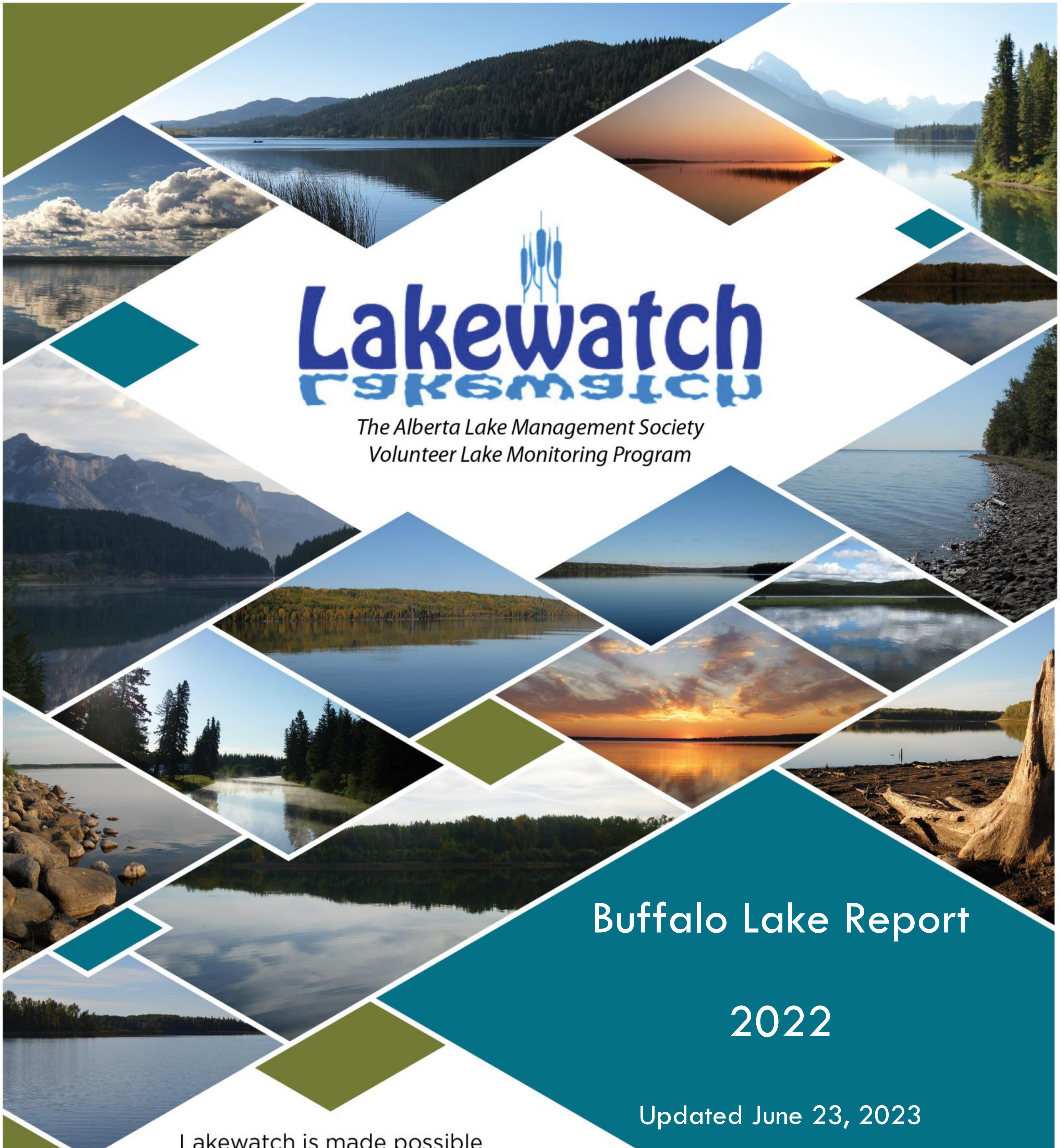

Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Buffalo Lake Report

2022

Updated June 23, 2023

Lakewatch is made possible with support from:

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LICA ENVIRONMENTAL STEWARDS

PIGEON LAKE WATERSHED ASSOCIATION

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.

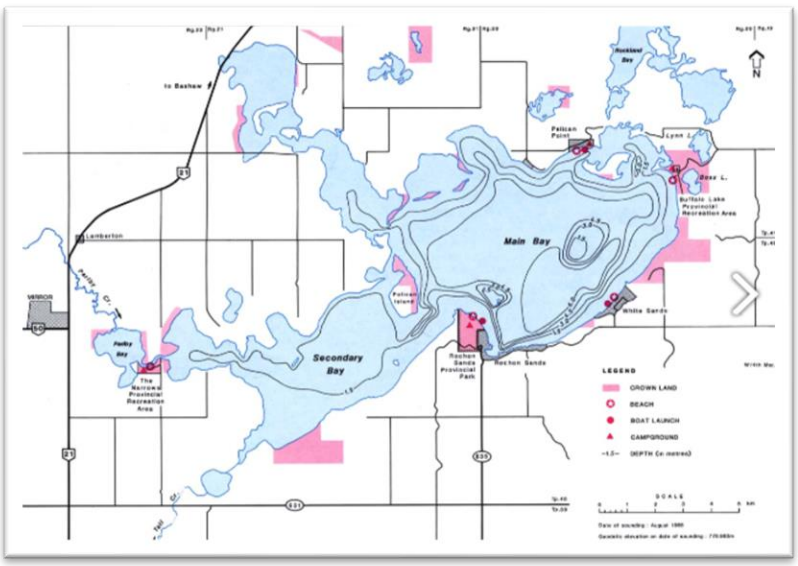
If you require data from this report, please contact ALMS for the raw data files.

ACKNOWLEDGEMENTS

The LakeWatch program is made possible through the dedication of its volunteers. A special thanks to Marc DeCnodder for his commitment to collecting data at Buffalo 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.

BUFFALO LAKE

Buffalo Lake is located in central Alberta, 40 km northeast of Red Deer. It resides in the counties of Camrose, Stettler and Lacombe. Buffalo Lake is host to four public recreation areas, with camping, picnic areas, swimming and boat launches.



Bathymetric map of Buffalo Lake (Source: Prepas & Mitchell 1990)

The Lake has four natural basins: Main Bay is the largest and deepest, Secondary Bay is smaller and very shallow, The Narrows is the channel west of Secondary Bay and is a popular fishing area, and Parlby Bay is shallow and home to dense aquatic plants and waterfowl. The lake was labelled as Buffalo Lake in 1814 on a map by David Thompson, named for its resemblance to a Buffalo with the legs to the north and the head to the east [1]. Buffalo were likely attracted to the lake with the surrounding trembling aspen and fescue grassland habitat. The lake was a favourite camping area for Cree and Blackfoot, and in 1858, Father Lacombe, a young missionary, travelled for two days to help the group of Blackfoot people dying from scarlet fever on the east shore of Buffalo Lake [2]. The settlement on the southwest side of Buffalo Lake was established in 1883 and was one of the first in central Alberta [2].

Buffalo Lake supports habitat for northern pike, burbot, white sucker and brook stickleback, which are all tolerant of high salinity and alkalinity.

The watershed area for Buffalo Lake is 1476 km^2 and the lake area is 96 km^2. The lake to watershed ratio of Buffalo Lake is 1:15. A map of the Buffalo Lake watershed area can be found at http://alms.ca/lake-watershed-maps/.

[1] Alta. Cult. Multicult. n.d.

[2] Lamerton Hist. Soc. 1974.

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.

Note that water chemistry described in this section from the July 28th sampling event is unavailable due to weather conditions during that sampling event.

The average total phosphorus (TP) concentration for Buffalo Lake was 41 µg/L (Table 2), falling into the eutrophic, or highly productive trophic classification. This value is on the lower end of observed historical averages going back to 1984 (Table 2). TP ranged from a minimum of 33 µg/L on the August 23rd sampling, to a maximum of 47 µg/L on September 20th (Figure 1).

