Comments Paper on the Riverstone Draft Leonard Lake Causation Study

prepared by

Leonard Lake Stakeholders Association - Water Testing Team

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INTRODUCTION:

We would like to express our appreciation to the District Municipality of Muskoka (DMM) for funding, implementing, and coordinating the Leonard Lake Causation Study, and to Riverstone Environmental Solutions Inc. (Riverstone) for undertaking and preparing the draft study report. We strongly endorse the purpose of Causation Studies as described in the DMM introduction to the Peninsula Lake Study on the Engage Muskoka website:

"*As outlined in the MOP, when a lake is listed as vulnerable, a waterbody-wide causation study should be initiated to determine the causes and relative contributing factors which lead to the identified water quality indicator, as well as to produce recommendations and mitigative actions that can be taken by stakeholders, the District, and others to ensure water quality may be enhanced in the long-term."*

The Leonard Lake Stakeholders Association (LLSA) Board and the members of the Leonard Lake water testing team led by Dr. Ken Riley (water team) have carefully reviewed the Riverstone draft report with the end goal of supporting the District and Riverstone in the finalization of a practical and relevant report that will enlighten stakeholders and lead to the best possible management practices and sound policy decisions. Gaps and omissions are discussed along with supplemental data and research findings that we suggest should be included.

Concurrently, we are preparing a detailed report on the findings of our 2017 through 2022 LLSA supported water sampling program, aimed at elevating our evidence-based understanding of bloom causation and possible mitigation measures for our lake. Some preliminary data from the 2022 project has been included in the notes to follow where deemed pertinent.

The 2022 Leonard Lake Water Study report, expected to be finalized and distributed in April 2023, will include:

1) Water column chemistry and algal taxonomy at 4 deep locations in the lake, in close proximity to the sites1, 2 and 3 as used by DMM,
2) Investigation of past and present shoreline blooms using taxonomy, site description, total phosphorus, and bloom pigments (phycocyanin and chlorophyll), and
3) Locating and testing pigments and nutrients at 12 intermittent shoreline runoff points into Leonard Lake, which were identified earlier this year.

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.

RIVERSTONE DRAFT REPORT SUMMARY:

Riverstone concluded the draft report summary as follows:

“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 members of the LLSA 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 LLSA members. Finally, the physical structure of the southern areas of Leonard Lake makes 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.”

COMMENTS:

Limited Data

1. 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.

Context

2. 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.

Climate Change

3. 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.
4. 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).
5. The causes of fall blooms at such low temperatures merit further investigation of the climate-weather association with blooms.
6. 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 March 2022 presentation *“Climate Change as a Stress Multiplier Governing Algal Blooms in Oligotrophic Lakes” (Hutchinson and Yan, March 2022)* proposes that *“if the lakes warm up earlier and the ice comes off earlier, your stratification is going to set up earlier..” (Science and Informed Speculation Manuscript in Preparation).*

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.

