have an agreed upon definition, in the scientific literature it is generally considered to be a cyanobacterial concentration that is significantly above the average for the waterbody (as reviewed in Newcombe et al. 2010).

4 CAUSATION STUDY LINES OF EVIDENCE

4.1 Algal Bloom History

The first recorded and recognized algal bloom in Leonard Lake, for which RiverStone was able to access data and records, occurred in 2017, with the LLSA sampling three blooms, two of which were issued incident numbers by the MECP. Subsequent blooms have occurred in 2019, 2020, 2021 and 2022. The LLSA has identified additional blooms occurring in 2018 (**Table 1**). Generally, the description recorded by the LLSA reports that the potential algal blooms consisted of surface blooms along the shoreline. Analyses conducted either by the MECP lab or by the algal expert contracted by the LLSA generally found that *Dolichospermum* species were the primary species identified in both the MECP and LLSA samples. In some instances, the LLSA reported multiple bloom events (e.g. Rpt 26 LL 2017, Rpt. 27 LL 2017, Rpt. 2017 28, Rpt 29 LL 2017, Rpt. 30 LL 2017, Rpt 31 LL 2018) during a season in which the MECP identified a single bloom suggesting that there is a discrepancy in the assessment of the onset and the resolution of a bloom event or that Leonard Lake has frequent and brief "bloom like events" where algal mats begin to form but are not stable enough in the water column for long enough to be documented by the MECP or identified by the Simcoe Muskoka District Health Unit as a cause for concern before the algal assemblages are broken up and dispersed throughout the waterbody.

4.2 Water Quality Analysis

4.2.1.1 Total Phosphorus Concentrations

Data collected by the LPP on Leonard Lake between 2002 to 2019 suggest that the total phosphorus concentrations are generally decreasing at sampling Station 1. Sampling was conducted annually from 2002 to 2006 and then resumed in 2019. Initially total phosphorus samples were 7.1 µg/L and 11.4 µg/L in May of 2002 and had decreased to 5 µg/L and 4.8 µg/L in May of 2019 (**Figures 2-4**). While six years of data is not enough to perform any meaningful statistical analyses to determine if the decrease in TP is significant across time, the general downward trend (with a slight increase in 2005 and 2006 before dropping to lowest values recorded) suggest that TP sampling values at this location do not suggest a link with the increasing occurrence of algal blooms and that TP concentrations in the water column alone are not responsible for the increased frequency of blooms on Leonard Lake. This is supported by an MECP report (Ingram and Patterson 2015) using data from 1979 – 2015 which demonstrates high variability in the yearly spring phosphorus values ranging from over 7 µg/L in 1979 and 2001 to TP spring values of 5 in µg/L 1987 and 2013. This suggests that there is not a distinct upward trend in phosphorus in Leonard Lake across time, and that phosphorus alone is not responsible for the change in bloom frequency and intensity that has been reported for Leonard Lake.

4.2.1.2 Other Water Quality Parameters

Nitrogen

Sources of nitrogen input into lakes can vary and include a variety of forms such as ammonia, nitrates, and nitrites which can be deposited into the lake via inflows, groundwater, precipitation and through nitrogen fixation of planktonic organisms such as cyanobacteria (blue-green algae). There are no long-term trends reported for nitrogen concentrations on Leonard Lake (1980- 2014, Ingram and Paterson 2015) and there appears to be large interannual variation. The DMM collected total nitrogen samples in spring/early summer in Leonard Lake between 2017 and 2019. Concentrations showed very little variation, ranging between 0.21 and 0.26 mg/L indicating that change in frequency and intensity of algae blooms documented in Leonard Lake cannot be attributed to changes in nitrogen concentrations.

Calcium

Water chemistry data provided to RiverStone from the DMM span sampling periods between 2007 and 2021. Concentrations of total calcium ranged between 2.0 mg/L and 2.6 mg/L, with an average value of 2.32 mg/L (**Figure 5**). These data suggest that the calcium concentrations in Leonard Lake have remained relatively stable since 2007. The MECP (Ingram and Patterson 2015) calcium data in Leonard Lake from 1980-2014 is consistent with the data that RiverStone reviewed from the DMM, with variable levels of calcium documented across time. Generally, the calcium concentrations in Leonard Lake were consistently between 2.1 mg/L and 2.5 mg/L. Data referenced in communication from Leonard Lake residents suggest that calcium values from the LPP program have indicated a decline in calcium with concentrations reported as low as 1.7 mg/L raising concerns among some residents that the decline in calcium may have resulted in a decline of algae grazers such as *Daphnia* sp. It is unclear whether the differences in calcium trends reported are attributed to different sampling locations or methodologies or differences in the interpretation of the results. Regardless, changes in zooplankton species cannot be attributed to calcium concentrations alone and are more likely the result of the complex interaction of a variety of factors including calcium concentrations in addition to the introduction of invasive species such as the Spiny Water Flea (*Bythotrephes longimanus*), shifts in the abundance and diversity of the fish community and the predation pressure they exert. Additionally, changes to the abiotic environment that can be associated with climate change have been reported as a global trend resulting in changes in distribution, range, and density for many species from a variety of freshwater taxa.

Alkalinity and pH

The DMM has conducted water chemistry sampling which has included alkalinity (**Figure 6**) and pH (**Figure 7**) measurements. Alkalinity data has been collected since 2007 with the addition of the total fixed endpoint method measurements starting in 2009. The alkalinity data suggests an upward trend with a low value of 2 mg/L in 2007 and an upper value of close to 5 mg/L in 2021. The alkalinity level in Leonard Lake is related to carbonates and bicarbonates in the water and is decreased by sewage outflow and aerobic respiration. The alkalinity of a lake represents the buffering capacity of the lake to acidification and changes in pH can impact alkalinity levels, as pH values decrease, this can also reduce alkalinity. The upward trend in the alkalinity data suggests that sewage outflows are likely not an issue contributing to water quality in Leonard Lake.

Past work by Ingram and Patterson (2015) from MECP suggested that between 1979 and 2015 the pH level (annual spring whole lake) increased from approximately 5.5 in 1979 to roughly 6.5 in 2015. Additionally, this report suggests that the overall increase in pH is associated with a recorded decrease in sulphate. The DMM has also taken pH measurements between the years of 2007 and 2021 in Leonard Lake. The pH values fluctuate yearly ranging from a low of 6 with a high of 7 with a gradual upward trend observed, consistent with the findings reported by the MECP (2015).

Within a 24-hour period, pH values can vary naturally. The process of photosynthesis uses hydrogen which increases pH levels, while respiration and decomposition can both decrease pH levels, while photosynthesis of algae and other aquatic vegetation can raise the pH resulting in fluctuations throughout the day (Sutherland et al. 2021).

Dissolved Organic Carbon and Water Clarity

The Secchi disk depth has been collected by the DMM from 1987-2021. There is no clear trend in the data that indicates an increase or decrease in Secchi depth, suggesting that there has not been a meaningful change in water clarity as blooms have increased. The depth of visibility of Leonard Lake demonstrates interannual variability with the bulk of the values falling between three and five meters (3-5) with a high of 8 metres in 1987 and a low of 2 metres in 1993. There is no marked change in Secchi depth that coincides with the onset of algal blooms in Leonard Lake.

Another measure of lake clarity that is often used is the measure of dissolved organic carbon (DOC), which is a measure to assess the level of dissolved organic compounds which can occur as a result of decomposing plant matter. In Leonard Lake, a slight increase in DOC between 1979 and 2015 has been recorded (Ingram and Paterson 2015). There is no clear trend in DMM DOC data, although, 2019-2021 DOC values of 4.8 mg/L suggest that there is a slight increase from 4.1 mg/L in 2007, although the ranges varied interannually with a high of 5.3mg/L occurring in 2015. The lack of trend observed in both data sets suggest that while there has been a slight increase in DOC across times, the high levels of interannual variation do not align with the onset of algal blooms Leonard Lake. This suggests that while there may be an increase in the amount of decomposing plant matter in the water column the increase in frequency and intensity of algal blooms in Leonard Lake are not linked to changes in DOC concentrations or the associated biological processes.

4.2.1.3 <u>Dissolved Oxygen Profiles and Deep-Water Sampling</u>

The depth profiles of temperature and oxygen (**Figure 7**) showed evidence of stratification until mixing of the water column occurred.

4.3 Climate History

4.3.1 Temperature

Globally, documented air temperatures have been increasing, resulting in an increase in water temperatures. The DMM has consistently collected water temperature at depths throughout the water column during multiple sampling events throughout the year starting in 1987. There is a general trend towards increasing water temperatures with surface temperatures consistently reaching over 25 degrees Celsius starting in May of 2015.

4.3.2 Wind Speed

Changes in wind speed, which is largely responsible for wave action and ultimately mixing of the water column, can result in changes in the exchange of water between the surface and depth, changes to stratification and conditions which may favour HAB formation. Local wind data specific to the region surrounding Leonard Lake was not available at the time of this report. These data were particularly difficult to access through the MECP. Data that is publicly available from the Harp Lake Meteorological station does show a marked decrease in wind speed in September of 2017, which coincides with the onset of a bloom reported by the LLSA in September of that year. Additional wind data was obtained from the North American Regional Reanalysis (NARR) which is a long term atmospheric and land surface hydrology data set (Mesinger et al. 2006) was reviewed and while there are some fluctuations in windspeed within and between years, it does not clearly explain the change in onset of bloom formation in Leonard Lake. Most of the algal blooms reported by the LLSA occur in the southern region of the lake and health advisories have been issued in both the southeast and southwest areas of the lake. Based on the physical structure of the lake, it is likely that the southern area of the lake does not experience the same wind and wave action, and therefore mixing, as other areas of Leonard Lake, suggesting the potential for increased stratification in this area favouring bloom formation. The differences in wind speeds in different areas of the lake are consistent with observations made by RiverStone staff. Stations 1 and 2 were sampled consecutively on the same day by Riverstone Staff, and station 1 had considerably more wave action than station 2, which is more sheltered by physical structures from wind and therefore experiences less wave action. Wind measurements from the surrounding area that do not address intralake differences in wind and, consequently, wave action, are therefore not the best measurement to use in assessing the importance of wind speed and wave activity in the formation of algae blooms on Leonard Lake.

5 WEIGHT OF EVIDENCE ANALYSIS

5.1 Climate

It is predicted that the risks associated with cyanotoxins and blooms will continue to increase globally due to clear changes in thermal regimes associated with climate change coupled with the increasing eutrophication of aquatic ecosystems (Chia et al. 2018). It is reasonable to conclude that climate, likely in interaction with several other factors, is a major factor contributing the occurrence of both algal blooms and HABs on Leaonard Lake.

5.2 Discussion and Summary of Findings

Defining what constitutes an algae bloom is not as straight forward as one would expect. This is particularly clear given the discrepancy between the number, date of onset and resolution, and severity of algae blooms confirmed by the MECP in comparison to those proposed by the LLSA over the past number of years (**Table 1**). Currently, there is not an agreed upon scientific threshold of what constitutes an algal bloom. The broad definition generally used is the rapid increase in the population of algae in an aquatic system. The Ontario Drinking Water Quality Standards and Guidelines outlines the acceptable concentration for microcystin-LR, a common algal toxin, as a maximum of 1.5 parts per billion or 15 micrograms per liter. The American Environmental Protection Agency (EPA) defines a harmful agal bloom as an overgrowth of algae in the water, some of which produce dangerous toxins, while acknowledging that even non-toxic blooms can cause damage to both the environment and the local economy (United States Environmental Protection Agency 2022).

Several theories as to possible causes of the recently observed algae blooms in Leonard Lake have been presented by members of the LLSA. Based on the historical data collected by the LLSA alongside data acquired from the DMM, LLP, MECP, and our own sampling efforts, RiverStone considered each theory that may be contributing to the occurrence of blooms on Leonard Lake. Based on a comprehensive literature review assessing changes in frequency and timing of blooms globally, specific information and history provided about Leonard Lake, alongside our own observations and analysis, it is our opinion that the documented blooms on Leonard Lake can be attributed to a few potential factors. These factors include changes in climatic factors (temperature primarily) associated with climate change, among others such as changes in patterns of precipitation and weather patterns, climate influenced changes in species range and abundance and interactions among and within species assemblages.

The blooms on Leonard Lake are recorded to have primarily occurred in the south and southwest portions of the lake. Site specific conditions in this area of the lake may also be contributing to the occurrence and/or persistence of bloom events. During our field sampling site visits, it was noted by RiverStone ecologists that the southwest region of Leonard Lake experienced considerably less wave action when compared with the other sampling sites in the deeper and more open portion of the lake. This indicates that the water column in the south and southwest areas of Leonard Lake is likely more stratified due to a lack of wind/wave action and the associated mixing of the water column which would occur as a result of the agitation caused by the wind and/or waves. Additionally, the past occurrence of algal blooms can, with some species, increase the probability of the occurrence of future blooms by "priming the water column" though changing the type and concentration of nutrients available. A lack of mixing in the areas of the lake that have been identified as prone to bloom occurrences is problematic in that it does not allow accumulated concentrations of minerals to be dissipated into the larger environment or for minerals in low concentrations in this region of Leonard Lake to be replenished from other areas of the lake.

This can impact trophic interactions and alter the composition of food webs that would otherwise help to keep the conditions in the water column less hospitable to bloom prone species. In Leonard Lake the MNRF reported that the Spiny Water Flea, an aggressive invasive invertebrate, was recorded as early as 2001. The introduction of this species is often associated with changes in the pelagic community, and in zooplankton diversity and abundance. The reported changes in the invertebrate and fish communities observed by some residents of Leonard Lake, while potentially associated with changes in water chemistry parameters or lake health, could also be indicative of interspecific interactions and a response to changes in global climatic conditions associated with climate change.

Climatic change and conditions are broader than simply changes in water and air temperature. Many changes reported by residents of Leonard Lake such as changes in zooplankton and fish abundance can also be attributed to changes in abiotic factors that are driven by climate. Based on an extensive literature review, RiverStone additionally suggests that ecosystem interactions, including interspecific competition between algal species, changes in nutrients available in the water column associated with changes in species assemblages, and the introduction of invasive species shifting plankton dynamics, may also have contributed to the observed changes in water quality reported by Leonard Lake residents.

Finally, the physical characteristics of the southern basin of Leonard Lake makes it more susceptible to bloom events due to past “priming of the water column” by bloom causing species, shallow waters that are easily stratified, and higher levels of stagnation in these areas due to reduced fetch and consequently wind and wave action which is not able to mix the water in these areas as efficiently as other areas in Leonard Lake.

6 GAP ANALYSIS AND RECOMMENDATIONS FOR LEONARD LAKE

6.1 Gap Analysis

One of the most challenging aspects for scientists, policy makers and program managers is to select an appropriate environmental time scale over which to conduct an assessment. For many, if not most lakes, consistent long-term monitoring data is not available. Where lake monitoring programs do exist, data have rarely been collected consistently for longer than a few years. Determining the nature and timing and magnitude of ecosystem changes based on the short-term data sets available is often difficult, if not impossible (Smol 2019), as the application of statistical tests to provide conclusive results cannot be completed. Additionally, it is often after a problem has been identified that studies are designed, or monitoring programs are implemented and critical baseline or pre-disturbance data is not available, limiting the understanding of the causes and contributing factors of a problem (Smol 2019).

In the case of Leonard Lake, multiple sampling programs have been conducted by various agencies and volunteers which have recorded data on a wide variety of parameters. A lack of consistency across time in sampling locations, methods and information gathered greatly limits the usefulness of this data in performing even basic statistical analysis upon which conclusions can be drawn. For example, in some instances, different sites within the lake are sampled on different days within the same season, which added increased variability to the data. Increased background variability in the data set results in a decreased ability of statistical analysis to differentiate legitimate trends from background noise making it difficult to identify variables, and in many cases the interactions between variables, which may be just as important as considering factors individually. The information does provide insight into trends; however, a more robust analysis would have been useful in weighing relative importance of both individual variables and interactions between factors. All future sampling efforts should focus on reducing the number of sites (a combination of nearshore and deep water would be ideal) and maintaining consistency across time in terms of sampling methods, locations and measures collected. If possible, and as mentioned in the Lake-Specific Recommendations section of this report, all sites selected for future monitoring by the LLSA or volunteers as part of the LLP should be sampled on each sampling trip to eliminate variability in date/time and changes in abiotic factors as potentially confounding factors in the analysis.

Paleolimnological studies are useful in establishing baseline information regarding the presence of algal species in oligotrophic lakes (Smol 2019). Similar studies in other regions have indicated that although cyanobacteria were present in the lake system since the 1950s and 1960s, it was not until the late 1990s that changes in the population(s) associated with the formation of HAB began to occur (Smol 2019). This type of study allows for valuable baseline data to be collected that can help identify critical factors and can be used as a tool to help streamline the design of sampling programs to identify the parameters that should be prioritized for ongoing monitoring. (Smol 2019).

The MNRF conducted extensive zooplankton surveys from 1981 to 1987 which characterized the plankton community in Leonard Lake. RiverStone did not obtain any data suggesting that this study had been updated since the introduction of the Spiny Water Flea to quantify potential shifts in the pelagic community or since the onset of algal blooms in Leonard Lake in 2017. This existing data could be used as baseline data for purposes of comparison in future studies that may help better characterize the role of plankton abundance, food web dynamics and top-down versus bottom-up impacts and how these are either contributing to or responding to bloom events.

6.2 Lake-Specific Recommendations

Generally, in order to effectively manage lake ecosystems and for ongoing monitoring of incremental environmental stressors, temporal sampling windows (which are often lacking with standard monitoring regimes) are required and can be achieved by supplementing ongoing monitoring effort with high-resolution lake sediment analyses (Smol 2019). In the case of Leonard Lake, both historical data and ongoing monitoring efforts through the Lake Partner Program could be used alongside paleolimnological methods to expand the timeline and scale at which the trends in Leonard Lake can be evaluated. This would allow for more meaningful analysis with greater statistical power and would provide a more robust assessment of the importance of the many contributing factors to the occurrence of algal blooms in Leonard Lake that have been outlined in this report. Lake sediment analyses or paleolimnology methods have been used in a variety of studies to perform retrospective assessments of ecosystem changes that have been occurring slowly and "under the radar". Using environmental proxies in dated sediment cores the relative contributions of natural and industrial sources of pollutants can be identified alongside the trajectory of the ecosystem (Smol 2019).