Average chlorophyll-*a* concentration in 2022 was 11.0 µg/L (Table 2), falling into the eutrophic, or highly productive trophic classification. Chlorophyll-*a* was lowest earliest in the season, at 9.3 µg/L on June 27th and peaked at 12.0 µg/L on September 20th.

The average TKN concentration was 2.7 mg/L (Table 2), and displayed little seasonal variation (Figure 1).

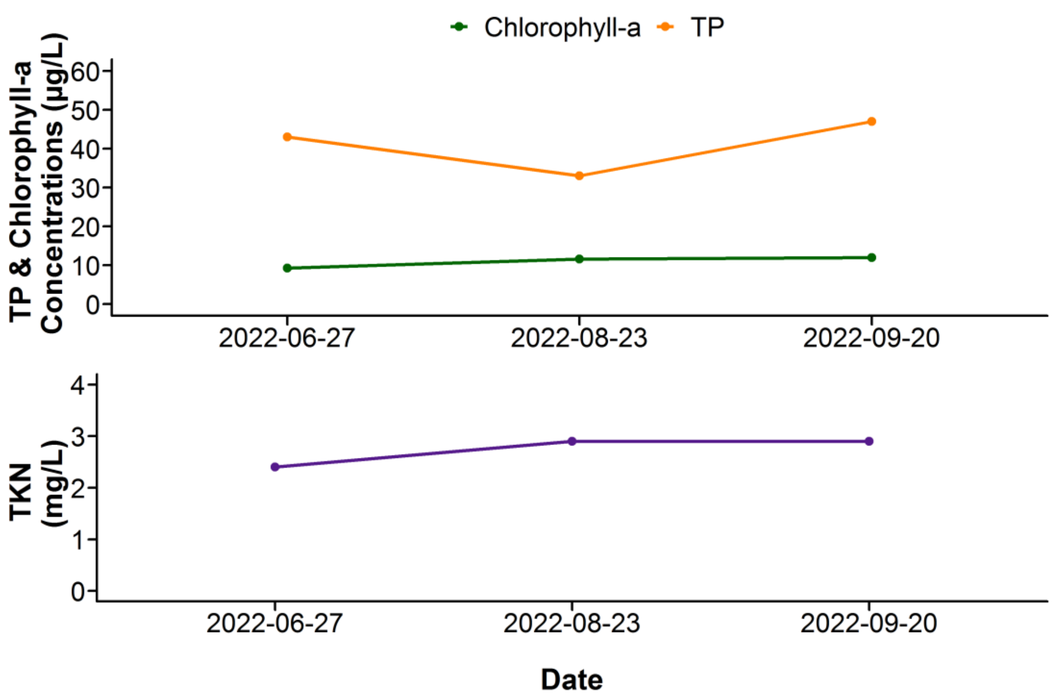


Figure 1. Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured three times over the course of the summer at Buffalo Lake.

Average pH was measured as 9.14 in 2022, buffered by high alkalinity (1133 mg/L $CaCO_3$) and bicarbonate (977 mg/L HCO_3). Aside from bicarbonate, sodium, sulphate, and carbonate were higher than all other major ions, and together contributed to a high conductivity of 2833 µS/cm (Figure 2, top; Table 2). Buffalo Lake is in the high end range of ion levels, compared to other LakeWatch lakes sampled in 2022, with the exception of calcium, having the lowest level of any lake sampled in 2022. (Figure 2, bottom).

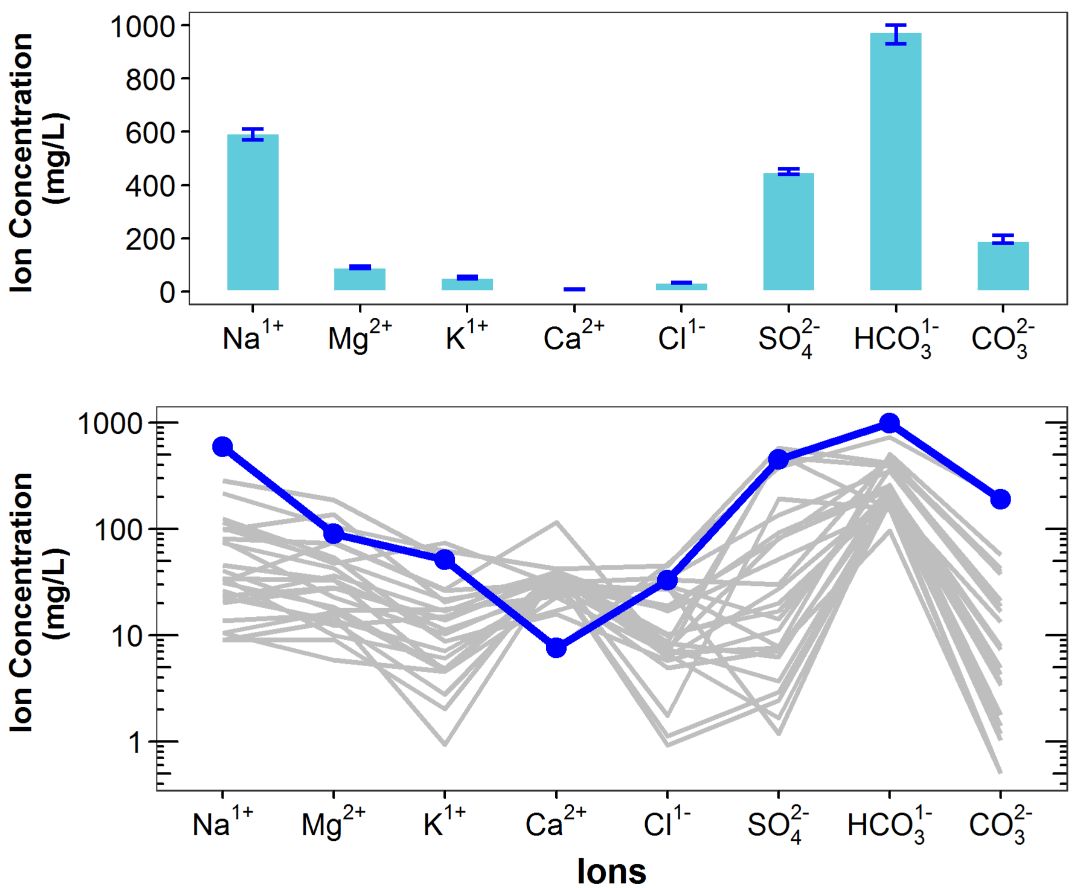


Figure 2. Average levels of cations (sodium = Na^{1+}, magnesium = Mg^{2+}, potassium = K^{1+}, calcium = Ca^{2+}) and anions (chloride = Cl^{1-}, sulphate = SO_4^{2-}, bicarbonate = HCO_3^{1-}, carbonate = CO_3^{2-}) from four measurements over the course of the summer at Buffalo Lake. Top) bars indicate range of values measured, and bottom) Schoeller diagram of average ion levels at Buffalo 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 not measured at Buffalo Lake in 2022, but historical levels are available in 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 Buffalo Lake in 2022 was 3.30 m, corresponding to an average Secchi depth of 1.65 m (Table 2). Euphotic depth varied over the season, ranging from as deep as 2.0 m on August 23rd to 1.45 m on both July 28th and September 20th (Figure 3). Euphotic depth appeared to vary more between sampling events than chlorophyll-a, suggesting more than algae and cyanobacteria growth impacted water clarity. Notably, dissolved organic carbon (DOC) levels, which can result in a brownish tinge to lake water, were twice as high during the September 20th sampling event at 98 mg/L, relative to the June and August sampling events. The elevated among of DOC possibly impacted the relatively lower water clarity in September.