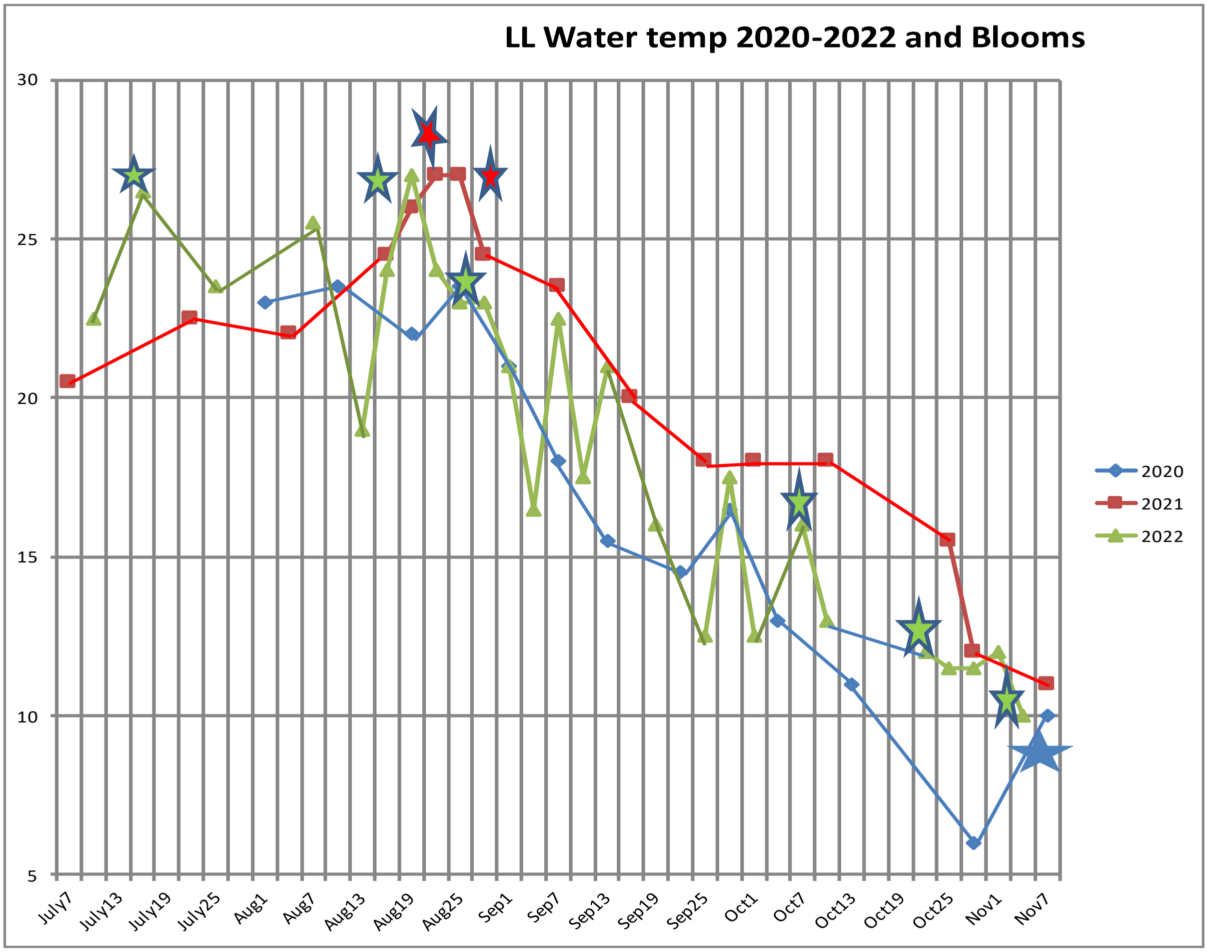

Figure 1. Leonard Lake water temperature (Centigrade degrees) and Bloom occurrence (stars), illustrating the very different water temperatures between summer and fall bloom occurrences.

Development

The agreed Riverstone-prepared Terms of Reference (TOR) for this study (posted on the Engage Muskoka Website) state in part: "*Determine the extent to which development is causing cyanobacterial blooms including measuring possible point source loadings caused by channeled runoff*".

7. We find that the Riverstone report has largely failed to address this TOR.
8. 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.
9. 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.
10. The only statement we could find related to development in the Riverstone report is in section 4.2.1.2 – *Alkalinity and pH*, which states "*The upward trend in the alkalinity data suggests that sewage outflows are likely not an issue contributing to water quality in Leonard Lake".* We consider this statement misleading and untrue. Septic system outflow can be either acidic, basic, or neutral in pH. Long-term monitoring (1975-2014) on Leonard Lake (Ingram and Paterson 2015) explain that improved control of sulphur dioxide in acid rain during this 40 year monitoring period can explain the observed rise in pH (and concurrently, alkalinity), resulting in decreased sulphates in our water, which have fallen from 7.5 to 3mg/L. Alkalinity rises along with pH, and the deposition of carbonates either internally or from runoff into the lake. (Schindler 1988). Thus, sewage outflows are unlikely to have any bearing on these observed changes, and this statement should be removed.
11. 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.
12. 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"*.
13. On page 9(5) of the draft report, Riverstone notes that "Previous work by HESL (2016) suggested that Leonard Lake should be classified as a lake requiring normal protection

from further lot development”. Further, HESL noted at the time that Leonard Lake would be unlikely to experience a Blue Green Algae bloom, and had no evidence of anoxia. Time has proven this outlook to be deeply flawed and we do not believe references to HESL’s historical commentary on Leonard Lake to be at all useful at this juncture. The comment should be removed.

It appears that the possible impact of development was simply discarded out of hand in the draft report. We feel more work is needed.

Assessment of Runoff into Leonard Lake

14. 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.

