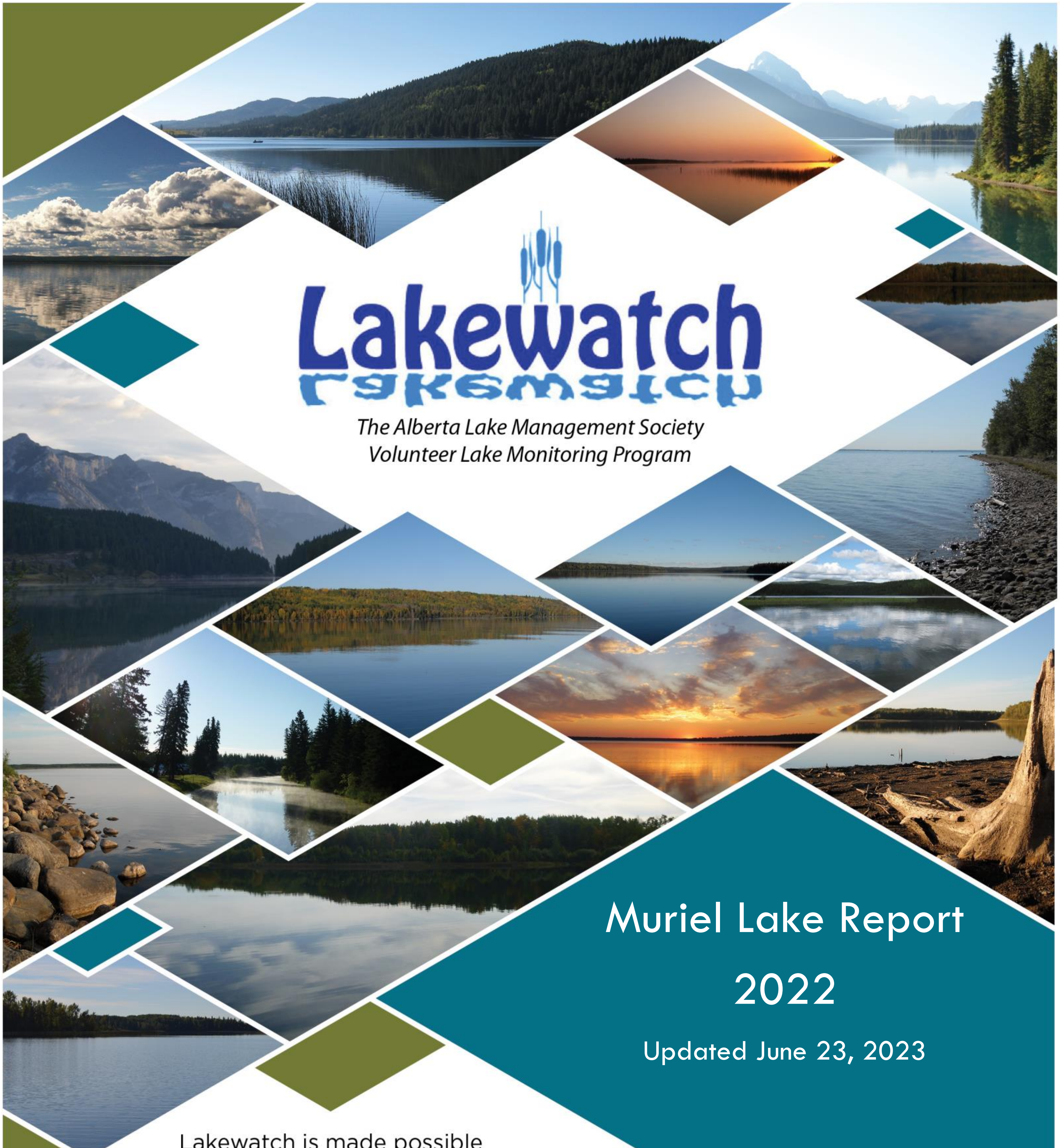

Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Muriel Lake Report 2022

Updated June 23, 2023

Lakewatch is made possible with support from:

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ALBERTA LAKE MANAGEMENT SOCIETY'S LAKEWATCH PROGRAM

LakeWatch has several important objectives, one of which is to collect and interpret water quality data from Alberta's Lakes. Equally important is educating lake users about aquatic environments, encouraging public involvement in lake management, and facilitating cooperation and partnerships between government, industry, the scientific community and lake users. LakeWatch reports are designed to summarize basic lake data in understandable terms for the widest audience, and are not meant to be a complete synopsis of information about specific lakes. Additional information is available for many lakes that have been included in LakeWatch, and readers requiring more information are encouraged to seek those sources.

ALMS would like to thank all who express interest in Alberta's aquatic environments, and particularly those who have participated in the LakeWatch program. These leaders in stewardship give us hope that our water resources will not be the limiting factor in the health of our environment.

If you require data from this report, please contact ALMS for the raw data files.

ACKNOWLEDGEMENTS

The LakeWatch program is made possible through the dedication of its volunteers. A special thanks to Richard Bourgeois and Jeff Hlewka for their commitment to collecting data at Muriel Lake. We would also like to thank Kurstyn Perrin and Dominic Wong, who were summer technicians in 2022. Executive Director Bradley Peter and Program Manager Caleb Sinn were instrumental in planning and organizing the field program. This report was prepared by Caleb Sinn and Bradley Peter.

MURIEL LAKE

Muriel Lake—photo by Ageleky Bouzetos 2015

Muriel Lake is located 13 km south of the town of Bonnyville and 250 km northeast of Edmonton. The first establishment in the area by non-aboriginal peoples was a fur-trading post in 1781 by the North West Company near the present-day hamlet of Beaver Crossing, about 35 km northeast of Muriel Lake. The first settlers came to the Bonnyville area in 1907 and established an economy based on the timber industry. Two sawmills were located at Muriel Lake, one at the northeastern tip and the other on the large island/peninsula on the eastern shore.

In the 1920's, a large fire forced the economic base to switch to agriculture. There are several subdivisions (391 lots) around the lakeshore, mostly on the south and east sides of the lake. Much of the watershed is occupied by the Kehewin Cree Nation Reserve 123, located on 8200 ha of land southwest of the lake. The largest recreational facility on Muriel Lake is Muriel Lake Park, which is operated by the Municipal District of Bonnyville.

Northern pike, yellow perch, lake whitefish, and walleye were once prevalent in the lake, however these fish are no longer stocked, and a 2012 netting of the lake performed by Environment and Sustainable Resource Development revealed no sport fishes are present in Muriel Lake; only brook stickleback and longnose suckers were captured in the 2012 netting[1]. Low winter dissolved oxygen levels (3.0 mg/L) leaves Muriel Lake at a high risk for fish kills.[1] Muriel Lake is a large (64.1 km^2) but shallow water body with a relatively small drainage basin, measuring only 4.8 times the size of the lake area. The shorelines consist primarily of steep rocky slopes, but there are also several attractive sandy beaches. Water levels have been monitored since the late 1960's and since then have dropped by as much as 4.5 m.

[1] Latty, D. (2012). Muriel Lake Fall Walleye Index Netting, 2012. Alberta Environment and Sustainable Resource Development. Retrieved on February 21st, 2012 from: http://srd.alberta.ca/FishWildlife/FisheriesManagement/FallWalleyeIndexNetting/Default.aspx

BEFORE READING THIS REPORT, CHECK OUT A BRIEF INTRODUCTION TO LIMNOLOGY AT ALMS.CA/REPORTS

WATER CHEMISTRY

ALMS measures a suite of water chemistry parameters. Phosphorus, nitrogen, and chlorophyll-a are important because they are indicators of eutrophication, or excess nutrients, which can lead to harmful algal/cyanobacteria blooms. One direct measure of harmful cyanobacteria blooms are Microcystins, a common group of toxins produced by cyanobacteria. See Table 2 for a complete list of parameters.

The average total phosphorus (TP) concentration for Muriel Lake was 51 μg/L (Table 2), falling into the eutrophic, or highly productive trophic classification. This value falls within the middle of the range of previously observed historical averages going back to 1988 (Table 2). TP ranged from a minimum of 45 μg/L on the June 29th and August 17th, to a maximum of 61 μg/L on September 16th (Figure 1).

Average chlorophyll-*a* concentration in 2022 was 15.1 μg/L (Table 2), falling into the eutrophic, or highly productive trophic classification. Chlorophyll-*a* was lowest during the June 29th sampling event at 10.1 μg/L, and peaked at 21.4 μg/L on September 16th.