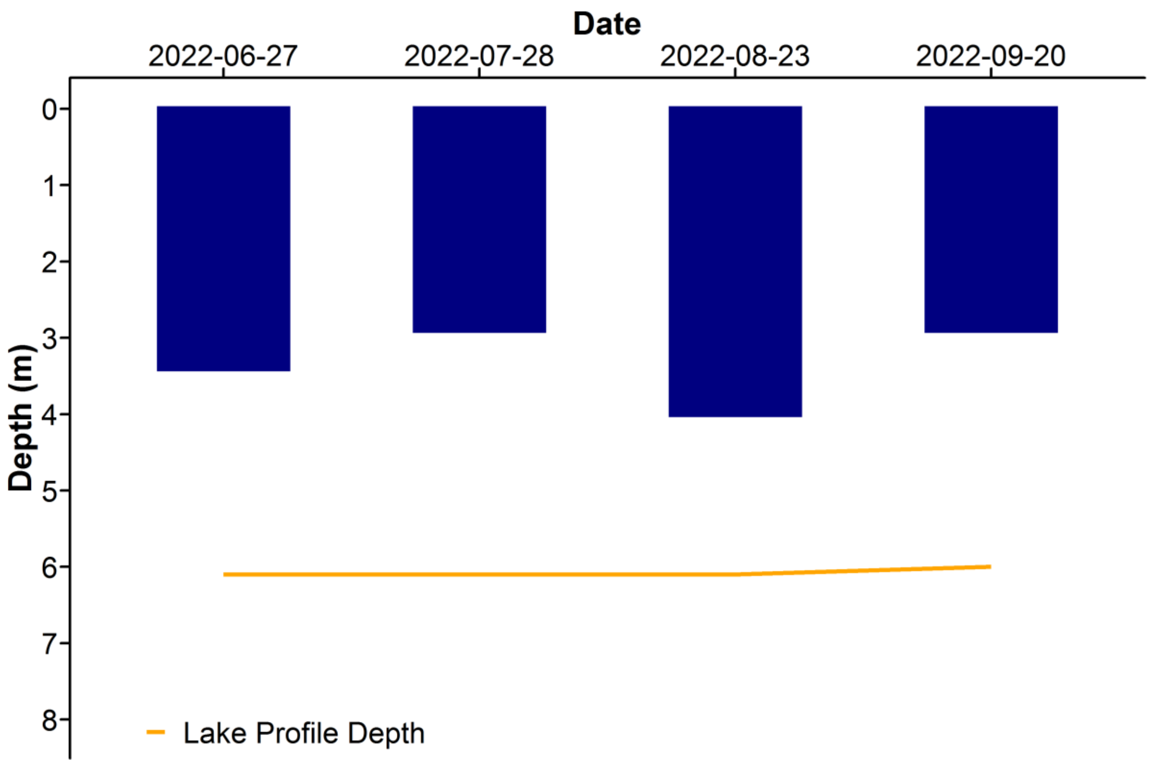


Figure 3. Euphotic depth values measured four times over the course of the summer at Buffalo Lake in 2022.

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 Buffalo Lake varied throughout the summer, with the July 28th sampling date having the warmest temperatures at 22.0°C (Figure 4a). The lake was mixed during all sampling trips, but some slight stratification was observed during the June 27th sampling event, and even more subtle stratification was observed during the July 28th sampling event.

Buffalo 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). There was an appreciable reduction in surface oxygen during the August 23rd sampling event, and an appreciable increase during the June 27th sampling event. Slight oxygen depletion was observed during the June and July sampling events, below 4.5 m depth.

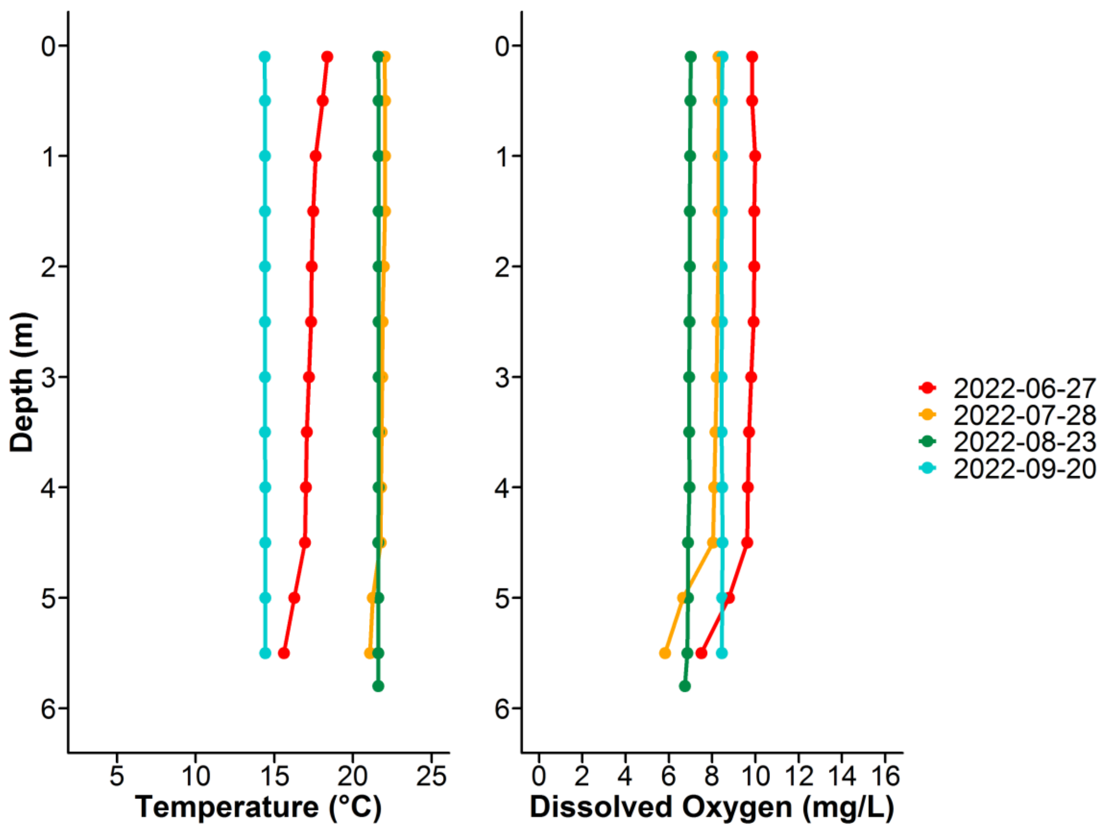


Figure 4. a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Buffalo Lake measured four times over the course of the summer of 2022.

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 Buffalo Lake fell below the recreational guideline of 10 µg/L during every sampling event in 2022. Even though low levels of microcystin were detected, caution should always be observed when recreating around cyanobacteria.

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

Date	Microcystin Concentration (µg/L)
27-Jun-22	0.27
28-Jul-22	Not Available
23-Aug-22	0.41
20-Sep-22	0.50
Average	0.39

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 Buffalo 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 suspect watermilfoil was observed or collected from Buffalo 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 Protected Areas.

Water levels at Buffalo Lake in 2022 were slightly above the historical average, but displayed an appreciable decline towards the end of the open was season (Figure 5). After nearly 30 years of gradual increasing water levels from 1990–2010, levels in the last decade have stabilized and started declining slightly.