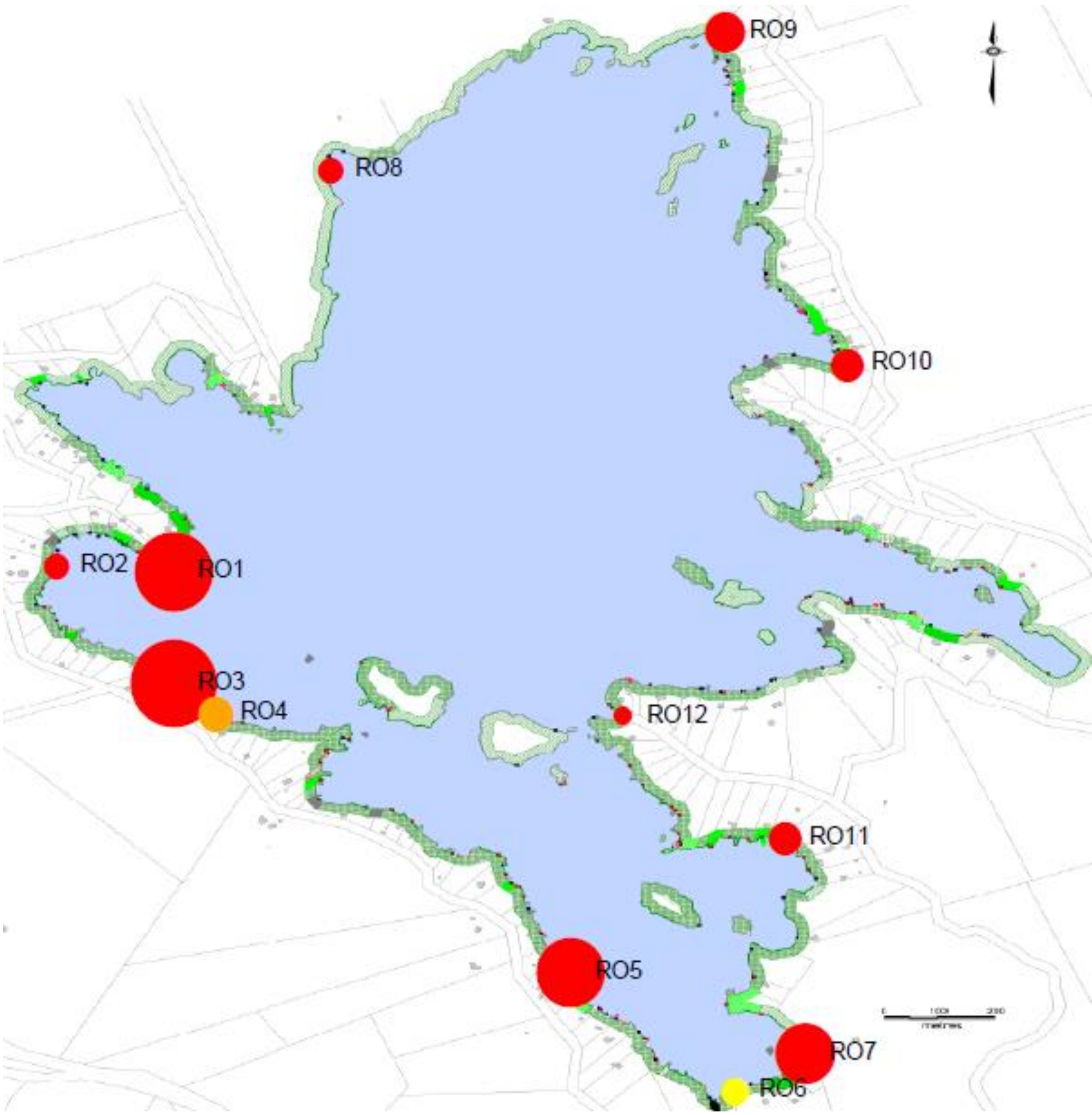

Figure 2. Runoff into Leonard Lake. November 2022. Circles show 12 intermittent runoff points around the entire lake. These were sampled 1-5m upstream from shore line on the same day during fall freshet. Circle size indicates TP (mean of duplicate samples): largest > 50ug/l, smallest <10 ug/l. Circle colour indicates estimated flow; red highest flow rate: orange, moderate flow; yellow, low flow.

Bloom Reports

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.
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”.