The average TKN concentration was 3.5 mg/L (Table 2), and displayed little seasonal variation, but increased slightly as the season progressed (Figure 1).

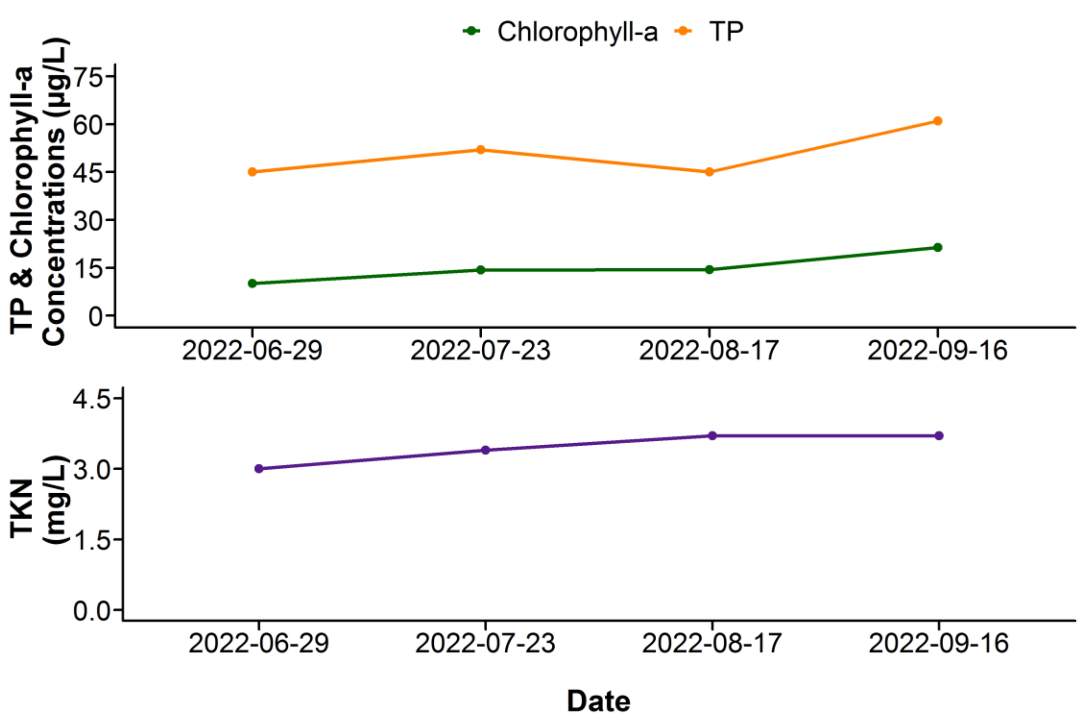


Figure 1. Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured four times over the course of the summer at Muriel Lake.

Average pH was measured as 9.12 in 2022, buffered by high alkalinity (932 mg/L $CaCO_3$) and bicarbonate (730 mg/L HCO_3). Aside from bicarbonate, sulphate, sodium, magnesium and carbonate were higher than all other major ions, and together contributed to a high conductivity of 2200 µS/cm (Figure 2, top; Table 2). Muriel Lake is in the high-end range of ion levels, compared to other LakeWatch lakes sampled in 2022, with the exception of calcium, being at a relatively low level. (Figure 2, bottom).

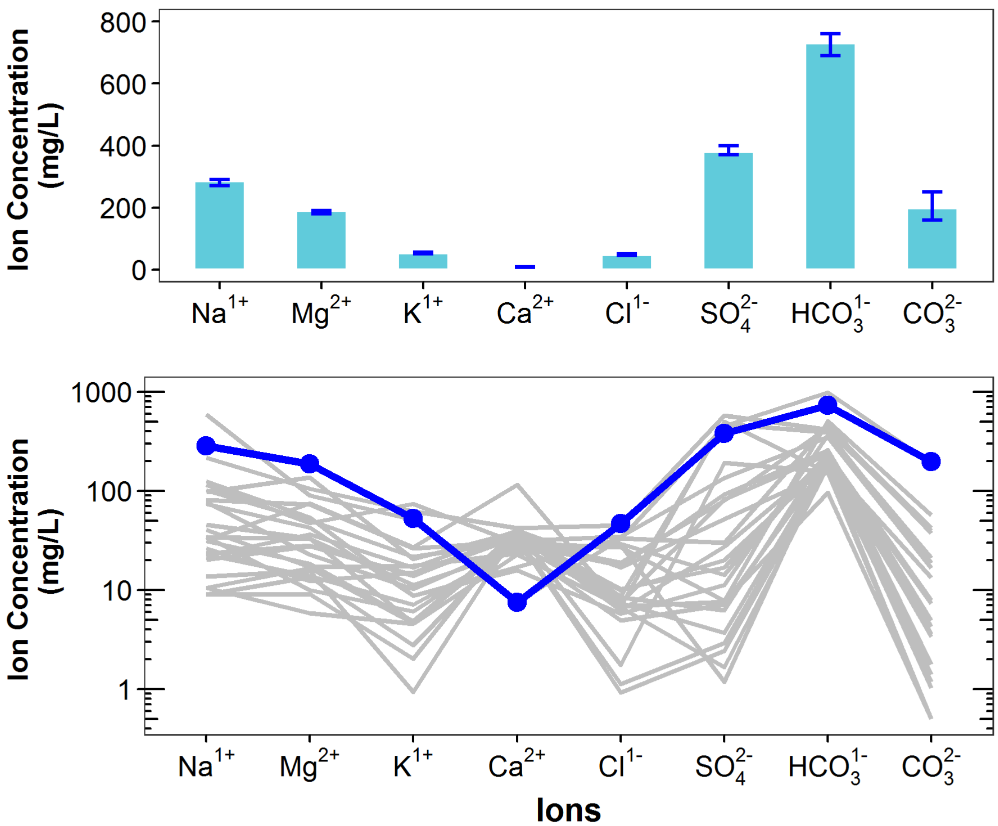


Figure 2. Average levels of cations (sodium = Na^{1+}, magnesium = Mg^{2+}, potassium = K^{1+}, calcium = Ca^{2+}) and anions (chloride = Cl^{1-}, sulphate = SO_4^{2-}, bicarbonate = HCO_3^{1-}, carbonate = CO_3^{2-}) from four measurements over the course of the summer at Muriel Lake. Top) bars indicate range of values measured, and bottom) Schoeller diagram of average ion levels at Muriel Lake (blue line) compared to 26 lake basins (gray lines) sampled through the LakeWatch program in 2022 (note $\log_{10}$ scale on y-axis of bottom figure).

Metals

Metals will naturally be present in aquatic environments due to in-lake processes or the erosion of rocks, or introduced to the environment from human activities such as urban, agricultural, or industrial developments. Many metals have a unique guideline as they may become toxic at higher concentrations. Where current metal data are not available, historical concentrations for 27 metals have been provided (Table 3).

Metals were measured at Muriel Lake in 2022, and Arsenic was the only metal to exceed the CCME guideline for the protection of aquatic life, chronic (Table 3).

WATER CLARITY AND EUPHOTIC DEPTH

Water clarity is influenced by suspended materials, both living and dead, as well as dissolved colored compounds in the water column. During the melting of snow and ice in spring, lake water can become turbid (cloudy) from silt transported into the lake. Lake water usually clears in late spring, but then becomes more turbid with increased algal growth as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi depth. Two times the Secchi depth equals the euphotic depth – the depth to which there is enough light for photosynthesis.

The average euphotic depth of Muriel Lake in 2022 was 2.24 m, corresponding to an average Secchi depth of 1.12 m (Table 2). Euphotic depth varied over the season, ranging from as deep as 2.70 m on June 29th, to 1.90 m on September 16th (Figure 3).