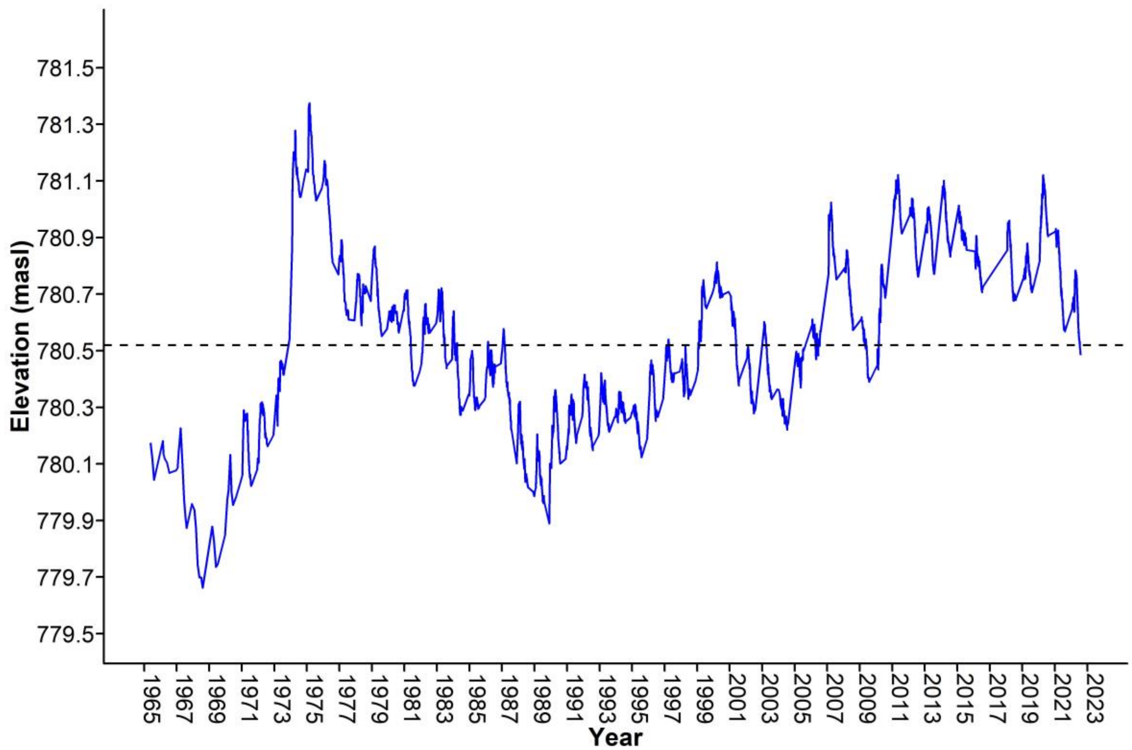


Figure 5. Water levels measured at Buffalo Lake in metres above sea level (masl) from 1965-2022. Data retrieved from Alberta Environment and Protected Areas and/or Environment and Climate Change Canada. Black dashed line represents historical yearly average water level.

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.

Buffalo Lake experienced a warmer, slightly wetter, and windier summer than normal (Figure 6). Warm days preceding the July and August sampling events lead to higher surface water temperatures. It is interesting that despite the high wind event leading up to the June sampling event, there is still slight stratification evident during the June 27th sampling event.

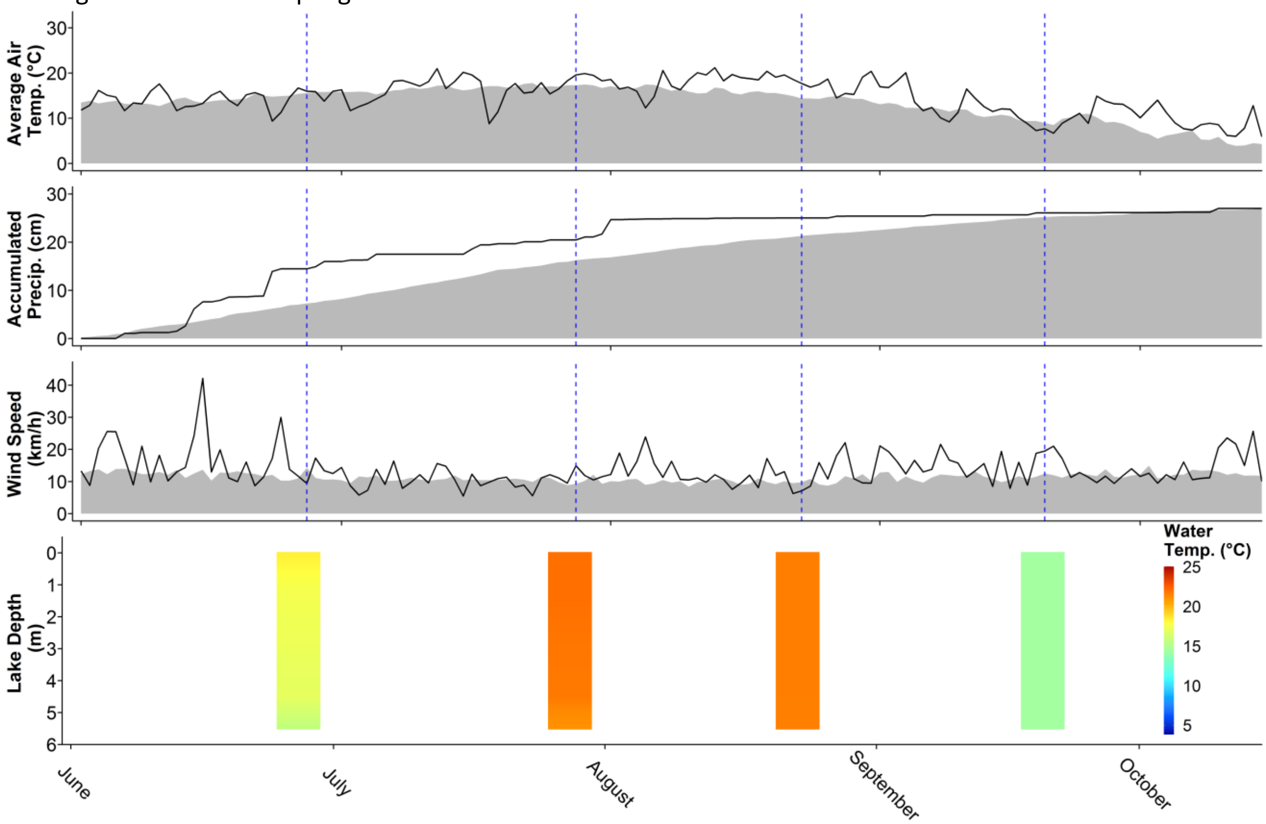


Figure 6. Average air temperature (°C) and accumulated precipitation (cm) measured from 'Parlby Creek near Mirror', and wind speed (km/h) measured from Stettler AGDM, as well as Buffalo Lake temperature profiles, interpolated (°C). Black lines indicate 2022 levels, gray indicates long-term normals, and blue lines indicate sampling dates for Buffalo 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). *Note that Solar Radiation is unavailable for either 'Parlby Creek near Mirror' or Stettler AGDM weather stations.

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

Parameter	1984	1985	1986	1989	1990	1992	1993	1994	1995	1996	1997
TP (µg/L)	65	44	58	80	69	66	/	79	66	72	80
TDP (µg/L)	/	/	/	/	/	/	/	/	36	36	39
Chlorophyll-*a* (µg/L)	9.5	8.3	6.2	14.0	12.2	10.8	19.1	4.1	8.2	10.0	12.9
Secchi depth (m)	3.36	2.22	2.88	1.59	2.00	2.10	1.37	2.05	1.97	1.67	1.74
TKN (mg/L)	/	2.5	/	/	/	/		/	2.0	2.4	2.7
NO_2-N and NO_3-N (µg/L)	30	30	30	10	10	10	/	10	10	10	20
NH_3-N (µg/L)	/	/	/	/	/	/	/	/	30	160	50
DOC (mg/L)	/	/	/	/	/	/	/	/	42	/	/
Ca^{2+} (mg/L)	8	7	7	6	6	12	/	5	5	5	7
Mg^{2+} (mg/L)	73	81	77	85	87	77	/	85	85	80	80
Na^{+} (mg/L)	508	535	520	612	590	485	/	600	604	577	572
K^{+} (mg/L)	37	40	38	43	42	35	/	42	43	45	44
SO_4^{2-} (mg/L)	412	390	401	478	478	402	/	495	507	485	463
Cl^{-} (mg/L)	12	13	12	15	14	14	/	16	16	17	18
CO_3^{2-} (mg/L)	/	172	161	212	210	158	/	199	199	194	190
HCO_3^{-} (mg/L)	976	997	952	1032	1004	1060	/	1235	1049	1035	1048
pH	9.20		9.26	9.32	9.34	9.27	/	9.48	9.30	9.16	9.23
Conductivity (µS/cm)	2450	2640	2536	2878	2795	2410	/	2850	2821	2864	2818
Hardness (mg/L)	320	349	334	362	374	346	/	362	363	342	348
TDS (mg/L)	1677	1720	1686	1957	1921	1625	/	1951	1974	1921	1899
Microcystin (µg/L)	/	/	/	/	/	/	/	/	/	/	/
Total Alkalinity (mg/L $CaCO_3$)	1044	1091	1051	1200	1174	1001	/	1179	1192	1175	1177