In order to increase the capacity for analysis, where the data is available, it may be beneficial for the DMM to consider a comparison across lakes in the immediate watershed of Leonard Lake using existing data to identify the key factors in multiple lakes that may, where possible, require policy or legislation at the municipal, regional, or provincial planning level to address.

Additionally, to better understand the role of trophic interactions and food web dynamics on the formation of algal blooms in Leonard Lake, RiverStone recommends that the zooplankton sampling conducted by the NDMNRF in the 1980s is repeated following the same methods and using the same sampling locations every three to five years to observe changes in ecosystem composition as they relate to the frequency, intensity, and toxicity of algal blooms in Leonard Lake. If this is something that the LLSA decides to implement, it could be accomplished relatively inexpensively with water samples collected by LPP volunteers and analyzed by a contracted expert, similarly to how the water/algae samples have been processed to date.

The ongoing program by the DMM and the LPP of water sampling and analysis should continue. Continued monitoring of oxygen depth profiles, water temperature, and air temperature can be easily and inexpensively completed by volunteers using a YSI meter. Additionally, pH, alkalinity, total phosphorus, nitrogen, calcium, and iron oxide should continue to be monitored. Methods should be kept consistent across time as should sampling sites to reduce any unnecessary variability in the data set that may reduce the efficacy of statistical tests.

Site specific wind measurements that will allow differences in wind speed to be documented and quantified should be collected. Shoreline measurements in the areas of the previous sampling locations, particularly in sampling areas adjacent to areas where algal blooms are known to occur, would allow the differences in wind speed to be quantified and would provide more relevant information than generalized wind data for the Muskoka area to be used in the event of future algal blooms on Leonard Lake.

Finally, while additional phosphorus deposition from overland flow and sewage is not identified as a primary cause of an increase in bloom events in Leonard Lake, RiverStone recommends that the LLSA seek to implement practices known to improve water quality wherever possible. It is well established that a vegetative buffer is important for fish habitat and water quality. RiverStone therefore recommends that the existing policies outlined in the official plan of the Township of Muskoka Lakes (Adopted 2022) and the Official Plan of the Muskoka District Area (Consolidated 2019) regarding the naturalization of the vegetative buffer along the shores of

Leonard Lake is implemented for all properties on the lake, and particularly those in the south and southwest areas of the lake.

Similarly, although septic runoff was not identified as a likely cause of the Leonard Lake bloom events, proper use and maintenance is a priority for each septic system and the general health of the lake ecosystem. RiverStone therefore recommends that the residents of Leonard Lake adhere to the following recommendations:

- Ensure the effluent filter on the septic tank is serviced regularly.
- Have the system pumped out every two to three years, depending on use.
- Never dump grease, oil, or fats into the drain.
- Do not use a garbage disposal system.
- Be conscious regarding the amount of water and waste dumped at one time.
- Never do more than two loads of laundry in one day.
- Practice water conservation (use low flow toilets and showerheads).

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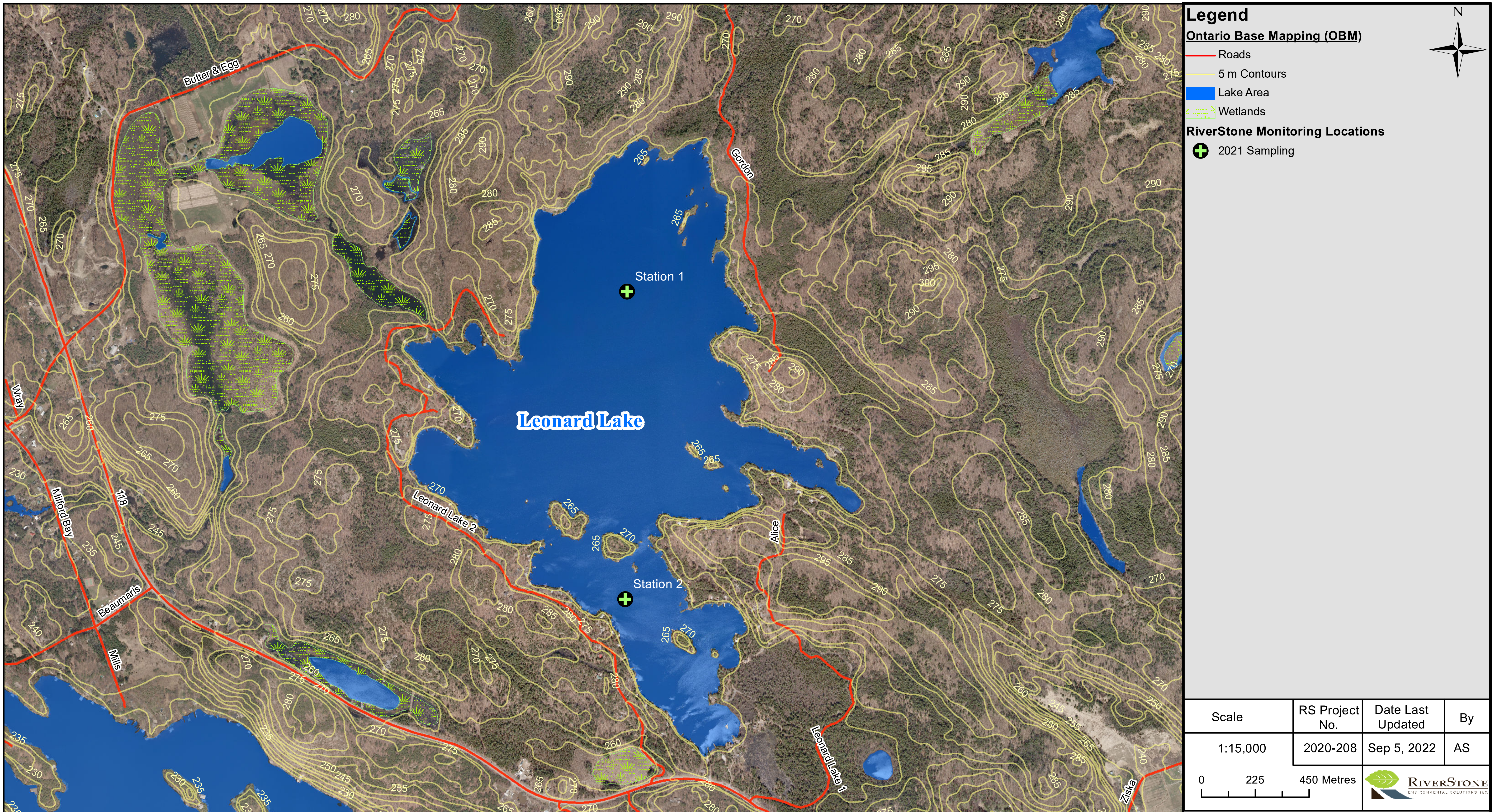

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Figure 1. Location of Leonard Lake and Monitoring Stations. Township of Muskoka Lakes.

Prepared for District Municipality of Muskoka

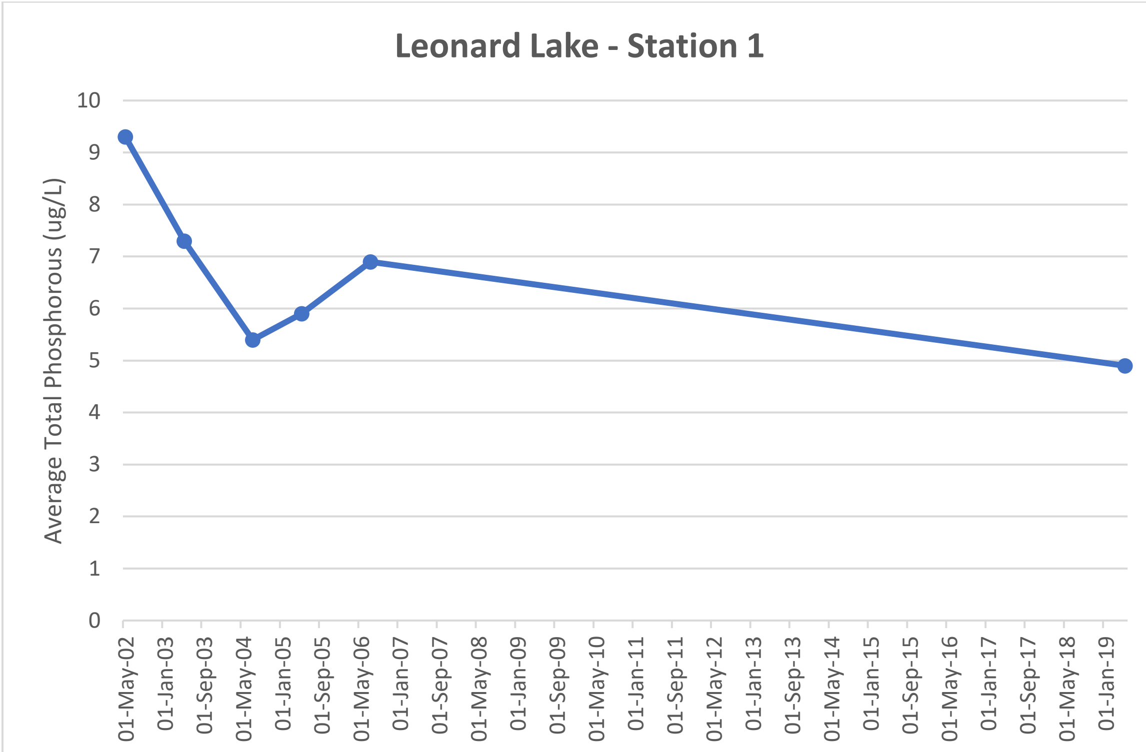


Figure 2 . Average Total Phosphorous data collected by volunteers as part of the lake partner program. The data was accessed July 2021.

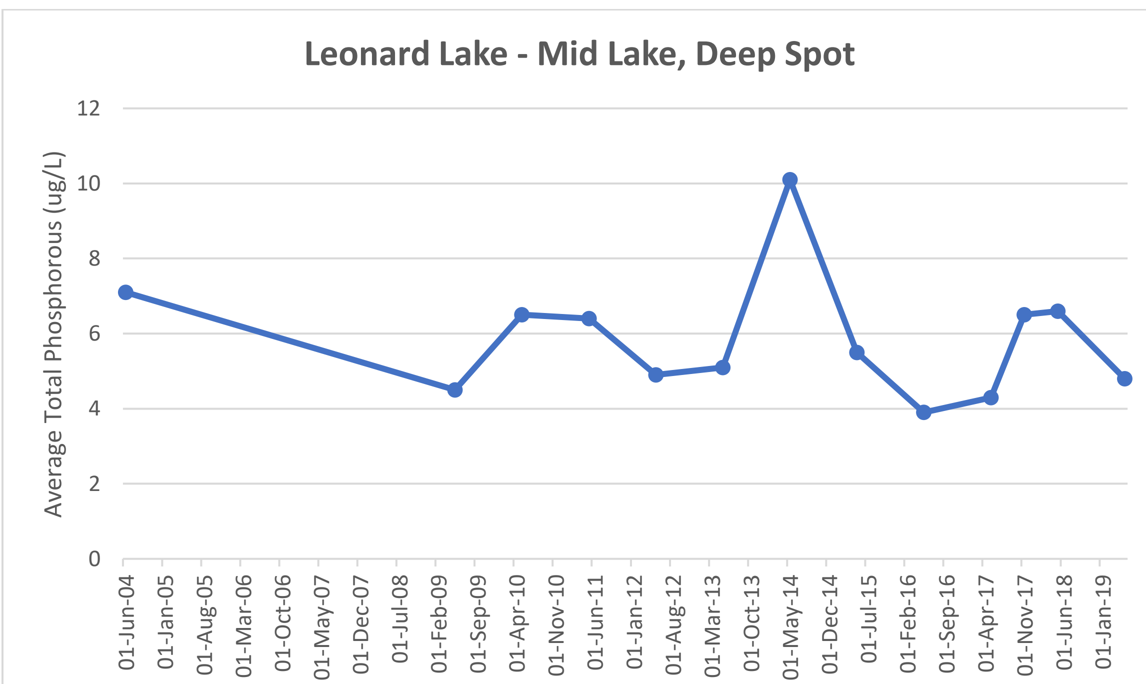


Figure 3 . Average Total Phosphorous data collected by volunteers as part of the lake partner program. The data was accessed July 2021.

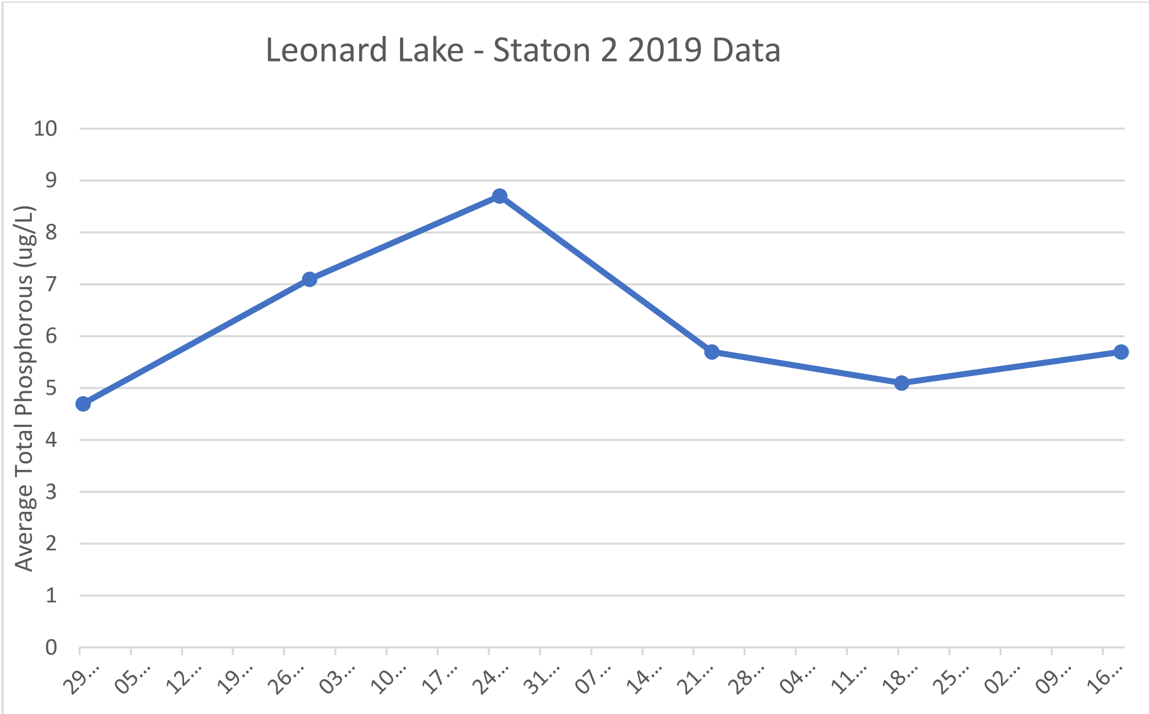


Figure 4 . Average Total Phosphorus data collected by volunteers as part of the lake partner program. The data was accessed July 2021.

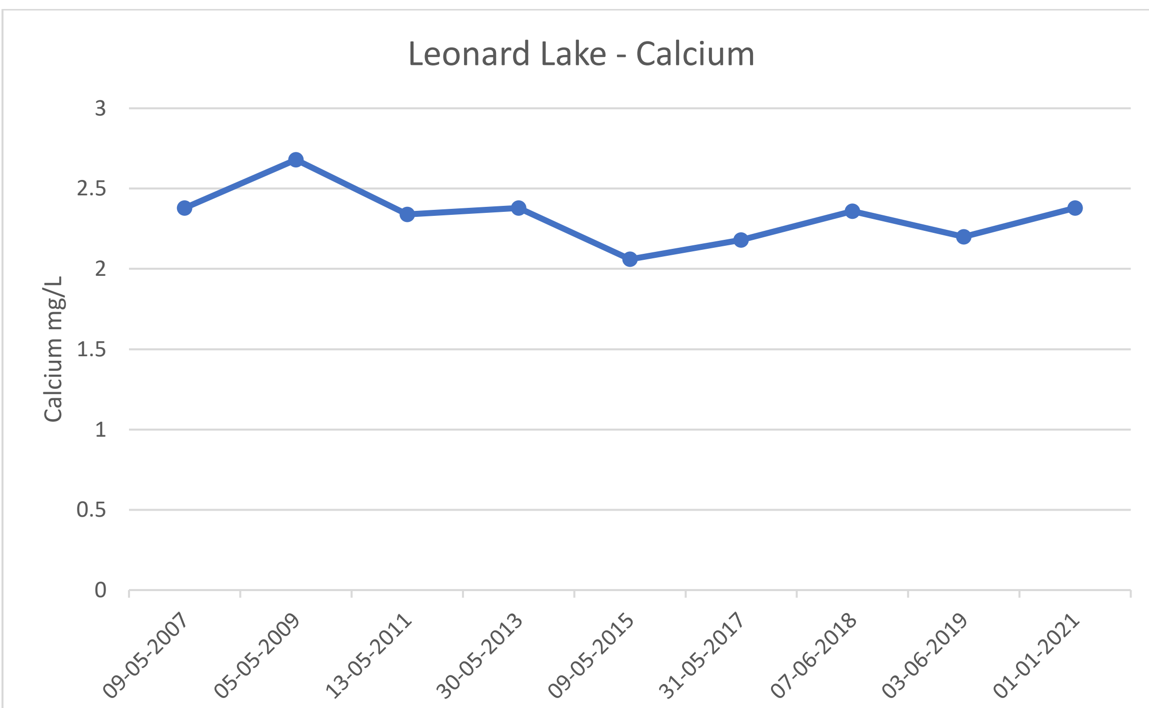


Figure 5. Calcium measurements in water samples collected form Leonard Lake from 2007-2021, data provided by the District Municipality of Muskoka

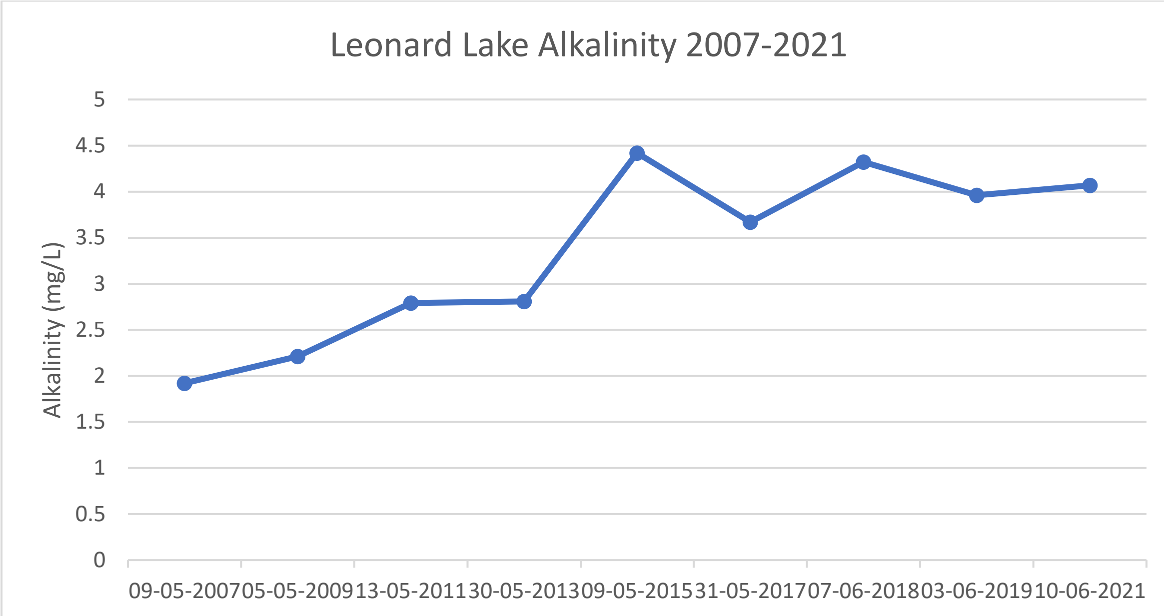


Figure 6. Alkalinity data from 2007 – 2021 provided by the District Municipality of Muskoka.