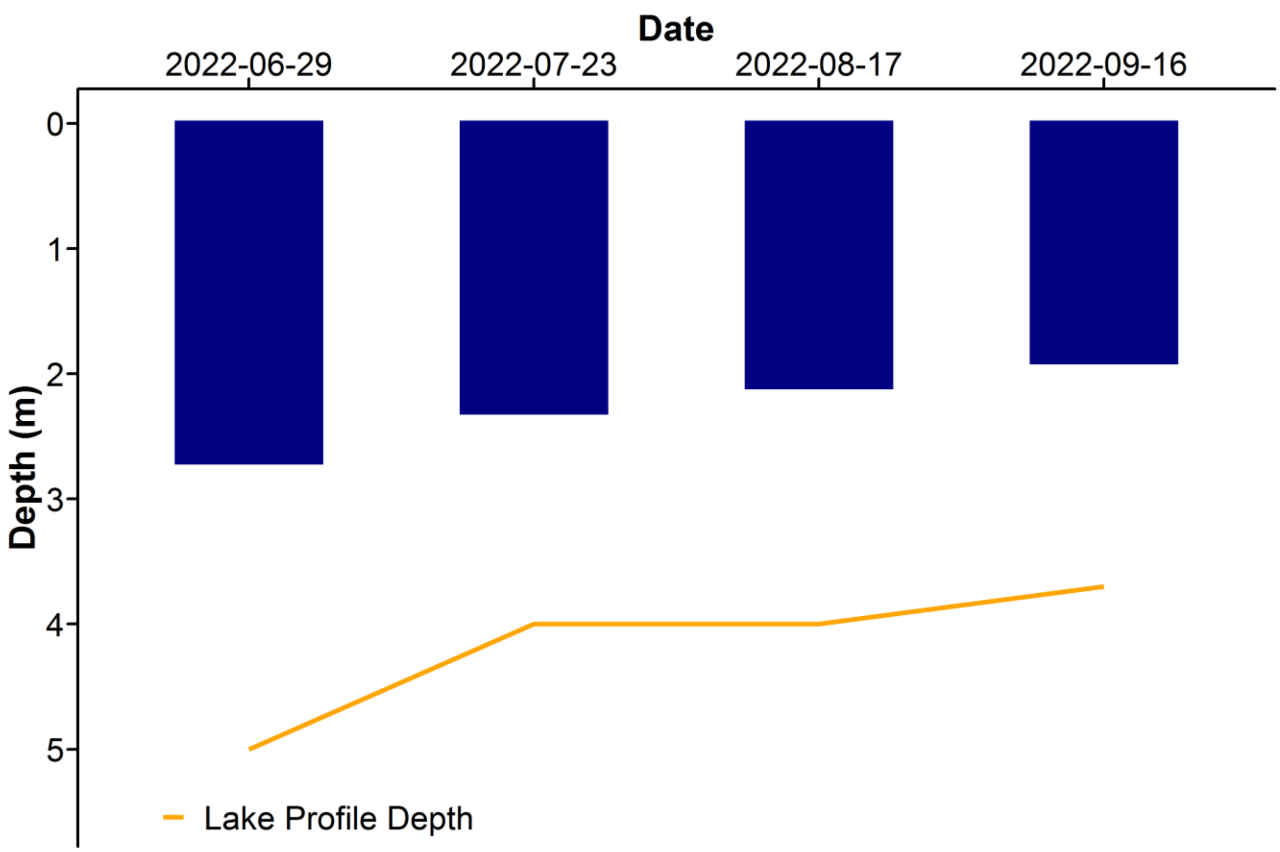


Figure 3. Euphotic depth values measured four times over the course of the summer at Muriel Lake in 2022.

WATER TEMPERATURE AND DISSOLVED OXYGEN

Water temperature and dissolved oxygen (DO) profiles in the water column can provide information on water quality and fish habitat. The depth of the thermocline is important in determining the depth to which dissolved oxygen from the surface can be mixed. Please refer to the end of this report for descriptions of technical terms.

Surface temperatures of Muriel Lake varied throughout the summer, with the August 17th sampling date having the warmest temperatures at 23.9°C (Figure 4a). The lake was completely mixed during each sampling event, with weak stratification measured during the August 17th sampling event, as the temperature decreased slightly with depth.

Muriel Lake was well oxygenated in the surface waters on all sampling dates, measuring above the CCME guidelines of 6.5 mg/L dissolved oxygen (Figure 4b). In addition, high oxygen levels were maintained through the entire water column during each sampling event. A slight decrease in oxygen was measured towards the bottom of the lake (3.5 m) during the August 17th sampling event, in accordance with the weak temperature stratification detected.

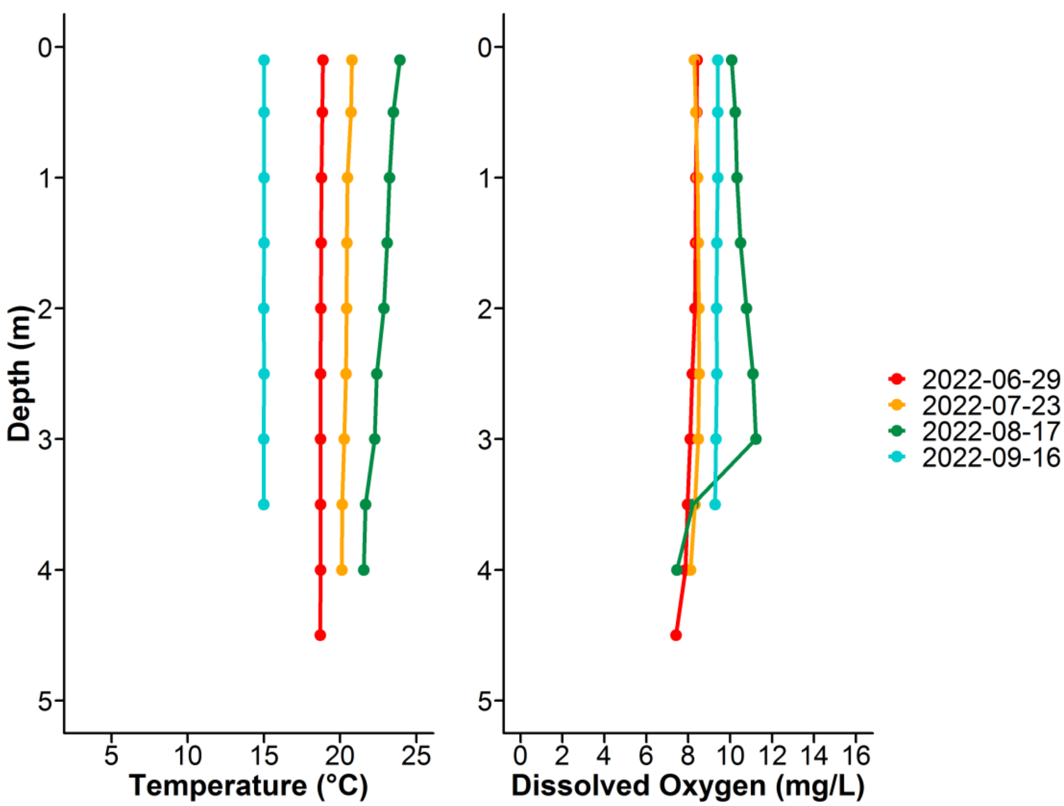


Figure 4. a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Muriel Lake measured four times over the course of the summer of 2022.

MICROCYSTIN

Microcystins are toxins produced by cyanobacteria (blue-green algae) which, when ingested, can cause severe liver damage. Microcystins are produced by many species of cyanobacteria which are common to Alberta's Lakes, and are thought to be one of the most common cyanobacteria toxins. In Alberta, recreational guidelines for microcystin are set at 10 μg/L. Blue-green algae advisories are managed by Alberta Health Services. Recreating in algal blooms, even if microcystin concentrations are not above guidelines, is not recommended.

Microcystin levels in Muriel Lake fell below the recreational guideline of 10 μg/L during every sampling event in 2022. Despite low levels of microcystin detected during each sampling event, caution should be observed in areas of the lake where significant cyanobacteria accumulation occurs.

Table 1. Microcystin concentrations measured four times at Muriel Lake in 2022.

Date	**Microcystin Concentration (μg/L)**
29-Jun-22	0.21
23-Jul-22	0.23
17-Aug-22	0.20
16-Sep-22	0.46
Average	0.28

INVASIVE SPECIES MONITORING

Dreissenid mussels pose a significant concern for Alberta because they impair the function of water conveyance infrastructure and adversely impact the aquatic environment. These invasive mussels can change lake conditions which can then lead to toxic cyanobacteria blooms, decrease the amount of nutrients needed for fish and other native species, and cause millions of dollars in annual costs for repair and maintenance of water-operated infrastructure and facilities. Spiny water flea pose a concern for Alberta because they alter the abundance and diversity of native zooplankton, as they are aggressive zooplankton predators. Through over-predation, they will impact higher trophic levels such as fish. They also disrupt fishing equipment by attaching in large numbers to fishing lines.