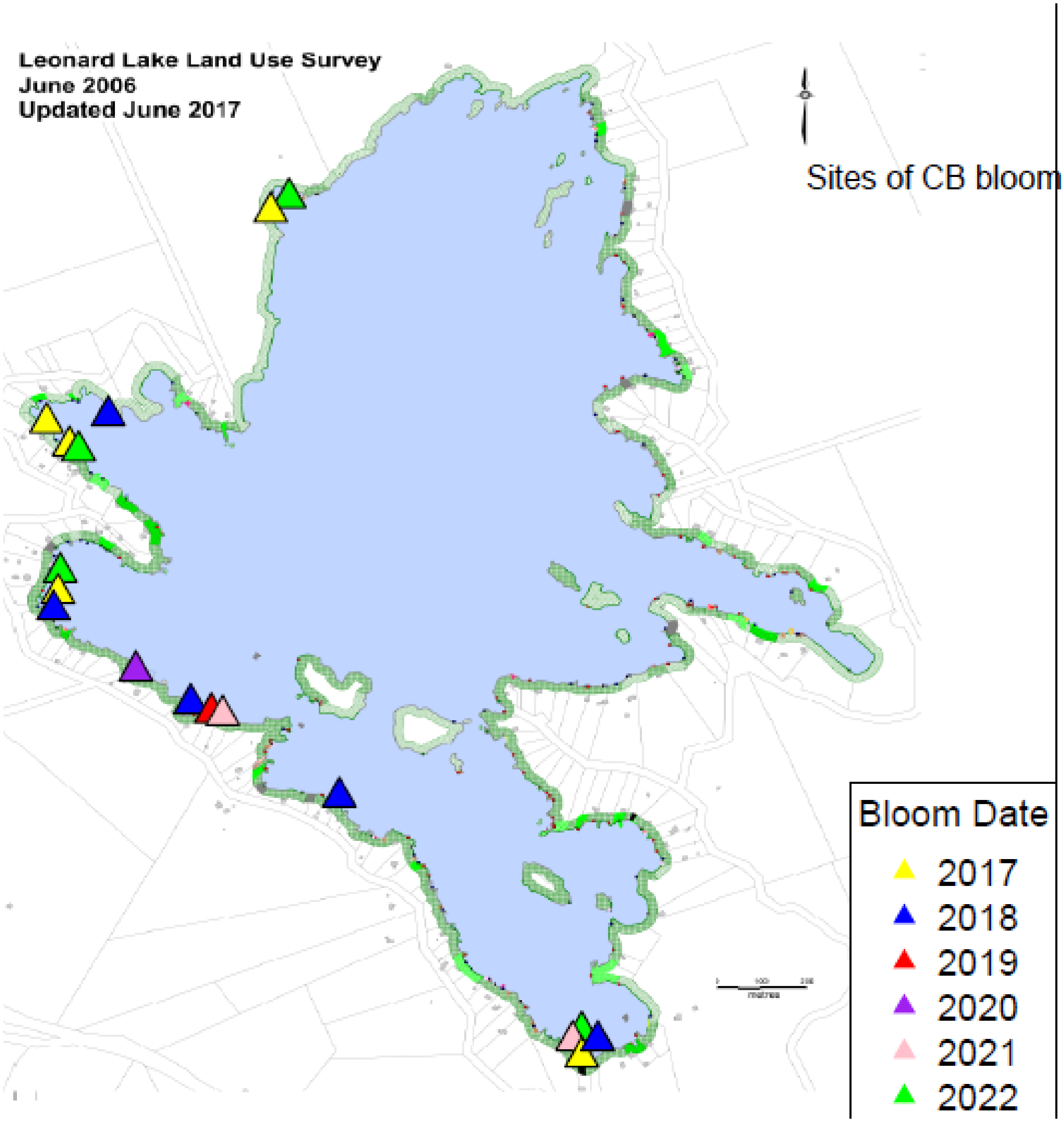

Figure 3. Locations of Cyanobacteria Blooms on Leonard Lake 2017-2022. Most reported blooms are along the western shoreline stretching to south and northern shores.

Dolichospermum Species Taxonomy

We note that Table 1 of the Riverstone draft report, lists algal species that are, in fact, genera.

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).
18. 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.

The following comments relate to the above noted points:

"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).

Ecosystem Interactions

19. 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*."

    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.

20. 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.
21. 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.
22. 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.
23. 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”*

Species Interactions

Section 3.1.2 *Gloeotrichia echinulata*.