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

Parameter	**1998**	**1999**	**2000**	**2001**	**2002**	**2007**	**2014**	**2016**	**2018**	**2019**	**2022**
TP (µg/L)	68	68	61	62	57	32	41	46	44	41	41
TDP (µg/L)	36	34	34	34	33	13	26	15	16	15	15
Chlorophyll-*a* (µg/L)	12.7	13.9	7.4	14.6	6.9	7.0	5.7	12.1	11.1	15.7	11
Secchi depth (m)	1.88	1.80	2.38	2.50	2.13	2.20	1.93	1.61	1.33	1.45	1.72
TKN (mg/L)	2.2	2.2	1.7	2.2	2.3	2.4	2.2	2.6	2.6	2.5	2.7
NO_2 and NO_3 (µg/L)	30	30	20	10	10	0	10	6	14	7	6
NH_3 (µg/L)	50	50	70	30	80	120	40	25	33	46	30
DOC (mg/L)	/	/	38	/	/	34	/	36	40	39	60
Ca (mg/L)	7	6	7	7	6	7	/	9	9	8	8
Mg (mg/L)	77	70	75	76	74	67	/	82	74	77	89
Na (mg/L)	529	504	574	555	613	519	526	558	538	515	593
K (mg/L)	42	39	43	44	42	39	/	46	44	45	51
SO_4^{2-} (mg/L)	469	395	443	454	467	413	405	408	418	435	450
Cl^- (mg/L)	17	17	17	17	19	20	22	26	28	30	33
CO_3 (mg/L)	192	197	174	187	209	177	176	185	173	225	190
HCO_3 (mg/L)	1001	976	954	924	1032	943	950	945	990	875	977
pH	9.16	9.05	8.99	9.09	9.24	9.17	9.19	9.22	9.18	9.22	9.14
Conductivity (µS/cm)	/	2722	2543	2508	2735	2563	2600	2650	2675	2650	2833
Hardness (mg/L)	336	300	327	330	318	295	334	365	325	340	387
TDS (mg/L)	1826	1710	1805	1796	1940	1705	1723	1775	1775	1750	1900
Microcystin (µg/L)	/	/	/	/	/	/	/	0.37	0.37	0.40	0.39
Total Alkalinity (mg/L $CaCO_3$)	1142	1128	1072	1070	1193	1070	1073	1100	1100	1100	1133

Table 3. Concentrations of metals measured in Buffalo 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)	1993	2014	2016	Guidelines
Aluminum µg/L	/	104.75	64.5	100[a]
Antimony µg/L	/	0.438	0.441	/
Arsenic µg/L	7.8	7.21	7.8	5
Barium µg/L	/	39.5	39.1	/
Beryllium µg/L	/	0.0075	0.004	100[c,d]
Bismuth µg/L	/	0.0005	0.003	/
Boron µg/L	/	347	382	1500
Cadmium µg/L	/	0.006	0.003	0.37[b]
Chromium µg/L	/	0.53	0.16	/
Cobalt µg/L	/	0.134	0.157	50,1000[c,d]
Copper µg/L	/	1.05	1.77	4[b]
Iron µg/L	/	97.7	110	300
Lead µg/L	/	0.069	0.075	7[b]
Lithium µg/L	/	134	155	2500[d]
Manganese µg/L	/	2.06	2.83	140[e]
Molybdenum µg/L	/	2.09	2.01	73
Nickel µg/L	/	0.621	0.75	150[b]
Selenium µg/L	/	0.25	1.18	1
Silver µg/L	/	0.003	0.003	0.25
Strontium µg/L	/	231	218	/
Thallium µg/L	/	0.0013	0.0015	0.8
Thorium µg/L	/	0.0201	0.018	/
Tin µg/L	/	0.045	0.019	/
Titanium µg/L	/	2.66	2.53	/
Uranium µg/L	/	/	2.77	15
Vanadium µg/L	/	1.69	1.71	100[c,d]
Zinc µg/L	/	1.6	2.5	30[f]

Values represent means of total recoverable metal concentrations.

[a] Based on pH ≥ 6.5

[b] Based on 2016 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 2016 avg. water hardness (as CaCO3) and avg. pH

[f] Based on 2016 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 Buffalo Lake. In sum, significant decreasing trends wer observed in TP, TDS, and Secchi Depth. No significant trend was detected for chlorophyll-*a*. 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 Buffalo Lake data from 1984 to 2022.

Parameter	Date Range	Direction of Significant Trend
Total Phosphorus	1984-2022	Decreasing
Chlorophyll-*a*	1984-2022	No Change
Total Dissolved Solids	1984-2022	Decreasing
Secchi Depth	1984-2022	Decreasing

Definitions:

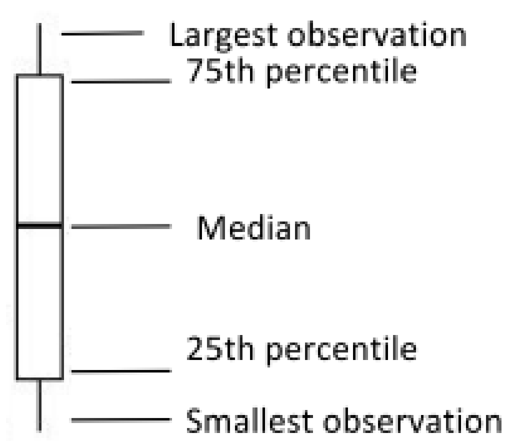
Median: the value in a range of ordered numbers that falls in the middle.

Trend: a general direction in which something is changing.

Monotonic trend: a gradual change in a single direction.

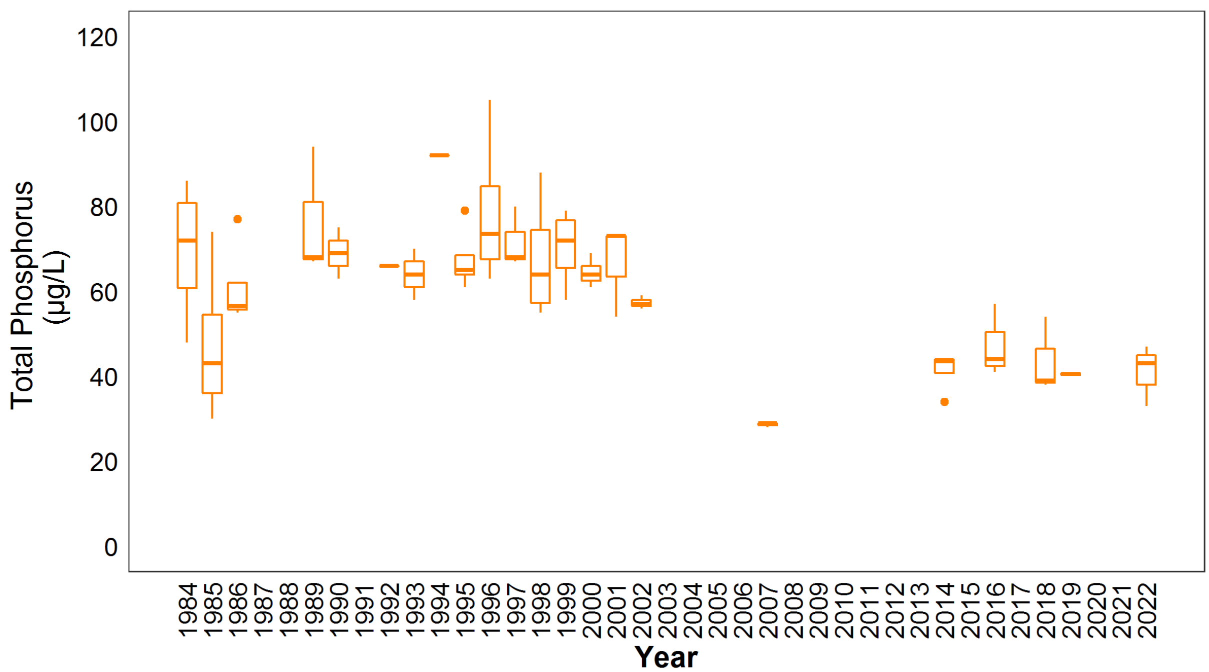
Statistically significant: The likelihood that a relationship between variables is caused by something other than random chance. This is indicated by a p-value of <0.05. Variability: the extent by which data is inconsistent or scattered.