Monitoring for aquatic invasive species involved sampling with a 63 µm plankton net at three sample sites. This monitoring is designed to detect juvenile Dreissenid mussel veligers and spiny water flea. In 2022, no mussels or spiny water flea were detected at Muriel Lake.

Eurasian watermilfoil is a non-native aquatic plant that poses a threat to aquatic habitats in Alberta because it grows in dense mats preventing light penetration through the water column, reduces oxygen levels when the dense mats decompose, and outcompetes native aquatic plants. Eurasian watermilfoil can look similar to the native Northern watermilfoil, thus genetic analysis is ideal for suspect watermilfoil species identification.

No watermilfoil specimens were collected from Muriel Lake in 2022.

WATER LEVELS

There are many factors influencing water quantity. Some of these factors include the size of the lake's drainage basin, precipitation, evaporation, water consumption, ground water influences, and the efficiency of the outlet channel structure at removing water from the lake. Requests for water quantity monitoring should go through Alberta Environment and Parks Monitoring and Science division.

Water levels in Muriel Lake have decreased since water level monitoring began in 1968 (Figure 5). Muriel Lake water levels decreased from 559.7 m in 1981 to its historical low of 555.2 m in 2016; 4.5 m down from the steady level of the 1960s and 1970s. Since 2016, levels have gone up slightly, about 1 m when comparing the low of 2016 to the levels in 2020. Between 2020 and 2022, levels have decreased slightly.

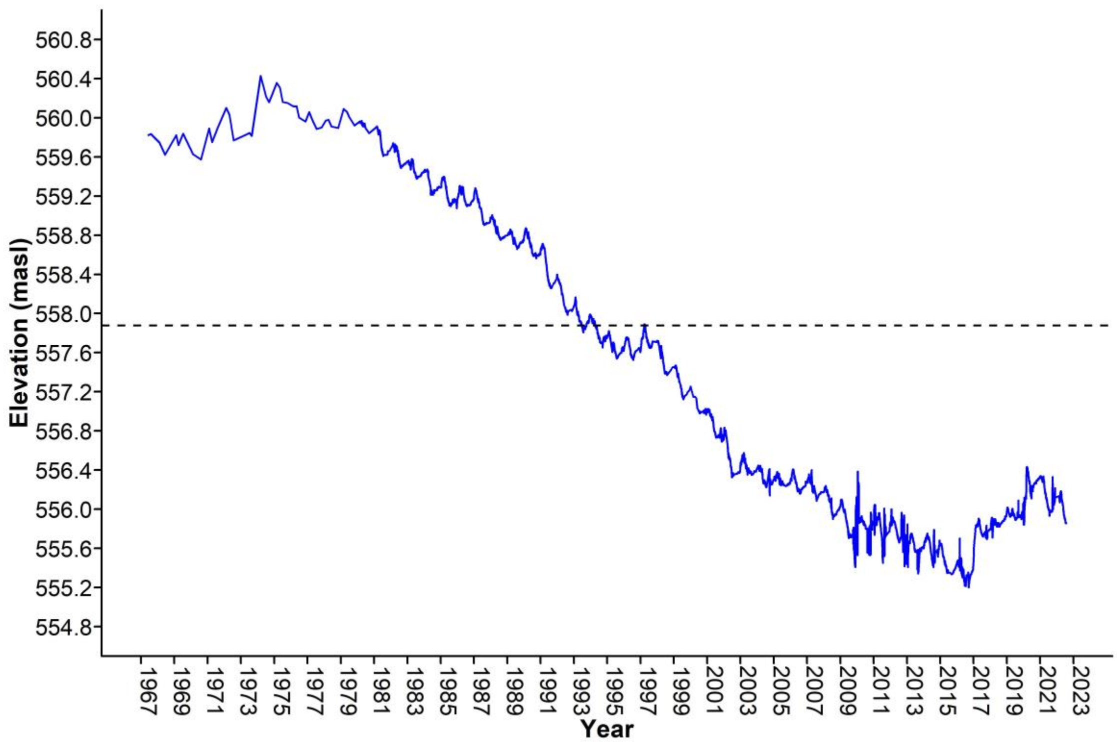


Figure 5. Water levels measured at Muriel Lake in metres above sea level (masl) from 1968-2022. Data retrieved from Alberta Environment and Parks and/or Environment and Climate Change Canada. Black dashed line represents historical yearly average water level.

WEATHER & LAKE STRATIFICATION

Air temperature will directly impact lake temperatures, and result in different temperature layers (stratification) throughout the lake, depending on its depth. Wind will also impact the degree to which a lake mixes, and how it will stratify. The amount of precipitation that falls within a lake's watershed will have important implications, depending on the context of the watershed and the amount of precipitation that has fallen. Solar radiation represents the amount of energy that reaches the earth's surface, and has implications for lake temperature & productivity.

Muriel Lake experienced a warmer, drier, and windier summer with more solar radiation than normal (Figure 6). A warm spell coupled with high solar radiation and low wind leading up to the August 17th likely lead to high water temperatures and weak stratification.

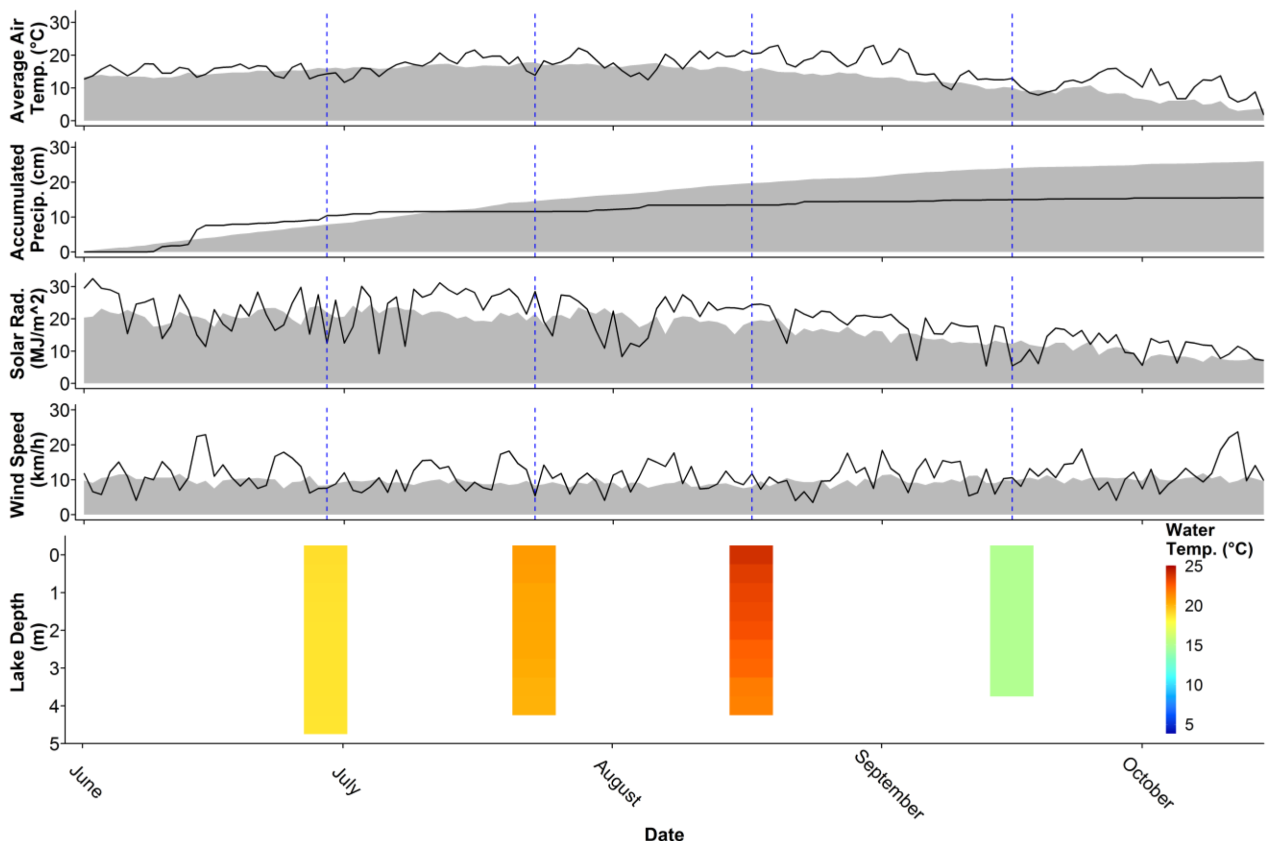


Figure 6. Average air temperature (°C), accumulated precipitation (cm), and wind speed (km/h) measured from 'Hoselaw AGCM, solar radiation (MJ/m^2) from 'Lindbergh AGDM,' as well as Muriel Lake temperature profiles, interpolated (°C). Black lines indicate 2022 levels, gray indicates long-term normals, and blue lines indicate sampling dates for Muriel Lake over the summer. Further information about the weather data provided is available in the LakeWatch 2022 Methods report. Weather data provided by Agriculture, Forestry and Rural Economic Development, Alberta Climate Information Service (ACIS) https://acis.alberta.ca (retrieved March 2023).

