Report on Phase 1 of the Lake Eugenia Water Quality Analysis

Dear Friends of Lake Eugenia patron:

Thank you for your interest and financial contribution to the Lake Eugenia Water quality study.

Hutchinson Environmental Sciences, Ltd. (HESL), was hired to assess the water quality of the lake. The study was funded largely through generous donations from lake and surrounding area residents.

Attached is a copy of HESL's completed Water Quality Analysis report.

Overall, from a chemical analysis perspective, the quality of the water in the lake is **quite good**. This is promising news! However, the concentrations of three chemicals, **Phosphorus, Chloride, and Nitrate** are above normal levels for a lake like Lake Eugenia.

Although elevated, nitrates and chlorides are relatively insignificant when dealing with overall health of the lake. Chlorides may be a discernable problem in 50 years and could easily be addressed by moving away from road salt in the winter. Nitrates tend to source to fertilizers and agricultural run-off, but these can be managed if we get the third chemical, phosphorus, under control.

Phosphorus in the lake promotes algae growth. Under present conditions, this algae growth (**Blue-green algae**) will continue to happen and force lake closures every summer. These closures are becoming increasingly common and are occurring earlier in the year. Closures limit recreational use of the lake and long-term could affect property value in the community. It needs to be addressed.

Simply put, to remedy the problems with toxic blue-green algae in Lake Eugenia, the focus needs to be on removing/controlling the level of **phosphorus** in the lake. These concerns are summarized in the next few pages and detailed in depth, within the HESL report.

Lake Eugenia is an important body of water for Grey Highlands and the surrounding area. We all benefit from a healthy and vibrant lake.

Friends of Lake Eugenia welcomes feedback on this report. We plan to share this information with all administrative bodies in the area and we look forward to continuing local resident involvement in dealing with Lake Eugenia's Phosphorus challenge.

Thank you,

Doug and Morgan
Friends of Lake Eugenia

The Report - Details
The overall report consists of 3 parts:

1. Full analysis and recommendations from Hutchinson Environmental Sciences, Ltd. (HESL), executed study from summer 2022.
2. One example of a phosphorus remediation execution involving Chesley Lake, a lake near Chesley, Ontario. It's smaller than Lake Eugenia, but this lake experienced and dealt with a similar phosphorus challenge.
3. A proposal from Hutchinson Environmental Sciences, Ltd., for a potential Phase 2 of the study. This second phase could help focus longer term solutions for dealing with phosphorus in Lake Eugenia.

Friends of Lake Eugenia will be sharing this information with all administrative bodies, including Grey Sauble Conservation Authority, The Municipality of Grey Highlands, Ontario Hydro, and the Ontario Ministry of Environment, Conservation and Parks.

These findings will also be shared with Lake Eugenia Property Owner's Association and the town residents of Eugenia in keeping with the overall philosophy of transparency and sharing.

Key Report Takeaways:

1. **According to HESL, the primary issue facing Lake Eugenia is algal growth (especially Blue-Green Algae) due to the amount of PHOSPHORUS in the lake/lakebed.**

Lake Eugenia is said to be "phosphorus limited"; meaning of all the available chemicals in the water, the more phosphorus available to aquatic plants and algae, the more these plants and algae will grow. Therefore, **manage this phosphorus concentration and you manage the algae.**

In HESL's report, phosphorus concentration was the only measure which was at/near Provincial Water Quality Objectives (PWQO's) for "a high level of protection against aesthetic deterioration". This is further explained in the report.

Factors which impact the phosphorus concentration in the lake include:

a. Phosphorus which already exists in the lake through history.
b. Phosphorus which enters the lake from fertilizer run-off.
c. Phosphorus from atmospheric deposition.
d. Phosphorus which enters the lake from sewage run-off.

2. **Nitrate and Chloride concentrations in the lake have both risen** when comparing studies conducted in 2022 with historical studies from the 1970's. Many of the other key chemical measures remain largely unchanged**.**

a. **Nitrate** concentration increases appear to be due at least in part to agricultural run-off and atmospheric deposition.
b. **Chloride** concentration increases appear to be due to lake salinization from road salt.

As mentioned above, while remedying Nitrate and Chloride levels are beneficial, their impact on the growth of algae in Lake Eugenia is less critical to the overall health of the lake than Phosphorus levels.

These results are detailed in the HESL report.

What does all this mean?

While phosphorus levels remain as they currently are, under the right climatic conditions, the lake will continue to have algae blooms with potential closures happening every summer.

According to HESL, there are several ways to affect phosphorus levels in the lake:

1. Addition of a phosphorus-binding agent that prevents the release of phosphorus from the lakebed sediments.
2. Physically removing the sediment from the lake bottom (Hypolimnetic withdrawal).
3. Oxygenation or aeration of lakebed to prevent the development of anoxia (absence of oxygen). Aeration prevents the release of phosphorus within the lakebed. (Real life example is highlighted in the attached **Chesley Lake Study – Part 2 of this report**).

Each of these potential solutions has limitations due to cost, permanence, implementation timing, etc., and each would require capital resources to execute. **Part 3 of this report,** a proposal from HESL for Phase 2 of the study is designed to determine which of the above solutions would be most cost effective.

Next Steps:

1. **Share study findings with area residents/donors; Educate on the science of algae growth and containment.**
    a. **Plan resident event with HESL scientists / Q&A on Lake quality**
2. **Develop presentation for administrative bodies to address phosphorus challenge and highlight potential solutions.**
    a. **Deliver this presentation in a targeted manner by end of Spring to all parties that may be able to assist.**
3. **Develop communication plans to ensure awareness of Lake Eugenia's phosphorus challenge.**
    a. **Answer questions/gain buy-in on Phase 2 of study.**
    b. **Start fund raising for Phase 2**
4. **Commence Phase 2 of lake study by May 1st, 2023.**

Hutchinson

Environmental Sciences Ltd.

Scoped Lake Eugenia Management Study

Prepared for: The Friends of Lake Eugenia
Job #: J220049

January 17, 2023

Final Report

Signatures

Report Prepared by:

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Executive Summary

Lake Eugenia was created in 1915 for hydroelectric generation. Many residents on the lake are concerned that water quality has deteriorated in Lake Eugenia, resulting in nuisance aquatic plant and algae growth. Hutchinson Environmental Sciences Ltd. (HESL) was retained by The Friends of Lake Eugenia, a not-for-profit organization dedicated to improving Lake Eugenia water quality, to complete a Scoped Lake Management Study. The Study included:

- a comprehensive background review of existing data (Section 2)
- a field investigation in the summer of 2022 to characterize water quality conditions (Section 2.2)
- reporting of
  - water quality and phytoplankton results (Section 2)
  - a gap analysis (Section 3)
  - management recommendations (Section 4.1)
  - recommendations for future monitoring (Section 4.2)

Most aspects of the water quality of Lake Eugenia do not appear to have changed appreciably since the 1970s although nitrate and chloride concentrations have increased. Of significant concern is water clarity and algal blooms, notably blue-green algal blooms which contain toxins and can be harmful to pets and humans. Biotactic (2018) noted that a blue-green algal bloom (*Microcystis spp.*) was observed to persist from mid-September to early-October in 2018. A recent bloom (26 July 2022) was sampled by the Ministry of Environment, Conservation and Parks and was found to be toxic and dominated by the species *Microcystis aeruginosa* (a common bloom-forming cyanobacterium). The sample had a microcystin concentration of 36.7 µg/L, greater than Health Canada's guidelines for drinking water (1.5 µg/L) and primary contact recreation (10 µg/L). Reid et al. (2019) noted that changing climate is expected to continue and is anticipated to exacerbate emerging threats to water quality including harmful algal blooms (Huisman et al. 2018). Recent blue-green algal blooms and the anticipated impacts of climate change indicate that algal bloom prevention should be the primary factor guiding the management of Lake Eugenia.

Aquatic plants and algae appear to be constrained by phosphorus availability (i.e. the lake is "phosphorus limited"). Internal loading likely contributes to the increase in total phosphorus concentration (~2 µg/L) observed between the lake's approximate inlet and its outlet; however, septic systems, atmospheric deposition, and runoff from shoreline properties are other potential contributors of phosphorus.

Active lake management is likely required to reduce internal phosphorus loading and the abundance of algal bloom formation. Several techniques can be used to reduce internal phosphorus loading: 1) oxygenation or aeration of the lakebed to prevent the development of anoxia and release of phosphorus from sediments, 2) addition of a phosphorus-binding agent that prevents the release of phosphorus from sediments (e.g., alum or Phoslock©), and 3) hypolimnetic withdrawal methods designed to remove internally loaded phosphorus from bottom waters. HESL recommends that additional data on water column stratification, dissolved oxygen, internal nutrient loading, and phytoplankton be collected (as described in Section 4.2) prior to pursuing any active in-lake methods for the management of sediment phosphorus release in Lake Eugenia.

Septic reinspection programs are commonly completed to identify substandard systems and provide an educational tool for shoreline owners that encourages maintenance or replacement of septic systems due to the potential impacts to water quality. Though phosphorus loading from septic systems is not likely to be as high as traditionally believed, it may still constitute a sizeable nutrient load to Lake Eugenia. Waterfront residents should be educated about septic system issues and an inspection program should be instituted to enforce necessary changes. The Municipality of Grey Highlands should also develop a Bylaw designed to ensure pump-out frequency and maintenance of all septic systems.

Shoreline buffers are a well-studied mitigation measure associated with waterfront development that mitigate the impacts of stormwater via enhanced filtration, infiltration, and attenuation. Vegetative buffers can also mitigate social density by screening the view of the shoreline from the lake, providing a buffer for view and noise between lots, and providing more of a wilderness aesthetic. It is therefore recommended that an educational program be developed to encourage the establishment of natural shoreline vegetative buffers and the Municipality of Grey Highlands develop policies and enforcement mechanisms to encourage the development of naturally vegetated shoreline buffers at waterfront lots on Lake Eugenia with reasonable provisions for allowing water access and views.

HESL did not observe extremely high densities of macrophytes during our August 2022 field survey. It is our recommendation that aquatic plant removal should be restricted to those areas where they threaten or impair water use (e.g. beaches), and, where removal is deemed necessary, hand pulling should be used and plant fragments should be controlled to minimize further dispersal. Pulling should be completed after July 15th (outside of the spring spawning period for resident fish species) so that sensitive life stages of fish are protected.

It is recommended that the status quo monitoring of Lake Eugenia (conducted via the Lake Partner Program and by the Grey Sauble Conservation Authority) be supplemented with more targeted investigations aimed at better understanding nutrient cycling, phytoplankton blooms, and macrophytes in the lake to inform the selection of in-lake management methods. The current monitoring of Lake Eugenia does not provide the information needed to fully understand the mechanisms underlying harmful cyanobacterial bloom formation, nor does it provide any information on the macrophyte community.

HESL recommends that the following actions be taken to improve Lake Eugenia water quality:

- Supplement status quo monitoring of Lake Eugenia with:
    - Targeted investigations to better identify the mechanisms underlying cyanobacteria formation and inform the development of a remedial action plan that identifies management strategies to control algal growth and improve water quality.
    - Citizen-science led algal bloom monitoring to record the onset, extent, and severity of cyanobacterial blooms for comparison against other environmental data to help characterize the conditions contributing to blooms.
- Educate waterfront residents about septic system issues, institute an inspection program to enforce necessary changes, and develop a Municipal bylaw designed to ensure pump-out frequency and maintenance of all septic systems.
- Educate waterfront residents and encourage the establishment of natural shoreline vegetative buffers. Develop Municipal policies and enforcement mechanisms to encourage the development

of naturally vegetated shoreline buffers at waterfront lots on Lake Eugenia with reasonable provisions for allowing water access and views.

- Develop a Municipal salt management plan to map vulnerable areas, identify and implement Best Management Practices such as optimizing the use of road salts, using alternatives to road salts and locating snow disposal sites outside of vulnerable areas.

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Acronyms

Ca – Calcium

CCME – Canadian Council of Ministers of the Environment

Chl-a – Chlorophyll-a

Cl – Chloride

DO – Dissolved Oxygen

GSCA – Grey Sauble Conservation Authority

HESL – Hutchinson Environmental Sciences Limited

LEPOA – Lake Eugenia Property Owners Association

LPP – Lake Partner Program

MNRF – Ministry of Natural Resources and Forestry

N – Nitrogen

OPG – Ontario Power Generation

MOE – Ministry of Environment

PWQMN – Provincial Water Quality Monitoring Network

PWQO – Provincial Water Quality Objective

TKN – Total Kjeldahl Nitrogen

TP – Total Phosphorus

TSS – Total Suspended Solids

ZSD – Secchi Depth

1. Introduction

Lake Eugenia (44.33°, -80.50°) is a naturalized reservoir located near Flesherton, Ontario, approximately 25-km south of Thornbury. The lake is approximately 700 ha in area[1] and shallow, with a mean depth of 1.5 m and a maximum depth of 13.3 m (Ministry of Natural Resources and Forestry [MNRF] 2022a). Lake Eugenia was created in 1915 for hydroelectric generation. Many residents on the lake are concerned that water quality has deteriorated in Lake Eugenia, resulting in nuisance aquatic plant and algae growth. Hutchinson Environmental Sciences Ltd. (HESL) was retained by The Friends of Lake Eugenia, a not-for profit dedicated to improving Lake Eugenia water quality, to complete a Scoped Lake Management Study. The Study included:

- a comprehensive background review of existing data (Section 2)
- a field investigation in the summer of 2022 to characterize water quality conditions (Section 2.2),
- and reporting of
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    - a gap analysis (Section 3)
    - management recommendations (Section 4.1)
    - recommendations for future monitoring (Section 4.2)

2. Water Quality Characterization

2.1 Review of Existing Data

Water quality data for Lake Eugenia were compiled from the following sources:

- Bobbette, R. and Bobbette, S. 1976. Preliminary Natural History of Lake Eugenia. Volume II of V: Chapter I. Lake Eugenia – A Preliminary Lake and Watershed Study.

- Butler, B. 1976. Water Quality Evaluation. Volume III of V, Chapter II. Lake Eugenia – A Preliminary Lake and Watershed Study.

- Hall, D.G. 1976a. Developing a Lake Management Programme for Lake Eugenia, Ontario. Senior Honours Essay. Department of Man-Environment Studies. University of Waterloo.

- Grey Sauble Conservation Authority (GSCA) – Surface Water Quality Monitoring Data (viewable at: https://www.greysauble.on.ca/water-management/water-quality-benthic-monitoring/)

- Jones, D. 1976. Lake Eugenia Cottage Survey. Volume IV of V, Chapter III. Lake Eugenia – A Preliminary Lake and Watershed Study.

- Lake Partner Program – Secchi Depth, Total Phosphorus, Chloride, Calcium: https://data.ontario.ca/dataset/ontario-lake-partner

[1] *The exact lake area at a given time is dependent on the water level at that time.*

- Lake Eugenia Beach 2022 bacteria testing results from the Municipality of Grey Highlands

- Ontario Ministry of Environment (MOE) 1973. Enrichment Status of Nine Lakes - Bruce Peninsula Area. M.F.P. Michalski, Biology Section, Water Quality Branch, Ministry of the Environment. 19 pages.

- MOE 1983. Water Quality Summary for the Inland Lakes of Grey and Bruce Counties. Water Resources Assessment Unit, Technical Support, Southwestern Region. Ontario Ministry of the Environment. January 1983. 44 pages.

- Provincial Water Quality Monitoring Network – Beaver River at Feversham – https://data.ontario.ca/dataset/provincial-stream-water-quality-monitoring-network

Ontario Power Generation (OPG) currently operates a facility on the west side of the lake and regulates the water levels. As per a written agreement with the Ministry of Natural Resources and Forestry, the water levels are maintained in the range of 433.96–434.23 m during the majority of the open-water season (24 May to 4 Sep) and in the range of 430.87–434.23 m from 5 Sep to 23 May (OPG 2019). HESL has estimated[2] that the average water residence time of Lake Eugenia is approximately 40 days.

The lake's drainage basin (~185 km^2) lies largely to the east, with major inputs from the Upper Beaver River and smaller contributions from the Little Beaver River and Black Creek (Figure 1). Land cover in the Upper Beaver River subwatershed (104 km^2) is predominantly agriculture and undifferentiated rural land use (61%), swamp (21%), and deciduous treed (7%; MNRF 2022b). Land cover in the Little Beaver River subwatershed (36 km^2) is largely agriculture and undifferentiated rural land use (72%) and swamp (18%). The Black Creek subwatershed is 32 km^2 in area. Similarly, the major land cover types here are agriculture and undifferentiated rural land use (50%), swamp (35%), and deciduous treed (7%). According to the Lake Eugenia Property Owners Association (LEPOA), there are approximately 400 lake-side residences, most of which (~80%) are occupied seasonally.

Results of the background review are organized by water quality parameter/feature or ecological feature in the following paragraphs. Lake Partner Program Data are presented in Appendix A, Provincial Water Quality Monitoring Network data summaries and trends are presented in Appendix B and trends in GSCA data are presented in Appendix C.