24. 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.
25. 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 2
26. 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.

Zooplankton and Invertebrate studies

27. 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.

Table S-4: Aquatic Invertebrate Surveys, Leonard Lake Site 1*

	2005	2006	2010	2011	2014	Leonard L. avg.	Muskoka avg **
Richness	14	16	14	14	19	15.17	14
%EOT	22	17	20	25	29	22.83	22
% Chironomids	12	11	9	16	15	13.67	12
% Predators	23	27	21	29	30	25.33	23
% Shredders	3	3	3	4	8	4.5	3
% Collectors / Gatherers	70	60	69	66	58	65.33	70
Hilsenhoff Index***	6.10	5.68	5.98	6.09	5.87	5.95	6.0

*Reference site

** 147 samples from 76 reference sites (2004-2011) from 9 mesotrophic and 26 oligotrophic lakes

***indicative of organic pollution: low score indicate good water quality

28. 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.

Chloride Changes – Road Salt Impacts

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.

29. 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.

Benthic Periphyton

These are a complex mixture made up mainly of algae, bacteria, and detritus, attached to rocks and other substrata in nearshore areas. They play important roles in food web dynamics in freshwater lakes. Importantly,

30. "*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.

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.

Two Sources for Blooms?

31. 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.

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.

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).

More evidence on internal loading provided by DMM is found later in this document.

32. 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.

Failure to Utilize the Watson Report

33. 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.

Discovery of Internal Nutrient Loading and the Failure to Report it

34. 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…"*

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*

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.

35. 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.

Failure to Consider Fluorometric Methods

36. 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.

Failure to Consider the Role of Reduced Iron and Nearshore Loadings and Recruitment in Bloom Causation

37. 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.

Sampling Locations, Methodology and Timing

38. 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.