Table 2. Average Secchi depth and water chemistry values for Muriel Lake.

Parameter	1988	1993*	1997	2003*	2006*	2009*	2012	2015	2017	2019	2020	2022
TP (µg/L)	36	32	41	48	54	64	54	100	48	58	44	51
TDP (µg/L)	12	17	16	18	22	29	32	21	16	14	10	11
Chlorophyll-a (µg/L)	6.7	/	6.7	9.2	8.5	9.6	4.6	31.7	20.9	21.7	20.2	15.1
Secchi depth (m)	2.16	/	1.86	1.13	1.50	1.08	2.86	0.75	1.03	1.50	0.72	1.12
TKN (mg/L)	1.5	1.8	2.0	2.5	2.7	3.4	3.1	3.9	3.4	3.4	3.3	3.5
NO2 and NO3 (µg/L)	1	1	3	3	3	23	4	3	2	7	2	12
NH3 (µg/L)	21	111	23	21	45	26	64	56	44	43	48	34
DOC (mg/L)	26	33	28	/	45	47	48	62	53	51	41	51
Ca (mg/L)	11	7	8	5	6	5	5	4	7	6	9	7
Mg (mg/L)	98	115	126	173	164	153	155	210	208	175	155	188
Na (mg/L)	118	140	160	238	245	289	283	313	303	278	255	285
K (mg/L)	21	27	30	39	41	54	58	56	59	51	46	53
SO42- (mg/L)	116	143	154	239	257	333	334	398	360	360	328	380
Cl- (mg/L)	17	/	23	34	36	41	41	51	45	48	42	47
CO3 (mg/L)	71	108	115	210	181	213	155	265	213	220	160	198
HCO3 (mg/L)	535	703	620	746	800	858	963	873	783	725	680	730
pH	9.03	9.15	9.18	9.28	9.24	9.25	9.19	9.27	9.30	9.19	9.15	9.12
Conductivity (µS/cm)	1143	1350	1354	/	1925	2157	2212	2475	2200	2200	2000	2200
Hardness (mg/L)	427	491	538	726	688	640	650	875	878	743	665	788
TDS (mg/L)	714	853	919	1305	1325	1510	1507	1725	1600	1500	1350	1525
Microcystin (µg/L)	/	/	/	/	0.18	0.22	0.36	16.25	0.30	0.37	0.36	0.28
Total Alkalinity (mg/L CaCO3)	556	667	696	961	957	1060	1050	1175	998	965	823	932

*1993 is based on one sampling event, 2003 & 2006 are based on two sampling events, and 2009 is based on three sampling events, two of which were done in August.

Table 3a. Concentrations of metals measured in Muriel Lake. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference. Note that metal sample collection method changed in 2016 from composite to single surface grab at the profile location.

Metals (Total Recoverable)	2003	2006	2009	2012	2015	2017	Guidelines
Aluminum μg/L	34	31.8	20.15	16.485	19.8	85.7	100[a]
Antimony μg/L	0.22	0.183	0.1825	0.2265	0.2435	1.31	/
Arsenic μg/L	7.6	8.54	9.21	8.72	10.7	54.8	5
Barium μg/L	3.9	5.13	3.105	2.88	2.63	15.2	/
Beryllium μg/L	0.07	0.0015	0.0015	0.00625	0.004	0.0055	100[c,d]
Bismuth μg/L	0.013	0.0032	0.0046	0.00245	0.008	0.0055	/
Boron μg/L	319	290	325.5	377.5	441	1760	1500
Cadmium μg/L	0.01	0.0088	0.00365	0.0077	0.006	0.025	0.37[b]
Chromium μg/L	0.63	0.696	0.72	0.6335	0.265	0.25	/
Cobalt μg/L	0.036	0.23	0.0576	0.0489	0.055	0.364	50,1000[c,d]
Copper μg/L	1	1.87	1.435	0.995	1.57	3.54	4[b]
Iron μg/L	15	26.3	14.585	23.3	20.3	63.8	300
Lead μg/L	0.115	0.0944	0.04865	0.0444	0.1005	0.174	7[b]
Lithium μg/L	114	132	154	195.5	227.5	819	2500[d]
Manganese μg/L	2.4	4.26	1.665	2.35	2.77	9.57	150[e]
Molybdenum μg/L	1.25	1.49	1.58	1.885	1.995	8.45	73
Nickel μg/L	0.08	0.206	0.1315	0.12535	0.1735	1.33	150[b]
Selenium μg/L	0.7	1.41	0.759	0.466	0.055	12.8	1
Silver μg/L	0.0025	0.0024	0.00575	0.0018	0.0015	0.018	0.25
Strontium μg/L	9.9	11	9.405	9.38	5.535	47.8	/
Thallium μg/L	0.077	0.0098	0.00155	0.000525	0.00045	0.018	0.8
Thorium μg/L	0.015	0.0134	0.00725	0.007825	0.00045	0.043	/
Tin μg/L	0.05	0.015	0.015	0.05495	0.076	0.15	/
Titanium μg/L	2.7	2.58	2.12	1.211	2.13	6.38	/
Uranium μg/L	1.55	1.44	1.595	1.56	1.9	7.23	15
Vanadium μg/L	0.9	0.597	0.703	0.578	0.51	4.55	100[c,d]
Zinc μg/L	2.8	2.46	1.525	1.42	1.7	14.8	30[f]

Values represent means of total recoverable metal concentrations.

[a] Based on pH ≥ 6.5

[b] Based on 2022 avg. water hardness (as CaCO3) with CCME equation

[c] Based on CCME Guidelines for Agricultural use (Livestock).

[d] Based on CCME Guidelines for Agricultural Use (Irrigation).

[e] Based on CCME Manganese variable calculation (https://ccme.ca/en/chemical/129#_aql_fresh_concentration), using 2022 avg. water hardness (as CaCO3) and avg. pH

[f] Based on 2022 avg. water hardness (as CaCO3), avg. pH, and avg. DOC with CCME equation

A forward slash (/) indicates an absence of data or guideline

Table 3b. Concentrations of metals measured in Muriel Lake. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference. Note that metal sample collection method changed in 2016 from composite to single surface grab at the profile location.

Metals (Total Recoverable)	2020	2022	Guidelines
Aluminum μg/L	16.8	32.2	100[a]
Antimony μg/L	0.232	0.28	/
Arsenic μg/L	9.96	9.98	5
Barium μg/L	5.51	5.83	/
Beryllium μg/L	<0.003	0.0015	100[c,d]
Bismuth μg/L	0.004	0.0015	/
Boron μg/L	305	388	1500
Cadmium μg/L	<0.01	0.005	0.37[b]
Chromium μg/L	<0.1	0.05	/
Cobalt μg/L	0.125	0.088	50,1000[c,d]
Copper μg/L	0.39	0.25	4[b]
Iron μg/L	37.6	45.9	300
Lead μg/L	0.103	0.087	7[b]
Lithium μg/L	155	182	2500[d]
Manganese μg/L	8.25	10.5	150[e]
Molybdenum μg/L	1.57	1.25	73
Nickel μg/L	0.39	0.25	150[b]
Selenium μg/L	1.4	0.1	1
Silver μg/L	0.003	0.0005	0.25
Strontium μg/L	21.2	20.1	/
Thallium μg/L	0.002	0.001	0.8
Thorium μg/L	0.009	0.009	/
Tin μg/L	<0.06	0.03	/
Titanium μg/L	1.72	1.05	/
Uranium μg/L	1.43	1.26	15
Vanadium μg/L	1.08	0.454	100[c,d]
Zinc μg/L	2.2	1.6	30[f]