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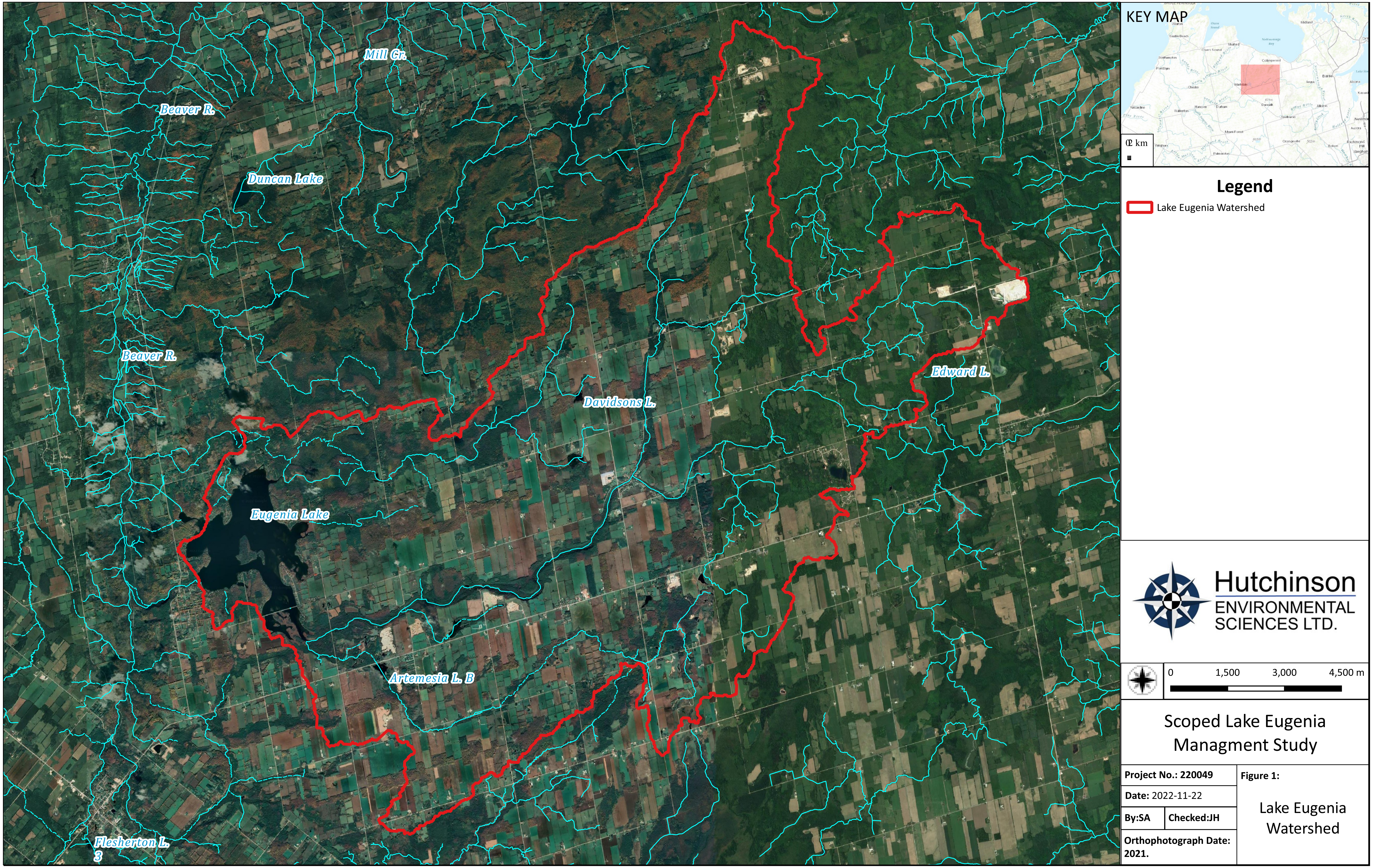
[2] *Based on areal prorating of discharge at Water Survey of Canada gauge "Beaver River near Vandeleur" (average annual discharge of 3.13 m^3/s) and an estimated lake volume of 10,716,000 m^3.*



Hutchinson ENVIRONMENTAL SCIENCES LTD.

Scoped Lake Eugenia Managment Study

Project No.: 220049	Figure 1:
Date: 2022-11-22	Lake Eugenia Watershed
By:SA Checked:JH	
Orthophotograph Date: 2021.	

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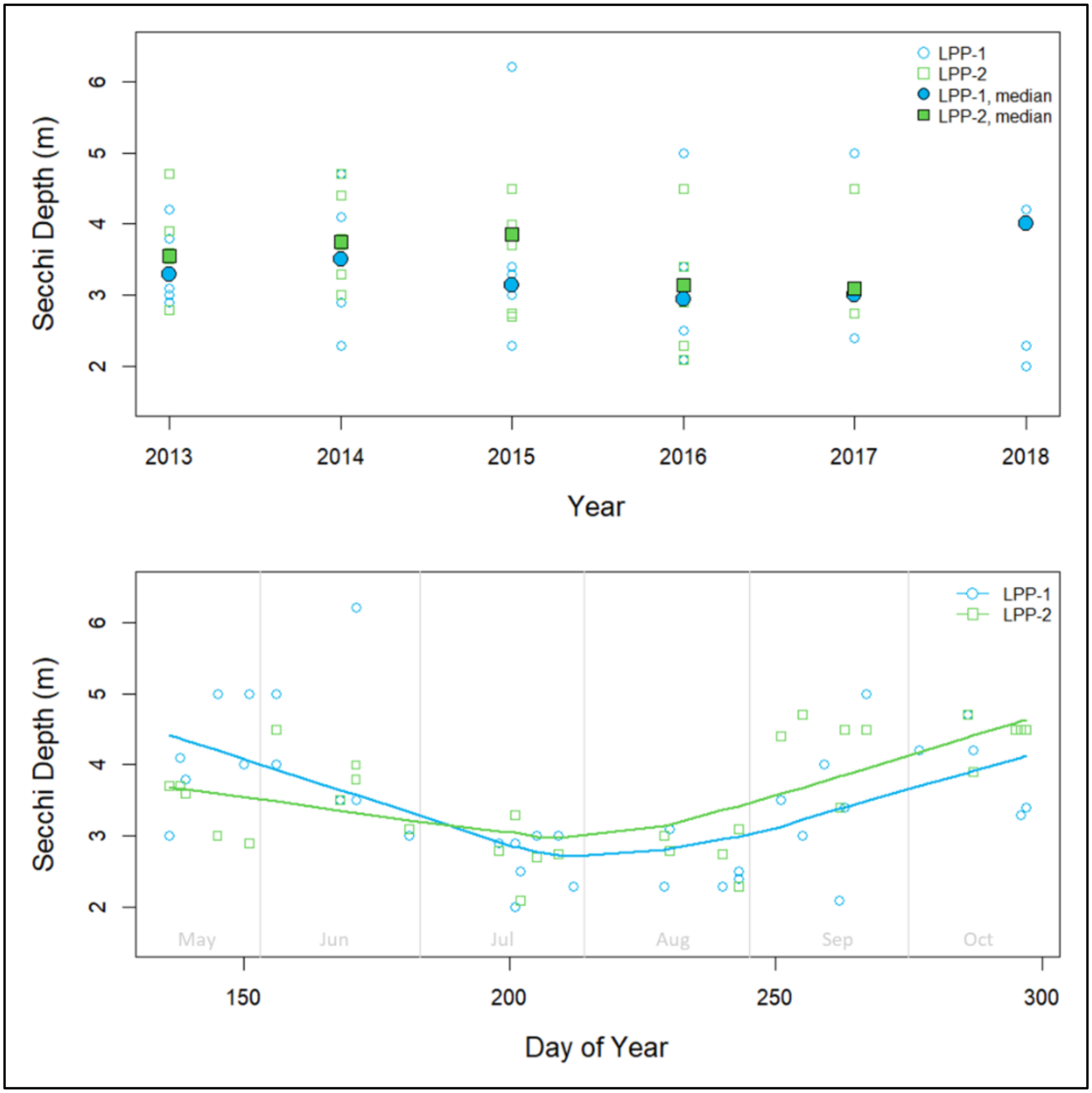
2.1.1 Water Clarity

Historical data sources indicate that Lake Eugenia is of moderate clarity. The average Secchi depth (ZSD) for the open-water season has been approximately 3 to 4 m, with some variability between years and sites (Table 1; Figure 2). While the available dataset is not sufficient to perform a rigorous trend analysis (i.e., there are large gaps, missing site information, variable timing of sampling within years, etc.), the average ZSD was 3.6 m in 1972, 3.7 m for 1977–1981, and 3.5 m for 2013–2018, so it can be inferred that the transparency of Lake Eugenia has been relatively stable over the past 50 years. There is seasonal variation in ZSD, with lower clarity in the summer relative to the spring and fall (Figure 2); this is likely the combined result of increased phytoplankton biomass and more concentrated tributary inputs of organic matter (i.e., less dilution from snowmelt/rainfall) during the summer.

Table 1. Secchi disc transparency of Lake Eugenia (1972–2018)

Secchi Depth (m)	Site Name	Period	Source	Notes
Avg = 2.5 (2.1–3.1)	East Station	Jul–Aug 1972	MOE (1973)	Exact site locations not specified.
Avg = 4.6 (3.3–5.7)	West Station			
Annual Avg = 3.9, 4.0, 3.4, 4.2, 3.0	*unspecified*	May–Aug, 1977–1981	MOE (1983)	Site location is presumably the deep spot near the dam.
Annual Min: 2.0–2.9 Annual Avg: 3.4–3.7 Annual Max: 4.2–6.2	1 - Main basin, deep spot	2013–2018	Lake Partner Program (LPP) data	Data in Figure 2
Annual Min: 2.1–3.0 Annual Avg: 3.3–3.8 Annual Max: 4.5–4.7	2 - Lagoon, deep spot			

Figure 2. Secchi depth at sites in the main basin ("LPP-1") and southern part of Lake Eugenia ("LPP-2"), based on Lake Partner Program monitoring



2.1.2 Stratification & Dissolved Oxygen

Water-column profiles of temperature and dissolved oxygen were collected from the deepest part of the lake (northeast of the dam) as part of the 1976 University of Waterloo study (Butler 1976). The surface temperature of Lake Eugenia varied from 12–23°C during May–Aug of 1976, with a surface mixed layer (epilimnion) depth of ~6 m. The average oxygen concentration just above the lakebed (i.e., at 10.7 m) was 2.1 mg/L with a minimum of 0.1 mg/L (i.e., hypolimnetic anoxia). Other profiles from the 1970s are presented by Hall (1976a), but these were only for shallow (<5 m) depths; even so, the average profile for 1975 indicates decreased dissolved oxygen concentration at depth relative to the upper water column.

2.1.3 General Water Chemistry

The average chloride concentration in Lake Eugenia increased from ~4 mg/L in the late 1970s (MOE 1983) to ~8–10 mg/L in 2013–2022 (LPP and GSCA monitoring). Historical chloride concentrations in the upper Beaver River were also relatively low (~5 mg/L; Appendix B) but increased significantly from 1978 to 1996 (+0.2 mg/L/year; $R^2 = 0.86$; $p < 0.001$; Appendix C) and have likely continued to rise as freshwaters across North America increase in salinity due to road salt application (Hintz et al. 2021). Despite the rising trends, these chloride concentrations are all well below the federal Canadian Council of Ministers of the Environment (CCME) water quality guideline of 120 mg/L for the protection of aquatic life (long-term exposure). Section 4.1.2.4 contains additional discussion regarding chloride concentrations and road salt management recommendations.

Average calcium (Ca) concentrations of 40 and 50 mg/L were reported for Lake Eugenia in 1978 and 1979 (MOE 1983), which are comparable to more recent (2015–2019) values from the LPP (avg = 52 mg/L; range: 43–64 mg/L; Appendix A); no significant trend in annual median Ca concentration was detected for the period 2015–2019 ($R^2 < 0.1$; $p > 0.5$).

Historical values of several other general limnological parameters of Lake Eugenia are summarized in Table 2, with more recent data in Table 3.

Table 2. General limnological parameters of Lake Eugenia surface water – 1970s historical data

	Sep–Oct 1975 Hall (1976a)	**1976 Butler (1976)**	**1977–1979 MOE (1983)**
Alkalinity (mg-$CaCO_3$/L)	–	170–194	185–187
Conductivity (µS/cm)	330–350	327–383	—
Hardness (mg-$CaCO_3$/L)	–	176–211	198–212
Iron (µg/L) - surface	40–340	35–100	40–120
Iron (µg/L) – off bottom	–	630	80–530
pH	8.4–8.5	8.54–8.64	8.36–8.53
Suspended Solids (mg/L)	–	—	2, <5
Turbidity (FTU)	0.90–0.94	0.85–1.0	0.76

Table 3. Grey Sauble Conservation Authority Water Quality Data (2012/2013–2022)

Variable	Site Description	n	Avg.	Min.	25th%ile	Median	75th%ile	Max.
Chloride (mg/L)	Beaver River at Sideroad 35	73	**11.2**	7.0	10.0	10.0	12.0	19.0
	Lake Eugenia at Concession Rd 8	73	**10.4**	2.0	9.0	10.0	11.0	17.0
	Lake Eugenia Outlet	71	**8.9**	6.0	8.0	8.6	9.0	13.0
E. coli (CFU/100mL)	Beaver River at Sideroad 35	82	**63**	2	18	30	48	900
	Lake Eugenia at Concession Rd 8	74	**43**	2	8	19	37	540
	Lake Eugenia Outlet	80	**11**	1	2	4	10	178
Nitrate (mg-N/L)	Beaver River at Sideroad 35	82	**1.7**	0.8	1.5	1.7	1.9	2.6
	Lake Eugenia at Concession Rd 8	74	**1.6**	0.6	1.2	1.6	1.9	3.2
	Lake Eugenia Outlet	80	**0.6**	0.1	0.3	0.5	0.9	1.8
Suspended Solids (mg/L)	Beaver River at Sideroad 35	73	**2.5**	2	2	2	3	9
	Lake Eugenia at Concession Rd 8	73	**2.5**	2	2	2	3	10
	Lake Eugenia Outlet	71	**2.4**	2	2	2	2	7
Total Phosphorus (µg/L)	Beaver River at Sideroad 35 (1976)	11	**9.2**	4.0	6.5	9.0	11.0	16.0
	Beaver River at Sideroad 35	82	**7.8**	3.0	4.0	9.0	9.0	20.0
	Lake Eugenia at Concession Rd 8	74	**9.0**	3.0	5.3	9.0	9.8	28.0
	Lake Eugenia Outlet	80	**10.0**	3.0	6.8	9.0	10.3	59.0

Notes: Beaver River at Sideroad 35 (44.3043°, -80.4730°) is ~700 m upstream of Lake Eugenia; Lake Eugenia at Concession Rd 8 (44.3097°, -80.4864°) is at the causeway close to the outlet of the Upper Beaver River into Lake Eugenia; Lake Eugenia Outlet (44.3401°, -80.5381°) is immediately downstream of the OPG station.