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 significantly decreased in Buffalo Lake since 1984 (Tau = -0.36, p = <0.001).



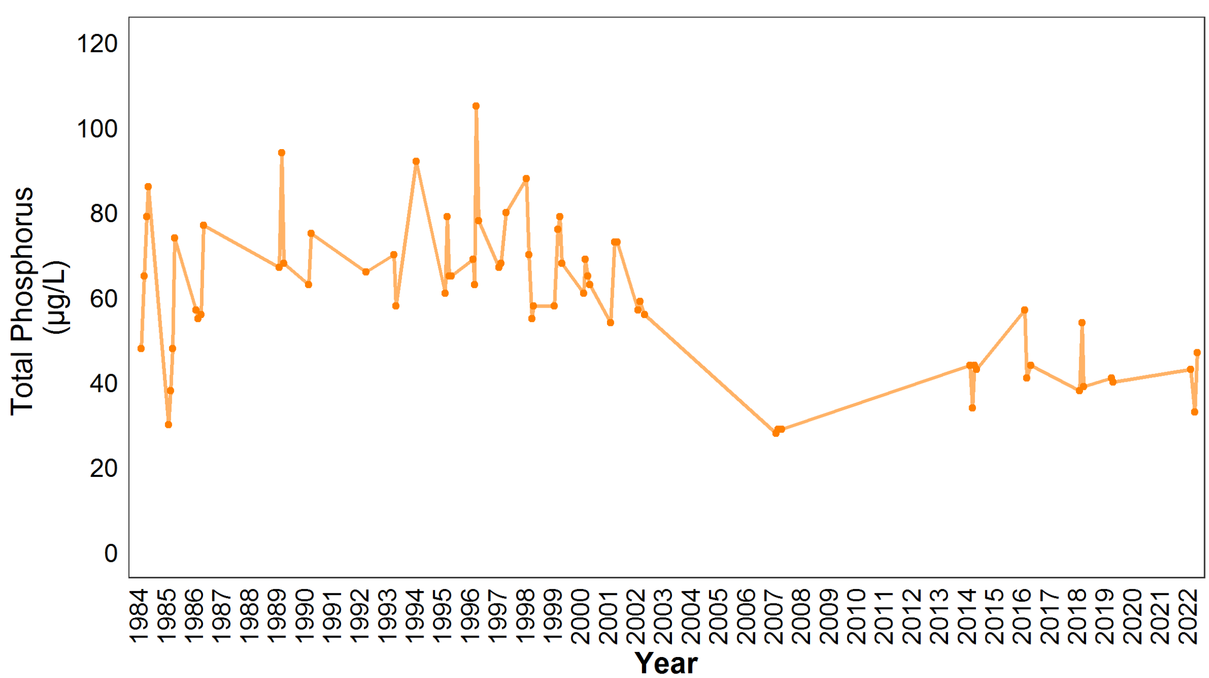
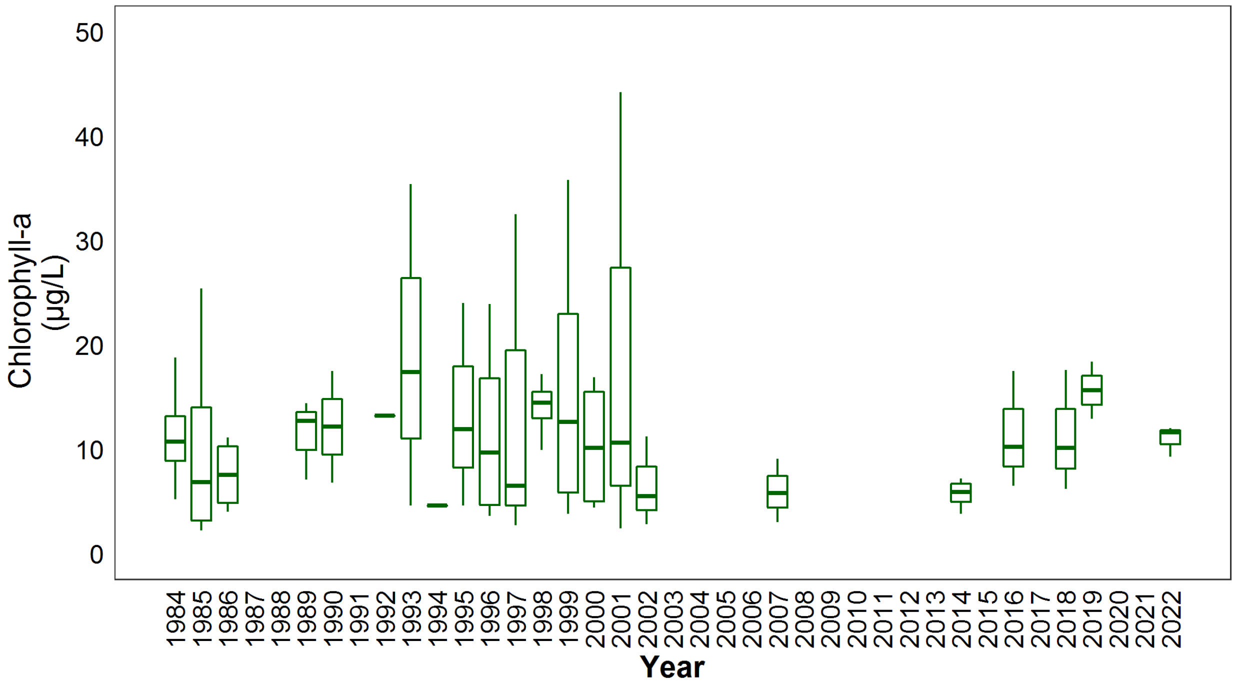


Figure 7. Monthly total phosphorus (TP) concentrations measured between June and September over the long term sampling dates between 1984 and 2022 (n = 68). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Chlorophyll-*a*

Chlorophyll-*a* has not significantly changed over time at Buffalo Lake (Tau = 0.05, *p* = 0.59).