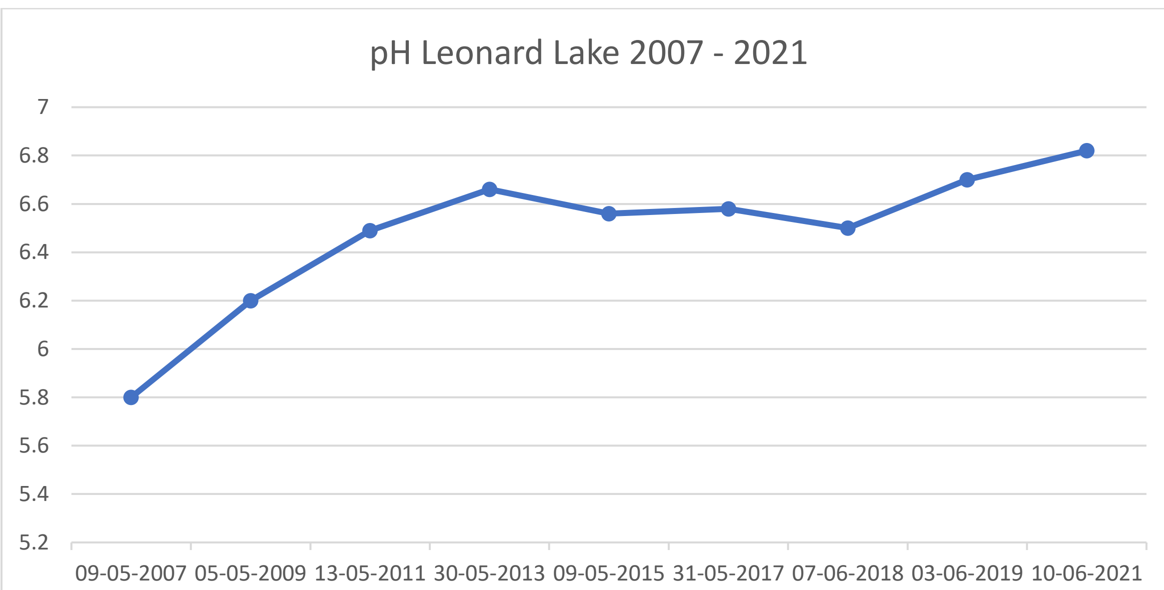
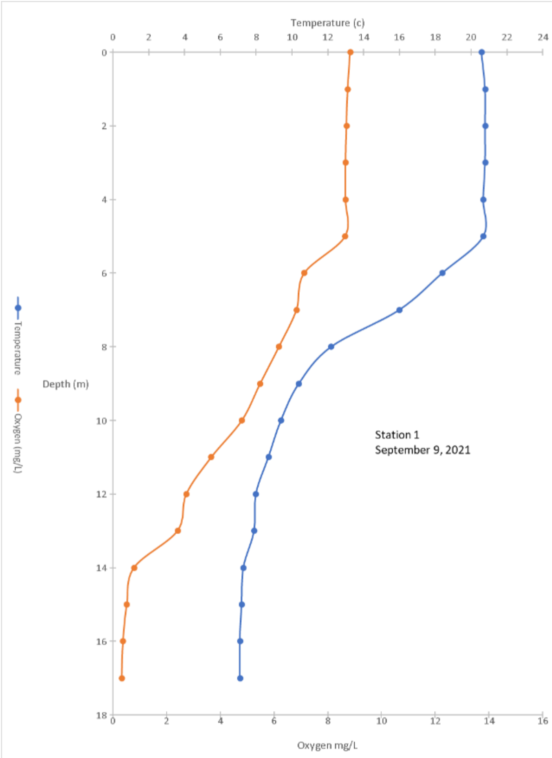


Figure 7. PH data provided by the District Municipality of Muskoka. Data was collected from 2007 to 2021.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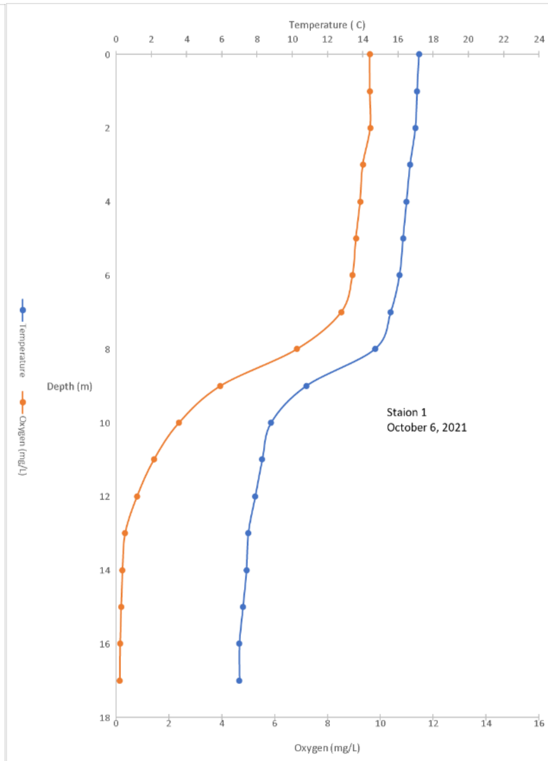
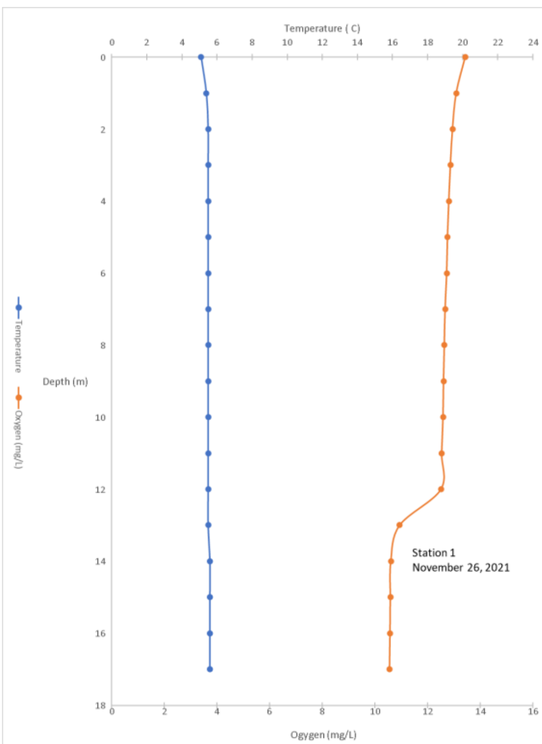
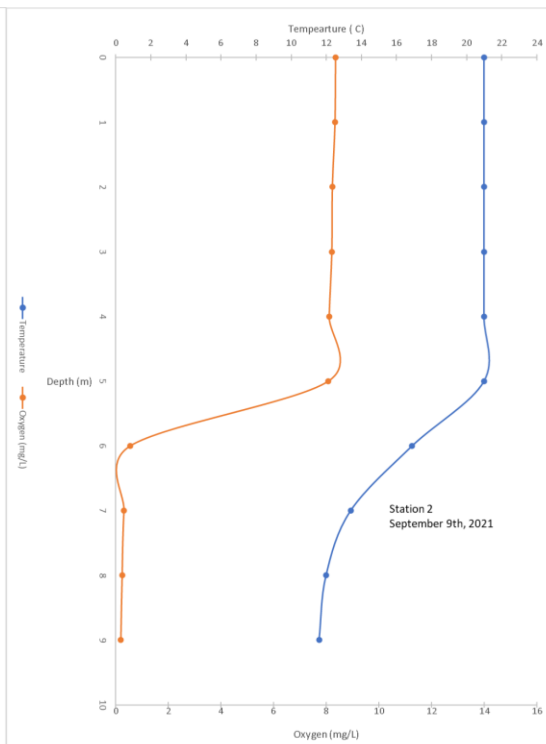
Depth (m)
Temperature
Oxygen (mg/L)
Station 1
September 9, 2021
Oxygen mg/L


Temperature (C)
Depth (m)
Temperature
Oxygen (mg/L)
Staion 1
October 6, 2021
Oxygen (mg/L)


Temperature (C)
Depth (m)
Temperature
Oxygen (mg/L)
Station 1
November 26, 2021
Ogygen (mg/L)


Tempearture (C)
Depth (m)
Temperature
Oxygen (mg/L)
Station 2
September 9th, 2021
Oxygen (mg/L)

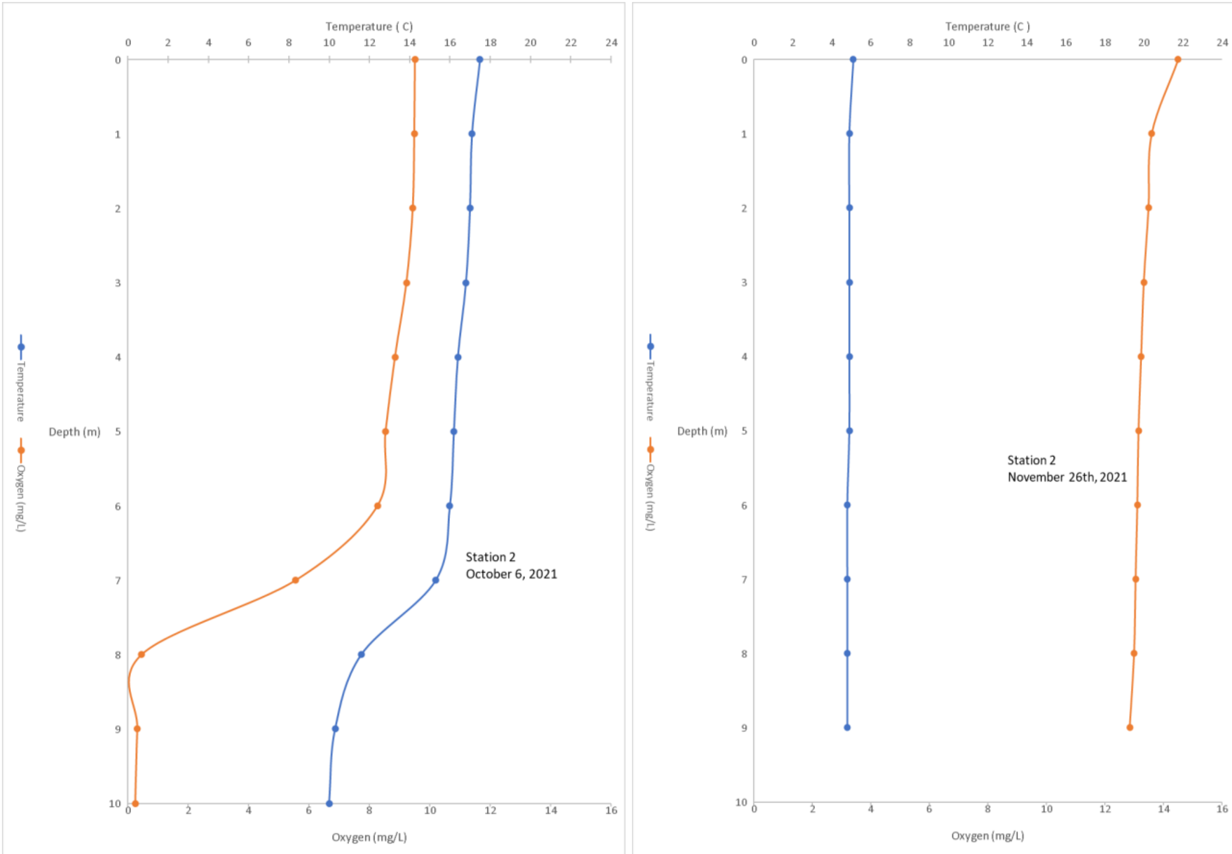


Figure 8. Temperature and oxygen data collected at Stations 1 and 2 from September to November 2021.

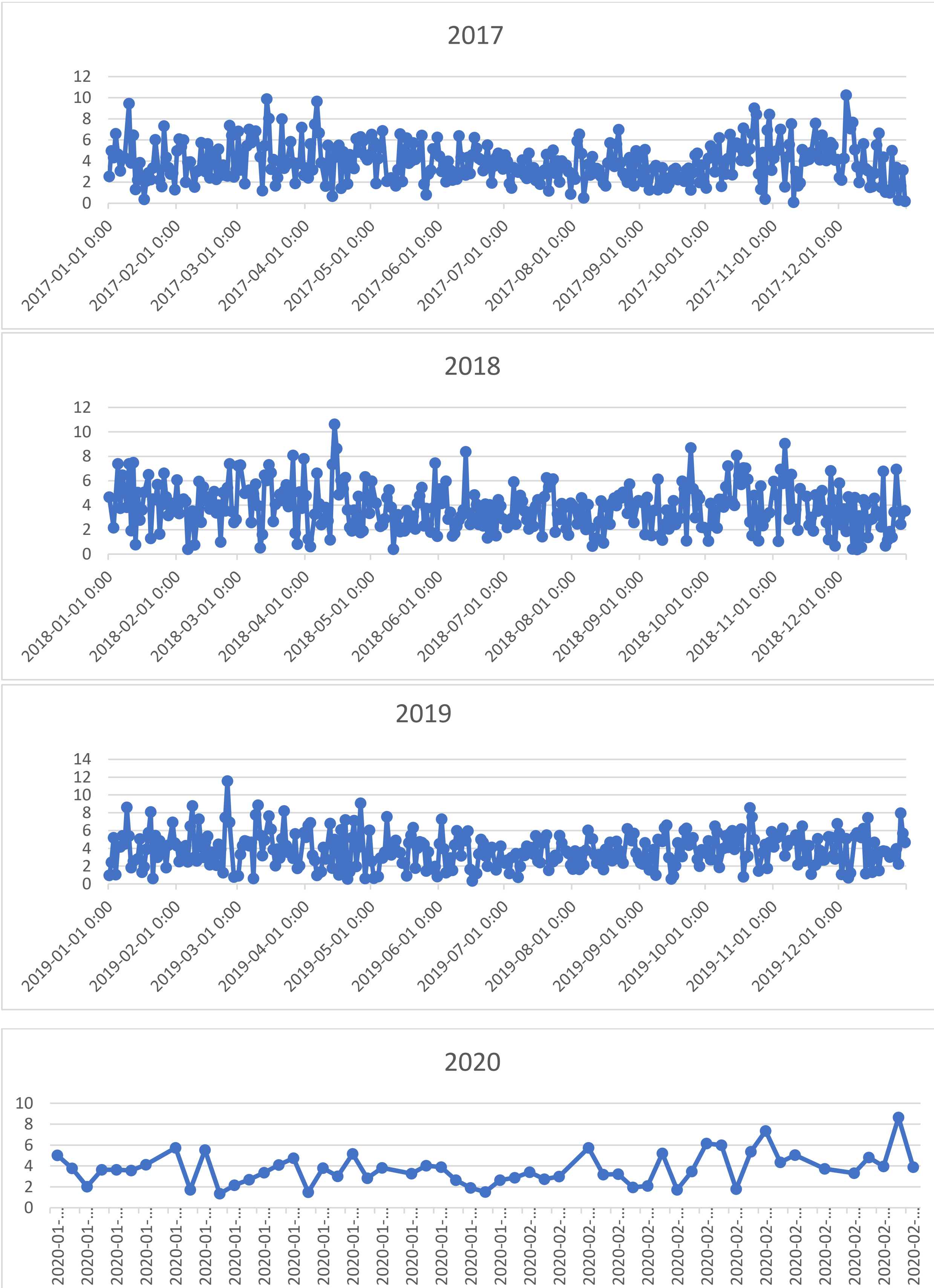


Figure 9. Wind data from North American Regional Reanalysis (NARR). Data was collected from 2017 to 2020.

RIVERSTONE
ENVIRONMENTAL SOLUTIONS INC.

Consultation Report

Leonard Lake Causation Study

Prepared for: The District Municipality of Muskoka

EcoVue Reference No.: 21-2115

Date: January 13, 2022

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Table of Contents

1.0 INTRODUCTION

The District Municipality of Muskoka (“the District”), along with RiverStone Environmental Solutions Inc. (Riverstone) and EcoVue Consulting (EcoVue), referenced in this report as the “project team”, have led a Causation Study for Leonard Lake in the District of Muskoka. In view of the lake’s status and recent history of algal blooms, the causation study was completed. EcoVue was included in the project team to provide advice on, and lead portions of the consultation process for the Study. This was particularly important for this Study given the significant public interest in the work and the active participation of the Leonard Lake Stakeholder Association in monitoring the lake and compiling local knowledge regarding the lake’s condition.

The consultation process for the Causation Study is intended to improve the project in two ways:

1. Ensuring local knowledge of Leonard Lake informed the scientific method and analysis that was used to develop conclusions and propose recommendations. This was to be accomplished ensuring locally collected data and observations could feed into the scientific process, where relevant, to allow for more accurate results and conclusions.

2. To ensure all stakeholders understand the scientific process being applied, how conclusions were be drawn, and understand the implications of these results both at the onset of the project and at its conclusion.