Values represent means of total recoverable metal concentrations.
[a] Based on pH ≥ 6.5
[b] Based on 2022 avg. water hardness (as CaCO3) with CCME equation
[c] Based on CCME Guidelines for Agricultural use (Livestock).
[d] Based on CCME Guidelines for Agricultural Use (Irrigation).
[e] Based on CCME Manganese variable calculation (https://ccme.ca/en/chemical/129#_aql_fresh_concentration), using 2022 avg. water hardness (as CaCO3) and avg. pH
[f] Based on 2022 avg. water hardness (as CaCO3), avg. pH, and avg. DOC with CCME equation
A forward slash (/) indicates an absence of data or guideline

LONG TERM TRENDS

Trend analysis was conducted on the parameters total phosphorus (TP), chlorophyll-*a*, total dissolved solids (TDS) and Secchi depth to look for changes over time in Muriel Lake. In sum, significant increasing trends were observed in chlorophyll-*a* and TDS, a significant decreasing trend was observed in Secchi depth, and no significant trend was detected for TP. Secchi depth can be subjective and is sensitive to variation in weather; therefore, trend analysis must be interpreted with caution. Data is presented below as both line and box-and-whisker plots. Detailed methods are available in the *ALMS Guide to Trend Analysis on Alberta Lakes.*

Table 4. Summary table of trend analysis on Muriel Lake data from 1988 to 2022.

Parameter	Date Range	Direction of Significant Trend
Total Phosphorus	1988-2022	No Change
Chlorophyll-*a*	1988-2022	Increasing
Total Dissolved Solids	1988-2022	Increasing
Secchi Depth	1988-2022	Decreasing

Definitions:

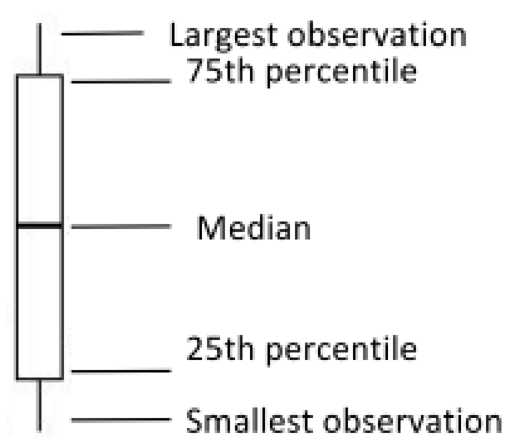
Median: the value in a range of ordered numbers that falls in the middle.

Trend: a general direction in which something is changing.

Monotonic trend: a gradual change in a single direction.

Statistically significant: The likelihood that a relationship between variables is caused by something other than random chance. This is indicated by a p-value of <0.05. Variability: the extent by which data is inconsistent or scattered.

Box and Whisker Plot: a box-and-whisker plot, or boxplot, is a way of displaying all of our annual data. The median splits the data in half. The 75th percentile is the upper quartile of the data, and the 25th percentile is the lower quartile of the data. The top and bottom points are the largest and smallest observations.



Total Phosphorus (TP)

Trend analysis of TP over time showed that it has not significantly changed in Muriel Lake since 1988 (Tau = 0.18, *p* = 0.16).

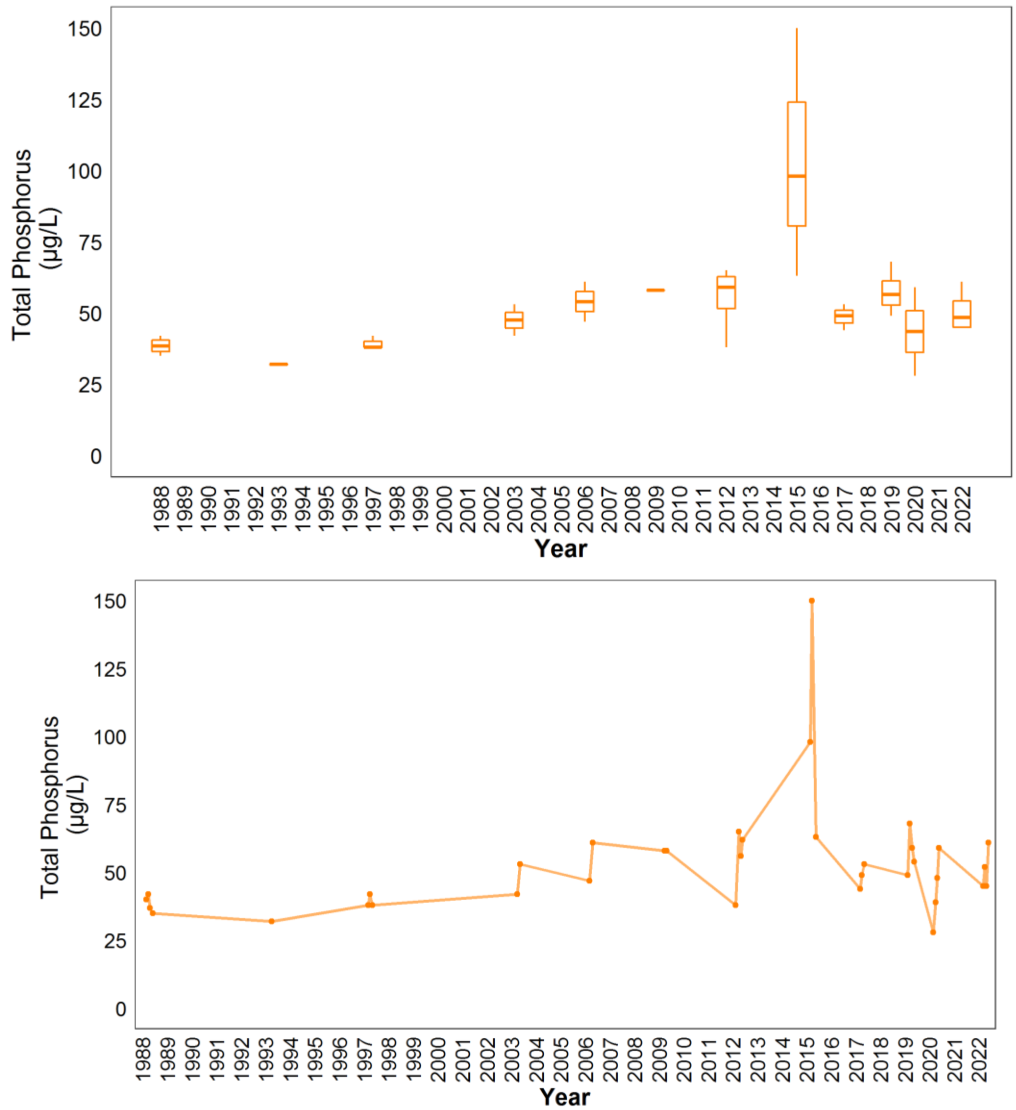
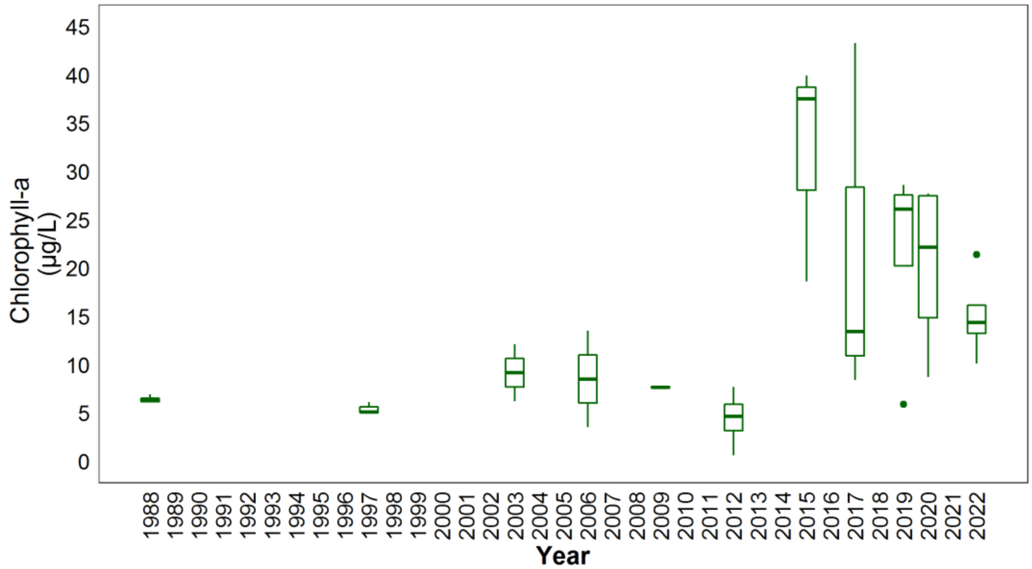


Figure 7. Monthly total phosphorus (TP) concentrations measured between June and September over the long term sampling dates between 1988 and 2022 (n = 36). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Chlorophyll-*a*

Chlorophyll-*a* has significantly increased over time at Muriel Lake (Tau = 0.45, p = 0.002).