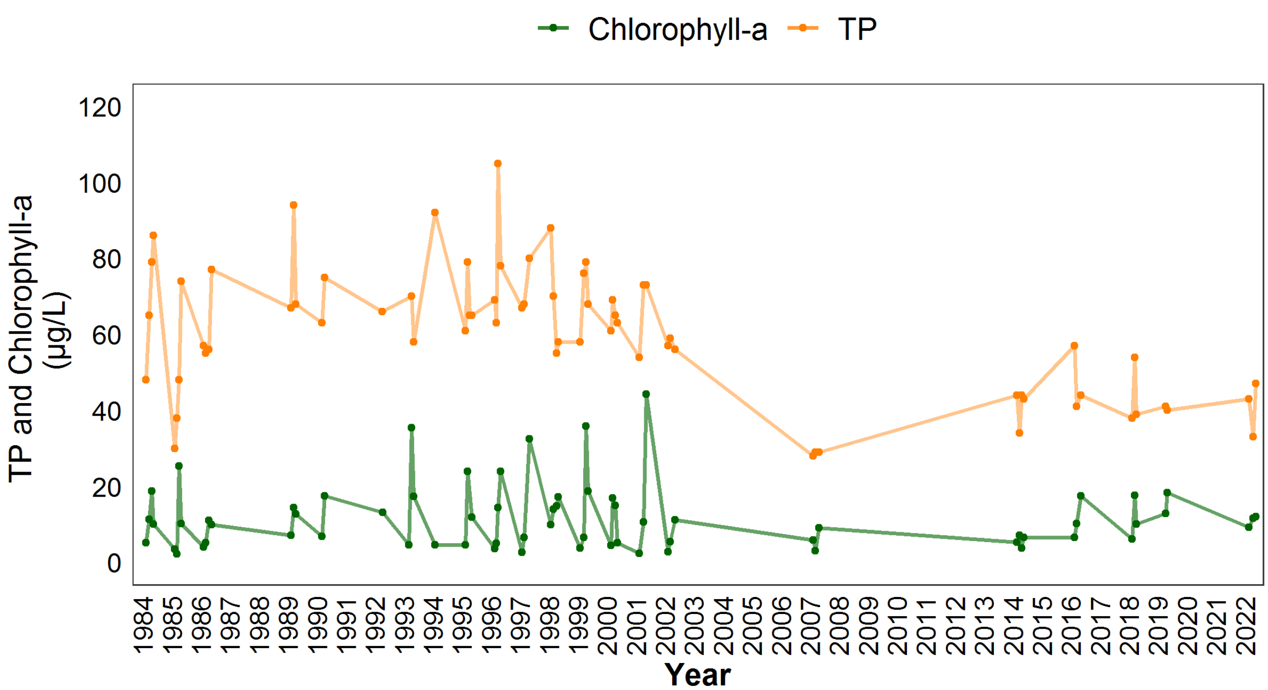


Figure 8. Monthly chlorophyll-*a* concentrations measured between June and September over the long term sampling dates between 1984 and 2022 (n = 68). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

Total Dissolved Solids (TDS)

Trend analysis showed a significant decreasing trend in TDS between 1984 and 2022 (Tau = -2.90, $p = 0.03$). Despite this statistical trend, the visual trend indicates a high variability in TDS within years, and between years over time (Figure 9). In the previous decade, TDS has been increasing.

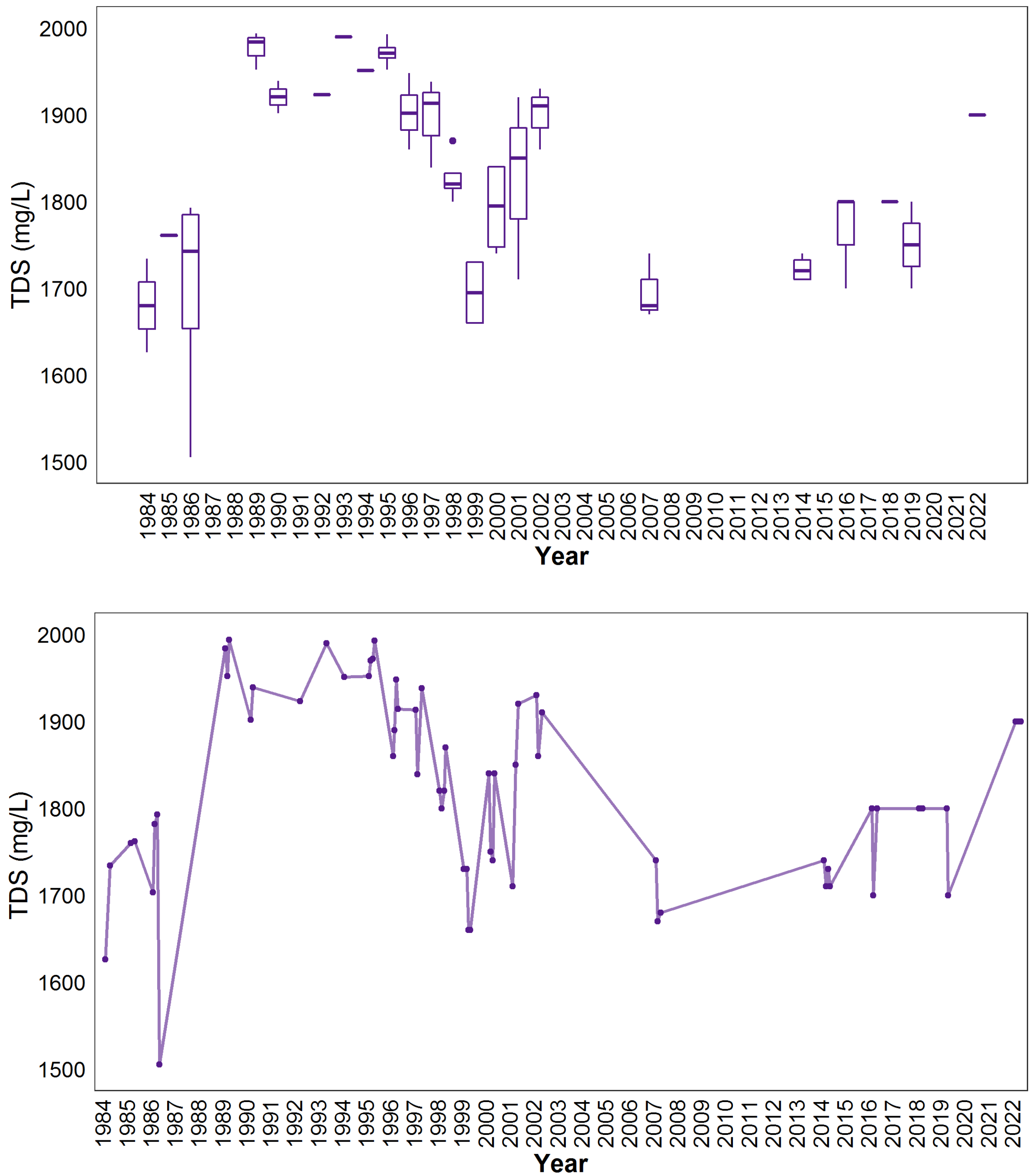


Figure 9. Monthly TDS values measured between June and September over the long term sampling dates between 1984 and 2022 (n = 63). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Due to the significant decreasing trend of TDS in Buffalo Lake, exploring the specific major ions which may be driving this trend is important to determine. Trend analysis of major ions at Buffalo Lake indicates that alkalinity (bicarbonate, carbonate) and sulphate are likely the key parameters that drove the historical decreases in TDS (Figure 10). Potassium, calcium, and chloride had significant positive increasing trends.