A Consultation Plan prepared by EcoVue, dated July 2nd, 2021, was developed for the Causation Study for Leonard Lake which set out the consultation program to be undertaken in conjunction with the study[1]. This report, in combination with the Causation Study prepared by Riverstone, summarizes the results of the Consultation Plan, and describes the ways that stakeholder’s concerns were addressed and contributed to the study process.

It should be noted that further communications by the District will occur to describe next steps as it relates to policy implications at the District level, after the completion of the final report. EcoVue is available to the District to advise on these matters, upon request.

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[1] The Consultation Plan was posted on the Engage Muskoka website at the following link: www.engagemuskoka.ca/leonard-lake

2.0 ENGAGEMENT TOUCHPOINT SUMMARY

The Consultation Plan was intentionally designed with several specific engagement efforts (i.e., “touchpoints”) to ensure stakeholder contributions were encouraged and welcomed throughout the study process. This section provides further details on the touchpoints of the project described in the Consultation Plan and their associated results.

2.1 Engage Muskoka Website Maintenance

The Engage Muskoka website for the Leonard Lake Causation Study[2] has been the primary touchpoint since the project launch. This website includes a general project description, District staff contact information for providing ongoing inquiries and comments, a “project lifecycle” chart showing where the project is, a newsfeed providing updates, when available, and relevant links to applicable documents. To date, the newsfeed has included seven posts, including:

1. Announcement of request for proposal, February 18th, 2021
2. First public meeting announcement, April 1st, 2021
3. Public survey release, April 29th, 2021
4. Posting of first public meeting recording, May 5th, 2021,
5. Public survey results report posting, July 26th, 2021
6. Causation Study update, with frequently asked question responses, August 24th, 2022;
7. Second public meeting announcement, November 11th, 2022; and
8. Posting of the second public meeting recording, December 2nd, 2022; and
9. Draft report posted on Engage Muskoka for public review, December 8th, 2022.

Maintenance of this website will continue to be maintained by District staff over the course of the project lifecycle.

[2] The website for the Leonard Lake Causation Study is found at the following link: www.engagemuskoka.ca/leonard-lake

2.2 Indigenous Consultation

Indigenous consultation was undertaken by District Staff and took place through the District's Muskoka Area Indigenous Table on April 9th, 2021. The purpose and scope of the ongoing Causation Studies, including the one being conducted on Leonard Lake, was communicated to participating Indigenous leaders and opportunity for further engagement was extended. It is EcoVue's understanding no additional engagement was requested or undertaken.

2.3 Stakeholder Meeting #1

The first stakeholder meeting was held on April 26th, 2021. The meeting, with a PowerPoint presentation and question/answer period, was held via Zoom and was attended by seasonal and year-round residents and members of the Leonard Lake Stakeholders Association, with some non-residents attending due to interest in the study. Key objectives of the meeting were to: (1) ensure stakeholders understood the scope of the study and the scientific process that would be undertaken to develop conclusions; and (2) obtain information or comments participating stakeholders were willing to provide. A recording of the meeting was made available on the Engage Muskoka website[3] on May 5th, 2021 for those who could not attend. All comments, questions, and associated responses were recorded and are included in the comment and response table in Appendix ** of the final Leonard Lake Causation Study report.

2.4 Survey

Subsequent to the first stakeholders meeting, a survey was made available to those who attended and other interested parties through the Engage Muskoka website. Seventy-three (73) respondents completed the survey with the majority identifying themselves as residential property owners on or near the lake. A summary of the results was posted to the Engage Muskoka Website on July 26th, 2021[4] and is available there for reference. The survey data was provided to Riverstone to use in their analysis and corroborate conclusions found in the overall analysis.

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[3] The first public stakeholder meeting recording is available at the following link Leonard Lake Causation Study - April 26, 2021 Public Meeting Recording - YouTube or https://www.youtube.com/watch?v=3OdfC26MTdA&t=3637s

[4] The survey results summary is available at the following link: https://www.engagemuskoka.ca/leonard-lake

2.5 Ongoing Stakeholder Feedback

The District contact for the project was provided on the Engage Muskoka throughout the study term. All correspondences, studies, and data available on the project were forwarded to the project team at the onset and throughout the study. This information was reviewed by Riverstone at length and was used to scope the research questions and analysis undertaken on the lake. Riverstone has listed the information provided in Appendix ** of the final Causation Study Report and indicates how this information was used.

2.6 Stakeholder Meeting #2

The second stakeholder meeting was held on November 28th, 2022. The meeting, which included a PowerPoint presentation and question/answer period, was held via Zoom and attended by approximately 18 stakeholders and the project team. Key objectives of the meeting were to ensure the stakeholders understood the research conducted, the draft results, and the associated conclusions. A recording of the video was posted on the Engage Muskoka website on December 6th, 2022[5]. All comments, questions, and associated responses were recorded and are included in the general comment and response table in Appendix ** of the final Leonard Lake Causation Study report.

3.0 ADDITIONAL CONSULTATION – COMMENTING PERIOD

Though not originally anticipated in the Consultation Plan, District staff requested an additional touchpoint with stakeholders to ensure comments and questions were appropriately considered and responded to in the final report. Specifically, a commenting period on the draft Causation Study was added to the project scope for this purpose.

To this end, the draft report was released on the Engage Muskoka website on December 8th, 2022 for public comment. Public comments were received until January 13th, 2023. Comments from four (4) individuals (including a letter from the Leonard Lake Stakeholders Association) were received. These comments were reviewed and considered by the project team. Responses to these comments are included in Appendix** of the final report, along with the comments received at the public meetings.

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[5]The video recording of the Second stakeholder meeting is available at the following link: Leonard Lake Causation Study - November 28, 2022 Public Meeting Recording - YouTube or https://youtu.be/1lAmOT_C-xM

4.0 SUMMARY

The importance of stakeholder engagement in providing information for the completion of the Causation Study and for the protection of the health of Leonard Lake cannot be understated. A robust consultation plan was prepared in support of the causation study efforts. In addition to efforts to keep stakeholders up to date, two public meetings and a survey were undertaken to compile comments and address issues of concern. Furthermore, comments were welcomed throughout the project timeline and an additional commenting period was added at the end of the project to ensure all comments and questions were addressed in the final report.

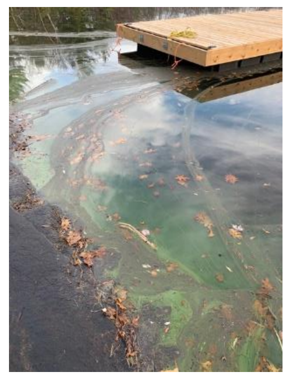
All comments and data received throughout the consultation program were distributed to, and considered by, the project team. Many of the comments informed the study design and conclusions or, at minimum, were used to corroborate the results of the study. Furthermore, comments and questions posed during the Stakeholder Meetings and within the commenting period are summarized and responded to in the final report.

We trust this report adequately summarized the consultation that has occurred on the project. Thank you for the opportunity to assist with this scientific effort.

Respectfully Submitted,

ECOVUE CONSULTING SERVICES INC.

B. Saunders, B.Sc., M.Sc.
Planning Supervisor



Representative Photos of Algae in Leonard Lake Submitted by Residents

Appendix 3 – Inventory of Use of Data Provided

Rpt	Report/Document Title	Report Date	Author(s)	Background/Context	Use in Study
1	Leonard Lake Water Quality and Algal Blooms: Status, Monitoring and Management	2017	S.B. Watson & H. Kling	A study to assess current lake status and vulnerability to the effects of human activities and shoreline development and develop more effective ongoing monitoring and stewardship programmes in partnership with regional and provincial agencies.	Cited in report
2	Internal Phosphorus Load	2017	G. Nurnberg	A study to investigate the carrying capacity of Leonard Lake from previous modeling studies, lake characteristics, limnological (lake-related) information including monitoring data, and general professional knowledge. The study also looked at the importance of taking into account internal phosphorus (P) loading and its effect on the phytoplankton.	Reviewed for report
3	Memo: Leonard Lake water quality in 2017 and 2018 and cautionary comments on the development plans for 1080 Glen Gordon Road, Township of Muskoka Lakes	2018	G. Nurnberg	A memo that summarizes the concerns raised in the Watson and Nurnberg reports in opposition to a Palmer WQIA report that supported a lake development application. Given the Watson and Nurnberg report finings, the memo also raises concerns with the use of TP from just one lake location as an indicator of overall water quality.	Reviewed for report
4	A novel model for cyanobacteria bloom formation: the critical role of anoxia and ferrous iron	2014	Molot et al	This paper and model links/supports to the Nurnberg report that internal P loading could be one factor contributing to cyanobacteria bloom formation.	Study reviewed as background

5	Internal iron loading and warm temperatures are preconditions for cyanobacterial dominance in embayments along Georgian Bay, Great Lakes	2017	Verschoor et al	This paper builds on Molot 2014.	Study reviewed as background
6	An Assessment of Lake Scugog Nearshore Water Quality and Ecological Condition (2017-2019)	2020	Smith, Kirkwood and Balika	This study examines the nearshore zone of Lake Scugog which is an important component to the overall lake ecosystem as it provides fish spawning and nursery grounds, and habitat and food to many other lake organisms with its high plant and algae growth. The nearshore zone was targeted not only because of its importance for fish spawning and nurseries, but also its nearshore zone is also where people enjoy the lake, whether it is at a beach, swimming, or kayaking. It's also where the impacts from our activities on land are directly felt. This study assess the relationship between nearshore water quality and land-use and concludes that land use does influence nearshore water quality. These findings are similar to Leonard Lake's water testing results where results differed based on sampling location and proximately to shallower nearshore areas.	Study reviewed as background
7	Low sediment redox promotes cyanobacteria blooms across a trophic range: implications for management	2021	Molot et al	A paper which further investigates link between sediment redox, anoxia, nitrates, P and cyanobacteria blooms. In association with Watson and Nurnberg which identifies anoxia and internal P loading from sediment, Molot's paper offers further evidence that lakes with lower P levels can exhibit cyanobacteria blooms.	Study reviewed, used as an explanation in study

8	Lake Water Level Data: Level vs Rainfall Summary	2020	LLSA	Weekly monitoring data of water outfall levels and rainfall data from Environment Canada.	Reviewed for report
9	TML 2018 Septic Inspection Report	2018	TML		Cited in report
10	Anomalous rise in algal production linked to lakewater calcium decline through food web interactions	2011	Korosi et al	This paper concludes that "Calcium decline has severe implications for the whole lake food webs and presents yet another mechanism for potential increases in algal blooms". As Leonard lake data indicates, low calcium is a concern.	Study reviewed, calcium is not a primary concern in Leonard Lake
11	Dr. Favot EH Presentation Blue-Green Algae in Ontario Lakes Full presentation at: https://youtu.be/tDQAyZ8XB34	2021	E. Favot	A presentation on recent research by Dr. Favot on what environmental conditions have changed in lakes that could be driving recent blooms and what are the environmental drivers? From her research, causes of blooms includes weather, elevated nutrients, and web of life alterations. There are suggestions from the data and observations on Leonard Lake that 3 of these causes need to be carefully studied. Dr. Favot's research findings related to anoxia and background TP levels not predicting cyanobacteria blooms is consistent with events that have occurred on Leonard Lake.	Presentation reviewed, recommendations incorporated in research and sample collection
12	Leonard Lake Water Quality	2015	Ingram & Paterson	DESC review of Leonard lake water data from late 1970's to 2015-2016	Cited in report
13	Leonard DESC Zooplankton Data 1981-1984		MOECP	Historical Water Quality Data from the Ministry of Environment as noted.	Cited in report

14	Leonard Lake Chemistry Data DESC 1979-2016		MOECP	Historical Water Quality Data from the Ministry of Environment as noted.	Cited in report
16	Leonard Lake Data 1979-2016		MOECP	Historical Water Quality Data from the Ministry of Environment as noted.	Cited in report
17	Leonard Lake Muskoka STN 2540 Secchi & TP 1993-2012		MOECP	Historical Water Quality Data from the Ministry of Environment as noted.	Cited in report
18	Leonard Lake Phytoplankton 1970-2004		MOECP	Historical Water Quality Data from the Ministry of Environment as noted.	Reviewed for report
19	Leonard Lake profiles - 1994		MOECP	Historical Water Quality Data from the Ministry of Environment as noted.	Cited in report
20	Recreational Carrying Capacity	2017	J. Dyment	An alternate measure of lake capacity and usage. Relates to the Watson and Nurnberg reports that discuss the shallow lake bays and narrows where surface activity can disturb bottom sediment and anoxic zones and release P.	Was reviewed, not directly cited in report
21	LL Temperature Comparison 2017-2020	2020	LLSA	This file contains the surface water temperature associated with confirmed blooms sampled on Leonard Lake from 2017-2020. Blooms were confirmed by either Hedy Kling, algal taxonomist in Winnipeg, or by the MECP. The relationship between an anomalous temperature rise and a bloom is apparent on the graph. On occasion a single yellow "bloom dot" refers to more than 1 bloom occurring on the same day at different locations, or blooms occurring within a day of each other.	Was reviewed, not directly cited in report
22	Lake Blooms 2017-Present	2020	LLSA	This Excel file is a summary of confirmed blooms on Leonard Lake from 2017-2020. Blooms were confirmed by either Hedy Kling, algal taxonomist in Winnipeg, or by the MECP.	Cited in report

23	The Power of the Past: Tracking Lake Ecosystem Changes in an Anthropocene World. Presentation at: https://foca.on.ca/wp-content/uploads/2021/03/TWF-JohnSmol-4Mar2021.mp4	2021	J.Smol	This presentation focuses on how humans have affected our lake ecosystems. Conclusions start at minute 59.	Presentation reviewed, recommendations incorporated in research and sample collection
24	LL Water Temp – Blooms 2017-2020		LLSA	A summary Word version of Excel document 21 above.	Reviewed for report
25	LL Sampling Sites and Stations 2017		LLSA	Map of sampling sites	Reviewed for report
26	LL 2017 Algae 1	2017	LLSA	Details of Algal Bloom - 1	Details used in report
27	LL 2017 Algae 2	2017	LLSA	Details of Algal Bloom - 2	Details used in report
28	LL 2017 Algae 3	2017	LLSA	Details of Algal Bloom - 3	Details used in report
29	LL 2017 Algae 4	2017	LLSA	Details of Algal Bloom - 4	Details used in report
30	LL 2017 Algae 5	2017	LLSA	Details of Algal Bloom - 5	Details used in report
31	LL 2018 Algae 3	2018	LLSA	Details of Algal Bloom - 3	Details used in report
32	LL 2018 Algae 3 Aug 12 photo, micrograph x350	2018	LLSA	Photo of 2018 Algae 3	Details used in report
33	LL 2018 Algae 5	2018	LLSA	Details of Algal Bloom - 5	Details used in report
34	LL 2018 Algae 7	2018	LLSA	Details of Algal Bloom - 7	Details used in report
35	LL 2018 Algae 7, photos, advisory		LLSA	Photo of 2018 Algae 7	Details used in report
36	LL 2018 Algae 8		LLSA	Details of Algal Bloom - 8	Details used in report

37	LL 2018 Algae 10 and 10 R		LLSA	Details of Algal Bloom - 10 and 10R	Details used in report
38	LL 2018 Algae 10 Outlet Photo Sep 17	2018	LLSA	Photos and Details of Algae 10	Outlet Photo Sep
39	LL 2018 Algae 10 R Sep 30 photo	2018	LLSA	Photos and Details of Algae 10R	R Sep 30 photo
40	LL 2018 Algae 11 and follow-up		LLSA	Details of Algal Bloom 11	Details used in report
41	LL 2018 Water Advisory Lifted	2018	LLSA	Notice of Algal Bloom 11	Details used in report
42	LL 2019 - Leo Algae 2	2019	LLSA	Details of Leo Algal bloom 2	Details used in report
43	LL 2020 Leo Algae 1, 2020.5.24	2020	LLSA	Details of Leo Algal bloom 1	Details used in report
44	LL 2020 Algae 1 May 20 #1	2020	LLSA	Details of 3 samples in May and June	Details used in report
45	LL	2020	LLSA	Details of Algae 2	Details used in report
46	LL	2020	SMDHU	Water Advisory	Details used in report
47	LL 2020 Water Advisory Lifted	2020	SMDHU	Water Advisory Lifted Notice	Details used in report

NOTE: Individual documents 24-47 contain additional information from each confirmed bloom are included which contain photographs, micrographs, taxonomy and toxicity information etc.

List of bloom files:

2017 algae 1,2,3,4,5;

2018 algae 3,5,7,8. 10, 11;

2019 algae 2;

2020 algae 1,2. Documents 46 and 47 associated with LL 2020 algae 2 includes a list of water advisories issued for the District in 2019 and 2020, and specifies when they were issued and lifted.

Comment	Response
Key lines of evidence relevant to Leonard Lake algal blooms were not explored, i.e., the impact of chloride, sampling for reduce iron, recognition of internal nutrient loading.	The impact of chloride was considered. Leonard lake is well below the levels considered concerning (and is generally below even the revised recommendations for Muskoka) and is not located near a major road where that is likely to contain chloride runoff
The draft report fails to acknowledge that limited data (sampling at only one spot, at one depth, once a year) cannot be construed as representative of the entire lake throughout the entire season.	Wherever possible RiverStone used data form multiple sources (DMM, MECP and LLP) to comment on trends in potential factors.
The draft report has largely failed to address the TOR issue that states "Determine the extent to which development is causing cyanobacterial blooms..."	We disagree. We did look at the factors that could cause the blooms. The data did not support the idea that shoreline development was responsible
The draft report has recommended few "mitigation actions that can be taken by stakeholders, the district, and others to ensure water quality may be enhanced in the longterm"	The best course of action for stakeholders at this time is to focus on actions that they can take to promote water quality (see Muskoka Watershed Council Best practices program (https://www.muskokawatershed.org/programs/best-practices-program/). For district studies future sampling methods have been recomended that will better address the questions needed to guide policy.
There is little evidence in the report to indicate that Climate Change is the primary contributing factor, (also termed primary driver) for algal blooms in Leonard Lake.	There is little eveidence of any other cause. There were no distinct changes in trends in water quality, spring turnover etc. or anyting else outside of climate that would provide an explanation and climate has been documented globally as causing blooms (recent evidence of a lake with no development experiencing multiple blooms) . Other causation studies such as the Penn Lake study also suggest climate as a factor suggesting that these issues are occuring on a broader scale than Leonard Lake.
Much of the Literature Review, Lines of Evidence and Weight of Evidence sections of the draft report are not based on data or evidence specific to Leonard Lake although data exists	RiverStone reviewed all of the data available to them in order to assess the potential causative factors in Leonard Lake. The Literature review was used to identify potential causative factors which should be considered and to provide background for
The 2017 study entitled "Leonard Lake, Water Quality and Agal Blooms", rich in lake specific data and extensive research, is authored by two of the most highly respected specialists in Harmful Algae Blooms and Algal Taxonomy in Canada. Riverstone failed to make use of this highly relevant resource.	RiverStone did review this resource and incorporated it into the report where possible. It was also used to guide the facotrs which were examined.
Riverstone has disregarded evidence and extensive data pertinent to the Leonard Lake Causation Study provided by LLSA. One example includes 5 years of Leonard Lake bloom report logs (2017-2021) which contain information on wind, water temperature and associated weather conditions	These bloom reports were used to identify proposed species and occurrence of potential blooms.