2.1.4 Nutrients

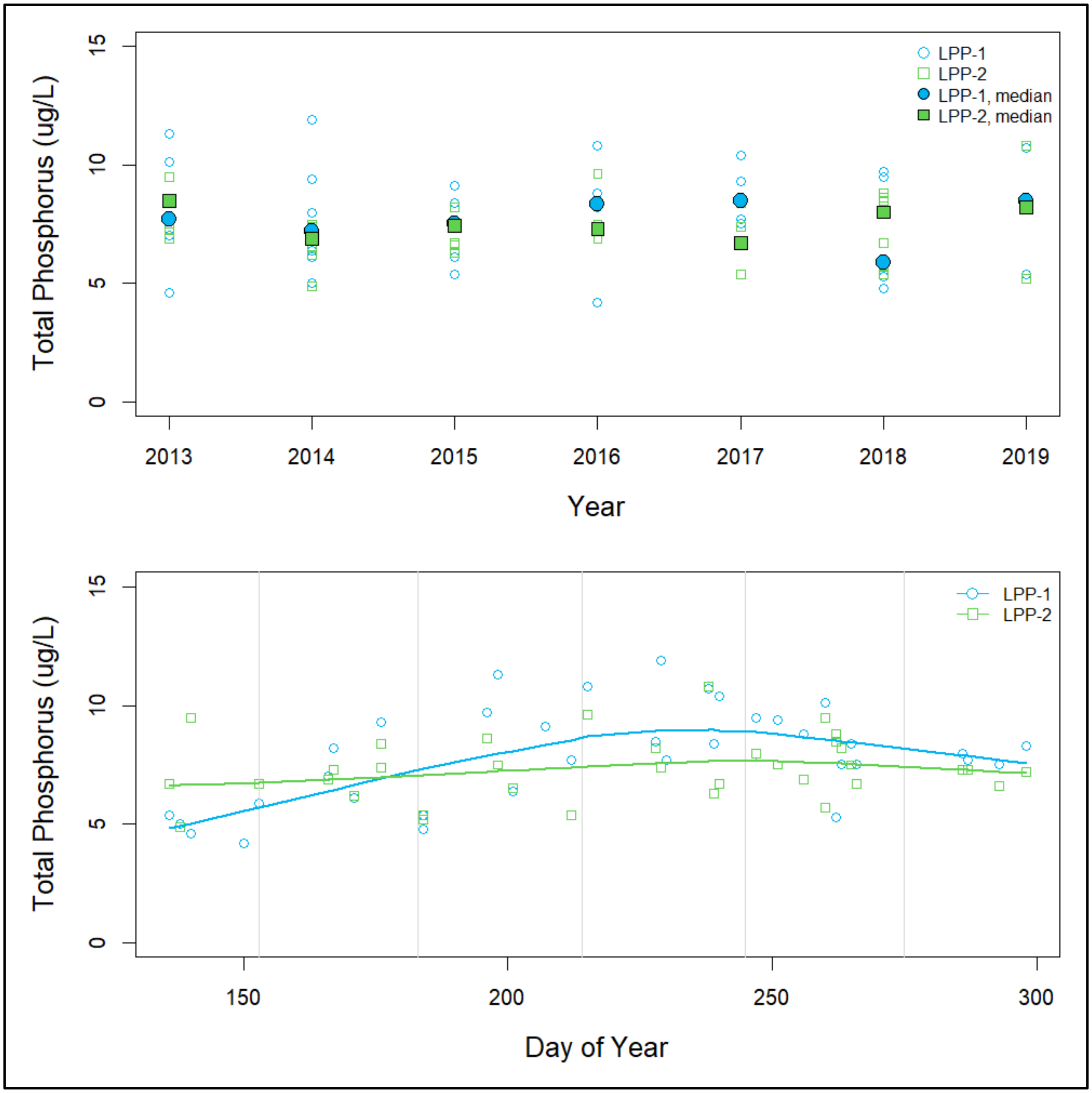
2.1.4.1 Phosphorus

Historically, phosphorus (P) concentrations in Lake Eugenia have been relatively low, with annual average total phosphorus (TP) concentrations indicative of oligotrophic conditions, and slightly below the Provincial Water Quality Objective (PWQO) for “a high level of protection against aesthetic deterioration”. Butler (1976) reported average (May–Aug) TP of 7–10 µg/L across 12 lake sites in 1976, with a much higher average off-bottom concentration of 31 µg/L (range: 9–58 µg/L) at the deepest site. Likewise, MOE (1983) reported average (May–Aug) surface concentrations of 8–10 µg/L and bottom concentrations of 14–26 µg/L for 1977–1979. Hall (1976a) reported concentrations in the range of 7–20 µg/L. More recently, the average TP concentration has been 9 µg/L based on both LPP (2013–2019) and GSCA (2013–2022; Table 3) monitoring. The LPP median TP concentration of 7.5 µg/L puts Lake Eugenia in the 38th percentile of lakes in the LPP database (i.e., 62% of the monitored lakes have a higher median TP concentration than Lake Eugenia). These recent TP concentrations are comparable to those reported from the 1970s (i.e., annual averages mostly in the 7–10 µg/L range). No linear trend in the LPP TP data was detected over the period 2013 to 2019 ($R^2 = 0.0$; $p = 0.9$). There was seasonality in TP at the main-lake LPP site (#1), with concentrations peaking in August (Figure 3). Butler (1976) reported seasonal average dissolved reactive phosphorus concentrations (as opposed to TP) of only 1 µg/L at most sites. Based on the moderate TP, low dissolved reactive phosphorus, and relatively high nitrogen concentrations (see following section), it is inferred that phytoplankton production in Lake Eugenia is constrained by phosphorus availability (i.e., the lake is “phosphorus limited”).

The moderate TP concentrations of Lake Eugenia are consistent with relatively low riverine TP measurements made upstream of the lake. Butler (1976) reported average TP (May–Aug 1976) of 9 µg/L (range: 4–16 µg/L) for the Upper Beaver River (which is consistent with recent data from the GSCA; see Table 3) and 15 µg/L for the Little Beaver River (range: 7–22 µg/L). Higher Upper Beaver River TP concentrations were measured via Provincial Water Quality Monitoring Network (PWQMN) monitoring at Feversham during 1978-1996 (avg = 20 µg/L; range: 3–133 µg/L), with a significant declining trend over that period (-0.6 µg/L/year; $R^2 = 0.50$, $p < 0.001$; see Appendix B). Butler (1976) reported much higher concentrations at Feversham (avg = 44 µg/L) than downstream (avg = 9 µg/L), suggesting that there is attenuation of TP downstream of Feversham and that the values there are not representative of what enters Lake Eugenia. Hall (1976a) measured phosphate[3] concentrations in the range of 1–12 µg/L in the lake's major tributaries in autumn of 1975.

[3] *The lake and stream phosphorus data presented by Hall (1976a) are referred to as "phosphate"; it is unclear whether the values are total phosphorus or dissolved reactive phosphorus concentrations.*

Figure 3. Total phosphorus concentrations at sites in the main basin ("LPP-1") and southern part of Lake Eugenia ("LPP-2"), based on Lake Partner Program monitoring[4]



[4] *The Y axis of the TP plot has been constrained; not shown are concentrations of 19.5, 19.8, and 87.8 µg/L for site #2. These values are outliers in the dataset. The highest value (87.8 µg/L) likely reflects sample contamination.*

2.1.4.2 Nitrogen

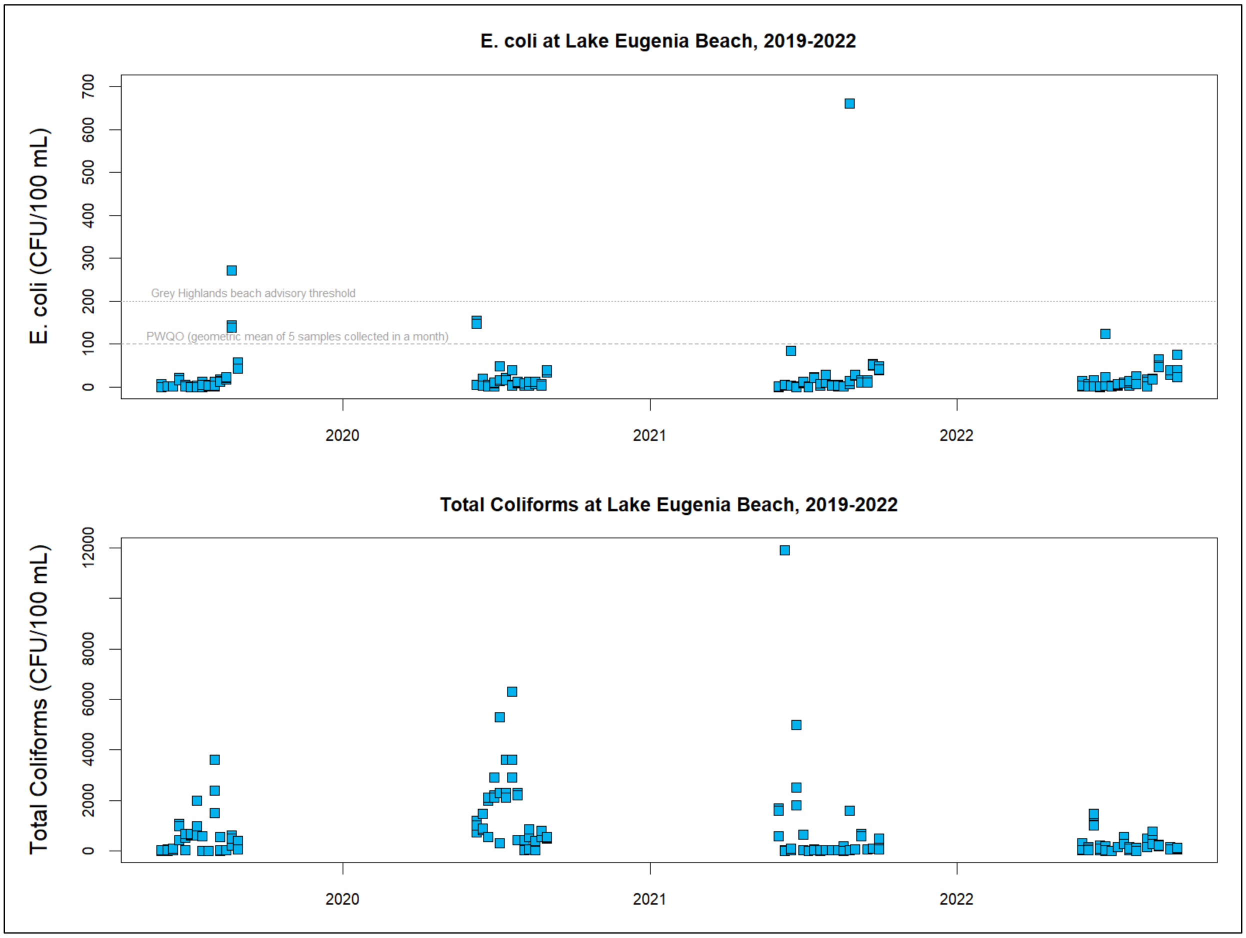
Historical nitrogen (N) data for Lake Eugenia comes from Butler (1976) who reported the following surface concentrations for the ice-free period for 12 sites: ammonia averaged 12–19 µg-N/L (range: <2–40 µg-N/L), nitrite averaged 2–4 µg-N/L (range: <1–6 µg-N/L), nitrate averaged 0.020–0.355 mg-N/L (range: <0.005–0.635 mg-N/L), and total Kjeldahl nitrogen averaged 0.330–0.370 mg-N/L (range: 0.200–0.590 mg-N/L). Off-bottom concentrations of ammonia were notable higher than surface concentrations, averaging 0.254 mg-N/L (range: 0.018–0.560 mg-N/L); these elevated ammonia concentrations likely occurred during periods of hypolimnetic anoxia (the biological conversion of ammonium to nitrate requires oxygen). Hall (1976a) measured nitrate in the range of 0.06–1.1 mg-N/L for the fall of 1975. More recently, nitrate concentrations have been higher, in the 0.6–3.2 mg-N/L range (avg. = 1.6 mg-N/L) according to GSCA monitoring (Table 3); this range entails occasional exceedances of the CCME guideline for nitrate (3 mg-N/L).

2.1.5 Bacteria

Historical data indicate that coliform bacteria concentrations in Lake Eugenia are generally low but also variable, occasionally exceeding 1,000 CFU/100 mL (i.e., higher than any guideline values for *E. coli* or *Enterococci;* see Health Canada (2012)). Jones (1976) reported fecal coliform concentrations for Lake Eugenia's nearshore of 10 to 5,100 CFU/100 mL (median = 52 CFU/100 mL) and total coliform concentrations of 0 to 5,800 CFU/100 mL (median = 100 CFU/100 mL). Butler (1976) reported relatively low seasonal mean concentrations of total coliforms (2–40 CFU/100 mL), fecal coliforms (1–5 CFU/100 mL), and fecal *Streptococci* (1–4 CFU/100 mL), with maximum values of 620, 76, and 52 CFU/100 mL, respectively. Hall (1976a) reported fecal coliform and *Enterococcus* values below 10 CFU/100 mL for the fall of 1975.

More recently, *E. coli* has averaged only 10–43 CFU/100mL (depending on location) based on monitoring by GSCA, though elevated concentrations (>100 CFU/100 mL) have been observed at times (Table 3). The public beach is monitored weekly by the Municipality of Grey Highlands and beach advisories issued at *E. coli* concentrations above 200 CFU/100 mL (Rob DelDuca, personal communication, 12 January 2023); this threshold has only twice been exceeded in the past 4 seasons (2019–2022; Figure 4). The PWQO for *E. coli* was not exceeded at the public beach during 2019–2022: monthly geometric means were in the range of 0–37 CFU/100 mL (i.e., less than 100 CFU/100 mL).

Figure 4. Bacteria at Lake Eugenia public beach (Municipality of Grey Highlands data; 2019–2022)



2.1.6 Phytoplankton

The term phytoplankton refers to microscopic algae and cyanobacteria ("blue-green algae") that are suspended in the water column. The concentration of the pigment chlorophyll-a (Chl-a) is a commonly used proxy for phytoplankton biomass. Historical Chl-a concentrations in Lake Eugenia are relatively low. MOE (1973) reported summer averages of 1.7 µg/L and 1.1 µg/L for two sites (range: 0.7–5.7 µg/L); Butler (1976) described Chl-a as "quite low" (never >2.8 µg/L); and MOE (1983) reported annual averages of 2.3–2.6 µg/L (May–Aug; 1978–1981). The MOE (1983) study also reported phytoplankton biovolume: annual averages ranged from 0.227 mm^3/L to 1.905 mm^3/L during 1977–1981 (median = 0.827 mm^3/L).

Historical information on the species composition of the Lake Eugenia phytoplankton community is not available (to our knowledge), but reports of algal blooms (presumably of cyanobacteria) date back to at least 1976 (Butler 1976). Biotactic (2018) noted that a *Microcystis* bloom was observed to persist from mid-September to early-October in 2018. A recent bloom (26 July 2022) was sampled by the MECP and was found to be toxic and dominated by the species *Microcystis aeruginosa* (a common bloom-forming cyanobacterium). The sample had a microcystin concentration of 36.7 µg/L, greater than Health Canada's guidelines for drinking water (1.5 µg/L) and primary contact recreation (10 µg/L).[5]

2.1.7 Macrophytes

Macrophytes are key components of lake ecosystems but can be of concern from a lake management perspective when present at high density. Despite their importance, macrophytes are not usually monitored as intensively as water quality. This is, in part, because macrophytes are more difficult to sample (divers are required for quantitative sampling at deeper sites) and because distributions are highly variable temporally (e.g., in early summer vs. early fall) and, especially, spatially (i.e., they exhibit patchy distributions, so that a large number of locations may need to be sampled to obtain data that are representative at the scale of an entire lake).

Historical macrophyte data for Lake Eugenia come from Bobbette and Bobbette (1976): they noted strong dominance by Water Milfoil (*Myriophylllum sp.*) and Stoneworts (*Characeae*), with the following taxa observed: *Characeae*, Whorl-leaf Watermilfoil (*Myriophyllum verticillatum*), Northern Watermilfoil (*Myriophullum exalbescens*), Common Bladderwort (*Utricularia vulgaris*), Flatstem Pondweed (*Potamogeton zosteriformis*), Canadian Waterweed (*Elodea canadensis*), Lesser Pondweed (*Potamogeton pusillus*), Small Pondweed (*Potamogeton berchtoldii*), Slender Naiad (*Najas flexilis*), and Needle Spikerush (*Eleocharis acicularis*), among others. In their (rather colourful and opinionated) report, they noted that "[c]learly, in terms of mass, few species dominate. The *Myriophyllums* and *Characeae* almost everywhere are overwhelmingly abundant, mostly along the bottom, but too often in dense floating or sub-surface mates, at least in many cottagers' eyes". Bobbette and Bobbette (1976) also noted that water depth appears to control macrophyte biomass over a large fraction of the lake, and that "the [area] between the weed-free deep areas and the naturally important marshes and wetlands is where aquatic weed management attention may be most profitably directed". Based on a social survey of lakeshore residents, Hall (1976b) noted that 82% of respondents believed at this time that there had been an increase in aquatic weed growth and that it was the primary problem on the lake. Hall (1976b) thus recommended that an "algae and weed control programme should be instigated by local cottage associations". Recently, Biotactic (2018) reported that in 2015 sparse aquatic macrophyte beds consisted of Richardson's Pondweed (*Potamogeton richardsonii*) and Water Celery (*Vallisneria sp*.), and that there appeared to be fewer large weed beds in 2016–2017 relative to 2015.

2.1.8 Fish

According to Hall (1976a), "until the early 1960's, Lake Eugenia was renowned for its excellent trout fishery", after which time it deteriorated, following the introduction of Rock Bass (*Ambloplites rupestris)*: angling success declined from 0.57 trout/h (1948–1961) to 0.20 trout/h (1964–1974). A 1970 fisheries assessment by the Ministry of Natural Resources counted 4,240 Rock Bass (*Ambloplites rupestris)*, 1,368 Suckers (*Catostomidae)*, 452 Common Shiners (*Luxilus cornutus*), 15 Brook Trout (*Salvelinus fontinalis*), 13 Bluntnose Minnows (*Pimephales notatus*), 4 Rainbow Trout (*Oncorhhynchus mykiss)*, 4 Brown Trout (*Salmo trutta*), and 1 Creek Chub (*Smotilus atromaculatus*) according to Hall (1976). At present, Lake Eugenia supports a variety of warm-water fish species including Largemouth Bass (*Micropterus salmoides*),

[5] *https://greyhighlands.civicweb.net/filepro/documents/154753/?notices=True&preview=292979*

Smallmouth Bass (*Micropterus dolomieu*), Yellow Perch (*Perca flavescens*), Sunfish (*Centrarchidae* spp.), Minnows (*Cyprinidae* spp.), Catfish (*Icaluridae* spp.), and Common Carp (*Cyprinus carpoio*), and is very popular with anglers (Biotatic 2018). Zebra mussels (*Dreissena polymorpha*) are also present in the lake.