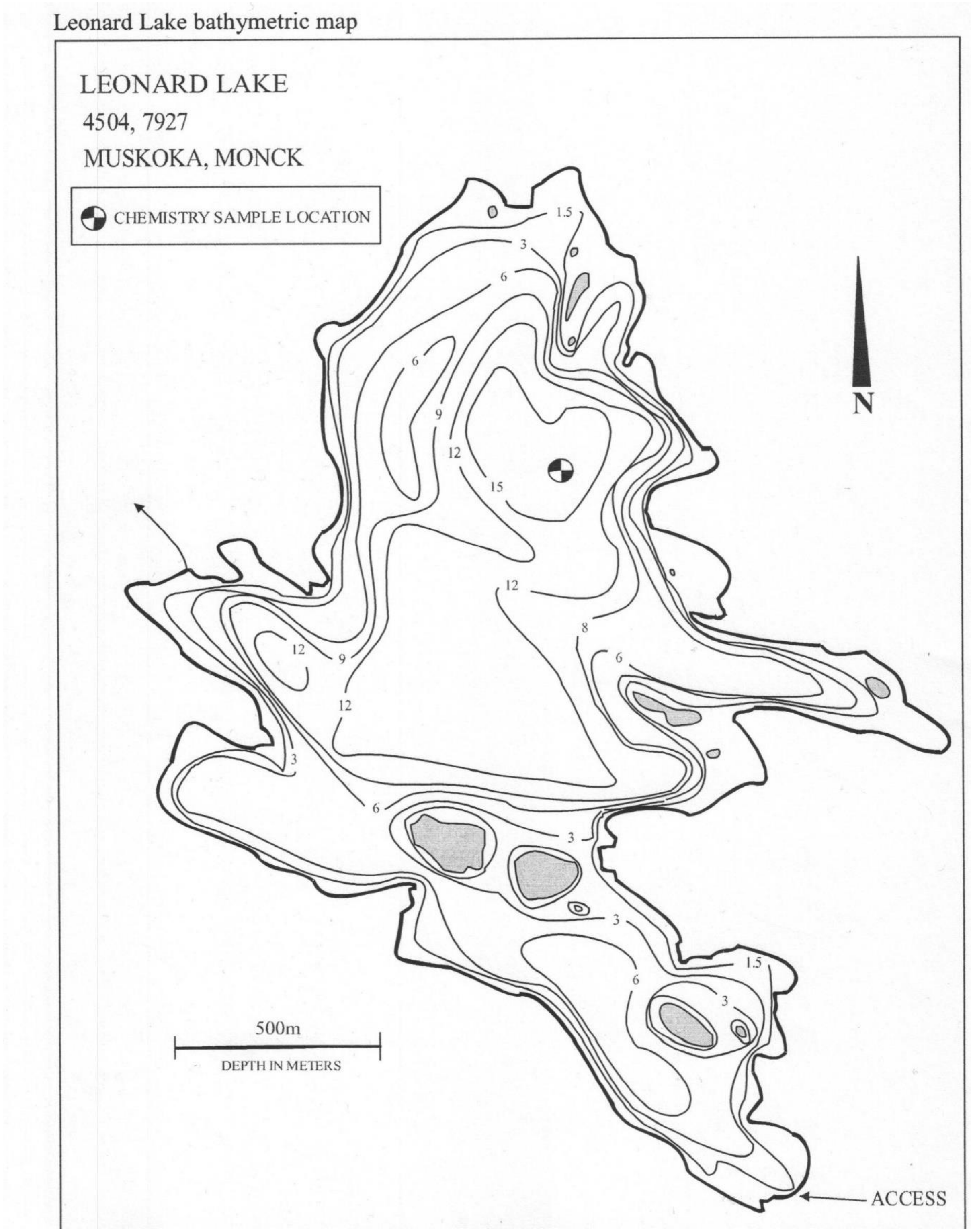

Figure 4. Bathymetric Map used to choose consistent deep water sites in Leonard Lake since 1971. Chemistry sample location 1979 - 2014. See Figure 5 for other deep water and shoreline site locations.