DOM's Official Plan includes, in a) iii) of C2.6.3.2, for WATER QUALITY INDICATORS: "A blue-green algal (cyanobacteria) bloom confirmed and documented by the Province and/or Health Unit." The study doesn't find Leonard Lake to be "vulnerable", despite C2.6.3.2 a) iii) being met.	RiverStone was asked to investigate factors contribtuting to algal blooms on Leonard Lake. We did not state that the lake was either vulnerable or not vulnerable as that is a policy issue. The District is currently in the process of reviewing the results of the current Causation Studies to determine a path forward that will seek to ensure the long-term recreational water quality of lakes and rivers in Muskoka. This review will include the current terms of reference, scope of work, budgetary requirements, policies, and implementation. Concurrently, District staff are reviewing the existing Lake System Health Program to identify opportunities to advance and improve both data being collected, and the extent of monitoring being completed. These improvements are intended to ensure that this program continues to provide high-quality data to inform policy from a scientific perspective.
Aquatic plants, algae and blue green algae are a natural part of an aquatic ecosystem and are present in healthy water bodies.	The report does not state otherwise
"Microcystin Exposure from Cyanobacterial Harmful Algal Blooms (cyanoHABs) <u>When cyanobacteria grow out of control</u>,	This is stated in the introduction/literature review of the study
Leonard Lake does <u>not</u> currently experience agricultural run-off.	Runoff can pertain to agricultural runoff or runoff from private properties in forms such as fertiliers, overalnd flow (septic)
Please include in Study whether the Leonard Lake blooms documented by the authorities are "inherently toxic" substances under the Canadian Environmental Protection Act.	This is outside the terms of reference of the study which sought to identify potential factors contributing to algae blooms on Leonard Lake.
Despite the Terms of Reference established for this study, the Request for Proposal, RFP # 20- 810028-02, states: "The consultant(s) will develop a waterbody-wide approach for determining the cause(s) and contributing factors that are impacting water quality for each of Bass, Echo, Leonard, Stewart and Three Mile Lakes as <u>separate</u> <u>but</u> <u>concurrent</u> <u>studies</u>." In Riverstone's November 22, 2022 cover letter accompanying their Study, the Penninsula Lake study is recognized and referenced where Riverstone appears to infer the historical data's integrity is cause to provide precautionary decisions on findings and recommendations.	Issues with data integrity were not implied, Riverstone stated that a lack of longterm data collected at consistent times and locations limited the statistical analysis that could be performed as part of the study. The data selected for inclusion was collected appropriately, and whenver possible we compared the data from multiple sources to further increase the robustness of the factor being considered.
From a mathematical perspective, it would appear fertilizers pose a much greater risk to nutrient loading than properly maintained septic systems. (Please maintain your septic systems.)	We recommend that the residents of Leonard Lake follow the best practices recommended by the Muskoka Watershed Council (https://www.muskokawatershed.org/programs/best-practices-program/)
Please provide rationale for study remaining silent on use of fertilizers and pesticides at Leonard Lake	See comment above. RiverStone suggests residnets follow best practices in terms of wate quality which includes use of fertilizers
Please, don't rake leaves into lake.	Leaves falling into the lake is a natural process that contributes to nearshore organic matter. The additional leaves being raked into the lake can be unsightly, but follow a natural process.

Drinking water threats identified in the Government of Ontario website include: agricultural; fertilizer; pesticide; road salt; de-icing materials; sewage; run-off; storm water; but, Not: boathouses; social values; lot coverage or setbacks	RiverStone has made no comment on social values, lot coverage or setbacks. The District is currently in the process of reviewing the results of the current Causation Studies to determine a path forward that will seek to ensure the long-term recreational water quality of lakes and rivers in Muskoka. This review will include the current terms of reference, scope of work, budgetary requirements, policies, and implementation. Concurrently, District staff are reviewing the existing Lake System Health Program to identify opportunities to advance and improve both data being collected, and the extent of monitoring being completed. These improvements are intended to ensure that this program continues to provide high-quality data to inform policy from a scientific perspective.
"The Clean Water Act ensures communities protect their drinking water supplies through prevention – by developing collaborative, watershed-based source protection plans that are locally driven and based on science."	The scope of this study was to address potential factors that may be contributing to algal blooms on Leonard Lake. Drinking water is a public health concern and outside of the scope of this study.
The Leonard Lake study apparently did not refer to the Township of Muskoka Lakes 2018 septic survey, and has provided no lines of evidence to suggest any systems currently exist on Leonard Lake that require cleaning out effluent filters	RiverStone reviewed the 2018 Septic study and did not find septic systems to be a primary contributing factor to algal blooms in Leonard Lake. Septic maintenance was metntioned in the context of encouraging residents to take whatever actions they can that will encourage improved water quality in Leonard Lake including reducing any additional phosphorous inputs
The Terms of Reference (TOR) explained the scope of study did not include completing a survey of septic systems, but, did not exclude consideration of TML's 2018 Septic Survey for Leonard Lake. The TOR was clear that its scope would not include investigation of overused septic systems, "particularly for rental units that advertise far more occupants than the septic can support…" and, "…It would be challenging for the use of a single cottage and associated septic inputs (if any) to be enough to raise the phosphorus levels enough to impact lake- wide TP concentrations."	See comment above
As the study did not appear to review data on septic systems, it may be inappropriate to make any recommendations on septic systems, since the WoE approach requires a more detailed review of available data, including the Township of Muskoka Lakes' 2018 septic survey results, among other lines of evidence, which the final TOR intentionally dismissed. Evidence of study's fish habitat data, and, detailed analysis of existing natural buffers, was not well documented	Riverstone did review the report. See comment above
Riverstone must therefore amend its recommendations and amend the wording concerning septic systems, where the study concludes: "Ensure the effluent filter on the septic tank is serviced regularly. Have the system pumped out every two to three years, depending on use."	See comment above

Riverstone's reference to best practices found in the Township of Muskoka Lakes (TML) 2022 Official Plan (OP) is premature and prejudicial given this OP has not been approved by the DOM. The science from this study should lead the OP	The District is currently in the process of reviewing the results of the current Causation Studies to determine a path forward that will seek to ensure the long-term recreational water quality of lakes and rivers in Muskoka. This review will include the current terms of reference, scope of work, budgetary requirements, policies, and implementation. Concurrently, District staff are reviewing the existing Lake System Health Program to identify opportunities to advance and improve both data being collected, and the extent of monitoring being completed. These improvements are intended to ensure that this program continues to provide high-quality data to inform policy from a scientific perspective.
"The idea of development and its contribution to lake water quality will be considered as part of the weight of evidence approach to the assignment."37 According to page 6 of Study, the MNRF "classified shoreline development as moderately dense, shoreline residential."	RiverStone did consider shoreline devleopment as part of the study. The shoreline devleopment ahs been classified as moderately dense shoreline residential well ahead of the increased fequency of potential bloom events in Leonard Lake.
On page 22 of the Riverstone study, it is recommended that naturalization of the vegetative buffer for all properties be implemented as set out in TML's 2022 OP, despite the same paragraph confirming overland flow and sewage is not a primary cause for increased bloom events.	See comments above. RiverStone continues to recommend, that where feasible residents implement the recommended best practies of the Watershed Council (https://www.muskokawatershed.org/programs/best-practices-program/) to encourage a healthy aquatic ecosystem.
The study's recommendations are perceived to be motivated by planning policy and not science. The recommendation may not be conforming to the Weight of Evidence (WoE) approach. Please consider, E8.3.3 of TML OP 2022, for Little Long Lake, reads, "Preserving natural shoreline vegetation…", whereas, E8.3.4 of TML OP 2022, for Leonard Lake, reads, "…the Township shall require an agreement to address matters such as… restoration of shoreline vegetation…". The Leonard Lake Stakeholder's Lake Plan calls for a "… 30-metre setback area or vegetation protection zone shall consist of natural, self-sustaining trees, shrubs, and plants."	RiverStone made no recommendations in the context of planning policy, this is the responsibility of the DMM. We recommended the measures that are generally considered to contribute to a healthy aquatic ecosystem.
Under C2.6 of the DOM's LAKE SYSTEM HEALTH C2.6.4.1 CONTEXT "At a minimum, 75% of the linear shoreline frontage of a lot shall be maintained in a natural state to a depth of 15 metres from the shoreline … the buffer should be achieved to the extent feasible. Where the length and depth cannot be met, a net improvement over the existing situation is required."	See previous comments.
If Riverstone had conducted an on-site visit to the entire lake, over water, the Study would recognize numerous properties having bedrock outcroppings along the shoreline, where "vegetative buffers" are not natural or feasible, where, despite property owners' attempts to create indigenous tree growth, the natural soil type and depth will not permit sustained growth	RiverStone did conduct multiple on-site visits over water. The recommendation stated was to encourage residents to follow best practices for water quality which are already in place and to discourage the removal an any existing vegetation wtihin the buffer.
Naturalizing the shoreline is acceptable and practical, where restoration is often best left to Mother Nature, and Father Time. In some cases, man-made shoreline restoration is required to prevent further shoreline erosion caused by adjacent man made run-off ditches and boat waves.	We agree with this statement and defintely encourage naturalization of the shorleine by natural means or active restoration with native species. This functions much beyond water quality alone.

Wording of planning policies must consider principles in the DOM's RFP # 20-810028-02, where it states, "…studies must be uniquely tailored to respond to the situation and context of individual lakes. " One size does not fit all, and naturalization is best left to time, and, is site specific. The DOM's wording in their Official Plan is most reasonable, and should be adopted at TML level. The fact that a 30 metre setback is cited most often does not work case by case.	The District is currently in the process of reviewing the results of the current Causation Studies to determine a path forward that will seek to ensure the long-term recreational water quality of lakes and rivers in Muskoka. This review will include the current terms of reference, scope of work, budgetary requirements, policies, and implementation. Concurrently, District staff are reviewing the existing Lake System Health Program to identify opportunities to advance and improve both data being collected, and the extent of monitoring being completed. These improvements are intended to ensure that this program continues to provide high-quality data to inform policy from a scientific perspective.
RFP# 20-810028-02 makes reference to: "…Current and past DOM initiatives on Leonard Lake include: annual water quality monitoring, benthic monitoring, Love Your Lake shoreline assessments in 2013, shoreline re-naturalization projects in 2014" Please provide site specific details of shoreline re-naturalization project in 2014 in a separate Appendix, and scientific evidence of direct linkage to project's improved water quality.	This is outside the scope of this study.
RFP # 20-810028-02 also called for a "…Review of lessons learned from the Pilot Causation Study on Peninsula Lake and the preliminary work on the Stewart Lake Causation Study	RiverStone reviewed the Pennisula Lake pilot study. Many of the recommendations were geared toward the DMM and how studies are implemented. Where possible, the pilot study was used to inform the work completed for Lenard Lake.
Hutchinson Environmental Sciences Ltd's (HESL's) "Assessment of Municipal Site Evaluation Guidelines for Waterfront Development in Eastern Ontario's Lake Country", dated April 10, 2014, stated: "Lakeshore Capacity Assessments are often required as part of shoreline development applications through Official Plan policies. In the Lakeshore Capacity Assessment Handbook (Province of Ontario 2010), it is recommended that lakeshore capacity assessments should be considered under the following circumstances: When developing or updating official plans; …" It would appear, HESL's Causation Studies for Three Mile Lake and Stewart Lake make reference to a "Lakecap" model, but discounted the reliance on the method partly due to past results of method being questionable for lakes impacted by flow from upstream lakes. Leonard Lake is not impacted by upstream lakes	This is outside the scope of this study.
The District Municipality of Muskoka (DMM) uses their Water Quality Model (MWQM), a variant of MOE's "Lakecap" Model (2010), as one component of the Lake System Health program to guide planning policies for recreational lake development in a large and complex watershed of over 500 lakes and lake segments. The MOECC released their "Lakecap" Model and guidance document in 2010 as their recommended means of Lakeshore Capacity Planning…."	Again, we are not sure how this relates to the results and recommendations of this study. A Lake Cap model was not proposed in the Terms of Reference for this study.

In addition, the emergence and testing of phosphorus abatement technologies for septic systems since 2010 resulted in OMB decisions favoring development beyond the "Lakecap" limits in several cases, such that the potential for OMB challenges, and resultant costs for the DMM, 38 Assessment of Municipal Site Evaluation Guidelines for Waterfront Development in Eastern Ontario's Lake Country, Hutchinson Environmental Sciences Ltd., April 10, 2014 39 Revised Water Quality Model and Lake System Health Program, HESL, Prepared for: District Municipality of Muskoka, Job #: J150074, April 2016 Page 9 of 15 warranted reconsideration of those aspects of "Lake System Health" and District policy that were based on the water quality model. The 2013 draft report was not, therefore finalized, further analysis undertaken and additional discussions held with DMM planning staff…." "…Many of the analyses required for the Causation Studies could be done using existing monitoring data, reviewing some aspects of the Muskoka Water Quality Model or by collecting additional samples through the DMM lake monitoring program. Others would require more detailed investigations. Estimated costs range from $1000 to $10,000 depending on the required complexity."	See previous comments. The District is currently in the process of reviewing the results of the current Causation Studies to determine a path forward that will seek to ensure the long-term recreational water quality of lakes and rivers in Muskoka. This review will include the current terms of reference, scope of work, budgetary requirements, policies, and implementation. Concurrently, District staff are reviewing the existing Lake System Health Program to identify opportunities to advance and improve both data being collected, and the extent of monitoring being completed. These improvements are intended to ensure that this program continues to provide high-quality data to inform policy from a scientific perspective.
The Leonard Lake August 31, 2021 Causation Study – Terms of Reference included: "Determine the extent to which development is causing cyanobacterial blooms including measuring possible point source loadings caused by channeled runoff…", and, "… "…The project does not include the assessment of individual channels or inflowing streams for TP, other than reviewing the relative contributions of the various subwatersheds through the lake capacity model that was previously completed for Leonard Lake…" (emphasis added)	We considered the inflowing tributaries in the context of how much influence they could have on the water quality of the lake. The contributions of the subwatersheds was not determined to be a significant factor. That is, their contribution in terms of flow and concentrations of TP could not posisbly influence whole lake water quality even if the TP concentrations were greatly elevated.
Please include in Appendix, the lake capacity model previously completed for Leonard Lake.	We cannot distribute the model calculations. They can be obtained from the author.
Please include the photographs of algal blooms in Appendix 3, as this information was omitted from Study currently posted at the DOM's website	Photos of algae blooms are included in the appendix. Photos submitted that show residences have been omitted.
Please explain why Riverstone and HESL fail to mention blue-green algae occurs naturally.	This is mentioned in the Introduction/Litterature review where it is explained that blooms occur when natural process of decoupled and algae formation exceeds the capacity of mechanisms such as grazers to exert top down control.
The US Food and Drug Administration (FDA) publishes information on human consumption of cyanobacteria when used as a food supplement.41 The FDA states, "Other types of cyanobacteria, such as Microcystis species, can sometimes grow in the same lake as AFA. These cyanobacteria produce natural toxins called microcystins, which can present health risks."	Health risks of mirocystins are acknowledged in the report, anything beyond this is outside the scope of the report.

Please include in the study the existence or absence of HABs (CyanoHABs) in Leonard Lake by adding an extra column to Table 1 of Riverstone's Report. It is recognized that Riverstone relies on HABs as being ecosystem disrupting. As we have seen no conclusive evidence using this debatable definition, can Riverstone confirm through the authorities' findings the toxin levels were in dangerously high concentrations for human exposure and/or consumption, and such events were excessive, and not small? (Page 18 of Study speaks to this.)	This is addressed in the existing table. It is up to the health unit to determine if there are potential risks to human health which is why a column was inlcuded to indicated whether an advisory was issued.
There does not appear to be any evidence or findings in Riverstone's study to confirm HABs have been documented in Leonard Lake, based on the understanding, using Riverstone's peers, a HAB event occurs when the bloom grows out of control and toxin concentrations pose a risk to humans and animals. To date, no one has reported catastrophic fish mortality from past blooms.	The definition of HAB varies in the literature as does the definition of algae bloom. We used public health advisory as an indication that there was potential for risk to humans and/or animals.
Please provide the concentration (µg/L) of microcystins and other cyanobacterial toxins found in Leonard Lake's recent algal blooms by adding an extra column to Table 1.	The study was to determine potential causes of algal blooms not to evaluate potential toxicity. This is outside the scope of the study.
The List of Figures Section of Study does not appear to include data on the toxicity levels found in algal blooms. Please provide this data as part of the Study, along with evidence to substantiate the extent of the blooms, including, as a minimum, the total square area the bloom occupied as a percentage of total surface area of Leonard Lake, and, the duration of the blooms, including additional monitoring of water quality during a bloom event.	The study was to determine potential causes of algal blooms not to evaluate potential toxicity. This is outside the scope of the study.
Please provide microsystin concentrations from documented blooms using Windsor- Essex County's exposure levels measured at 20 ppb for recreational use, 10 ppb for safe recreational use, 1.5 ppb for drinking water, and .3 ppb for infant drinking water49.	This is outside the scope of this study and it is not appropriate to apply the policies of another region to the DMM. This is the mandate of public health.
Does report clearly show toxic microsystin levels relative to safe drinking water requirements? Does report clearly identify which blooms were HABs, the extent of additional testing, depth and breadth (extent/coverage of bloom – in terms similar to Recreational Carrying Capacity model, where the bloom is measured in size of bloom as a % of the lake's water surface?)	Again, this is outside the scope of a causation study which was to examine factors contributing to the onset of algal blooms.
Please provide the data used by Riverstone to determine the Trophic State Index (TSI) for Leonard Lake when they found the lake was Oligotrophic, and not Mesotrophic or Eutrophic	Leonard Lake was classified as Oligotrophic based on past reports from the lake.