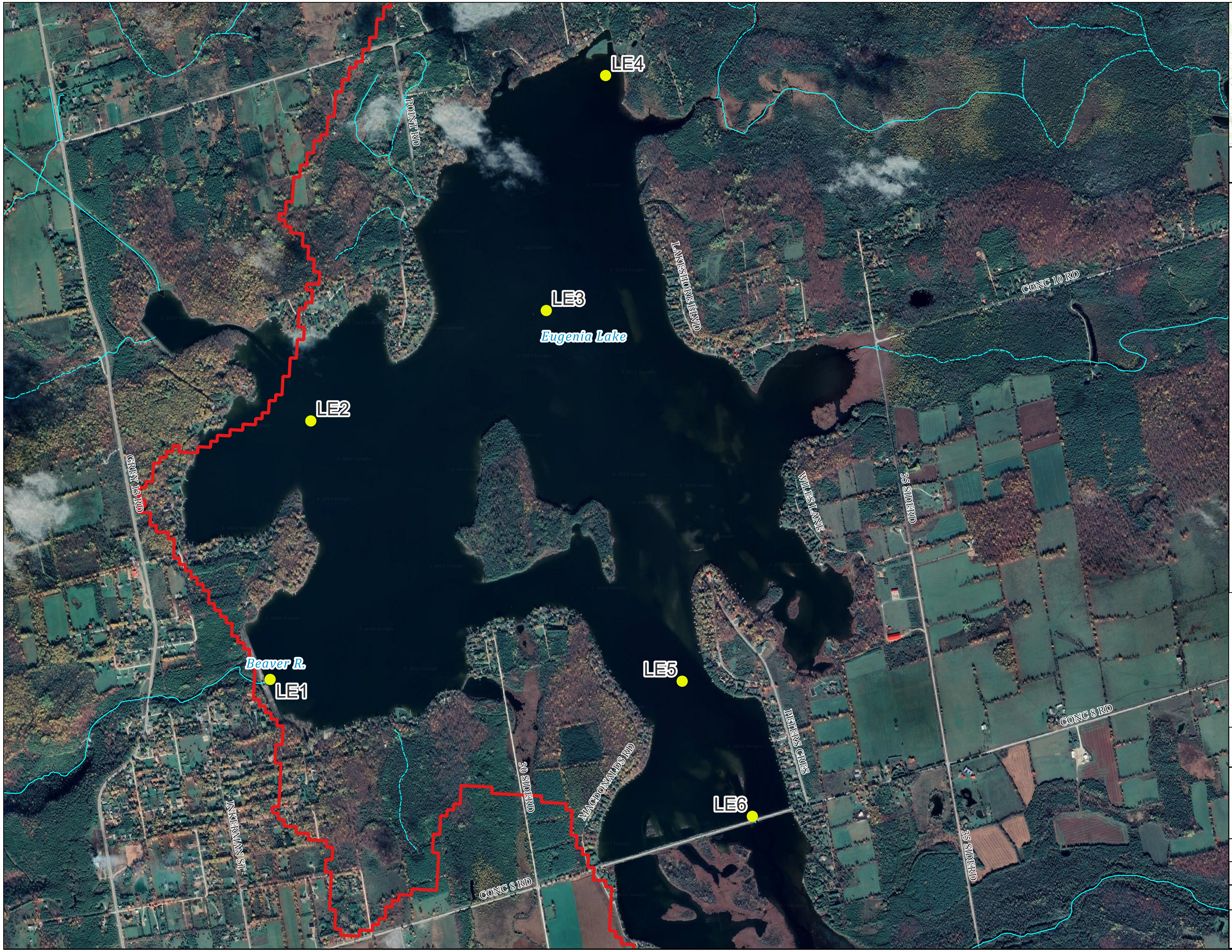
2.2 August 2022 Lake Survey

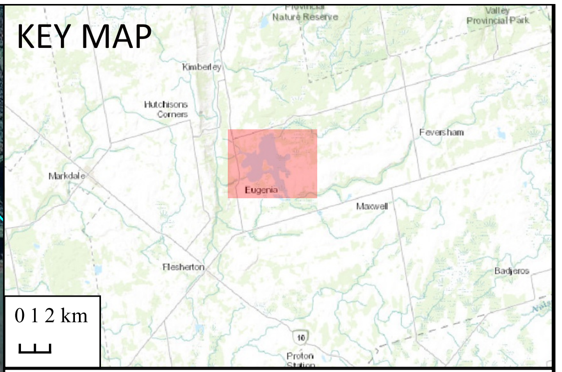
2.2.1 August 2022 Survey Methods

HESL conducted a limnological survey of Lake Eugenia on 10 August 2022; six sites were sampled (Table 4; Figure 5).

Table 4. Sampling locations for 10 August 2022 survey of Lake Eugenia

	Site Depth (m)	Lower Depth of Integrated Sample (m)	Off-Bottom Sampling Depth (m)	Latitude	Longitude
LE1	7.0	6.0	6.0	44.3159	-80.5156
LE2	4.6	3.5	3.5	44.3271	-80.5130
LE3	2.5	1.5	1.5	44.3318	-80.4988
LE4	1.2	1.0	-	44.3420	-80.4951
LE5	3.0	2.0	2.0	44.3158	-80.4907
LE6	2.3	1.0	-	44.3099	-80.4866





Legend

- Lake Eugenia Watershed
- Sampling Locations
- Permanent Watercourse
- Intermittent Watercourse

Hutchinson ENVIRONMENTAL SCIENCES LTD.

0 300 600 900 m

Scoped Lake Eugenia Management Study

Project No.: 220049	Figure 5:
Date: 2022-11-22	Lake Eugenia Sampling Sites (August 2022)
By:SA / Checked:JH	
Orthophotograph Date: 2021.	

C:\Users\SarahAitken\Hutchinson Environmental Sciences Ltd\2022 Projects - 220049 - Lake Eugenia Management\Job\GIS\Lake Eugenia Watershed.qgz - Sarah Aitken

The following measurements/samples were collected at each site:

- Secchi depth was determined with a standard 20-cm black-and-white Secchi disc on the shaded side of the boat.
- Surface water samples for biological and chemical analyses were collected by weighted bottle (i.e., from the surface to depths of several meters); the exact sampling depth at each site depended on the photic zone determined by the Secchi disc, and site depth. The samples were analyzed for hardness, pH, alkalinity, ammonia, chloride, total Kjeldahl nitrogen, dissolved reactive phosphorus, TP, sulphate, dissolved organic carbon, *E. coli,* total coliform bacteria, total suspended solids (TSS), and total metals.
- Off-bottom water samples were collected from the deeper sites (LE1, LE2, LE3, LE5). These samples were analyzed for TSS, TP, and total iron.
- Sediment cores were collected by gravity corer at all sites. The cores were extruded, and the top 5 cm of sediment sent for analysis of total nitrogen, phosphorus, and moisture content.
- Vertical profiles of the following parameters were measured using a YSI sonde: water temperature, dissolved oxygen (DO), pH, and conductivity.

Water and sediment samples were shipped to ALS Labs in Waterloo, Ontario for analysis.

2.2.2 August 2022 Survey Results

2.2.2.1 Epilimnetic Water Quality

The water quality of Lake Eugenia, as assessed by HESL on 10 August 2022, was quite good (Table 5). The Secchi depth (ZSD) was ~2–3 m, with the highest clarity at LE1 (ZSD = 3.3 m) and lowest at LE3 (ZSD = 2.3 m); ZSD was greater than the site depth at LE4 and LE6. Bacteria concentrations were low at most sites, with *E. coli* below 100 CFU/100 mL at all sites except for LE3[6]. There were no chemical parameters above PWQO (or the CCME guideline in the case of chloride). pH was at the upper limit of the PWQO range at 8.5. The median TP concentration was 10.3 µg/L, well below the PWQO of 20 µg/L for avoiding nuisance algal growth, and only slightly above the 10 µg/L concentration recommended for a high level of protection against aesthetic deterioration (MOEE 1994). Dissolved reactive phosphorus was below the detection limit of 3 µg/L at all sites. Chlorophyll-a was also relatively low (median = 1.9 µg/L; range: 1.6–2.3 µg/L). All metals met their respective PWQO, with concentrations of many metals below detection at all sites.

Chloride was less than 10% of the CCME guideline of 120 mg/L at all sites. Ammonia (NH_3) was below the PWQO at the time of sampling (when surface water temperatures were ~23°C).

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[6] According to ALS Laboratories, an exact value could not be determined for this sample because "the plate was overgrown with bacteria". It is likely that the sample was contaminated.

Interestingly, there was little spatial variation in water quality (i.e., only minor differences were noted among sites; Table 5). The only possible exceptions were for alkalinity (much lower at LE2 than elsewhere) and *E. coli* (much higher at LE3 than elsewhere), but considering the consistency in all other parameters, these results may reflect laboratory error.

Given that chlorophyll-a and TP were low, phosphate below detection, and total ammonium (ammonium+ammonia) was ~80 µg/L, it can be surmised that the biomass of phytoplankton was likely limited by phosphorus availability at the time of sampling. The low chlorophyll-a concentrations suggest that the moderate water clarity (i.e. limited Secchi depth) must largely be due to the moderate concentrations of (coloured) dissolved organic carbon (~4 mg/L), with phytoplankton playing a comparatively minor role in light attenuation.

Table 5. Epilimnetic water quality from HESL Survey (10 August 2022)

Parameter*	Guideline**	Median	LE1	LE2	LE3	LE4	LE5	LE6
Secchi Depth (m)***	–	–	3.3	2.6	2.3	*>1.2*	2.9	*>2.3*
Alkalinity (as CaCO3)	–	**205**	203	80	202	207	215	216
Aluminum (µg/L)	75	**36.2**	36.7	45.9	36.8	35.7	29.7	26.6
Arsenic (µg/L)	5	**0.52**	0.52	0.52	0.56	0.57	0.43	0.43
Bacteria - *E. coli* (CFU/100mL)	100	**10**	13	81	>200	10	8	3
Bacteria - Total Coliforms (CFU/100mL)	–	**30**	30	140	330	30	10	20
Barium (µg/L)	–	**13.1**	13.2	13.0	13.0	12.4	13.3	13.5
Boron (µg/L)	200	**<10**	11	10	<10	<10	<10	<10
Calcium	–	**43.7**	45.5	42.9	42.6	42.3	45.0	44.5
Chloride	120	**9.76**	9.87	9.75	9.72	9.47	9.76	9.76
Chlorophyll-a (µg/L)	–	**1.92**	1.64	2.22	2.29	2.12	1.72	1.49
Dissolved Organic Carbon	–	**4.23**	4.20	4.25	4.16	4.64	4.30	4.07
Hardness (as CaCO3)	–	**218**	227	217	214	214	220	219
Iron (µg/L)	300	**47**	48	59	42	40	50	46
Lead (µg/L)	5	**0.09**	0.09	0.10	0.09	0.08	0.11	0.08
Magnesium	–	**26.3**	27.5	26.6	26.0	26.3	26.1	26.2
Manganese (µg/L)	–	**8.51**	7.81	8.51	8.51	8.82	8.26	8.77
Molybdenum (µg/L)	–	**0.35**	0.37	0.36	0.35	0.35	0.33	0.33
Nitogen, Total Kjeldahl	–	**0.52**	0.449	0.657	0.477	0.531	0.542	0.518
Nitrogen, Ammonia (µg/L)	16.4	**10.9**	10.7	7.1	12.8	12.5	9.6	11.0
Nitrogen, Ammonia+Ammonium	–	**0.08**	0.086	0.050	0.088	0.092	0.069	0.078
pH	6.5–8.5	**8.5**	8.5	8.5	8.5	8.5	8.5	8.5

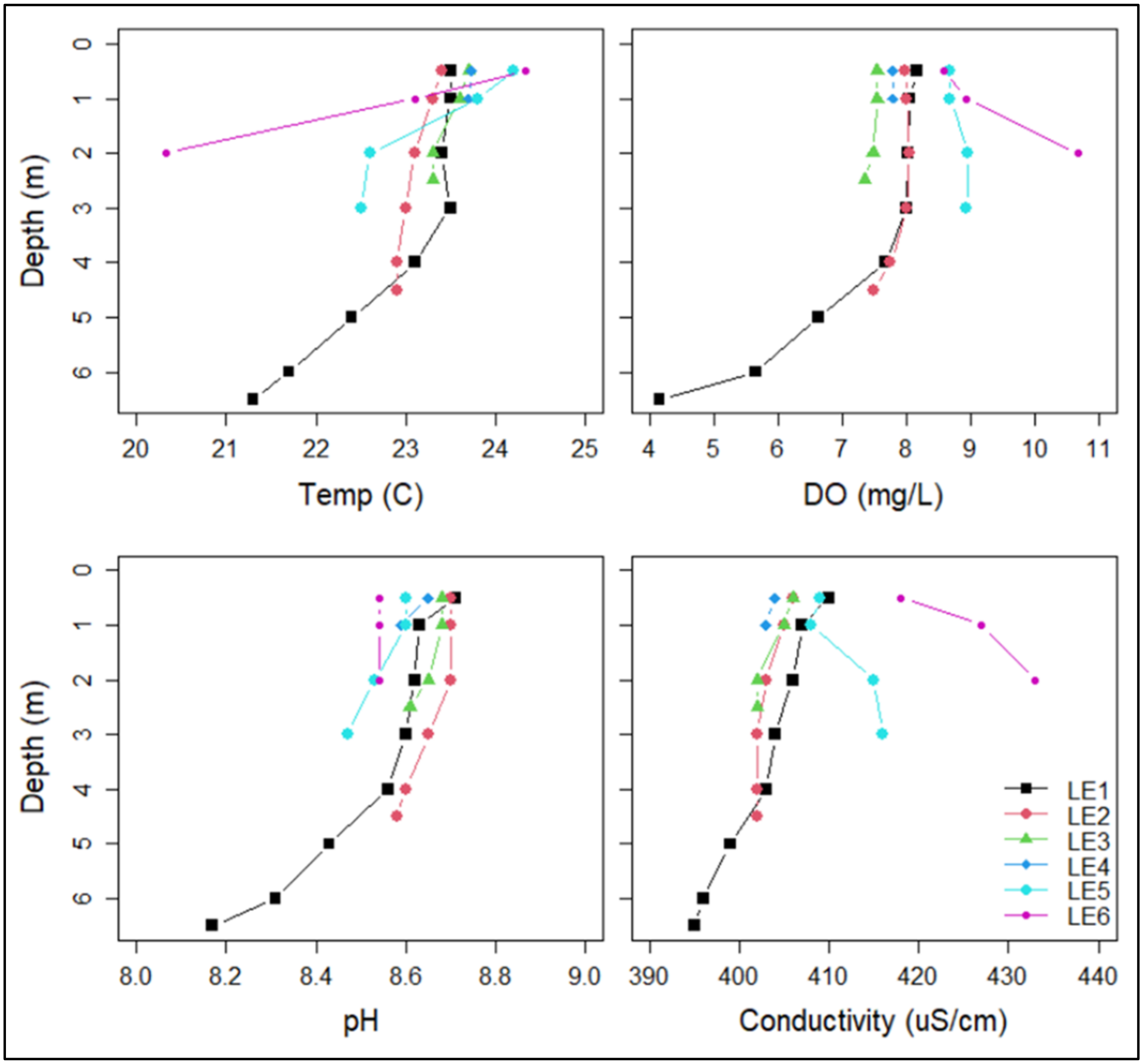
Phosphorus, Dissolved Reactive (µg/L)	–	**<3.0**	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Phosphorus, Total (µg/L)	***10, 20	**10.3**	9.5	10.1	8.9	10.4	10.5	11.0
Potassium	–	**1.13**	1.16	1.13	1.16	1.12	1.10	1.12
Rubidium (µg/L)	–	**0.64**	0.65	0.59	0.63	0.61	0.69	0.66
Selenium (µg/L)	100	**0.08**	0.08	0.08	0.07	0.07	0.08	0.06
Silicon	–	**1.29**	1.20	1.13	1.17	1.38	1.70	1.71
Sodium	–	**4.56**	4.68	4.53	4.55	4.44	4.57	4.68
Strontium (µg/L)	–	**54.0**	54.3	53.6	53.7	51.6	54.6	54.7
Sulfate	–	**4.56**	4.64	4.55	4.5	4.34	4.61	4.57
Sulfur	–	**1.86**	1.85	1.93	1.99	1.77	1.81	1.86
Titanium (µg/L)	–	**<0.8**	<0.90	1.22	<0.80	0.67	0.76	0.69
Uranium (µg/L)	5	**0.33**	0.33	0.33	0.33	0.32	0.29	0.31
Vanadium (µg/L)	6	**0.77**	0.76	0.79	0.80	0.78	0.65	0.63
Zinc (µg/L)	20	**<3.6**	6.8	3.6	<3.0	<3.0	4.2	<3.0

*Notes: *Units are mg/L unless otherwise indicated. **Guideline values are PWQOs except for the CCME guideline for chloride.* ***Secchi depth was greater than the site depth at LE4 and LE6. *****The TP (interim) PWQO of 10 µg/L is for "a high level of protection against aesthetic deterioration"; the (interim) PWQO of 20 µg/L is "to avoid nuisance concentrations of algae in lakes". The following metals had concentrations below the detection limit at all sites: Antimony, Beryllium, Bismuth, Cadmium, Cesium, Chromium, Cobalt, Copper, Lithium, Nickel, Silver, Tellurium, Thallium, Thorium, Tin, Tungsten, and Zirconium.*

2.2.2.2 Stratification, Sediments, and Off-Bottom Chemistry

Vertical temperature gradients were evident at several sites on 10 August 2022, even in shallow areas of the lake (e.g., LE6; Figure 6). These non-isothermal conditions were due to the low wind conditions on the survey date; under even moderate winds, the water column would be expected to mix to the lakebed at depths shallower than approximately 4–5 m. Dissolved oxygen decreased with depth at the deepest site surveyed (LE1), reaching a minimum of ~4 mg/L near the lakebed. The lake-wide average temperature, DO, pH, and conductivity values for the surface mixed layer (<= 4 m) were 23.3°C, 8.1 mg/L (96% DO saturation), pH of 8.61, and 409 µS/cm, respectively (data in Figure 6).