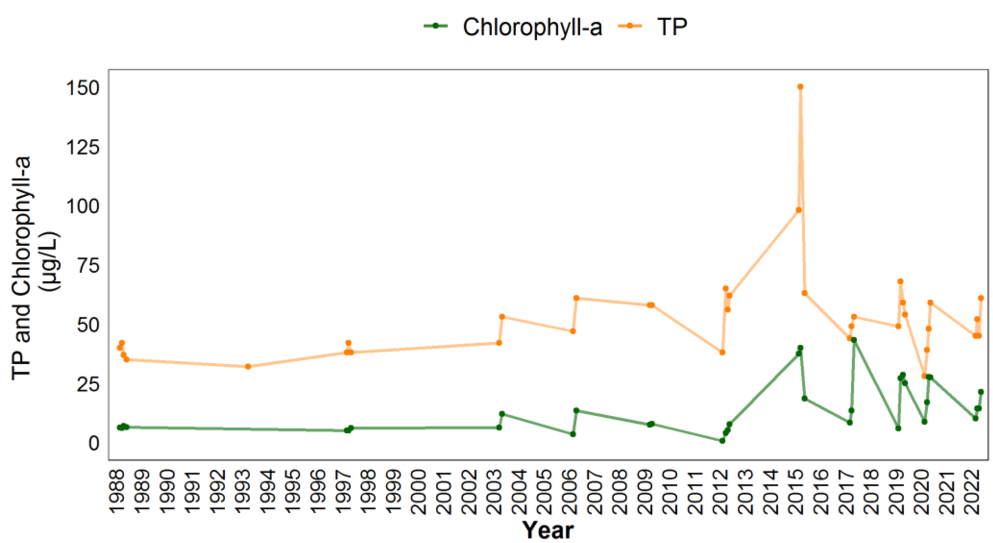


Figure 8. Monthly chlorophyll-*a* concentrations measured between June and September over the long term sampling dates between 1988 and 2022 (n = 35). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

Total Dissolved Solids (TDS)

Trend analysis showed a significant increasing trend in TDS between 1988 and 2022 (Tau = 0.45, p = <0.001) in Muriel Lake.

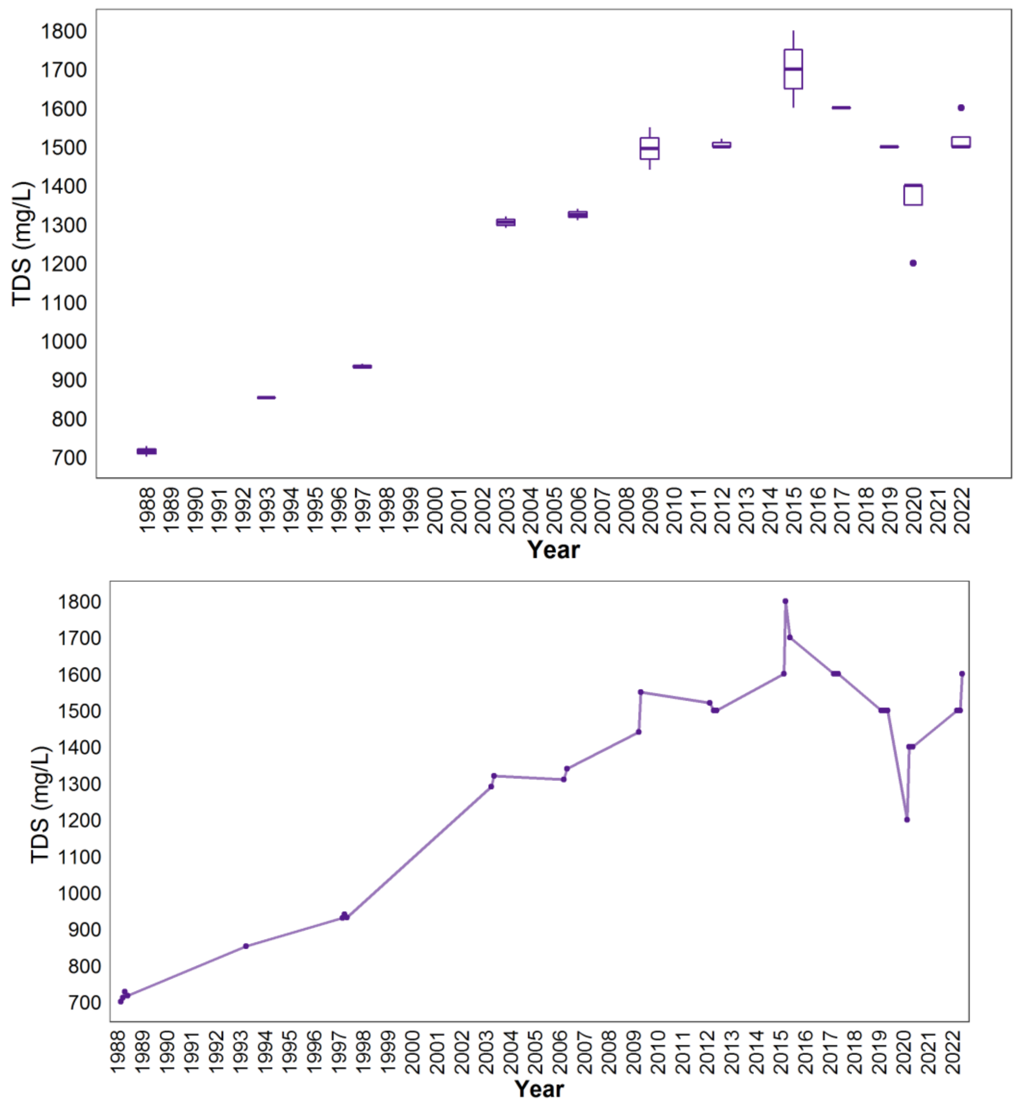


Figure 9. Monthly TDS values measured between June and September over the long term sampling dates between 1988 and 2022 (n = 35). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Due to the significant increasing trend of TDS in Muriel Lake, exploring the specific major ions which may be driving this trend is important to determine. Trend analysis of major ions at Muriel Lake indicates that alkalinity (bicarbonate, carbonate), sulphate, and sodium are likely the key parameters that drove the historical increase in TDS (Figure 10). Chloride and potassium also display significantly increasing trends over time, but their slopes are much lower than alkalinity, sodium, and sulphate. While magnesium and calcium have insufficient data to perform trend analysis, the visual trend of magnesium indicates that it has also increased in recent years.