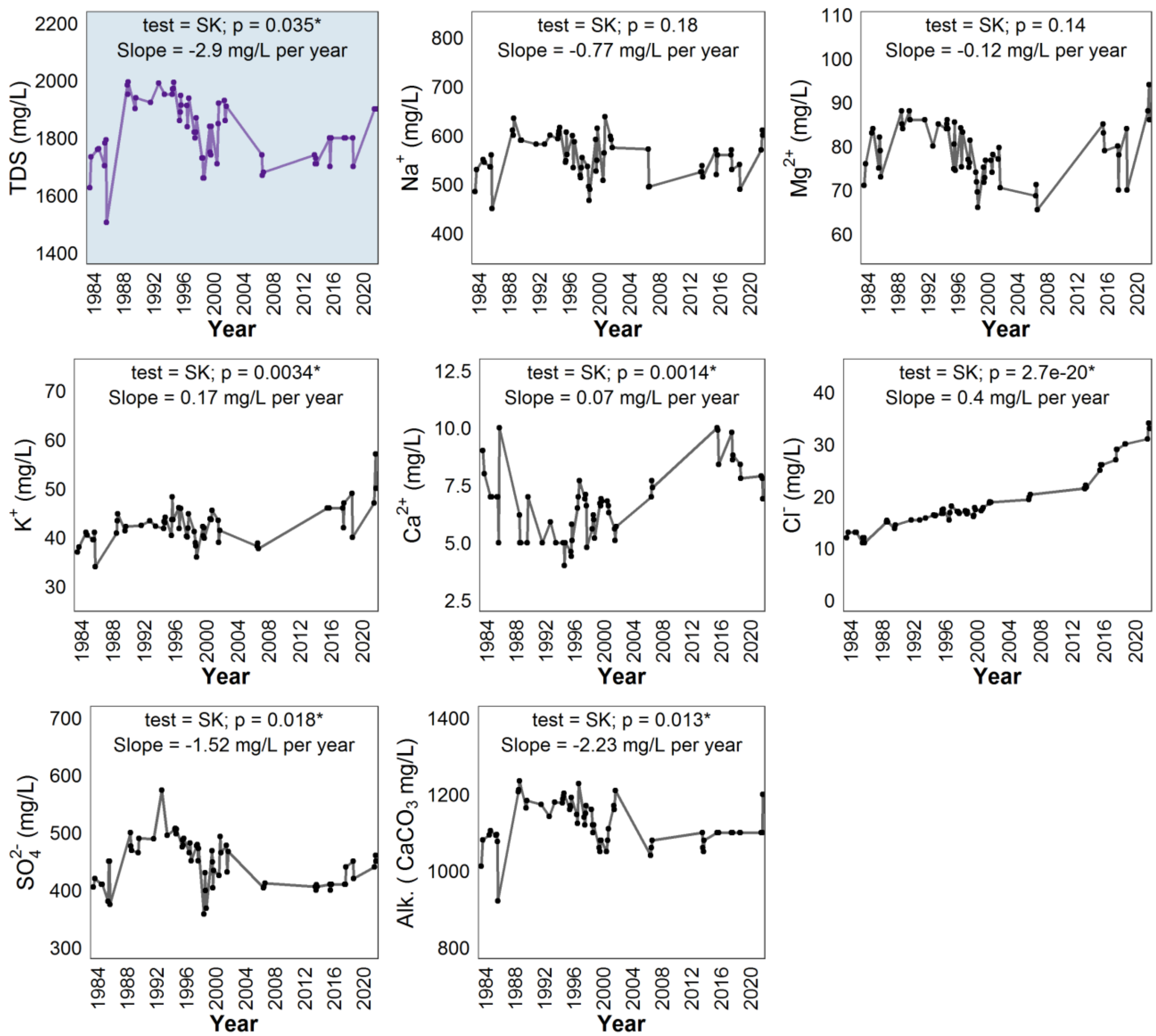


Figure 10. Concentrations of TDS (top left, blue panel), major ions (sodium = Na^+, magnesium = Mg^{2+}, potassium = K^+, calcium = Ca^{2+}, chloride = Cl^-, sulphate = SO_4^{2-}), and total alkalinity (Alk., as mg/L $CaCO_3$) measured monthly between June and September on sampling dates between 1983 and 2021. 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 (become less clear) in Buffalo Lake since 1984 (Tau = -0.23, *p* = <0.01).

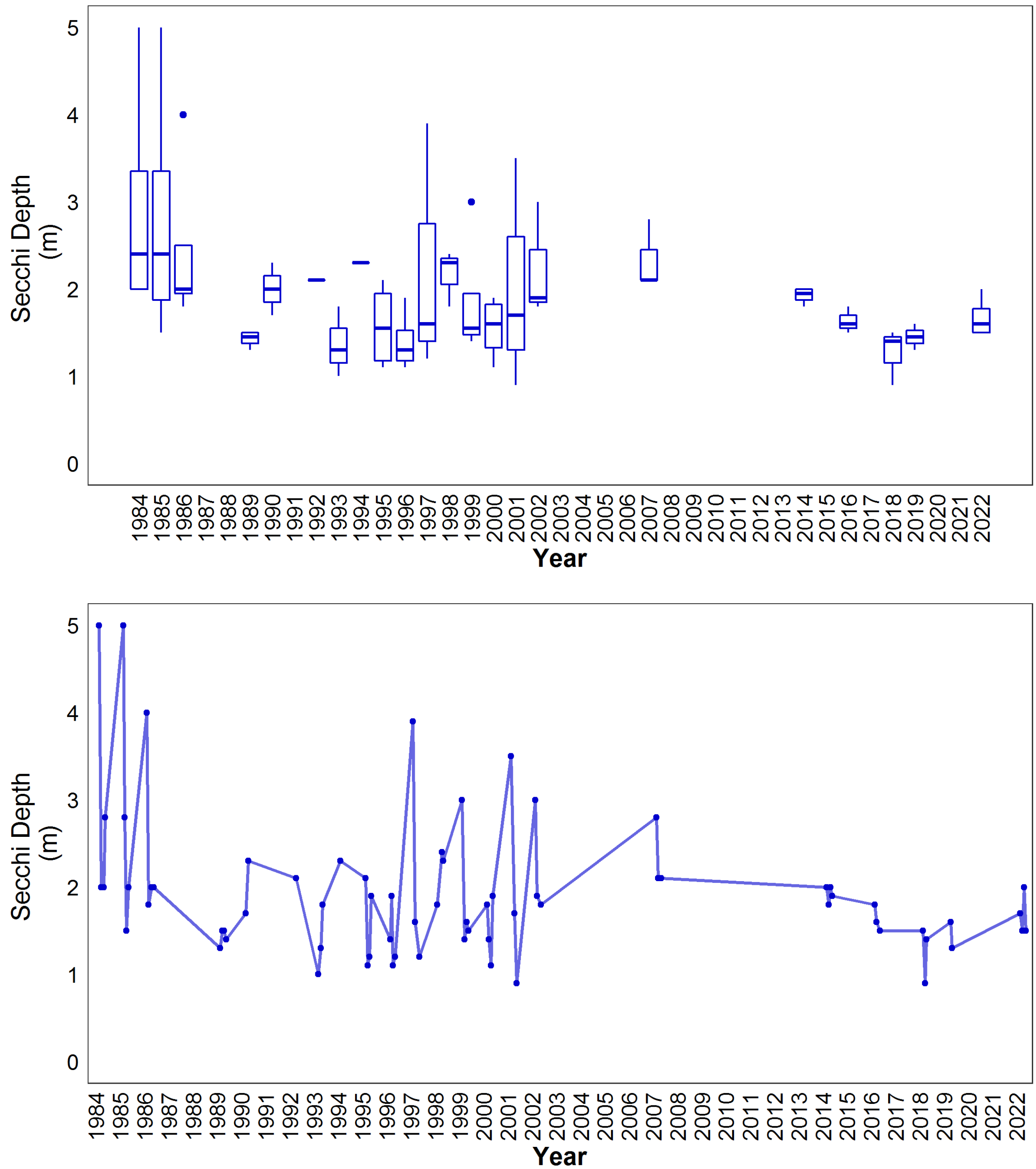


Figure 11. Monthly Secchi depth values measured between June and September over the long term sampling dates between 1984 and 2022 (n = 70). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

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 1984-2022 on Buffalo 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	-0.36	0.05	-0.20	-0.23
The extent of the trend	Slope (units per Year)	-0.86	0.03	-2.90	-0.01
The statistic used to find significance of the trend	Z	-4.05	0.53	-2.11	-2.64
Number of samples included	n	68	68	63	70
The significance of the trend	*p*	5.22×10^{-5}*	0.59	0.03*	8.30×10^{-3}*

*$p < 0.05$ is significant within 95%