Figure 6. Profiles of temperature, DO, pH, and conductivity from HESL Survey (10 August 2022)



Sediment moisture content and sediment nutrients (nitrogen and phosphorus) were relatively consistent among sites (Table 6), with some correlation (not statistically significant at the 90% confidence level) between site depth and sediment nitrogen content (i.e., higher sediment nitrogen at shallower sites; R^2 = 0.52, p = 0.11). Total phosphorus concentrations bordered the Lowest Effect Level (0.6 mg/kg) identified in the Provincial Guidelines (Ministry of Environment and Energy, 1993) but were not particularly high (cf. Oluyedun et al. 1993 or Bojakowska 2016). In any case, the processes governing the release of nutrients from sediments are generally of greater importance (in terms of fuelling phytoplankton production) than are the absolute concentrations in the sediments.

Table 6. Lake Eugenia sediment data from HESL Survey (10 August 2022)

	Median	**LE1**	**LE2**	**LE3**	**LE4**	**LE5**	**LE6**
Site Depth (m)	**2.8**	7.0	4.6	2.5	1.2	3.0	2.3
Moisture (%)	**75.4**	74.0	76.6	76.1	74.6	77.9	70.7
Nitrogen, total (g/kg)	**5.62**	4.09	5.53	5.70	6.38	6.32	4.76
Phosphorus (g/kg)	**0.56**	0.620	0.538	0.394	0.420	0.582	0.620
N:P mass ratio	**10.6**	6.6	10.3	14.5	15.2	10.9	7.7

Despite the stratified state of the water column and lower DO concentrations at depth, TP and iron concentrations were only slightly elevated ~1-m above the lakebed relative to the overlying water (Table 7). These minor differences cannot be considered evidence of internal phosphorus loading (i.e., a flux of phosphorus from the lakebed into the water column due to the dissolution of iron-phosphorus complexes in the sediments). It is possible that internal loading was not yet occurring at the time of our mid-August survey, as hypolimnetic oxygen is generally lowest at the very end of the stratified period (as late as October in some Ontario lakes).

Table 7. Off-bottom water quality from HESL Survey (10 August 2022)

	LE1	**LE2**	**LE3**	**LE5**
Site Depth (m)	7.0	4.6	2.5	3.0
Sample Depth (m)	6.0	3.5	1.5	2.0
Solids, total suspended (mg/L)	3.9	4.5	7.5	<3.0
Phosphorus, total (µg/L)	10.5 (9.5)	11.8 (10.1)	11.6 (8.9)	9.6 (10.5)
Iron, total (µg/L)	58 (48)	76 (59)	58 (42)	50 (50)

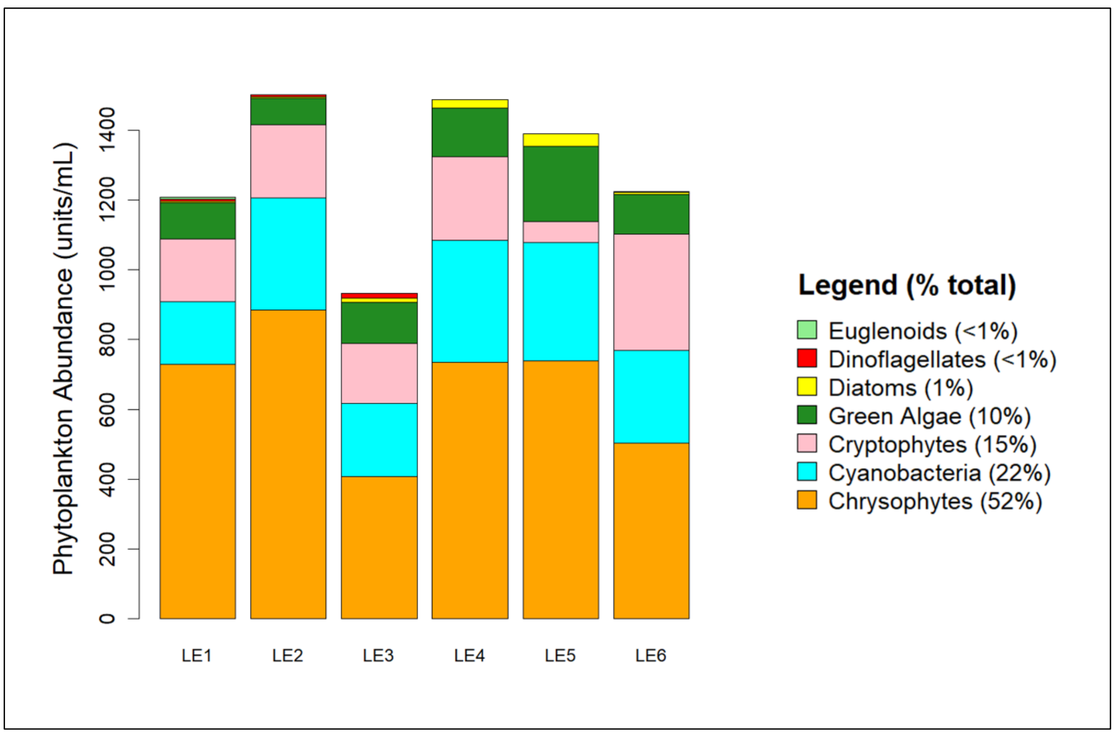
Note: Numbers in parentheses are from integrated samples from the surface to ~1 m off bottom (i.e., the layer above the off-bottom samples; see Table 4).

2.2.2.3 Phytoplankton

Total phytoplankton concentrations[7] ranged from 933 units/mL at LE3 to approximately 1,500 units/mL at LE2 and LE4 (Figure 7); phytoplankton concentration was not correlated with site depth (Pearson's r=-0.06; $p = 0.9$) and exhibited no conspicuous spatial pattern across the lake. Chrysophytes were the most common taxon (in terms of cell concentrations), comprising approximately half of the phytoplankton community; cyanobacteria, cryptophytes, and green algae were also common; diatoms, dinoflagellates, and euglenoids were rare or absent (Figure 7).

Cyanobacteria concentrations (179–351 units/mL) were, on average, 22% of total phytoplankton concentrations (Figure 7), and below the federal guideline for recreational waters of 50,000 cells/mL (Health Canada 2022) at all sites (assuming filament/colony sizes of <100 cells/unit). *Pseudanabaena* was the most abundant taxon of cyanobacteria at all sites, ranging from 156–313 filaments/mL; this genus contains non-N_2-fixing cyanobacteria capable of producing cyanotoxins and taste-and-odour compounds (Chorus and Welker 2021). *Microcystis,* the genus responsible for the 2018 and 2022 blooms, was not overly abundant at the time of sampling (10 August 2022), comprising only 3–17 colonies/mL or 0.3–1.8% of the total phytoplankton (based on concentrations (as units/mL) at the 6 sites).

Figure 7. Lake Eugenia Phytoplankton (10 August 2022)



[7] *The comparisons in this section are based on concentrations of either single cells or groups of cells (colonies or filaments), depending on the type of phytoplankton enumerated. Biovolume data were requested by HESL but were not provided by ALS Laboratories.*

2.3 Current vs. Historical Water Quality

Most aspects of the water quality of Lake Eugenia do not appear to have changed appreciably since the 1970s. Indicators of lake trophic status appear stable. The average transparency (Secchi depth) on 10 August 2022 was 2.8 m; this is within the range observed (at various times of year) in the late 1970s (2.1–5.7; see Table 1) and for the month of August during 2013 to 2018 (2.3–3.1 m; see Figure 2). Consistent with the unchanged water clarity, total phosphorus concentrations have been stable: TP was generally in the range of 7–10 µg/L in the 1970s, 5–12 µg/L from 2013–2019 (5th to 95th percentiles of LPP data), and most recently, 9–11 µg/L (HESL survey). Moreover, present chlorophyll-a concentrations (1.5–2.3 µg/L) are in line with those measured in the 1970s (seasonal averages of 1.1–2.6 µg/L), suggesting that the phytoplankton biomass has not increased over time.

Bacteria concentrations are inherently variable through space and time, which makes comparison of different datasets difficult (e.g., beach data to open-water data), but a comparison of the HESL total coliform data (median = 30 CFU/100 mL; range: 10–330 CFU/100 mL) to the Butler (1976) results (means of 2–40 CFU/100 mL; overall range of 0–620 CFU/100 mL) suggests that current bacterial concentrations are stable, or perhaps improved, relative to the 1970s.

Other water quality characteristics also appear to have changed little since the 1970s. Calcium concentrations are stable in Lake Eugenia, with the 44-mg/L average observed in 2022 within the historical range of ~40–50 mg/L. In 2022, hardness (a measure of dissolved minerals such as calcium and magnesium) was slightly higher than, but comparable to, historical concentrations (218 mg/L vs.176–212 mg/L). Ammonia in 2022 was slightly lower than observed historically (~10–12 µg-N/L vs. 12–19 µg-N/L)8. Total Kjeldahl nitrogen (TKN) was somewhat higher (520 µg-N/L vs. 330–370 µg-N/L), though TKN was within the overall range (200-590 µg-N/L) observed by Butler (1976). The August 2022 lake-wide average pH (8.61) is within the range observed in the late 1970s (8.36–8.64). The maximum water temperature observed in 2022 was 24.3°C, slightly warmer than the maximum of 23.0°C observed in 1976 and roughly in line with what would be expected due to regional climate warming.

In 2022, as in 1976, there was evidence of thermal stratification of the water column and hypolimnetic oxygen depletion; a deeper mixed layer and lower off-bottom DO concentrations were reported for 1976, but differences in the exact sampling locations and time of year make a direct comparison impossible. In contrast to our findings, Butler (1976) reported off-bottom (hypolimnetic) concentrations of TP (31 µg/L) and iron (630 µg/L) that were much higher than surface concentrations, which is reflective of anoxia-driven internal (sediment) phosphorus (and iron) loading. As noted above, a direct comparison is not possible with the available data, but it is considered likely that internal TP loading is still significant during late summer–early fall in the deepest part of Lake Eugenia. Indeed, the establishment of the filter-feeding zebra mussels in the lake between the 1970s and present day may have enriched the nutrient content of the sediments, though present values are not particularly high (see Section 2.2.2.2). Internal loading likely contributes to the increase in TP concentration (~2 µg/L) observed between the lake's approximate inlet (Beaver River at Sideroad 35) and its outlet (see Table 3); however, septic systems, atmospheric deposition, and runoff from shoreline properties are other potential contributors of phosphorus.

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[8] *This assumes that what Butler (1976) reported as "Free Ammonia" is in fact NH_3 and not what is known as "Total Ammonium" (the sum of NH_3 and NH_4^+). Total ammonium in the 2022 survey samples was ~80 µg-N/L.*

While most aspects of Lake Eugenia's water quality have been stable for decades, nitrate and chloride concentrations have increased. The average nitrate concentration in 1976 was 0.020–0.355 mg-N/L (depending on location) whereas the average concentration at the causeway site has been 1.6 mg-N/L for the period 2013–2022, according to GSCA monitoring. Though concentrations are still largely below the CCME guideline of 3 mg-N/L, this represents a large relative increase in nitrate. The increase in the lake appears to be due at least in part to increased catchment loading (i.e., increased concentrations in the Upper Beaver River; see Appendix B); this is likely due to a combination of agricultural runoff and atmospheric deposition.

There is much concern over salinization of freshwaters in North America (e.g., Hintz et al. 2021), primarily due to road salt runoff. Lake Eugenia does appear to be getting saltier, with chloride increasing from ~4 mg/L in the late 1970s, to ~8 mg/L during 2015–2019, to ~10 mg/L in 2022. Consistent with the increases in chloride, conductivity (409 µS/cm) was higher in 2022 than observed in 1975 (335–350 µS/cm) or 1976 (327–383 µS/cm).

3. Gap Analysis

Lake Eugenia's historical water quality was comprehensively assessed by Butler (1976). In recent decades, regular monitoring of key water quality parameters (clarity (ZSD), phosphorus, calcium, chloride, nitrate, TSS, *E. coli*) has been, and continues to be, conducted by the GSCA and through the MECP's LPP. Such long-term, regular monitoring is valuable because it provides data to assess spatial and, especially, temporal patterns (trends) in water quality. While useful in this regard, the current monitoring of Lake Eugenia does not provide the information needed to fully understand the mechanisms underlying harmful cyanobacterial bloom formation, nor does it provide any information on the macrophyte community. The cyanobacteria and macrophytes of Lake Eugenia obtain most of their nutrients from the sediments (either indirectly or directly); thus, it is vital to understand the processes controlling the flux of nutrients from the sediments to these organisms.

3.1 Stratification, Mixing, and Sediment-Water Column Dynamics

Most of Lake Eugenia is too shallow to stably stratify during the open-water season; that is, the water column in most of the lake is completely mixed, vertically, by wind-induced currents many times during the open-water period. However, some of the lake is deep enough to stratify, and in these areas the bottom layer (hypolimnion) becomes depleted in oxygen (see Section 2.2.2.2 and Figure 6). In lakes with anoxic hypolimnia, insoluble iron-phosphorus complexes in the sediments dissolve into the overlying water column where these nutrients become available to phytoplankton. Oxygen-mediated sediment phosphorus release (internal loading) is likely important in the deep areas of Lake Eugenia – historical data included elevated iron and TP concentrations at depth (see Section 2.1.4.1). This type of internal P loading may also occur in pulses (intermittently) when shallower areas undergo transient stratification (e.g., on hot, calm days). The strength and duration of water column stratification (and consequent oxygen depletion and internal phosphorus loading) will likely increase for the foreseeable future due to climate change. Finally, resuspension of nutrient-rich sediments by common carp (bioturbation) or during strong-wind events is another potential internal loading mechanism. To our knowledge, water column profiles of temperature &

DO and hypolimnetic chemistry data for Lake Eugenia are very limited, as is information on the spatial distribution, quantity, and quality of sediments.

3.2 Phytoplankton Community Composition

We are not aware of any data on Lake Eugenia's phytoplankton (planktonic algae and cyanobacteria) community composition except for the recent *Microcystis aeruginosa* bloom that was sampled by MECP and data from the HESL Aug 2022 field survey (see Section 2.2.2.3). Data on the phytoplankton species in the lake and how their biomass changes over time is needed to understand what is causing the harmful algal blooms. For instance, only some cyanobacteria can fix atmospheric nitrogen (i.e., can use N_2) which gives them an advantage over other types when nitrogen is limiting phytoplankton growth. Similarly, only certain types of phytoplankton produce toxins. Some phytoplankton can change their position in the water column to take up nutrients released by lake sediments, and others (e.g., certain cyanobacteria) may grow on the sediments early in the summer (assimilating sediment nutrients), then "bloom" later in the year when the cells are mixed to the surface by strong winds.

3.3 Macrophytes

To our knowledge, the only scientific data on the macrophytes of Lake Eugenia comes from Bobbette and Bobbette (1976) and Biotactic (2018). As with phytoplankton, the paucity of information and importance of this issue to residents make the lack of information on macrophytes (biomass, community composition, patterns of spatial coverage within the lake) a major data gap.

4. Recommendations

4.1 Management Recommendations

4.1.1 Macrophytes

At high density, macrophytes can foul shorelines and interfere with recreational activities such as boating and swimming. As early as 1976, residents of Lake Eugenia's shoreline expressed concern that macrophyte abundance had increased[9]. A variety of physical (i.e. raking, hand pulling, rotovating), chemical (e.g., Reward) and biological (e.g., weevils) removal options exist, but management of macrophytes will be a challenge for several reasons. First and foremost, the inherent characteristics of Lake Eugenia that encourage macrophyte growth cannot be appreciably changed (for instance, its bathymetry). Other considerations are the positive effects of climate change on macrophyte growth, the likely presence of a dense seed bed in the sediments, and that removal often results in the generation of plant fragments (many of which can root directly, so any reductions in macrophyte coverage will be temporary). Also, removal of macrophytes can result in oxygen depletion, shifts in zooplankton abundance, sediment disturbance, and, most notably, increased phytoplankton growth, especially toxic cyanobacteria (Wojciechowski et al. 2016). Macrophytes provide habitat for various animals (e.g., fish), stabilize sediments (maintaining water clarity),

[9] *"Many of the cottagers on the lake feel that the amount of vegetation in the lake has increased over the past few years, as more areas of the lake have been subjected to development." – Butler (1976)*

and store nutrients in their biomass that could otherwise fuel phytoplankton growth[10]. Shifting a lake from a macrophyte-dominated state to a phytoplankton-dominated state decreases water clarity and increases the risks of cyanobacterial blooms, cyanotoxins, and taste and odour issues.