According to a Memorandum dated September 24, 2018, to Ms. Christy Doyle, Director of Watershed Programs. District Municipality of Muskoka, from Mr Neil Hutchinson, Re: Technical Review – Final; "Leonard Lake: Water Quality and Algal Blooms: Status, Monitoring and Management: "Comment #16 p. 20 This section begins with the statement that "Anecdotal reports of increased surface algal blooms in Leonard Lake over the past few years indicated a decline in water quality and a need to continue to monitor the lake and restrict further development". This statement is not substantiated by any evidence that water quality has declined (other than the presence of small algal growths in several nearshore areas of the lake on two occasions) and provides no evidence that development has impaired water quality or that restricting further development is warranted. There is no merit in restricting further development in response to "anecdotal reports" and in the absence of evidence that changes in water quality are a response to shoreline development. OPA 45, as proposed would require a Causation Study to specifically examine the role of shoreline development in a documented algal bloom and would allow for development restrictions if they were warranted.	The District is currently in the process of reviewing the results of the current Causation Studies to determine a path forward that will seek to ensure the long-term recreational water quality of lakes and rivers in Muskoka. This review will include the current terms of reference, scope of work, budgetary requirements, policies, and implementation. Concurrently, District staff are reviewing the existing Lake System Health Program to identify opportunities to advance and improve both data being collected, and the extent of monitoring being completed. These improvements are intended to ensure that this program continues to provide high-quality data to inform policy from a scientific perspective.
The report does not provide anything more than speculation that sewage systems are a problem– the ongoing research of Robertson and colleagues, the attenuating soils at Leonard Lake as well as the lack of observed responses all provide no evidence that domestic septic systems are degrading the water quality in Leonard Lake. Outside of small and localized algal proliferation the report indicates that water quality is excellent. In fact the lake appears to be resilient. It is located in a catchment of soils suitable for attenuation of ~76% of the phosphorus from septic systems (Gartner Lee Ltd. 2005) and incorporation of this attenuation was required in order for the model to generate reasonable estimates of TP concentrations in the lake6. The need for improved stewardship of shorelines was identified in the study but did not result in a recommendation. Stewardship is a component of the existing Lake System Health Program."	The report states that sewage systems are likely not an issue, however, recomends best practices to ensure that they do not become an issue for water quality in Leonard Lake.
In summary, if the septic system meets Ontario Building Code (OBC) specifications, and is properly maintained, don't replace it, and, there is no justification to include in Official Plans additional costly and onerous systems beyond OBC specifications. Page 16 of the Study suggests sewage outflow is not the "issue"	See previous comments.The District is currently in the process of reviewing the results of the current Causation Studies to determine a path forward that will seek to ensure the long-term recreational water quality of lakes and rivers in Muskoka. This review will include the current terms of reference, scope of work, budgetary requirements, policies, and implementation. Concurrently, District staff are reviewing the existing Lake System Health Program to identify opportunities to advance and improve both data being collected, and the extent of monitoring being completed. These improvements are intended to ensure that this program continues to provide high-quality data to inform policy from a scientific perspective.
If it is natural, don't tamper with it, let it go, and it will grow. Please discourage use of fertilizers, and rely on nature to find balance between sun, wind, rain and nutrients.	See previous comments and refer to Watershed Council Best Practices Recommendations https://www.muskokawatershed.org/programs/best-practices-program/

Riverstone's reporting identifies phosphorus as the primary limiting nutrient required for cyanobacteria development, acknowledges more research may help to establish optimal (TN:TP) ratios, but, does not conclude findings for perfect combination of nitrogen and phosphorus required to accelerate growth of cyanobacteria. Under Section 4.2, page 15 of Study, it was determined that phosphorus alone was not sole cause for any increased frequency or intensity for blooms on Leonard Lake. Consequently, unnatural nutrients, such as fertilizers applied "overland", and their direct impact on water quality and ecosystems should not be ignored	See previous comments.
Through the 1960's through 1980's, Leonard Lake's bays all had palpable concentrations of white water lilies (Nymphaea alba), but are currently on the cusp of extinction on the lake.	This is an intersting observation but it is unknown as to whther this is related to the changing TP concentrations or changing climatic conditions, or somehting unrelated. It would need further investigation that is outside the scope of this review.
Page 22 of Study promotes a vegetative buffer for fish habitat and water quality, where Riverstone states, "It is well established that a vegetative buffer is important for fish habitat and water quality." This study's findings seems consistent with other similar studies, appearing somewhat silent on the important role of the littoral zone, and, it would seem the MNRF are more concerned about disturbances to lakebed when it comes to fish habitat and water quality, as is evident from a review of their "Crown Land Work Permits"54 website, and "O. Reg. 239/13: ACTIVITIES ON PUBLIC LANDS AND SHORE LANDS - WORK PERMITS AND EXEMPTIONS under Public Lands Act, R.S.O. 1990, c. P.43."	Alteration to the lakebed and littoral zone is not permitted without underoing a permitting process through either DFO or MNRF (or both) depending on the nature of the work so RiverStone did not make any recommendations in this regard.
Please provide the scientific evidence Riverstone collected from the Leonard Lake study when promoting a vegetative buffer as it relates to fish habitat zones, as these zones were identified during LPAT Case # PL180844, per attached Leonard Lake Fish Habitat Map. The scientific evidence must clearly show a decline in fish habitat in the identified fish habitat zones where a vegetative buffer has been altered from its natural state. RFP # 20810028-02, states: "The study approach must be: …Evidence-based and defensible – ensures results are scientifically robust and can be defended if challenged or reviewed by peers…"	We are very confident in our opinoin that how a riparian area is treated has direct influence on adjacent fish habitat. The science is well established in that regard.
Please provide the scientific evidence Riverstone collected from the Leonard Lake study when promoting a vegetative buffer as it relates to water quality.	See previous comment.
A property owner recently provided TML with evidence from DOM's Geo Hub56 showing a significant number of residences on Leonard Lake that straddle, or fall within a 20 metre setback from the high water mark (HWM). Given HESL's September 24, 2018 memo to DOM, and the study's findings, an objective and pragmatic view would support the notion that "well established" buffers may have no material impact on water quality and cyanoHABs on Leonard Lake.	See previous comment.

Please provide the scientific evidence to refute the above quotes from HESL, where HESL says there is, "no evidence that development has impaired water quality or that restricting further development is warranted…" and reconcile HESL's report to the DOM with Riverstone's promotion of a well established "statement" on "vegetative buffers". Please reconcile HESL's conclusion where it states, " Outside of small and localized algal proliferation the report indicates that water quality is excellent. In fact the lake appears to be resilient." If Riverstone did not gather irrefutable scientific evidence for Leonard Lake on vegetative buffers, and there environmental impact, as it relates to the purpose of this study, then, readers may "buy in" if the authors of study limit their comments to the TOR. Readers may also accept that the MNRF have rules/regulations to protect fish habitat zones on Leonard Lake.	The role of RiverStone was not to gather evidence of the role of vegetative buffers on Leonard Lake. Buffers are recommended as they are generally considered to be one of the tools residents can use to encourage a healthy aquatic ecosystem.
Encourage rehabilitation of fragrant water lilies as they have been pushed out by invasive plants57&58, and the lilies serve to block the sunlight, reduce photosynthesis, and restore past ecosystems. Some Southeastern bays on Leonard Lake appear to be experiencing excessive growth of either the Waterwheel59 plant, Eurasian Water-Milfoil60, but, likely the native Northern water-milfoil61, or invasive Hydrilla62 in shallow protected bays. Whether invasive or native, these aquatic plants appear to have contributed to the reduction in numbers of the fragrant water lilies. Property owners are permitted to remove aquatic plants, within limitations63, and may require permits64. The study may argue aquatic plants impact on water quality, the water cycle, water temperature and evaporation rates were beyond its scope, and considering impacts on the littoral zone, being the lungs65 of our lake, is speculative, anecdotal, and not a primary cause for concern.	RiverStone does not recomend that residents either remove aquatic vegetation (unless they have an permit giving them express permission to do so by the appropriate authority) or try to reintorduce aquatic specis. We also note that aquatic plant growth is a natural process that contribues to habitat for fish, aquatic invertebrates etc and contributes to dissolved oxygen.
If one were to compare Leonard Lake with Lily Lake, despite both lakes suffering declines in water lilies, Lily Lake has sufficient nutrients to sustain these plants, and has not been subject of any documented CyanoHABs. Lily Lake has no shoreline vegetation where it borders part of Highway 118, is exposed to direct runoff from salted highway, and remains a relatively healthy shallow lake for amphibian life. Lily Lake is likely a "eutrophic lake", and is the closest lake to Leonard Lake for additional comparative analysis.	We have not reviewed Lily Lake as part of the causation study on Leonard Lake an it is outside the scope of the study.
Site Plan Alteration and Tree Cutting by-laws may be excessive tools for shoreline preservation	The District is currently in the process of reviewing the results of the current Causation Studies to determine a path forward that will seek to ensure the long-term recreational water quality of lakes and rivers in Muskoka. This review will include the current terms of reference, scope of work, budgetary requirements, policies, and implementation. Concurrently, District staff are reviewing the existing Lake System Health Program to identify opportunities to advance and improve both data being collected, and the extent of monitoring being completed. These improvements are intended to ensure that this program continues to provide high-quality data to inform policy from a scientific perspective.

There was value for money in the Penninsula Lake Causation Study, where subsequent studies were mandated by DOM's OP, and, were necessary exercises for health and safety reasons.	The District is currently in the process of reviewing the results of the current Causation Studies to determine a path forward that will seek to ensure the long-term recreational water quality of lakes and rivers in Muskoka. This review will include the current terms of reference, scope of work, budgetary requirements, policies, and implementation. Concurrently, District staff are reviewing the existing Lake System Health Program to identify opportunities to advance and improve both data being collected, and the extent of monitoring being completed. These improvements are intended to ensure that this program continues to provide high-quality data to inform policy from a scientific perspective.
As with every ecosystem, everything is connected. Algal blooms are a global phenomenon. Individually, we can all do our part to reduce reliance on man-made chemicals in the future. It may be appropriate to simply recommend lake stewards seek "Best Practices" from provincial authorities when disseminating information on septic systems and proper maintenance.	See previous comments. We recommend following the Best Practices Recommendations from the Watershed Council.
Please incorporate wording, consistent with other studies, to encourage the reduction of the "use of fertilizers and other products containing phosphorus".	See previous comments.
Please amend DOM's Official Plan under a) iii) of C2.6.3.2, WATER QUALITY INDICATORS: to read: "A significant cyanoHAB confirmed and documented by the Province and/or Health Unit."	The District is currently in the process of reviewing the results of the current Causation Studies to determine a path forward that will seek to ensure the long-term recreational water quality of lakes and rivers in Muskoka. This review will include the current terms of reference, scope of work, budgetary requirements, policies, and implementation. Concurrently, District staff are reviewing the existing Lake System Health Program to identify opportunities to advance and improve both data being collected, and the extent of monitoring being completed. These improvements are intended to ensure that this program continues to provide high-quality data to inform policy from a scientific perspective.
Please consider attached documents and above recommendations in search of a balanced approach to lake stewardship and ensuring sustainable water quality to "swim, fish, drink".	RiverStone has reviewed the additonal documents provided and they are not inconsistent with our report or recommendations.
Good stewardship must share complete and accurate information, and reduce misinformation	We agree.
We believe our 2022 Leonard Lake Water Study findings will complement the Causation Study for Leonard Lake with the addition of data relevant to the Terms of Reference set out for the lake in 2021.	It is good news that the 2022 finding would compliment our assessmnet. Unfortunately the additional data could not be incorporated.
While we agree that climate change, as manifested by increased periods of calm weather and higher than normal water temperature during the summer and fall bloom season, has been associated with observed blooms in Leonard Lake (2022 Leonard Lake Water Study report, in preparation), we note that Riverstone was not able find credible data pointing to increased water temperatures, nor to reduced wind speeds around Leonard Lake that link to bloom events.	Localized wind data for Leonard Lake was not available and this has been included as a recommendation.

We find it puzzling that the Leonard Lake bloom reports provided to Riverstone by LLSA, were not used. We encourage Riverstone to review the 5 years of Leonard Lake bloom report logs (2017-2021) which contain information on wind, water temperature and associated weather conditions. The measurements are taken as part of standard LL water team bloom protocol and should be acknowledged as 'in place' rather than 'recommended' in Lake Specific Recommendations pg21. We have shown some of this data (2020-2022) in Figure 1., where July to August blooms are associated with higher water temperatures (24-28C). However, October to November blooms occur at much lower temperatures (9-17C).	RiverStone has revewied the bloom reports, and where possible included the informatinon in the report.
The causes of fall blooms at such low temperatures merit further investigation of the climate- weather association with blooms.	Climate change is not simply associated with changes in temperature but can also lead to changes in weather patterns (such as earlier ice out periods, wind speed and frequency of weather events) which can translate to changes in species ranges, assemblages, and changes in ecosystem. Warmer temperatures are associated with more frquent blooms but there are a number of additinal factors that are associated with climate change that may be contributing to algae blooms on Leonard Lake that are not just temperature.
We are puzzled that available data indicating that the ice-in period on Muskoka lakes has decreased by about 2 weeks in recent decades, was not mentioned by Riverstone https://www.muskokacottageexperts.com/muskoka-ice-out-info. Ice cover determines water turnover and mixing: a shorter fall-spring water turnover period means a longer stratification period when the water column in a lake is not mixing, leading to an increase in the potential for anoxia, and the threat of blooms being elevated (Sharma et al 2021, Jane et al 2022).	The idea of the "reduced time of ice cover" contrbuting to the proliferation of algae is valid. Reduced ice cover essentially prolongs the growing season, potenitally allowing species of algae in the lake sediment to bloom, where they could not do so when the growing season was reduced. This is consistant with our conclusions that climate change is a significant driver of algae blooms in the lake.
In summary, while we agree that climate change can play a role in changes in our water quality, including algal blooms, we find that there is insufficient evidence to indicate that Climate Change is the primary contributing factor, (also termed primary driver) for algal blooms in Leonard Lake. Much more review and discussion of evidence that accounts for other stressors and possible causes is required.	RiverStone reveiwed the data made available to us, and examined the factors that (based on previous studies and published peer reviewed areticles in the litterature) has the potential to be contributing to algal blooms on Leonard Lake and have made recomendations for the type of data/studies that would be necessary for a more indepth approach that has the capacity to quantify the interactions of potential factors.
Human impacts, including septic runoff have been clearly shown to increase nutrient loadings (as measured by total phosphorus), and algal blooms in freshwater lakes around the world. For the past 40 years, this relationship has been the basis of lake management in Canada at the Federal, Provincial MOE, and District DMM levels. (Muskoka Official Plan- Lake Health System 2005, 2016). Yet no historical review of research and management on Leonard Lake is included in the draft report	There is no clear trend of incresing phosphorus in Leonard Lake documented by either the MECP or the DMM. We reviewed the septic report conducted in 2018 that indicated that septic systems are not a major area of concern on Leonard Lake.
A key historical document, OWRC (Ontario Water Resources Commission, Report on Water Quality of Leonard Lake, 1971) reports extensive masses of green algae in the South Bay area in Leonard Lake. The OWRC report concludes that the trophic status in the lake is increasing to mesotrophic. These problems were attributed to waterfront cottages and a resort which apparently did not possess adequate septic systems at the time.	Multiple reports published more recently have identified Leonard Lake as Oligotrophic.

Recent reports on Leonard Lake (Watson and Kling 2017, Nurnberg 2017, 2018) previously provided by LLSA to Riverstone, point out the relationship between development and algal blooms. All 3 reports caution that lakefront development must be controlled or stopped if blooms are to be avoided on Leonard Lake. Although the Watson and Nurnberg reports were provided to Riverstone, they do not seem to have been used in the draft report.	The Watson and Kling report was cited in the report. More recent evidence (some from the Muskoka area) suggest lakes witout any development have begun to experience algal blooms. Without an demonstrated increase on phosphorous which is thought to be the primary impact of development on algal blooms there is no justificaiton to comment on development as a causative factor to algal blooms. Particularly, when the LLSA cites that they have evidence of internal loading.
Key points to consider are that Leonard Lake is a small headwater lake, with long water residence time, and extensive residential development around the lake, making it vulnerable to nutrient inputs. The lake has been modelled as “over threshold” for phosphorus, in part because of lakefront development. All 3 reports (referenced above) noted extensive anoxia and possible internal loading of nutrients. Nurnberg (2018) concludes: “Increased anthropogenic usage and development around Leonard Lake should be avoided and best management practices employed in the catchment basin so that the cyanobacterial blooms do not continue and become more frequent. Especially development at such steep sites and low soil cover… can be expected to increase the Lake’s vulnerability”.	This is not consistent with the data we examined or what what internal memos say about lake model on Leonard Lake. We have not seen an actual model and associated data stating it is over development capacity.
It appears that the possible impact of development was simply discarded out of hand in the draft report. We feel more work is needed.	The impact(s) of development were considered but there was no data to indicate that development was the primary cause of the observed algal blooms on Leonard Lake.
In 2022 an extensive search was made to locate all possible intermittent streams and runoff points of any significance around the lake. Twelve runoff points were identified. During late June and the fall (October/November) freshet, these points were sampled, slightly upstream of the water entering the lake. Elevated levels of chlorophyll and total phosphorus were found in all samples, with many samples over 10 times the historic reported TP levels for Leonard Lake. Total Phosphorus appeared to be highest at points of entry into the lake close to bloom sites. Full details of this ongoing work will be presented in the 2022 Leonard Lake Water study report once completed as previously noted. Preliminary results are found in Figure 2. More work on this study is needed, but we believe it indicates that shoreline inputs play a role in bloom occurrence. We suggest that a thorough review of lake front development, runoff, and algal bloom causation on Leonard Lake be undertaken, to fulfill the TOR.	These results were not available for RiverStone to review at the time of this study. The District is currently in the process of reviewing the results of the current Causation Studies to determine a path forward that will seek to ensure the long-term recreational water quality of lakes and rivers in Muskoka. This review will include the current terms of reference, scope of work, budgetary requirements, policies, and implementation. Concurrently, District staff are reviewing the existing Lake System Health Program to identify opportunities to advance and improve both data being collected, and the extent of monitoring being completed. These improvements are intended to ensure that this program continues to provide high-quality data to inform policy from a scientific perspective.
Much of the Literature Review, Lines of Evidence and Weight of Evidence sections of the draft report are not based on evidence from Leonard Lake. Instead, ecological theories and speculation are often presented without supporting evidence or discussion. For example, in the draft Summary of Findings, “… Riverstone additionally suggests that ecosystem interactions including interspecific competition between algal species, changes in available nutrients in the water column associated with changes in species assemblages, and the introduction of invasive species shifting plankton dynamics may also have contributed to the observed changes in water quality by LLSA members.”	Repeated blooms in the same general area are proof of a shift in species assemblages as bloom forming species are outcompeting other algal forms and grazing zooplakton species other do not consume these species or are not able to consume them the rate necessary to prevent blooms from forming.
The draft report fails however to investigate these suggestions with any specific Leonard Lake data or testing with sufficient rigour to warrant placing any weight on these speculations.	Scientific theories are not speculations. All potential causative factors were investigated the extent we were able to given the data available.

