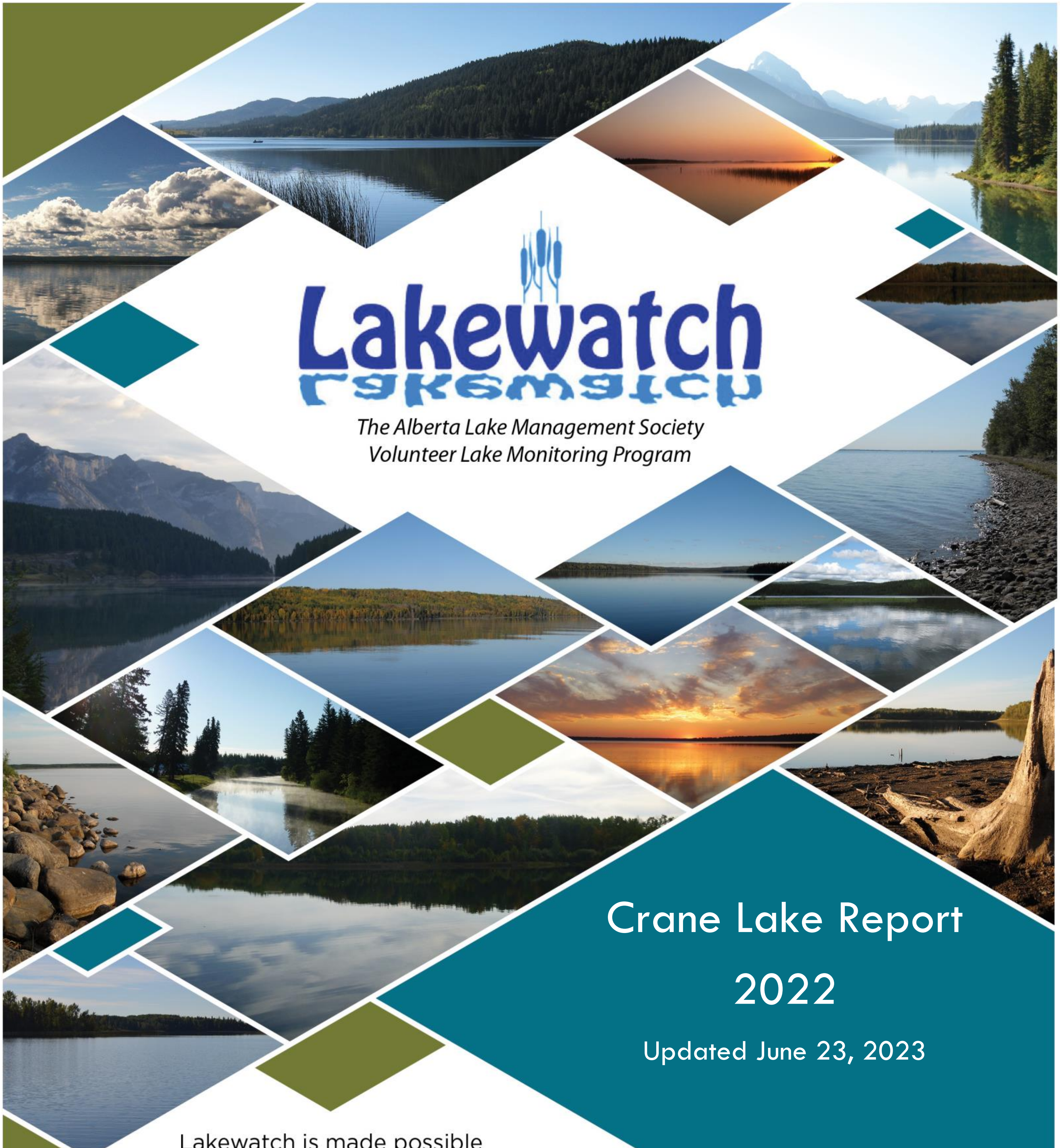

Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Crane Lake Report 2022

Updated June 23, 2023

Lakewatch is made possible with support from:

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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.

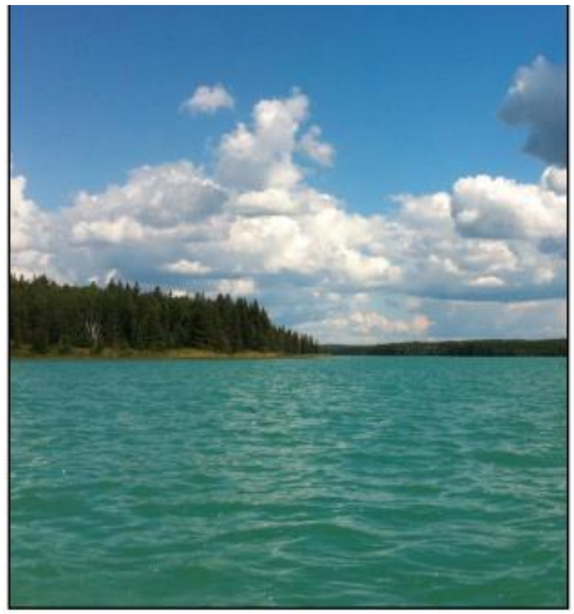
ALMS would like to thank all who express interest in Alberta's aquatic environments, and particularly those who have participated in the LakeWatch program. These leaders in stewardship give us hope that our water resources will not be the limiting factor in the health of our environment.

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 Ron Young for his commitment to collecting data at Crane 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.