HESL did not observe extremely high densities of macrophytes during our August 2022 field survey. **It is our recommendation that aquatic plant removal should be restricted to those areas where they threaten or impair water use (e.g. beaches), and, where removal is deemed necessary, hand pulling should be used** and plant fragments should be controlled to minimize further dispersal. Pulling should be completed after July 15th (outside of the spring spawning period for resident fish species) so that sensitive life stages of fish are protected.

4.1.2 Phosphorus and Cyanobacterial Blooms

While the water quality of Lake Eugenia is generally good, cyanobacterial blooms have been observed both historically and recently. As noted previously, water column phosphorus concentrations are relatively low (and have not changed in decades) and nitrate is moderately high (and increasing), which suggests that phosphorus is the nutrient that constrains the growth of the phytoplankton (planktonic algae and cyanobacteria) in the lake. Given the generally low water-column phosphorus and Chl-a concentrations, evidence of hypolimnetic oxygen depletion, and episodic nature of the cyanobacterial blooms, we suspect that the growth of bloom-forming cyanobacteria in Lake Eugenia is supported by sediment phosphorus released under anoxic conditions (i.e., internal phosphorus loading). Cyanobacteria are particularly well-suited to exploit persistent or transient fluxes of phosphorus from sediments: some taxa transition between benthic (bottom-dwelling) and planktonic (water-column) growth phases and others (those that can produce gas vacuoles) can migrate vertically throughout the water column on the timescale of hours. The magnitude of internal phosphorus loading is expected to increase due to climate change: the ice-free season is lengthening, water column stratification is becoming stronger (Woolway et al., 2022), and hypolimnetic (deep-water) oxygen concentrations are decreasing (Jane et al., 2021); these factors are expected to increase the frequency and severity of cyanobacterial blooms (Pearl and Huisman, 2008).

There are various in-lake management techniques that can be used to reduce internal phosphorus loading. We evaluate these options for Lake Eugenia in the following section. It is important to note that phosphorus is cycled within a lake between the water column, biota (e.g., phytoplankton), and the sediments. Thus, while internal loading is likely the proximate cause of the blooms, ultimately, measures to control external inputs of phosphorus are also important. In this respect it is important to manage expectations: improvements in water quality can take years or even decades to become apparent.

4.1.2.1 Mitigation of Internal Loading

Several techniques can be used to reduce internal phosphorus loading: 1) oxygenation or aeration of the lakebed to prevent the development of anoxia and release of phosphorus from sediments, 2) addition of a

[10] *This was recognized by Butler (1976): "Nutrient levels in the water are surprisingly low. Lake Eugenia is quite productive, to the point where the aquatic vegetation has become a nuisance to sMOE cottager activities such as swimming and boating. It may be that the aquatic vegetation is utilizing the phosphorus and nitrogen available to its fullest extent, i.e. nutrients are concentrated within the plant tissues and so are not evident in the water."*

phosphorus-binding agent that prevents the release of phosphorus from sediments (e.g., alum or Phoslock©), and 3) hypolimnetic withdrawal methods designed to remove internally loaded phosphorus from bottom waters.

Oxygenation/aeration is typically accomplished either via direct injection of oxygen (or air) into the hypolimnion by a diffuser or through water column destratification (i.e., promotion of water circulation throughout the entire water column). For example, Prepas et al. (1997) utilized a fine-bubble, pure-oxygen diffuser system in Amisk Lake, Alberta to increase oxygen concentrations in bottom waters and reduce cyanobacterial blooms. Hypolimnetic dissolved oxygen concentrations were maintained above 5 mg/L, TP in the hypolimnion decreased by >50%, phytoplankton biomass decreased by 33% and the dominant phytoplankton shifted from cyanobacteria to diatoms.

Laminar Flow Inversion and Oxygenation System (offered by Clean Flo) and SolarBee systems are two water-circulation systems that are designed to mix water vertically to prevent stratification of the water column. The Laminar Flow Inversion and Oxygenation System pumps compressed air through a ceramic diffuser which creates a laminar flow as it rises to the surface. The SolarBee system is a solar-powered circulation system that draws water from a specified depth and discharges it to the surface. SolarBees could be used to circulate the surface waters in the shallow portions of Lake Eugenia and more importantly, the deep waters in the central portion of the lake by setting intake hoses at different depths.

Sediment phosphorus “inactivation” is a technique used to bind organic and inorganic phosphorus in sediment so that it is not released under anoxic conditions. Commonly used chemical binding agents are aluminum sulfate (alum) and Phoslock© (lanthanum-modified bentonite). Alum and Phoslock are commonly applied in the United States, Europe, and elsewhere, but not in Canada due in part to regulatory hurdles. Phoslock was applied to 5-ha Swan Lake, Markham in 2013 (Nürnberg and LaZerte, 2016) and other applications were planned (Nürnberg, 2017) but the importation of Phoslock into Canada has since been banned by the federal government. Alum currently faces similar regulatory hurdles in Ontario. Phoslock Environmental Technologies scientists and environmental toxicologists are trying to assist the Government of Canada determine the appropriate classification of Phoslock under the Canadadian Environmental Protection Act New Substance Program and concurrently lobbying provincial and federal Canadian governments towards approving Phoslock as a remedial tool in Canada (N. Trail, personal communication, October 25, 2022). Therefore, tt is possible that as cyanobacterial blooms continue to worsen and public awareness of the issue increases, phosphorus-binding agents may eventually be approved for use in Ontario.

Hypolimnetic withdrawal involves siphoning or pumping out anoxic, nutrient-rich water from the bottom layer of the water column. This is a relatively old and simple technique, but one that is not commonly used (Nürnberg 2020). One reason may be the need to treat the polluted hypolimnetic water prior to discharging it downstream.

HESL recommends that additional data on water column stratification, dissolved oxygen, internal nutrient loading, and phytoplankton be collected (as described in Section 4.2) prior to pursuing any active in-lake methods for the suppression of sediment phosphorus release in Lake Eugenia.

Little is known about the stratification/mixing regime of Lake Eugenia and its effects on internal nutrient loading and cyanobacterial bloom formation, particularly in the shallow areas of the lake (see Section 3.1). If internal phosphorus loading is restricted to the deepest (e.g., >9 m), stably stratified (i.e., for months) part of the lake, this entails treating only ~10 ha of the lake's surface area[11]. If transient water-column stratification (on the timescale of hours to days) in shallow water is causing internal loading (sufficient to support cyanobacterial growth) this entails treating much more of the lake, perhaps several hundred hectares. In the latter scenario, it is unlikely that treatment would be practical given the large area and the relatively low severity of the problem (i.e., the cyanobacterial blooms have not been spatially extensive or common, to HESL's knowledge).

4.1.2.2 Septic Inspections

Septic system effluent has traditionally been considered the primary human source of phosphorus from waterfront development (MOE, 2010). However, research over the past 20 years has consistently shown that a portion of septic system phosphorus is immobilized in soils. Robertson et al. (2019) utilized data collected over a 30-year period in Ontario and noted that phosphorus removal in septic drainfields averaged 66% at sites where sediments were calcareous, such as locations found in the Lake Eugenia watershed.

Septic reinspection programs are commonly completed to identify substandard systems and provide an educational tool for shoreline owners that encourages maintenance or replacement of septic systems due to the potential impacts to water quality. Municipalities and Conservation Authorities often complete visual inspections to identify septic systems with symptoms of failure (e.g., soft ground or ponding). The re-inspection programs are important in diagnosing failing septic systems, many of which were designed for much less use than they receive, and to increase awareness because it is ultimately the homeowner's responsibility to ensure that their septic system is operating effectively (Ontario Building Code (OBC), 2006, Section 8.9.2.3 (2)) and complies with OBC regulations. However, visual septic system inspections are limited by landowners providing access and the visual nature of the assessment.

The impacts of sewage systems should be considered in terms of both design and maintenance. Visual inspections are helpful to identify obvious failure and as an educational tool. However, a more detailed, in-depth examination of sewage treatment systems that are often completed as part of home inspections would be more beneficial to assess design and functionality. Detailed sewage treatment system surveys should include the following components:

- Building permits and associated documentation for each sewage treatment system should be gathered to determine the age of each system, the capacity of each system to handle the size of the associated residence and other OBC requirements.

- The functionality of each system should be determined through an examination of tank condition, liquid levels, baffles, scum and sludge depth. A flush test should also be completed to determine the ability of the leaching bed to disperse effluent.

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[11] *Based on bathymetry depicted in Hall (1976), it was determined via a GIS that approximately 7 ha is deeper than 30 feet (9.1 m); this represents ~1% of the lake's total area.*

- Replacement of dysfunctional systems with systems that meet the OBC and consideration of systems that are specifically designed to attenuate phosphorus (such as the Waterloo EC-P or Ecoflo DpEC systems), or utilization of iron-rich, non-calcareous “B” horizon soils for construction of leaching beds.

Though phosphorus loading from septic systems is not likely as high as traditionally believed, it may still constitute a sizeable nutrient load to Lake Eugenia. **Waterfront residents should be educated about septic system issues and an inspection program should be instituted to enforce necessary changes. The Municipality of Grey Highlands should also develop a Bylaw designed to ensure pump-out frequency and maintenance of all septic systems.**

4.1.2.3 Shoreline Buffers and Stormwater

A shoreline buffer is an area along the shoreline that is naturally vegetated or re-vegetated. Shoreline buffers are a well-studied mitigation measure associated with waterfront development. The availability of information results from the well-known and established effectiveness of shoreline buffers in mitigating the impacts of stormwater via enhanced filtration, infiltration, and attenuation. Buffers filter sediment and other pollutants, and absorb nutrients from runoff, thereby helping to mitigate impacts of stormwater (Beacon Environmental, 2012). Vegetative buffers can also mitigate social density by screening the view of the shoreline from the lake, providing a buffer for view and noise between lots, and providing more of a wilderness aesthetic.

Shoreline development practices on Lake Eugenia predominantly comprise the creation and maintenance of manicured lawns. Such lawns, especially when fertilized, have a wide variety of environmental repercussions but are particularly bad practice when adjacent to a waterbody. Natural shoreline vegetation filters runoff, prevents erosion, provides wildlife habitat, and ultimately help to mitigate impacts to water quality associated with residential development. Natural shorelines are also generally avoided by nuisance species like Canada Geese (*Branta canadensis*), which produce phosphorus-rich excrement that degrades water quality.

A vegetated buffer zone of sufficient size provides a range of ecological services. A width of 30 m is commonly recommended in the peer-reviewed literature focused on shoreline development, aligning with Provincial guidance (HESL, 2021). While smaller buffers provide some benefits for water quality and aquatic habitat protection, larger buffers provide more ecological services, more completely. Buffers will likely become more important in protecting lake health as climate change effects on freshwater systems continue to intensify.

It is therefore recommended that an educational program be developed to encourage the establishment of natural shoreline vegetative buffers and reduce the use of pesticides and fertilizers. The Municipality of Grey Highlands should develop policies and enforcement mechanisms to encourage the development of naturally vegetated shoreline buffers at waterfront lots on Lake Eugenia with reasonable provisions for allowing water access and views.

4.1.2.4 Salt Management

Chloride concentrations are relatively low in Lake Eugenia (~8–10 µg/L) as discussed in Section 2.1.3, but concentrations are increasing over time and mid-lake (open-water) sampling results might under-represent chloride concentrations found in nearshore environments, especially after spring freshet (i.e., when tributary inputs are greatest). Salinization of freshwaters in Ontario has been an ongoing area of research and remains one of the most pressing environmental issues for recreational lakes near roadways such as Concession Road 8 which passes over the southern section of Lake Eugenia. Analysis of spatial patterns in long-term chloride data from the Lake Partner Program and broad-scale monitoring data collected by the MECP has shown that proximity to urban centres and major roadways was a substantial factor in determining chloride concentrations of freshwaters; this suggests that winter road maintenance and urban land use are the primary drivers of chloride concentrations in Central Ontario lakes (Sorichetti et al. 2022). Elevated concentrations of chloride are toxic to freshwater biota, with the current guideline for the protection of aquatic life being set at 120 mg/L. However, recent research has shown that the CWQG is not sufficient to protect lake food webs and should be reassessed (Hintz et al. 2022) while McClymont et al. (2022) noted that increased chloride concentrations, even at concentrations less than 120 mg/L, led to increased cyanobacteria abundance. **A Salt Management Plan should be developed by the Municipality to map vulnerable areas and identify Best Management Practices such as optimizing the use of road salts (e.g. pre-wetting), using alternatives to road salts, and locating snow disposal sites outside of vulnerable areas.** Training and certification is available through *Smart about Salt*, a not-for-profit organization that provides training to improve winter-salting practices and recognizes industry leaders through certification.

4.1.2.5 Common Carp

As noted by Biotactic (2018), the bottom-feeding activity of Carp spp. disturbs the sediments of Lake Eugenia, decreasing water clarity. By resuspending sediments, bioturbation by carp makes sediment nutrients more available within the water column (i.e., to phytoplankton) and reduces macrophyte coverage and habitat quality. While public response is likely to be underwhelming, any increase in the recreational harvest (angling, spearing, bow hunting, etc.) of common carp would benefit the lake's water quality and should be encouraged.

4.2 Monitoring Recommendations

It is recommended that the status quo monitoring of Lake Eugenia (conducted via the LPP and by the GSCA) be supplemented with more targeted investigations aimed at better understanding nutrient cycling, phytoplankton blooms, and macrophytes in the lake. These data will inform the management strategies described above (Section 4.1).

4.2.1 Water Column Structure and Internal Loading

At a minimum, vertical profiles of temperature and dissolved oxygen should be measured at the deepest location (44.317, -80.515) at a monthly frequency during the ice-free period. Water samples should be collected from the hypolimnion and analyzed for phosphorus, nitrogen, iron, manganese, and sulfur to quantify the rate of internal nutrient loading and to understand the controls on phosphorus efflux from the lakebed (i.e., sediment biogeochemistry). In addition to temperature and dissolved oxygen profiling, the measurement of additional parameters (specific conductance and phytoplankton fluorescence) via a multi-parameter sonde (e.g., YSI EXO2) would provide valuable data to explore the link between stratification, anoxia, internal nutrient loading and cyanobacterial growth. The optimal data collection method would be the installation of a monitoring buoy over the deepest part of the lake. A monitoring buoy outfitted with weather sensors and a series of water quality probes (suspended at various depths) would provide the high-frequency data needed to understand the correlation between weather, mixing, water chemistry and phytoplankton production.

Importantly, additional buoys with chains of sensors should be moored in other areas of the lake to ascertain how frequently the water column transiently stratifies in the shallows, to what degree the water immediately above the sediments loses oxygen under stratified conditions, and how these processes affect nutrient concentrations (as inferred from specific conductance) and phytoplankton biomass (as inferred from fluorescence). As noted above, if internal phosphorus loading is to be managed, it is critical to first understand its magnitude and where in the lake it is occurring.

4.2.2 Phytoplankton Assessment

The phytoplankton of Lake Eugenia should be sampled at several locations on a monthly basis during the ice-free season and its biomass and community composition determined by a trained taxonomist. If the financial resources are not available for comprehensive assessment of the phytoplankton community rapid assessments of the dominant taxa should be performed, at a minimum (HESL has this capability). Conspicuous surface aggregations of phytoplankton (i.e., cyanobacterial blooms) should continue to be reported to the MECP and sampled opportunistically (i.e., when they occur).

4.2.3 Macrophyte Surveys

The macrophytes in Lake Eugenia should be surveyed at least twice a year, in the summer and fall, to determine their biomass and what species are dominant, while aerial or satellite imagery should be used to map the distribution of emergent and submergent (if possible) species. A large number of sampling transects is recommended due to the patchy distributions that macrophytes typically exhibit so that the abundance and extent of macrophyte can be tracked over time.

4.2.4 Citizen-Science Led Algal Bloom Monitoring

Citizen scientists (i.e., local volunteers) should be prepared to record the onset, extent, and severity of cyanobacterial blooms for comparison against other environmental data to help characterize the conditions contributing to blooms. Potential options for collecting and storing data on blooms are numerous, from simple paper data sheets to more sophisticated options; for example, the US Environmental Protection Agency currently employs several smartphone applications (i.e., CYAN and Bloomwatch) to allow citizens to document harmful algae blooms including location, photos, and other metadata. If a bloom is suspected, it is important to contact the MECP's Spills Action Centre (1-800-268-6060 or 416-325-3000) to report the incident.

5. Summary

Lake Eugenia is a shallow lake with relatively low water-column nutrient concentrations that have changed little since the 1970s. However, recent algal blooms are a source of concern, and climate change is anticipated to exacerbate algal blooms in the future. The level of macrophyte coverage and the observation of occasional phytoplankton blooms in Lake Eugenia are not unexpected given the lake's morphometry, water clarity, and the importance of the sediments as a nutrient source for plants and phytoplankton. Based on the lake's water quality and short water residence time, HESL recommends that management action be focused on reducing loading of phosphorus from wastewater and stormwater through the implementation of a septic inspection program and development of naturally vegetated shoreline buffers. A more detailed understanding of water quality and phytoplankton processes is required before in-lake treatments such as sediment phosphorus inactivation (e.g., Phoslock) can be recommended. Lake management recommendations should be implemented to improve water quality and counteract the negative impacts that climate change is anticipated to have on water quality and recreational use of Lake Eugenia.