We believe additional relevant evidence is available, and should be used, particularly evidence found in the more than 40 documents provided by LLSA to Riverstone	RiverStone reviewed all of the documents provided and used the data that was relevant and/or collected in a consistent fashion.
Of particular importance is the report “Leonard Lake: Water Quality and Algal Blooms” (2017). The authors of this report, Susan Watson and Hedy Kling, are among the most highly respected specialists in Harmful Algal Blooms and Algal Taxonomy in Canada. This report (hereafter referred to as the Watson report) includes an exhaustive review of historical reports and data on Leonard Lake, as well as comprehensive water chemistry and detailed inventories of over 200 algal species, taxon diversity, and abundance, sampled from May to November 2017.	This report was reviewed (and cited where appropriate). An exaustive taxonomic list was not relevant as a causative factor but it did help to guide which factors we considered.
In addition, our forthcoming “2022 Leonard Lake Water Study” builds upon the findings of the Watson report, by following the same methodology and testing locations after 5 years	This report was not available for RiverStone to review and is outside the scope of the report
Both the Watson report and the 2022 Leonard Lake Water Study can provide specific evidence-based findings regarding cyanobacteria algal bloom causation. The following summary from the Watson report (p34) should be considered as being of key importance: “The collective data from 2017 indicate that Leonard Lake has a low-to-moderate level of productivity and a generally robust and diverse algal community, dominated by lipid-rich diatoms and flagellates (representing high quality food for the upper food web) and small celled picocyanobacteria and green algae. However, the water quality data show nutrient levels that periodically exceed those measured by the provincial and regional agencies, who have largely concentrated their efforts on spring samples collected as depth composites”	This is not inconsistent with our findings (our RiverStones sampling data)
Section 3.1.2 Gloeotrichia echinulata. This species is the predominant bloom-forming Cyanobacteria species found in Stewart Lake (Engage Muskoka Causation study), but evidence shows that it does not occur in Leonard Lake	This species was listed one document RiverStone received as occuring in very small amounts. It is not currently responsible for bloom formation on Leonard Lake but was included in case it becomes more important in furture bloom events.
The Riverstone draft report uses this species as a model of a possible species interaction with Dolichospermum lemmermanni , stating “…it does likely exist in the environment and may interact with other bloom-causing species, contributing to harmful bloom events in the future.“ Specific evidence in the Watson report refutes this: Table S-7 on pages 56 and 57 of this report list 45 species of cyanobacteria. Significantly, Gloeotrichia echinulata is not recorded at any of the 12 algal sampling sites around the lake in 2017. a. For interpretation of sites in this table; i.Watson 36 = DMM site 3 ii.Watson NDH = DMM site 1 iii. Watson 2 = DMM site	This species was recorded in very small amoutn sby the MECP. See above.
Therefore section 3.1.2 of the Riverstone draft report is pure speculation and should be removed, or qualified appropriately. Although we agree that species interactions are probable, there is no evidence that species, or ecosystem interactions are causing a “trophic shift”, making the lake more vulnerable to blooms as speculated by Riverstone.	See previous comments.

We are again puzzled by the following statement in the draft report "Changes reported by members of the LLSA such as changes in zooplankton … ". We are not aware of any recent zooplankton studies in Leonard Lake to which this statement might be attributed, however, an aquatic invertebrate study conducted in 2008-2014 across 34 lakes, including Leonard Lake (Watson and Kling 2017, (Table S-4, pg.50)) indicates slightly improving richness and presence of sensitive species (%EOT), but overall, the Hilsenhoff Index indicates significant organic pollution (Hilsenhoff 1987). Therefore, we see no evidence of decline.	Concern for the aquatic ecosystem including zooplankton and fish health by a resident was included in the intial information provided by the DMM. RiverStone was asked to include and consider ideas/statements form residents whenever possible.
The Riverstone draft report contains another puzzling statement in section 6.1: "The MNRF conducted extensive zooplankton surveys from 1981 to 1987 which characterized the plankton community in Leonard Lake. Riverstone did not obtain any data suggesting that this study had been updated since the introduction of the Spiny Water Flea (in 2001) to quantify potential shifts in the pelagic community or since the onset of algal blooms in Leonard Lake in 2017.This existing data could be used as baseline data for purposes of comparison in future studies that may help better characterize the role of plankton abundance, food web dynamics and top-down versus bottom-up impacts and how these are either contributing to or responding to bloom events" We request that Riverstone modify this statement to include the evidence in Table S-4 above indicating that up to 2014, a relatively healthy and stable Zooplankton/Invertebrate community has existed on the lake. We strongly agree that more Zooplankton/Invertebrate studies are warranted, and we hope a recommendation to this effect can be part of the final Riverstone report	There is a difference between benthic invertebrates and zooplankton. We are recomending repeating the zooplankton studies conducted by the MNRF. The studies from 2004-2014 focused on benthic invertebrates so RiverStone cannot comment on the zooplankton community after 1987 as the data to determine this is not available. From a report by Watson and Kling (2017) "Zooplankton were surveyed in the 1980s by the MOECC, which reported a community dominated by species of Daphnia (D. ambigua, D. catawba, D. pulex), Eubosmina tubicen, Leptodaphnia minutus, calanoid copepods and Holopedium glacialis (Table S-3). The invasive spiny waterflea (Bythotrephes longimanus) was first recorded in Leonard Lake in 2001 (MNR 2010); this species has invaded many North American lakes including the Great Lakes where it has had serious impacts on the aquatic foodweb. It is inedible to many natural predators due to its long abdominal barbed spine, and preys on smaller keystone zooplankton (Barbiero and Tuchman 2004). Aquatic **benthic invertebrate surveys between 2004 and 2014** show little evidence of environmental impacts on these organisms; long term data indicate a diverse, stable community composition aligned well with the Muskoka average, with a high species richness and percentage of gatherers/shredders and low fractions of chironomids and predators (DMM 2015 datasheet; Table S-4)"
The Friends of the Muskoka Watershed has described the application of road salt as a serious threat to lake health, and a possible driver of algae blooms (FOTMW, Dec 2022). Yet the Riverstone draft report failed to examine this threat to Leonard Lake.	RiverStone did examine road salt. Chloride concentrations in Leonard Lake are below the levels determined to be potentially harmful.
Long term monitoring of chloride (the harmful component of road salt) in Leonard Lake (Ingram and Patterson 2015), reveals that Chloride levels increased 10 fold in the last 45 years - from 0.5 mg/l in 1978, to more than 5 mg/l since 2003. The chloride level has hovered just above 5 mg/l since then (DMM, Muskoka WaterWeb). Recent studies (Arnott et al 2020) have shown that concentrations as low as 5 mg/l will damage Daphnia and other zooplankton vital to the food web. Thus, Chloride levels may be contributing to algae blooms by weakening the algae predators. We believe that Riverstone must investigate chloride as yet another line of evidence for algal blooms in Leonard Lake.	This is incorrect. Based on data provided by the DMM the chloride level in Leonard lake dropped below 5mg/L in 2012 where it reamined until a brief period in 2017 where it was 5.2mg/L. It dropped below 5mg/L in 2018 where it remained until 2019 which is when the dataset ends.

"periphyton on all substrata is the first community to respond to increased inputs resulting from lake recreational development. The measurement of littoral (lakefront) algal biomass and chemical composition may represent a better tool for early detection of lake perturbation than classic methods based on pelagic characteristics." (Lambert and Catteno 2008). A presentation on this topic at the LLSA 2022 Annual General Meeting, included an informal survey of hands of those who had observed an increase in this type of material over the years on Leonard Lake. Of the 60+ lake residents attending, almost all long-time residents agreed that Benthic Periphyton biomass was increasing in Leonard Lake. This change, based on local knowledge, may be evidence of disturbance, or increased nutrients in the lake caused by lakefront development.	This information was not available to review prior to completing this report.
While the Riverstone draft report concludes that "water chemistry data suggests that consistent water quality has been documented in Leonard Lake for several decades prior to the onset of bloom events that have occurred in recent years", local knowledge-based evidence is pointing in the other direction.	There is a difference in opinioin between the collected scientific data and what local perception notes. It is difficult to reconcile the two opinions, other than to continue to follow both lines and compare.
While no direct evidence for internal loading of nutrients in pelagic areas was provided in the Riverstone draft report (Riverstone did not report nutrient levels from their September October and November 2021 sampling), we do have earlier reports (Ingram and Patterson 2015, and the Watson Report, 2017) which confirm seasonal late summer/fall anoxia.	RiverStone does not dispute that internal loading and seasonal anoxia are occuring and this is consistent with our sampling results.
While anoxia increases vulnerability of a lake to blooms, Nurnberg (2017) points out that while anoxia has been found in approximately half of Muskoka lakes, internal loading has been found in only a few.	Yes, both internal loading and anoxia can increase the vulnerability of lakes to algae blooms
An important paper for consideration by Dr Lewis Molot and colleagues (2014) hypothesised 2 sources of bloom formation: "...akinete germination and activation of overwintering vegetative cells in oxic sediments is light and temperature-dependent, and they need nutrients to support population growth (p 1324)." "…it is the availability of ferrous iron that regulates the ability of CB to compete with eukaryotic competitors" (p1323). "…ferrous iron diffusing from anoxic sediments is a major source of iron for CB, which acquire it by migrating downwards into ferrous rich anoxic waters...subsequent siderophore production provides a supply of ferric iron for reduction at CB cell membranes..." (p1323). "...Internal loading of ferrous iron appears to precede bloom formation by about 2 weeks" (p1331) "Hypolimnetic aeration has had some success in mitigating CB blooms..." (p 1335) Molot's theory is consistent with the results of combined evidence on Leonard Lake and merits further testing on Leonard Lake.	The District is currently in the process of reviewing the results of the current Causation Studies to determine a path forward that will seek to ensure the long-term recreational water quality of lakes and rivers in Muskoka. This review will include the current terms of reference, scope of work, budgetary requirements, policies, and implementation. Concurrently, District staff are reviewing the existing Lake System Health Program to identify opportunities to advance and improve both data being collected, and the extent of monitoring being completed. These improvements are intended to ensure that this program continues to provide high-quality data to inform policy from a scientific perspective.

As stated earlier, the Watson report (2017) is an excellent resource for further studies. The Watson report makes several important conclusions pp 33-34, particularly: “The seasonal and spatially-resolved phytoplankton data represent a vital resource against which future change can be assessed”. The Riverstone draft report apparently failed to make any use of this resource. “A continued assessment of water quality and particularly, inshore and internal nutrient loading.” This recommendation forms the basis of LLSA Leonard Lake testing (2017-2022), but was not discussed in the Riverstone draft report. Several additional useful recommendations were made in the Watson report (pp33-34), yet most of these were apparently neither reviewed nor addressed in the Riverstone draft report. It is therefore recommended that the Riverstone authors update their draft report based on the evidence presented and discussed in the Watson report.	RiverStone reviewed the Watson report (and cited it where appropriate in the causation study report). See previous commnets.
Although the Riverstone draft report (p6) describes water column and chemistry sampling at the DMM sites 1 and 2 in September, October and November 2021, there is no presentation of the TP data or discussion about the results of this sampling. Recently (Dec 20, 2022,) we were kindly provided the following information from DMM (Cassie Emms, personal communication) “RiverStone advised that unfortunately, the labels for the September and October Station 1 and 2 samples that were submitted to the lab do not match the labels they received in return, so RiverStone is not comfortable with releasing this TP data. RiverStone did however confirm that the TP data ranges from 6.21 ug/L to 26.91 ug/L in September, and 4.88 ug/L to 21.7 ug/L in October. This data range is similar to the values obtained by the District. The data collected in November is: -Station 1 Surface: 7.2 ug/L, 7.19 ug/L -Station 1 Bottom: 6.83 ug/L, 6.98 ug/L -Station 2 Surface: 7.11 ug/L, 6.01 ug/L -Station 2 Bottom: 6.89, ug/L 9.39 ug/L	The DMM only has a single sampling site (site 3). RiverStone sampled two sites that were identified as station 1 and station 2.
In 2021, when District staff were conducting their regular sampling at Site 3, the bloom was occurring (Late August- see fig 1 above). So, District staff sampled the site of the bloom (composite sample from surface to secchi depth which was 3.6 m), and bottom samples were collected using a VanDorn (horizontal sampler) at station 2 and Site 3. This additional District sampling was for the purpose of the causation study only. Data is as follows: -Bloom: 4.49 ug/L, 4.59 ug/L -Site 3 (District usual site): 11.3 ug/L, 12.7 ug/L -Station 2: 21.2 ug/L, 21.4 ug/L	The second site sampled by the distrcit was not station 2 but a second sampling site that was roughly where the bloom was thought to have been occuring.
We believe this additional data is extremely important for 2 reasons: a)for the first time these data confirm that internal nutrient loading is occurring at the bottom at site 2 (south Bay, Figure 5). This was a key recommendation of the Watson report in 2017. b)the wide range of TP values (4.88ug/l to 26.91ug/l) reveal a wider variability in TP levels than previously acknowledged in DMM or LPP reports	It is important to note that 26.1ug/L was a only present during a single sampling event just after the bloom occurred and returned to the values that would be expected in Leonard Lake during subsequent sampling events.

Our 2022 sampling has revealed clear evidence of internal nutrient loading (significant levels of ferrous iron and dissolved phosphorus) at the south bay site (DMM site 2), as well as indications of loading at both the NDH (DMM Site 1) and Mid-lake sites (DMM site 3) (2022 Leonard Lake Water Study report - in preparation.) The LLSA water team documented internal loading of ferrous iron in mid September; the blooms that occurred at several areas along the western shoreline began October 6, and persisted for several weeks. Ferrous iron release from anoxic sediments in late summer is possibly more vital to CB bloom formation than sporadic increases in phosphorus Therefore, we urge that the Riverstone report be redrafted to include at least the DMM 2021 results and include a full examination and discussion of internal nutrient loading evidence in Leonard Lake, as a factor in bloom causation.	This data was not avilable for RiverStone to review prior to the prepration of the causation report.
. Levels of phycocyanin, the telltale pigment found in Cyanobacteria, and chlorophyll, the pigment in all photosynthetic algae including cyanobacteria, can be easily measured in a previously frozen and thawed water sample by using inexpensive benchtop fluorimetry (FluoroQuik, Amiscience Corporation, Fremont CA). Since 2019, the Algae sub-committee of the Muskoka Watershed Council has been testing and refining this methodology in several Muskoka Lakes, including Leonard Lake. LLSA volunteers have used this method extensively to assess where blooms might develop, how long they persist, and how long signs of the bloom remain after it has disappeared. This data was passed to DMM/Riverstone by LLSA, yet no mention or consideration of the use of this data appears in the Riverstone draft report.	We focused on blooms that were confirmed by the MECP.
Molot’s 2014 paper (see #33) also discusses the role of nearshore loading, cyanobacteria migration, and deep water loading of nutrients in bloom formation. Pg 1330 states: “However, coastal regions and lakes have shallow sediments located along the sides of their basins and, hence, internally loaded Fe^{2+} in inshore regions with anoxic surficial sediments could be accessible when mixing conditions permit.” Our 2022 Leonard Lake Water Study report (in preparation), has found elevated levels of reduced iron associated with anoxia and internal loading of phosphorus in Leonard Lake. We find it puzzling Riverstone did not consider this paper or consider sampling for reduced iron. The Molot paper seems to provide a possible explanation for the blooms in Leonard Lake.	RiverStone was not able to sample for iron during our site visits. The Molot et al. (2014) paper states that "When light and temperature are physiologically suitable for bloom growth that bloom onset is regulated by the internal loading of Fe^{2+}". This indicates that iron alone cannot provide an explanation for the increased frequency of bloom events on Leonard Lake. Changes in both light and temperature are linked to climate change as we have discussed. Furthermore, in the "Research challenges and knowledge gaps" section the authors outline that the minimum extracellular Fe^{2+} concentrations to establish cyanobacterial dominance are unknown. Migration rates and maximum migration distances are also unknown under a range of mixing conditions and frequencies. While this is an interesting stud,y assiging causation based on this work is premature. The study suggests that at best, iron is one of many factors that may contribute to algae blooms. RiverStone would have tested the significance of the interatction of factors such as iron, temperture, light etc. using statistical tests if the data was available.

The Riverstone draft report repeatedly states that inappropriate sampling has been a problem in making sense of the data. The 2017 Watson report recommended better coordination between agencies with respect to sampling sites, sampling protocols, sampling frequency, sampling duration, analytes tested, and labs used. Leadership and a cooperative effort on the part of agencies and levels of government would be required to realize this goal. We have investigated sampling locations in historical reports since 1971 and compiled a database of all recent sampling coordinates. These include: a.the Ontario Water Resources Commission, 1971, b.the Lake Partner Program since the 1980s, c.the DMM 3 sites and d.the Muskoka Watershed Council algal program sites 2020-22 (Full table of all sites with coordinates is available upon request). In choosing appropriate locations for deep water sampling sites, a bathymetric map is needed. The Bathymetric map for Leonard Lake (Figure 4) reveals 4 internal basins. The map of our present deep site locations (Figure 5) reveals that the LLSA sites are coincident with both the 1971 OWRC sites as well as the DMM sites 1, 2, and 3. Anchored buoys were placed in the 3 basins in 2019. The 4 deep sites chosen for the 2017 study were nearly identical to the 3 DMM sites, as well as the site near the outlet, while the QL sites were those where residents had reported water issues in 2017 (See map Watson report pg. 44). The methodology followed was specified by each agency. The 2017 protocol was described in the Watson report, and repeated in 2022. Thus, we believe a good information base of our testing sites is available. We find the assertion that data should be ignored because of site location irregularities to be without basis and would like to have this matter settled	The DMM only samples at a single site called site 3. They do not (nor have they ever) sampled at multiple sites. RiverStone did not state that the data was unseable, we stated that the time frames and sample designs are not such that we can perform parametric statistical tests that would allow us to quantify the significance of changes in parameters across time and also the importance of interactions beween various parameters. Additonally, the LLSA data (and sometimes the LPP data) while following the correct smapling protocal often broke up sampling sites across more than one date adding an uncessary level of background variaiton in the sample that will reduce the power and efficacy of statistial tests. RiverStone completed the analyses were were able to given the data (timescle) and methods available to us. Recomendations for a palelimnological study that would provide longer timelines and could be collected from multipel locations would allow for the type of analysis that we would have preformed had we had access to the necessary data.