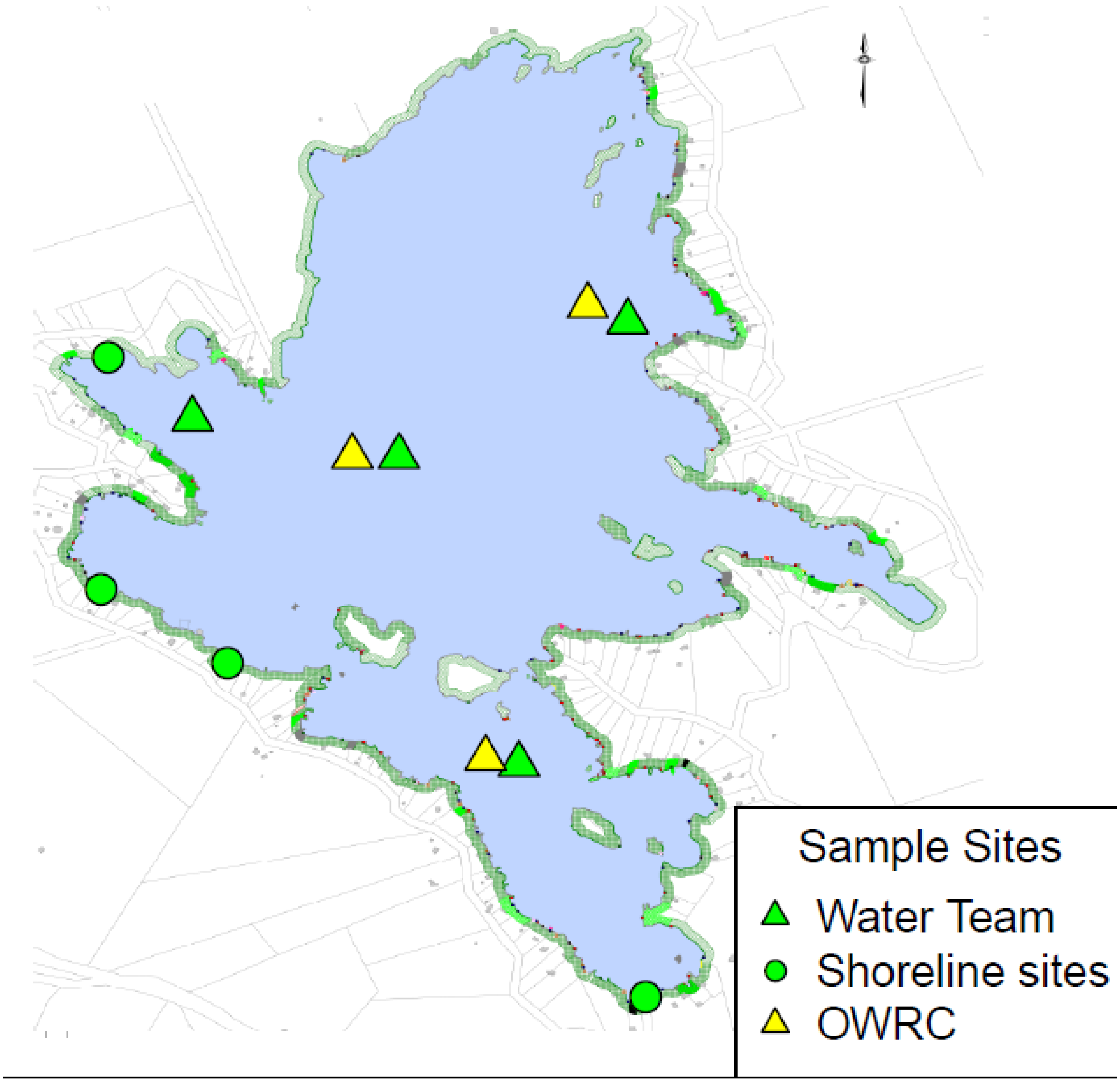

Figure 5. Leonard Lake locations used by LLSA (2017-2022), and OWRC (1971). Note that DMM testing locations (site 1, site 2, and site 3) (not shown) very closely match those of OWRC and LLSA.

Closing Comments and Next Steps

The Riverstone Causation Study for Leonard Lake offers interesting ecological theories and speculation concerning climate change, food web dynamics, water column priming, and trophic shifts, which we agree can potentially have an impact on algal blooms.

However, the report fails to use Leonard Lake based evidence to back up these theories. In addition, it appears that relevant papers by leading experts were not used to take a more comprehensive approach to related lines of evidence, and that certain reports prepared for Leonard Lake by experts in their fields were not considered by Riverstone.

Further, we feel the Terms of Reference have not been fully addressed, as noted in our comments. Of particular interest is to have "*recommendations and mitigative actions that can be taken by stakeholders, the district, and others to ensure water quality may be enhanced in the long-term*" as mandated in the Engage Muskoka material.

Accordingly, we feel the conclusions drawn in the draft Riverstone report cannot be properly supported and are incomplete at this time. If this draft is to achieve the stated terms of reference and the stated purpose of the causation study, it must be extensively updated. Further detailed study of the lake is required to obtain the necessary data to prove or disprove the various causation theories presented by Riverstone.

We realize that Riverstone was required to work within the study's financial budget and this cannot be overlooked in the context of the work effort undertaken. The District has a responsibility to consider the financial commitment required to allow their consultant to fully explore a given matter, which in this case was not sufficient in our view. A pre-determined fixed financial budget will necessarily impact the extent of work that can be undertaken. Given that water resources are perhaps the most important resource within the District, we would ask the District to look carefully at this issue and consider modifying its approach to the financial commitment made for these causation studies.

We area also cognizant that Riverstone may have been constrained in some fashion by the stated terms of reference. It seems with all the draft reports on the various causation studies completed to date, the consultants have referenced "lack of data" as being a major challenge. Further there seems to be a reluctance to use citizen science collected data, and lake association-initiated study data. Against this backdrop, the various government bodies that are charged with collecting data are collecting minimal data that has appears to have minimal relevance to what is a complex and changing area of study. We would encourage the District to look carefully at the TOR and consider how they could be changed to allow for more flexibility in what data is used.

With respect to financial challenges for small lake associations, 6.2 of the Riverstone draft report recommends that the Leonard Lake water team expand the type of testing currently undertaken by volunteers and funded by property owners. The expansion of algal related testing would be welcomed, but it is unrealistic to expect that residents will be financially responsible for the expanded work. In terms of mitigative actions, small amounts of funding assistance to lake associations for additional and perhaps innovative algal related water testing would be recommended.

In terms of next steps, we believe an open and constructive discussion is needed between the DMM, Riverstone, LLSA, and concerned lake residents. The purpose of the discussion would be to summarize and agree on what additional work can and should be done to examine all the lines of evidence and provide the best possible set of findings on causation, and to develop a solid set of recommendations for mitigation.

We would reiterate that LLSA wants to continue to work with Riverstone and the DMM cooperatively on this important project. Further, LLSA will continue to put significant resources available into the lake health mandate, just as we have demonstrated our commitment to do so thus far.

The content of a cover letter from the Leonard Lake Stakeholders Association dated January 10, 2023 should be read in conjunction with our comments in this report.

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