It is recommended that the status quo monitoring of Lake Eugenia (conducted via the Lake Partner Program and by the Grey Sauble Conservation Authority) be supplemented with more targeted investigations aimed at better understanding nutrient cycling, phytoplankton blooms, and macrophytes in the lake to inform the selection of in-lake management methods. The current monitoring of Lake Eugenia does not provide the information needed to fully understand the mechanisms underlying harmful cyanobacterial bloom formation, nor does it provide any information on the macrophyte community.

HESL recommends that the following actions be taken to improve Lake Eugenia water quality:

- Supplement status quo monitoring of Lake Eugenia with:
    - Targeted investigations to better identify the mechanisms underlying cyanobacteria formation and inform the development of a remedial action plan that identifies management strategies to control algal growth and improve water quality.
    - Citizen-science led algal bloom monitoring to record the onset, extent, and severity of cyanobacterial blooms for comparison against other environmental data to help characterize the conditions contributing to blooms.
- Educate waterfront residents about septic system issues, institute an inspection program to enforce necessary changes, and develop a Municipal bylaw designed to ensure pump-out frequency and maintenance of all septic systems.
- Educate waterfront residents and encourage the establishment of natural shoreline vegetative buffers. Develop Municipal policies and enforcement mechanisms to encourage the development of naturally vegetated shoreline buffers at waterfront lots on Lake Eugenia with reasonable provisions for allowing water access and views.
- Develop a Municipal salt management plan to map vulnerable areas, identify and implement Best Management Practices such as optimizing the use of road salts, using alternatives to road salts and locating snow disposal sites outside of vulnerable areas.

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Appendix A. Lake Partner Program Data

Lake_Name	Township	STN	Site_ID	Site_Description	Latitude	Longitude	Date	Var	Value	Units
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2013-05-20	Calcium	55.8	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2013-05-20	Calcium	56.6	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2013-06-15	Calcium	47.5	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2013-06-15	Calcium	46.1	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2013-07-17	Calcium	47.1	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2013-07-17	Calcium	42.7	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2014-05-18	Calcium	57.2	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2014-05-18	Calcium	58.2	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2014-06-20	Calcium	56	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2014-06-20	Calcium	53.8	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2014-07-20	Calcium	45.3	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2014-07-20	Calcium	44.3	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2015-05-16	Calcium	49.4	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2015-05-16	Calcium	54.4	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2015-06-20	Calcium	54.6	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2015-06-20	Calcium	51.6	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2016-05-29	Calcium	52.5	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2016-06-15	Calcium	47.4	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2016-06-15	Calcium	46	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2017-06-25	Calcium	51.1	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2017-06-25	Calcium	49.7	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2018-06-02	Calcium	64.4	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2018-06-02	Calcium	61.7	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2018-07-03	Calcium	51.8	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2018-07-03	Calcium	51.4	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2019-07-03	Calcium	50.6	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2019-07-03	Calcium	49	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2015-05-16	Chloride	6.76	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2015-05-16	Chloride	6.99	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2015-06-20	Chloride	7.04	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2015-06-20	Chloride	7.07	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2016-05-29	Chloride	8.15	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2016-06-15	Chloride	8.71	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2016-06-15	Chloride	8.13	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2017-06-25	Chloride	8.4	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2017-06-25	Chloride	8.31	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2018-06-02	Chloride	8.47	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2018-06-02	Chloride	8.33	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2018-07-03	Chloride	7.92	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2018-07-03	Chloride	8.02	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2019-07-03	Chloride	8.1	mg/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2019-07-03	Chloride	8	mg/L

Lake_Name	Township	STN	Site_ID	Site_Description	Latitude	Longitude	Date	Var	Value	Units
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2013-05-19	Secchi Depth	3.8	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2013-05-19	Secchi Depth	3.6	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2013-06-17	Secchi Depth	3.5	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2013-06-17	Secchi Depth	3.5	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2013-07-17	Secchi Depth	2.9	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2013-07-17	Secchi Depth	2.8	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2013-08-18	Secchi Depth	3.1	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2013-08-18	Secchi Depth	2.8	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2013-09-12	Secchi Depth	3	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2013-09-12	Secchi Depth	4.7	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2013-10-14	Secchi Depth	4.2	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2013-10-14	Secchi Depth	3.9	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2014-05-18	Secchi Depth	4.1	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2014-05-18	Secchi Depth	3.7	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2014-06-20	Secchi Depth	3.5	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2014-06-20	Secchi Depth	3.8	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2014-07-20	Secchi Depth	2.9	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2014-07-20	Secchi Depth	3.3	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2014-08-17	Secchi Depth	2.3	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2014-08-17	Secchi Depth	3	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2014-09-08	Secchi Depth	3.5	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2014-09-08	Secchi Depth	4.4	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2014-10-13	Secchi Depth	4.7	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2014-10-13	Secchi Depth	4.7	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2015-05-16	Secchi Depth	3	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2015-05-16	Secchi Depth	3.7	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2015-06-20	Secchi Depth	6.2	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2015-06-20	Secchi Depth	4	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2015-07-24	Secchi Depth	3	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2015-07-24	Secchi Depth	2.7	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2015-08-28	Secchi Depth	2.3	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2015-08-28	Secchi Depth	2.75	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2015-09-20	Secchi Depth	3.4	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2015-09-20	Secchi Depth	4.5	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2015-10-23	Secchi Depth	3.3	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2015-10-23	Secchi Depth	4.5	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2016-05-30	Secchi Depth	5	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2016-05-30	Secchi Depth	2.9	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2016-06-04	Secchi Depth	5	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2016-06-04	Secchi Depth	4.5	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2016-07-20	Secchi Depth	2.5	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2016-07-20	Secchi Depth	2.1	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2016-08-30	Secchi Depth	2.5	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2016-08-30	Secchi Depth	2.3	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2016-09-18	Secchi Depth	2.1	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2016-09-18	Secchi Depth	3.4	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2016-10-23	Secchi Depth	3.4	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2016-10-23	Secchi Depth	4.5	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2017-05-25	Secchi Depth	5	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2017-05-25	Secchi Depth	3	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2017-06-30	Secchi Depth	3	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2017-06-30	Secchi Depth	3.1	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2017-07-28	Secchi Depth	3	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2017-07-28	Secchi Depth	2.75	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2017-08-31	Secchi Depth	2.4	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2017-08-31	Secchi Depth	3.1	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2017-09-24	Secchi Depth	5	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2017-09-24	Secchi Depth	4.5	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2017-10-22	Secchi Depth	16	m
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2017-10-22	Secchi Depth	4.5	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2018-05-30	Secchi Depth	4	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2018-06-05	Secchi Depth	4	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2018-07-20	Secchi Depth	2	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2018-07-31	Secchi Depth	2.3	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2018-09-16	Secchi Depth	4	m
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2018-10-04	Secchi Depth	4.2	m

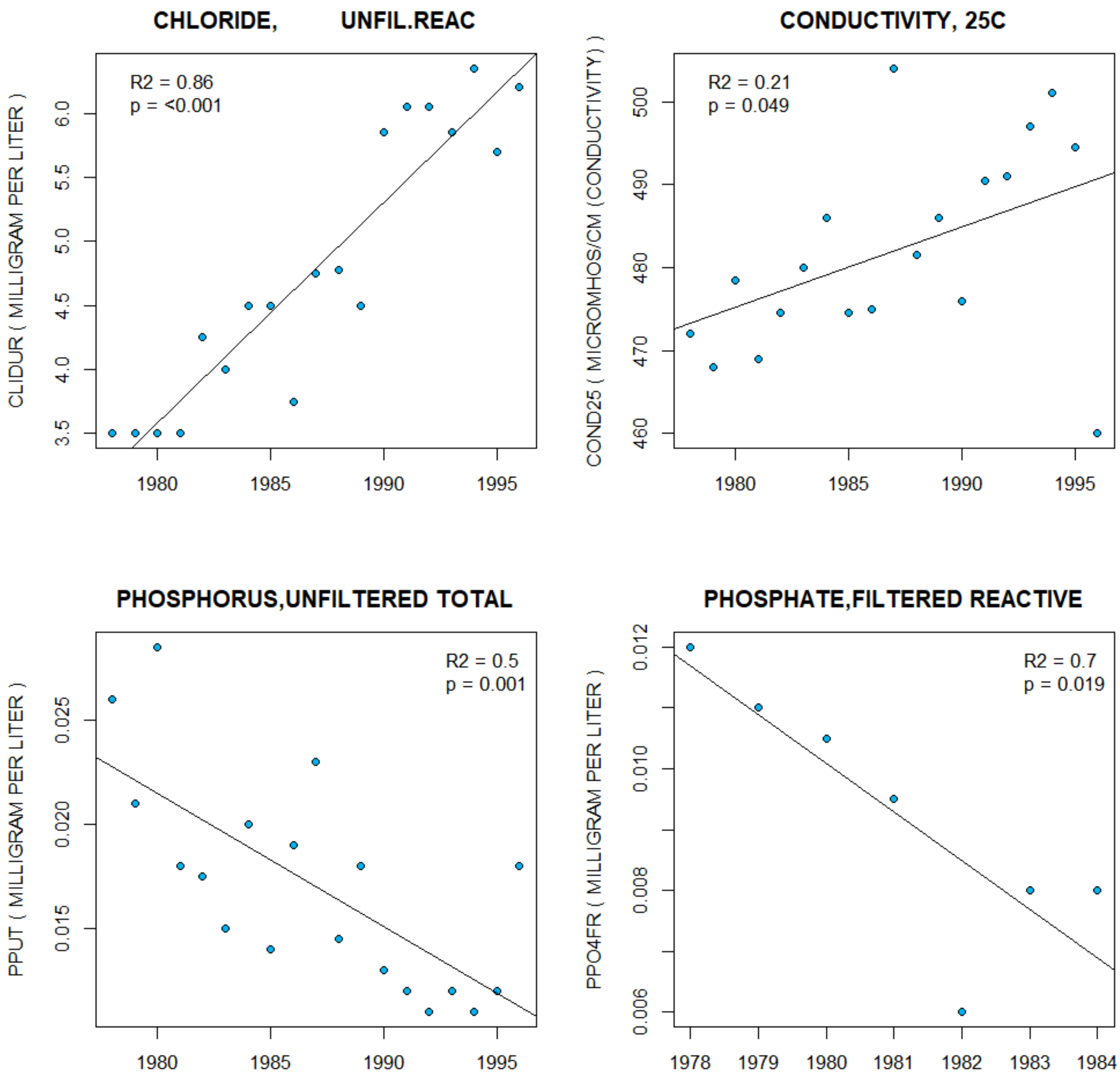
Lake_Name	Township	STN	Site_ID	Site_Description	Latitude	Longitude	Date	Var	Value	Units
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2013-05-20	Total Phosphorus	4.6	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2013-05-20	Total Phosphorus	9.5	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2013-06-15	Total Phosphorus	7	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2013-06-15	Total Phosphorus	6.9	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2013-07-17	Total Phosphorus	11.3	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2013-07-17	Total Phosphorus	7.5	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2013-08-18	Total Phosphorus	7.7	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2013-08-18	Total Phosphorus	87.8	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2013-09-17	Total Phosphorus	10.1	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2013-09-17	Total Phosphorus	9.5	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2013-10-14	Total Phosphorus	7.7	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2013-10-14	Total Phosphorus	7.3	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2014-05-18	Total Phosphorus	5	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2014-05-18	Total Phosphorus	4.9	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2014-06-20	Total Phosphorus	6.1	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2014-06-20	Total Phosphorus	6.2	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2014-07-20	Total Phosphorus	6.4	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2014-07-20	Total Phosphorus	6.5	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2014-08-17	Total Phosphorus	11.9	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2014-08-17	Total Phosphorus	7.4	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2014-09-08	Total Phosphorus	9.4	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2014-09-08	Total Phosphorus	7.5	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2014-10-13	Total Phosphorus	8	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2014-10-13	Total Phosphorus	7.3	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2015-05-16	Total Phosphorus	5.4	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2015-05-16	Total Phosphorus	6.7	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2015-06-20	Total Phosphorus	6.1	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2015-06-20	Total Phosphorus	19.8	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2015-07-26	Total Phosphorus	9.1	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2015-07-26	Total Phosphorus	19.5	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2015-08-27	Total Phosphorus	8.4	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2015-08-27	Total Phosphorus	6.3	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2015-09-20	Total Phosphorus	7.5	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2015-09-20	Total Phosphorus	8.2	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2015-10-20	Total Phosphorus	7.5	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2015-10-20	Total Phosphorus	6.6	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2016-05-29	Total Phosphorus	4.2	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2016-06-15	Total Phosphorus	8.2	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2016-06-15	Total Phosphorus	7.3	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2016-08-02	Total Phosphorus	10.8	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2016-08-02	Total Phosphorus	9.6	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2016-09-12	Total Phosphorus	8.8	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2016-09-12	Total Phosphorus	6.9	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2016-09-21	Total Phosphorus	8.4	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2016-09-21	Total Phosphorus	7.5	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2016-10-24	Total Phosphorus	8.3	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2016-10-24	Total Phosphorus	7.2	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2017-06-25	Total Phosphorus	9.3	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2017-06-25	Total Phosphorus	7.4	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2017-06-25	Total Phosphorus	8.4	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2017-07-31	Total Phosphorus	7.7	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2017-07-31	Total Phosphorus	5.4	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2017-08-28	Total Phosphorus	10.4	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2017-08-28	Total Phosphorus	6.7	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2017-09-23	Total Phosphorus	7.5	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2017-09-23	Total Phosphorus	6.7	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2018-06-02	Total Phosphorus	5.9	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2018-06-02	Total Phosphorus	6.7	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2018-07-03	Total Phosphorus	4.8	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2018-07-03	Total Phosphorus	5.4	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2018-07-15	Total Phosphorus	9.7	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2018-07-15	Total Phosphorus	8.6	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2018-09-04	Total Phosphorus	9.5	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2018-09-04	Total Phosphorus	8	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2018-09-17	Total Phosphorus	5.7	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2018-09-19	Total Phosphorus	5.3	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2018-09-19	Total Phosphorus	8.5	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2018-09-19	Total Phosphorus	8.8	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2019-07-03	Total Phosphorus	5.4	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2019-07-03	Total Phosphorus	5.2	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2019-08-16	Total Phosphorus	8.5	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2019-08-16	Total Phosphorus	8.2	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	1	Main basin, deep spot	44.3306	-80.4947	2019-08-26	Total Phosphorus	10.7	ug/L
EUGENIA LAKE	GREY HIGHLANDS	6853	2	Lagoon, deep spot	44.3128	-80.4892	2019-08-26	Total Phosphorus	10.8	ug/L

Appendix B. Provincial Water Quality Monitoring Network data summaries

Table B1. Water quality summary for the upper Beaver River (1978-1996) based on PWQMN station 03003600602 (Beaver River at Feversham)