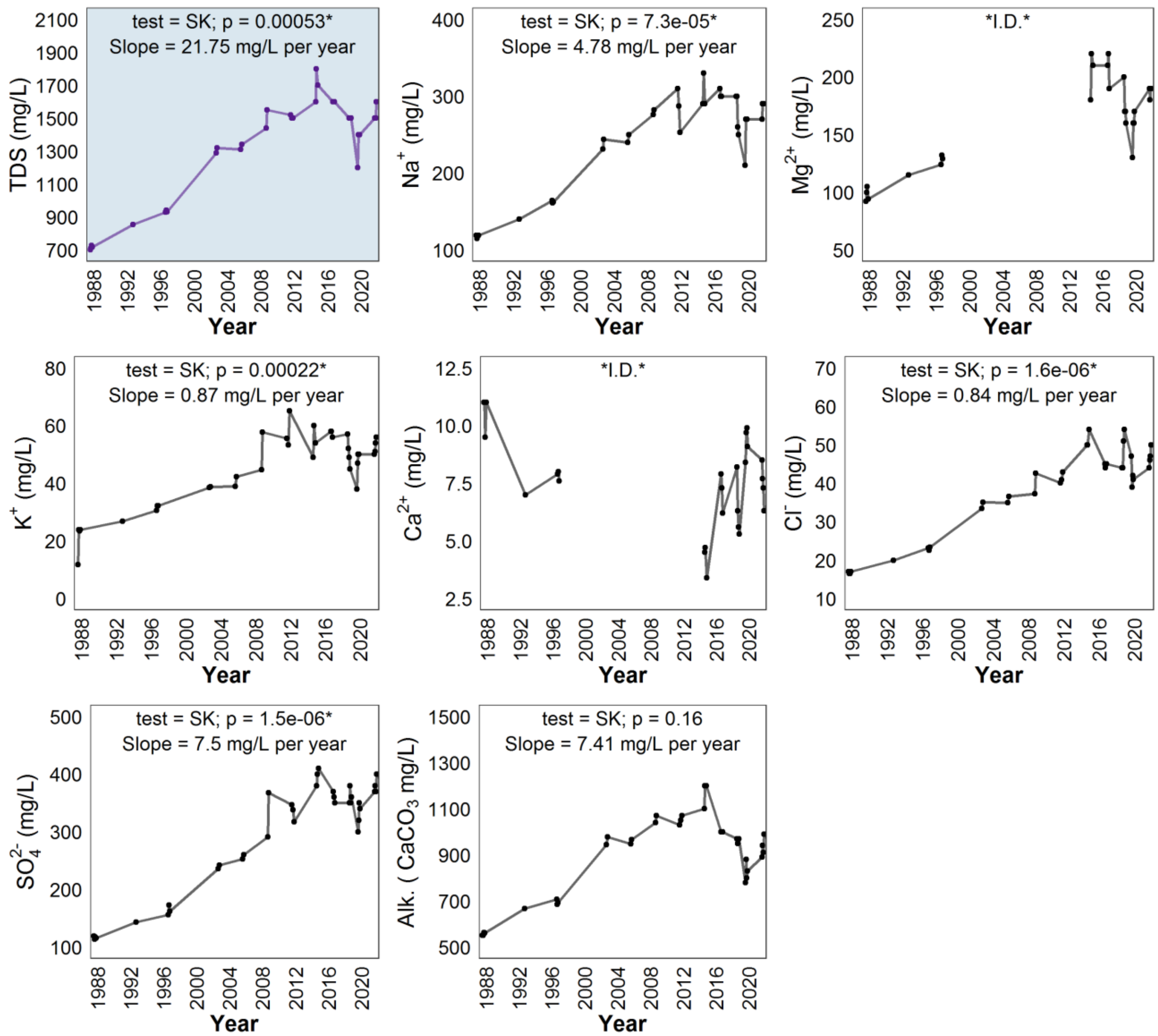
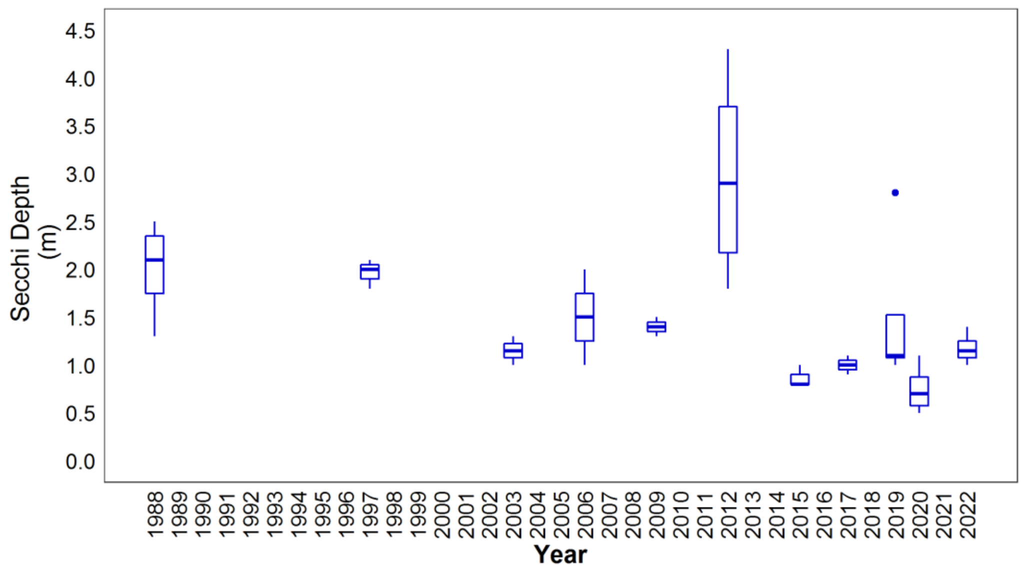


Figure 10. Concentrations of TDS (top left, blue panel), major ions (sodium = Na^+, magnesium = Mg^{2+}, potassium = K^+, calcium = Ca^{2+}, chloride = Cl^-, sulphate = SO_4^{2-}), and total alkalinity (Alk., as mg/L $CaCO_3$) measured monthly between June and September on sampling dates between 1988 and 2022. Also represented is the monotonic trend results for each parameter; test used (MK = Mann Kendall, SK = Seasonal Kendall), significance of test (p; assessed as significance when $p < 0.05$, marked with '*' if significant), and the slope of the trend. Test selection follows method outline in the *ALMS Guide to Trend Analysis on Alberta Lakes.* Note that some ions had insufficient data (*I.D.*) therefore trends were not calculated. The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Secchi Depth

Secchi depth has significantly decreased (the lake has become less clear) in Muriel Lake since 1988 (Tau = -0.37, p = 0.009).



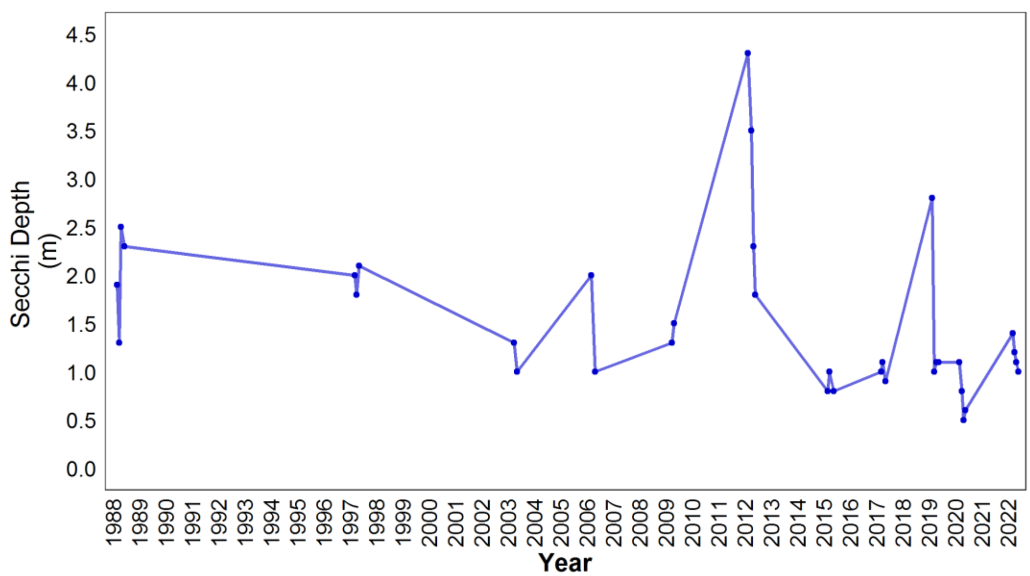


Figure 11. Monthly Secchi depth values measured between June and September over the long term sampling dates between 1988 and 2022 (n = 35). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Table 5. Results of trend tests using total phosphorus (TP), chlorophyll-*a*, total dissolved solids (TDS) and Secchi depth data from June to September, for sampled years from 1988-2022 on Muriel Lake data.

Definition	Unit	Total Phosphorus (TP)	Chlorophyll-a	Total Dissolved Solids (TDS)	Secchi Depth
Statistical Method	-	Seasonal Kendall	Seasonal Kendall	Seasonal Kendall	Seasonal Kendall
The strength and direction (+ or -) of the trend between -1 and 1	Tau	0.18	0.45	0.45	-0.37
The extent of the trend	Slope (units per Year)	0.29	0.40	21.75	-0.03
The statistic used to find significance of the trend	Z	1.39	3.12	3.47	-2.63
Number of samples included	n	36	35	35	35
The significance of the trend	*p*	0.16	1.82×10^{-3}*	5.29×10^{-4}*	8.65×10^{-3}*

*$p < 0.05$ is significant within 95%