	The reluctance, or caution is maybe a bette word, to use citizen science is based in a couple of areas. The collection of data often requires decisions to be made in the field on how protocols are applied. If these decisions are made without the scientific background, the data can be compromised, creating large issues of data interpretation. This has happend with us previously working wiht a lake association who collected water samples and used wine corks to seal the colelction tubes. This lead to skewed data and investigations into the cause. The second thought is that the best data is that which is collected consistantly in time space and methodology. When changes happen, which you can see in the Leonard Lake data, it again introduces uncertainty in the data. We do not think that citizen science data is not useful, on the contrary, consistant and accurate data collected by lake association can be very useful, when applying the principals of good data colelction. The District is currently in the process of reviewing the results of the current Causation Studies to determine a path forward that will seek to ensure the long-term recreational water quality of lakes and rivers in Muskoka. This review will include the current terms of reference, scope of work, budgetary requirements, policies, and implementation. Concurrently, District staff are reviewing the existing Lake System Health Program to identify opportunities to advance and improve both data being collected, and the extent of monitoring being completed. These improvements are intended to ensure that this program continues to provide high-quality data to inform policy from a scientific perspective.
The methodology followed was specified by each agency. The 2017 protocol was described in the Watson report, and repeated in 2022. Thus, we believe a good information base of our testing sites is available.	This statement is incorrect. Discussing trends is appropriate given the data available. Parametric statistical tests (which were not performed in any of the causation studies or the pilot study) would have allowed us to measure the relative importnace of each factor and determine if the interaction of parameters were contributing to blooms. As a general high level study, trends were the most appropriat decision given the data available. Recomendations are included that would allow for more detailed and nunanced analyses in the future.
We find the assertion that data should be ignored because of site location irregularities to be without basis and would like to have this matter settled	This is how things are stated in scientific reports.
Did not see this recommendation at the end of the report. Who is performing the recommended work and who is funidng it? (In response to statement that RiverStone has included recommendations for sampling moving forward).	RiverStone recommended that the citizen science program continue as part of the LPP but that the DMM works with the LLSA to devleop the best strategies in terms of sampling sites, fequencey and measures taken.
"No evidence of change in nutirents of dissovled oxygen prior to the onset of frequent bloom events" Need to qualify this statement to the one deep water sampling site that is used by the MOECP and DMM	Data source is acknowledged as being from the DMM sampling site.
"paticularly duringht summer months of 2017, in the souterhn basin, but water chemistry data suggests that consistent water quality has been documented in Leonard Lake for several decades" What sampling lcoation and data is this referring too?	MECP and DMM data provided.
"were likely triggered by climatic conditions" Triggered maybe but caused by climate change?	Yes, triggering of necessary factors to result in a bloom indicates that one of the causative factors is climate.

"suggest that biotic factors may also be an important component in the causation of algal blooms in Leonard Lake" This is theoretical and not supported by data presented	It is reasonable given the literature, supported by the fact that algae is growing at a rate where grazers are not able to contain it.
"based on an extensive literature review" RS is basing their causation theories on a literature review and not evidence or fact. IF this is occuring further work needs to be done to confirm these theories.	RiverStone used the literature review to identifiy potential causative factors an then examined the data available to evaluate these factors for Leonard Lake.
"Finally, the physical strucure of the southern areas of Leonard Lake make those areas more susceptible to bloom events due to past "priming of the water column" by bloom causing species, shallow waters that are easily stratified and high levels of stagnation in these areas due to reduced fetch and consequently wind and wave action which is not able to mix the water to disperse or restore nutrients" Has the physical structure of te sourthern basin been studied in this report? Where is the physical structure detial referenced in the report?	RiverStone was on site and examined the area. Additonally, it can been seen on maps that there are small island in the southern and mid western area of the lake and the open water area is not as wide in the southern versus northern areas of the lake indicating that fetch will be reduced because of landmass.
"Riverstone incorporated these data into the report wherever possible" Specifically, where has the LL data been used?	Occurrence of bloom events and species present.
"The MNRF reported that the invasive Spiny Water flea was introduced in 2001" Curios. Did the MNRF report how did this happen?	They did not report how the introduction occurred, only that there is a record of this species.
"Further research is needed to fully understand the interactions of plankton dynamics and invasive species on ecosystem health and bloom formation, particularly in oligotrophic lakes that have begun to experience bloom events" Is this a recomendaiton? If yes, it shojld be clearly stated at the end of the report.	This is ment to contextualize our results. As the understanding of how these factors interact increasese the recommendations for how best to address algal blooms on Leonard Lake may also change.
"Which was initially throught to be associated with the icnreased occurrence of algal blooms"Who thought this? WA this from commenct submitted by steakholders? Context here would help.	This was included in the communicaiton and information provided from the LLSA by the DMM. RiverStone was asked to consider the ideas/theories of residents whenver possible.
"communicaition with a residnet of Leonard ake suggested that perhaps some of the change in clarity has occurred due to recovery in Leonard Lake from the impacts of acid rain" Same as above. Riverstone did not have dirct contact with satekholders so how did this communicaiton with a resident occcur and why i sthis significant enough to include in the report? It is a single data point.	This was included in the communicaiton and information provided from the LLSA by the DMM. RiverStone was asked to consider the ideas/theories of residents whenver possible.
"Generally, high levels of phosphorous alone are not sufficient to trigger the formation of algae blooms" This is not consistent with and is contrary to the District water quality model and triggers.Is there a recommendation that the model should be reviewed and updated given this statement?	High levels of phorporous are one fo the "risk factors" associated with algal blooms and should continue to be monitored. However, there are some lakes with relatively low levels of phorphorous that are still experiencing algal blooms which suggests that addtional factors may need to be considered and monitored moving forward.

"While six years of data is not enough to perform any meaningful statistical analyses to determine inf the decrease in TP is significant across time" Is sampling just form 1 location sufficient to determine if TP across the lake is decreasing? Other data form this study and the LLSA suggests tha tTP varies significantly across the lake and at different times of the year"	Sampling from one locaiton following spring turnover when the lake has mixed has shown a strong relationship in the litterature to be representative of lake wide phosporous levels. Additional sampling locations would be helpful at other points duirng the year.
"do not suggest a link with the increasing occurrence of algal blooms" As stated above, if the Station 1 locaton is not representative of the lake as a whole and where the blooms are corruing, this atemetn cannot be made.	Globally, alagal blooms have been shown to be increasing on lakes where the phoprours has not increased significantly suggesting that the issues is not wheahter Sation 1 is representative but that potentially multiple factos (phosphorous along with others) may be contributing to algal blooms.
"This suggests that there is not a distinct upwatd trend in phosporous in Leonard Lake across time" The overarching premise that Station 1 TP results and other associated water characeristics is representative of the lake as a whole has not been proven with data, nor has any work/analysis been done related to the potential impacts of TP from internal loading. This statement is incomplete and misleading.	This statement is based on DMM and MECP data and is true based on the data available. Collecting water in the centreal deeper locations of the two basins is meant to approximate conditions across the lake. Historically, sampling the deep water poriton of a lake during spring-turnover was meant to provide a whole lake context for TP. I believe there is some belief that this may not be as representative as once thought, which also has reprecusions in regard to the lake capacity model. In the meantime, if there is to be any interpretation of the lake water quality we reviewed the data form the stations where data was collected.
"There are no long-term trends reported for nitrogen concentrations on Leonard Lake (1980-2014, Ingram and Paterson 2015) and there appears to be large interannual variation" Same concern as above. It the sampling data from Station 1 representative of the lake as a whole? Actual data says no.	RiverStone made use of the data available to us in order to complete the report. Recommendations have been made for future studies that will allow more in depth statistical analysis in the future.
"It is unclear whether the differences in calcium trends reported are attributd to methodologies or differences in the interpretation of the results." This should be very easy to clarify. You should be able to rule out methodologies as an issue with a sample inquirey. If there is conflicting data from various sources, more investigation should occur to clarify.	It is unclear where the LLS A got the calcium value of 1.7 referenced in communicaiton as it is not consistent with the values in the calcium datasets RiverStone was provided.
"changes to the abiotic environment" Has this occurred? If not, then statement should be qualitfied that no such trend in LL has been confirmed.	Yes, changes in weather events, temperature (as evidenced by the ice out comment suggetion that light has changed).
"The upward trend in alkalinity data suggests that sewage outfllows are likely not an issue contributing to water quality in Leonard Lake" This assumes Station 1 results are representative of the whole lake. This has not been validated.	This has been further validated by the septic inspection that occurred on Leonard Lake suggesting that only 10 residences had minor issues to be resolved.
"Most of the algal blooms reported by the LLSA occur in the southern region of the lake and helath advisories have been issued in both the southeast and southwest areas of the lake." Since most blooms are occuring the the southern basin and western shore area, it is critical to confirm if historical test results from station 1 are representative of the southern basin.	The DMM only samples one station referred to as station 3. The spring values following turnover have been demonstrated in the litearture to be a good measure of lake wide TP.

"it is likely that the southern area of the lake does not experience the same wind and wave action, and therefore mixing, as other areas of Leonard Lake" This confirms at least partially that southern basin is different from the main body of water where station 1 is located.	Yes, in terms of wind and wave action and the capacity for stagnation, more sheltered areas of the lake will be at higher risk for bloom events.
These factors include changes in climatic factors (temperature primarily) associatd with climate change, among others such as changes in patters of precipitation and weather patterns, climate invludenced changes in species range and abundance and interactions among and within species assemblages" No discussion on anoxia or itnernal P loading as documented/discussed in the Watson and Nurnberg reports. Why?	This has been previously proposed for this lake and we did not have the data to further investigate.
"Site specific conditions in this area of the lake may also be contributing to the occurrence and/or persistance of bloom events." If this is the case, water quality and chemistry results from Station 1 cannot be extrapolated to the whole lake and the various trends documented in this reprot can only apply to hte main body of water.	See previous commnets about DMM Station 3.
"This can impact trophic interactions and alter the composition of food webs" yes, but this has not been proven only theorized. This is being stated as fact.	The shift in algale species present is evidence of shifting trophic interactions as are bloom events as they represnet a decoupling of top down control (grazing) on alagle. Whether this is due to shift in species that the zooplankton do not consume or a reduction in zooplaknton is unknown.
"For many if not most lakes, consistent long-term monitoring data is not available. Where lake monitoring programs do exist, data has rarely been collected consistently for longer than a few years". Is this also a reference to LL? If yes, many earlier statements related to long-term trends in TP, PH, C, N etc. would have to be qualified as a result of this statement. Or take it out. Is there a corresponding recomendation for better data?	Where longterm data is available RiverStone has examined and and made the level of statement that the data can support. However there are other factors we would have like to have examined where there is not local longterm data. Recomendations include continuing with sampling program to increase the dataset available and paleolim. studies to answer questions that cannot be addressed with the current dataset.
Nothing in the entire repot on anoxia. RS talks about every other possible factor. With the Watson/Nurenberg reprots you would have thoughg anoxia would habe been addressed. Why not?	Anoxia and internal loading are consistent with the samples RiverStone collected and the potential for internal loading as a mechnism of bloom formation is well covered in the literature review as a potentially contributing factor.
"The information does provide insight inot trends; however, a more robust analysis would have been useful in weighing realtive importance of both individual variable an interations between factors" Given this statement, what agency/stakeholder data was used to inform this report given the stated concerns about data variability?	Primarily data from the MECP and the DMM. LPP data was used where possible and the LLSA data on the occurrence of potential algal blooms along with the reports from Hedy Kling were also referenced.
"reducing the number of sites (a combination of nearshore and deep water would be ideal)" Why reduce the number of sites? Are more sites not better than fewer as long as the methods, locations and measures collected consistent? Also the district is not references as a partner in this endeaveor? Why not?	The recommendation is to simplify sites and invest more in sampling each site consistently (all sites on the lake in a single day not split over multiple days) to reduce unnecessary background variability that reduces the efficacy fo statistical tests.
It would be helpful if the recomedations were clearly listed by numbers or bullet point. This way they are clear and can be easily tracked.	Recomendaitons have been formatted with bullet points.

Our 2022 sampling has revealed clear evidence of internal nutrient loading (significant levels of ferrous iron and dissolved phosphorus) at the south bay site (DMM site 2), as well as indications of loading at both the NDH (DMM Site 1) and Mid-lakes sites (DMM site 3) (2022 Leonard Lake Water Study report - in preparation).	This data was not available for RiverStone to evaluate in time for the preparation of this report.
15.For the past 5 years, a Bloom Alert protocol known as “Eyes on the Lake” has been followed on Leonard Lake. This has resulted in both heightened awareness about lake health issues (not just blooms) by residents, but also has produced a good data base with the location, weather and water conditions, taxonomy, bloom photos, duration, and associated pigments around each bloom event. This data base has been provided to Riverstone - we are puzzled why more use was not made of this data in order to better understand these blooms	This was reviewed, the bloom phoots are included in the appendix (as long as they do not reveal exact location of the bloom) and bloom events and species present were incorporated into the report. Weather data taken only at the time of the bloom in not particularly useful without baseline data collected in the same manner to compare it to.
16.An error on page 5 of the Riverstone draft report needs correction: “Previous blooms were also identified along the southeast shoreline in November of 2020”. The November 2020 bloom was found on the western shore parallel to Leonard Lake Road 2, close to all other blooms. (see map of bloom locations Figure 3). Simcoe Muskoka District Unit was advised of the error at the time and on November 11, 2020 SMDU issued a revised notice entitled “Residents and visitors to the mid-western side of LEONARD LAKE, Township of Muskoka Lakes are being cautioned about a confirmed blue-green algae bloom”.	This has been corrected.
We note that Table 1 of the Riverstone draft report, lists algal species that are, in fact, genera.	They were referred to as genus sp. In order to refer to a group of species within a genus.
17.Our algal taxonomist, Hedy Kling (Algal Taxonomy and Ecology Inc.), has confirmed the differences between D. lemmermanni, the predominant species in all Leonard Lake blooms, and D planktonicum, which was found as an associated species in one bloom, as well as in the pelagic water column samples (2022 Leonard Lake Water Study, in preparation).	RiverStone addressed species within Dolichospermum, but focued primarily on causative factors that could promote algal blooms in general.
We note that there are physiological, adaptation, genetic, and morphological differences in these two species, which may be important in species interaction, discussed later in this document. In addition, the right-hand column of Table 1 in the draft Riverstone report titled “species”, should list both the genus and the species names. It is suggested that Riverstone make this correction for clarity	RiverSotne did not have the data or budget to investigate species interactions as a mechanism contributing to bloom formation. It is an intereting. We limited the list in table one to Genus sp. as way of indicating when there are multiple species documented.

“They are not the same organism. D. planktonicum has different shaped cells (oval to round) colony formation is straight filaments and placement/ shape of heterocysts and Akinetes within the filaments when present are separate while in D. Lemmermanni cells are elongate more or less sausage shaped. The akinetes then develop on either side of the heterocyst and filaments are coiling and looping. They have been cultured and sequenced and are distinct species. One that could resemble D planktonicum if it becomes a straight filament is D crassum which is usually spiraling and has larger cells. Also sequenced and is a distinct species. D lemmermanni usually appears before any of the others as it likes cooler water. But they often appear together in lakes by mid to late summer. (Hedy Kling, Dec 13, 2022) This distinction is also important as we attempt to link algal species’ interactions between littoral (shoreline) areas where blooms occur and deep water pelagic anoxic sites, where internal nutrient loading is occurring (2022 Leonard Lake Water Study report - in preparation).	The 2022 report was not available for review priror to the completion of this report.
We believe one of the limitations of the Riverstone draft report is the failure to acknowledge that limited data (sampling at only one spot, at one depth, once a year) cannot be construed to be representative of the entire lake throughout the entire season. Throughout the draft report, using such highly limited data has in our view produced unsupportable conclusions or conclusions that are based on weak or speculative evidence. Sampling at multiple deep sites as well as several shoreline locations, at various depths (including Deep Chlorophyll Maxima), from May until November has revealed numerous important differences and variations that should not be ignored in favour of the very limited “one spot, one depth, once per year” type of data	RiverStone made use of the data available to us in order to complete the report. Recommendations have been made for future studies that will allow more in depth statistical analysis in the future.
The stewardship of Leonard Lake water is the responsibility of all Leonard Lake residents and property owners and is treated as such by LLSA. There are two references to observed changes reported by “LLSA members” in the Riverstone draft summary that for accuracy purposes should be edited to read “by Leonard Lake residents.” Water quality is a stewardship challenge for all lake residents and the survey itself was open to all lake residents.	This change has been made in the report.
I would like to firstly thank all those involved in the causation study for their hard work and time to review and put forth this report. In addition I would like to thank Mr. Bill Tryon for the work on his submission that he kindly forwarded for our review and comments, and state that we the LLCA support his submission. It is our hope that only scientifically based and supported data be used throughout this process. It appears conclusive that the number one contributing factor to blooms on Leonard Lake Is “Climate Change”. Turin Robinson also stated there is no direct evidence that new development contributes to Blue Green Algae blooms. Moving forward I don’t believe Leonard Lake should be identified as a vulnerable lake using the current wording within the District Op or the scientific data available. Thanks again for all the work put forth and the information provided to the owners of Leonard Lake.	The District is currently in the process of reviewing the results of the current Causation Studies to determine a path forward that will seek to ensure the long-term recreational water quality of lakes and rivers in Muskoka. This review will include the current terms of reference, scope of work, budgetary requirements, policies, and implementation. Concurrently, District staff are reviewing the existing Lake System Health Program to identify opportunities to advance and improve both data being collected, and the extent of monitoring being completed. These improvements are intended to ensure that this program continues to provide high-quality data to inform policy from a scientific perspective.