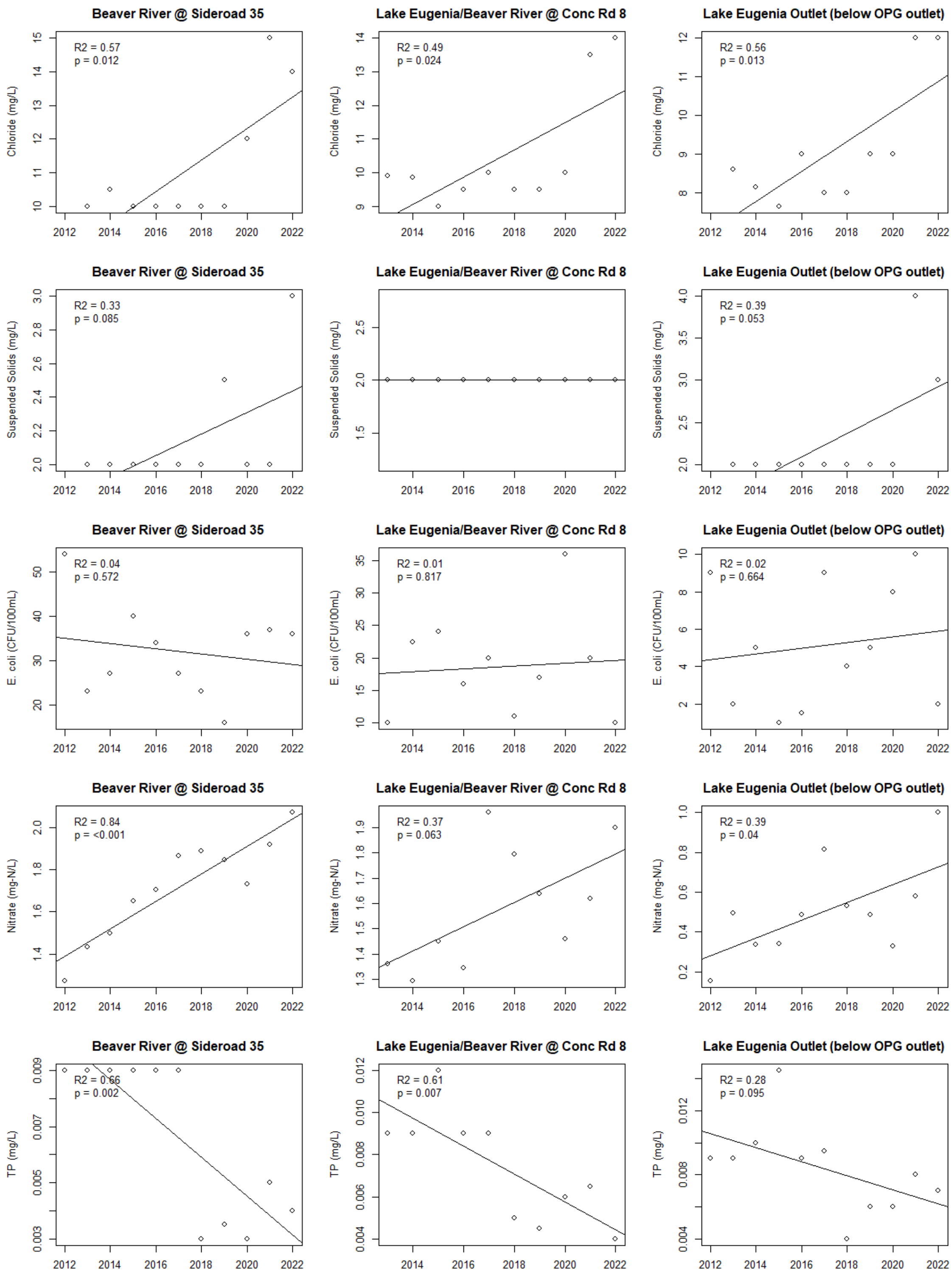
	#	Years	From	To	Min.	10th%ile	25th%ile	Average	Median	75th%ile	90th%ile	Max.
Ammonium, Total (mg-N/L)	133	19	1978	1996	0.001	0.005	0.005	0.016	0.010	0.015	0.024	0.335
Biochemical Oxygen Demand (mg/L)	50	5	1978	1982	0.10	0.20	0.30	0.56	0.50	0.78	0.90	2.10
Chloride (mg/L)	133	19	1978	1996	2.3	3.0	3.5	4.6	4.5	5.4	6.3	7.6
Specific Conductance (uS/cm)	133	19	1978	1996	322	428	462	472	477	496	504	530
Dissolved Oxygen (mg/L)	47	5	1978	1982	8.3	9.0	9.8	11.6	11.0	13.0	15.0	17.6
Nitrate (mg-N/L)	66	7	1978	1984	0.62	1.02	1.19	1.36	1.35	1.54	1.68	2.20
Nitrite (mg-N/L)	133	19	1978	1996	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.05
TKN (mg-N/L)	133	19	1978	1996	0.17	0.21	0.23	0.31	0.28	0.35	0.41	0.82
pH	132	19	1978	1996	7.8	8.0	8.1	8.2	8.2	8.2	8.3	8.4
Filtered Reactive Phosphorus (ug/L)	66	7	1978	1984	1	4	6	12	9	14	20	110
Total Phosphorus (ug/L)	133	19	1978	1996	4	9	12	20	15	26	34	133
Dissolved Solids (mg/L)	49	5	1978	1982	226	248	268	280	282	297	306	324
Particulate Solids (mg/L)	133	19	1978	1996	0.1	1.0	2.3	4.7	4.7	5.0	8.1	24.3
Total Solids (mg/L)	50	5	1978	1982	224	254	274	286	287	302	316	326
Water Temperature (Deg. C)	129	19	1978	1996	0.3	1.0	2.5	8.2	8.5	13.0	15.4	19.7
Turbidity (FNU)	80	12	1978	1989	0.4	0.5	0.8	1.5	1.0	1.3	2.2	11.2

Figure B1. Water quality trends for the upper Beaver River based on PWQMN station 03003600602 (Beaver River at Feversham).



Appendix C. Trends in GSCA Data

Figure C1. Trends in annual median water chemistry (Grey Sauble Conservation Authority data)

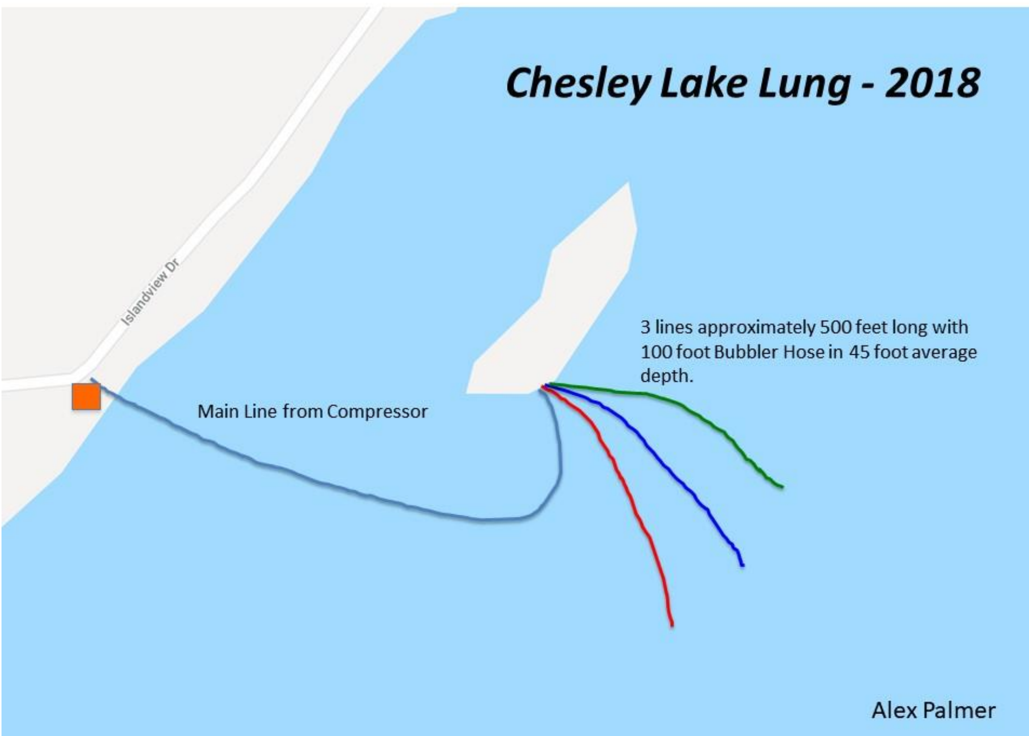


Chesley Lake has successfully employed aeration (they have named it the "lung") to improve water quality. We have attached The Chesley Lake Cottage Association's report on the success of the installation.

Lung Info

Background

In the late 1970's Chesley Lake began to exhibit some water quality problem, noticeable to the residents in the form of algae blooms and lack of sport fish. Spawning shoal enhancements were made (walleye) met with some success, but poor water quality conditions appeared to be the limiting factor preventing fish community growth.



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Chesley Lake Lung Project

The Lake Lung Project was an innovation proposed to restore water quality of Chesley Lake through hypo limnetic oxygenation through an aeration system to assist the recovery. However the Lake Lung Project could not alone recover and maintain water quality of the lake. The CLCA also began educating residents through newsletters and public meetings to use phosphate free products, not use fertilizers, and be more environmentally aware of their daily behaviour on the health of the lake. The Chesley Lake Sewage Systems Survey prepared by the Grey-Bruce-Owen Sound Health Unit, Environmental Division (1994) resulted in numerous septic systems upgraded under the C.U.R.B. program (Clean-Up-Rural-Beaches). Tighter building restrictions were placed around the lake. A hatchery was started to improve walleye stock and a programme of fish stocking which continues to present day.

Through the 1990's and into the 2000's the oxygen equipment was working well, only requiring maintenance of equipment and underwater pod cleaning. Water testing was ongoing with oxygen and phosphorus levels being monitored. There were many other changes going on around the lake; older cottages replace by new ones, some of which are permanent homes. Better septic systems and more awareness on the on the environmental impacts residents have on daily living on the lake contributed to improved water quality.

Bubbler Aeration - Linear Oxygen Diffuser

In the spring of 2001, a severe storm with high winds and shifting ice severed the unit from its anchors and severely damaged the oxygen lung beyond repair. It was eventually removed from the lake. The Association received an insurance claim totaling $55,000.00 which allowed us to proceed with an alternate underwater system.

In 2002 it was decided to try an alternate method of Lake Oxygenation using bubbler aeration technology. In 2003, the bubbler system was revamped to include ceramic modules which produce much finer bubbles that are more easily absorbed by the water.

Fine bubble aeration is an efficient way to transfer oxygen to a water body. A compressor on shore pumps air through a hose, which is connected to an underwater aeration unit. Fine bubble diffused aeration is able to maximize the surface area of the bubbles and thus transfer more oxygen to the water per bubble. This equipment was installed in 2002 and was fully operational in 2003.

The next stage was to plan for the future direction of Chesley Lake. A $25,000.00 study was approved by the Ministry of Natural Resources under the Provincial Fish & Wildlife Enhancement & Protection Program. The report released in May 2002 confirmed the work done to date, including the ongoing addition of oxygen to deeper areas of the lake, was helping restore the lake, but it continued to be environmentally sensitive.

By 2015 the equipment was aging and beginning to fail, thus some new investments into equipment replacement were necessary, such as a compressor, building repairs, oxygen generation plant reconditioned, as well as updating the in water bubbler system. Since the bubbler was installed the quality of the lake water has shown steady improvement. The chart below shows the phosphate level improvement in the lake water over the last 25 years.

1988 shallow .019 mg/l - deep .062 mg/l
2005 shallow .013 mg/l - deep .020 mg/l
2012 shallow .008 mg/l - deep .013 mg/l

The goal of the Chesley Lake Cottage Association is to bring those numbers down even further with the hope of reaching the Ministry standard of .002 mg/l.

In the spring of 2018 new bubble tubing was installed with micro bubble technology using Bubble Tubing®. These tubes produce smaller bubbles and the smaller the bubble diameter, the higher oxygen transfer rate. Millions of fine micro-bubbles create a larger surface area to transfer oxygen than fewer larger (coarse) bubbles. Additionally, smaller bubbles take more time to reach the surface so not only is the surface area maximized but so are the number of seconds each bubble spends in the water, allowing it more time to transfer oxygen to the water. The tubing is be placed in 3x 100 foot lengths about 400' east of the island, in approximately 45' of water.

Phosphorus readings (Provincial acceptable limit is < .010 mg / l)		
Year	**Shallow**	**Deep**
1988	.019 mg / l	.062 mg / l
2005	.013 mg / l	.020 mg / l
2012	.008 mg / l	.013 mg / l
2019	0.011 mg / l	0.012 mg / l
2021	0.012 mg / l	0.013 mg / l

Email : info@chesleylakecottageassociation.com

January 17, 2023

Mr. Doug Hill
Friends of Lake Eugenia
dghmanagement@yahoo.com

Dear Mr. Hill,

Re: Lake Eugenia 2023 Monitoring Proposal

The Friends of Lake Eugenia are concerned about water quality and cyanobacterial blooms in Lake Eugenia. In our recent report (Hutchinson Environmental Sciences Ltd. (HESL) 2023[1]), we noted data gaps and made recommendations for enhanced study of the lake to inform management options. Specifically, we made the following observations:

- internal phosphorus loading is likely appreciable in deep areas and may also occur intermittently when shallower areas undergo transient stratification;
- there is limited information on stratification/mixing, hypolimnetic chemistry, and sediments; and
- data on the phytoplankton community is limited but is needed to understand what is causing the harmful algal blooms.

We recommended that additional data on water column stratification, dissolved oxygen, internal nutrient loading, sediment chemistry and phytoplankton be collected prior to pursuing any active in-lake methods for the suppression of sediment phosphorus release in Lake Eugenia (i.e., water-column circulation, hypolimnetic aeration or withdrawal, or sediment phosphorus inactivation by alum or Phoslock).

In the following paragraphs we provide a detailed plan for the recommended monitoring of Lake Eugenia in 2023.

Workplan

The proposed 2023 field program for Lake Eugenia involves monitoring water quality, sediment phosphorus, water-column structure, and cyanobacterial blooms (Table 1).

[1] *HESL. 2023. Scoped Lake Eugenia Management Study. Prepared for the Friends of Lake Eugenia.*

Table 1. Proposed 2023 field program for Lake Eugenia

Type	Frequency	Parameters	Period	Surveys	Sites	Sub-sites	Samples
water quality	monthly	total P, total N, NO_3, NO_2, TKN, metals (all sites) Chl-a & phytoplankton (deep site only)	May–October	6	3	surface & 0.5-m off bottom	36
sediment	once	sediment phosphorus fractions	May/June	1	3	1	3
water-column structure	continuous	temperature, dissolved oxygen, conductivity	May–October	–	3	surface & 0.5-m off bottom	–
blooms	as necessary	biomass, taxonomic affiliation, cyanotoxins	as necessary	–	–	–	–

Water Quality Surveys

Water quality surveys will be completed monthly, from May through October, at 3 sites (Figure 1): the deepest location (~12 m) near the dam (LE1), and near the Ministry of Environment, Conservation and Parks (MECP) Lake Partner Program locations in the northeastern (LE3) and southeastern (LE5) areas of the lake. In the field, proximity to the intended site locations and target depths will be verified upon arrival by consulting GPS and navigational charts (e.g., Navionics). At each site, the Secchi depth will be determined, and integrated water samples collected by weighted bottle from the upper mixed layer (surface to Secchi depth) and by Van Dorn bottle from 0.5-m above the lakebed. The water column will be profiled by YSI sonde for temperature, dissolved oxygen, specific conductance, and pH, and by FluoroProbe for fluorescent dissolved organic matter and phytoplankton pigment fluorescence. The water samples will be shipped to ALS Laboratories for determination of nutrients and metals (all sites and depths), and chlorophyll-a and phytoplankton (surface samples from LE1 only; Table 1).

Sediments

The sediments will be sampled at the 3 water quality survey sites and analyzed for phosphorus content of various fractions to determine the mass of potentially releasable phosphorus (i.e., the amount of phosphorus that could contribute to internal loading). Three sub-samples will be collected from the top 10 cm of the lakebed by gravity corer at each site and composited for analysis yielding 1 composite sample per site. The sediment samples will be collected early in the season (May or June), ideally following calm conditions (i.e., of minimal vertical mixing); sampling at this time will ensure that the maximum mass of releasable phosphorus is contained in the sediments rather than the water column and thus prevent underestimation of the mass of phosphorus that would need to be accounted for if sediment phosphorus inactivation were to be employed.

Water-Column Structure

Water temperature will be recorded at high frequency to characterize temporal variation in water column stratification. High-frequency dissolved oxygen data will be recorded to characterize the potential for anoxia-driven internal phosphorus loading; this will be especially important at the two shallow sites (LE3, LE5) where vertical mixing and oxygen concentrations are likely very dynamic. Information is needed on how often the water column stratifies at these shallower sites and whether stratification is sufficiently strong and persistent to cause anoxia (oxygen depletion) above the lakebed. Specific conductance will be monitored as a surrogate for phosphate and iron ion concentrations.

Buoys will be moored at each of the three sites with loggers attached near the surface and near the lakebed. Water temperature and specific conductance will be monitored in the surface waters (1 m) and above the lakebed (0.5-m off bottom) and dissolved oxygen will be monitored above the lakebed (minimum surface oxygen concentrations are predictable based on temperature and thus do not need to be measured). Data offloads and maintenance of the sensors will be performed monthly.

Figure 1. Proposed 2023 Lake Eugenia Sampling Locations

Cyanobacterial Blooms

Cyanobacterial blooms should be characterized by Lake Eugenia citizen scientists (volunteers) whenever observed and then reported to the MECP. Citizen scientists should record the onset, extent, and severity of cyanobacterial blooms for future comparison against other environmental data. The MECP should confirm the status of the suspected bloom (i.e., is it a cyanobacteria bloom or, e.g., just pollen or disturbed macroalgae?) and if the bloom is confirmed, identify the species and assay for cyanotoxins. HESL will sample any blooms that exist at the time of the scheduled monthly surveys.

Reporting

The 2023 Lake Eugenia Monitoring Report will build on the *Scoped Lake Eugenia Management Study* (HESL 2023) and focus on developing specific management recommendations, including the potential effectiveness of in-lake active management techniques, based on a comprehensive understanding of water quality processes and phytoplankton assemblages in Lake Eugenia.

Budget

The total cost to complete the tasks described herein is $49,853 + HST, including $19,468 in disbursements which are primarily laboratory fees associated with water chemistry analysis and taxonomic identification of phytoplankton assemblages. If you agree with our understanding of the terms of this engagement as described above, please provide me with written authorization to proceed. We look forward to working with you to bring this project to a successful conclusion. If you have any questions, please feel free to give me a call.

Table 2. Budget

Task	Fees	Disbursements	Total
Field Investigations	$17,025	$19,468	$36,493
Reporting	$13,360		$13,360
		Total	$49,853

Sincerely,
Per. Hutchinson Environmental Sciences Ltd.

Brent Parsons, M.Sc.
Senior Aquatic Scientist