CRANE LAKE



Crane Lake- Photo by Ageleky Bouzetos 2015

Crane Lake was originally named Moore Lake, after Dr. Bromley Moore, a former president of the College of Physicians and Surgeons and a friend of the surveyor Marshall Hopkins[1]. Moore Lake is locally referred to as Crane Lake. Crane Lake is a medium sized (surface area = 9.28 km^2) and deep (max depth = 26 m, mean depth = 8.3 m) water body located in the Beaver River Watershed.

The lake is situated about 280 km northeast of Edmonton in the municipal district of Bonnyville. The town of Bonnyville, south of the lake, and Cold Lake, east of the lake, are the principal urban centers of the area. Most of Crane Lake's shoreline is crown land. Two former Provincial Areas, Crane Lake East and West, have been disestablished and divested to the Municipal District of Bonnyville. There are two commercial resorts on the south shore. Crane Lake is a headwater lake with a small drainage basin that is only four times the size of the lake. The only inlets are two minor streams: one on the northeast shore and one on the west shore. The outlet flows from the east shore into nearby Hilda and Ethel Lakes and eventually into the Beaver River.

The watershed area for Crane Lake is 43.90 km^2 and the lake area is 10.29 km^2. The lake to watershed ratio of Crane Lake is 1:4. A map of the Crane Lake watershed area can be found at: http://alms.ca/wp-content/uploads/2016/12/Crane.pd

[1] Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes, University of Alberta Press. Retrieved from http://sunsite.ualberta.ca/projects/alberta-lakes/

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 Crane Lake was 9 µg/L (Table 2), falling into the oligotrophic, or minimally productive trophic classification. This value falls below all previously observed historical averages going back to 1980 (Table 2). TP ranged from a minimum of <3 µg/L on the August 10th, to a maximum of 16 µg/L on September 12th (Figure 1). Note that a value of 1.5 µg/L was used to calculate the average TP, and to plot in Figure 1, where the levels were below the detection limit of 3 µg/L.

Average chlorophyll-*a* concentration in 2022 was 5 µg/L (Table 2), falling into the mesotrophic, or moderately productive trophic classification. Chlorophyll-*a* was lowest during the July 15th sampling event at 4.3 µg/L, and peaked at 5.6 µg/L on September 12th.

The average TKN concentration was 0.9 mg/L (Table 2), and displayed little seasonal variation (Figure 1). TKN and TP were significantly positively correlated (r = 0.96, p = 0.04)

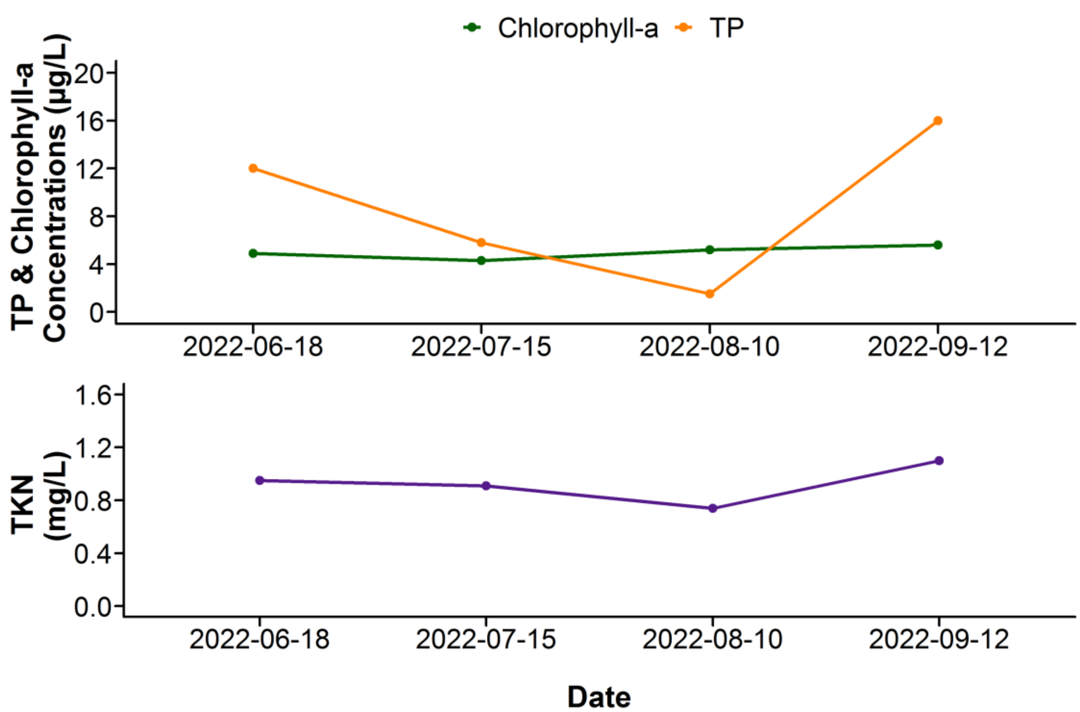


Figure 1. Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured four times over the course of the summer at Crane Lake.

Average pH was measured as 8.80 in 2022, buffered by high alkalinity (440 mg/L $CaCO_3$) and bicarbonate (460 mg/L HCO_3). Aside from bicarbonate, sodium and magnesium were higher than all other major ions, and together contributed to a moderate conductivity of 898 µS/cm (Figure 2, top; Table 2). Crane Lake is in the moderate to high end range of ion levels, compared to other LakeWatch lakes sampled in 2022, with the exception of calcium (Figure 2, bottom).

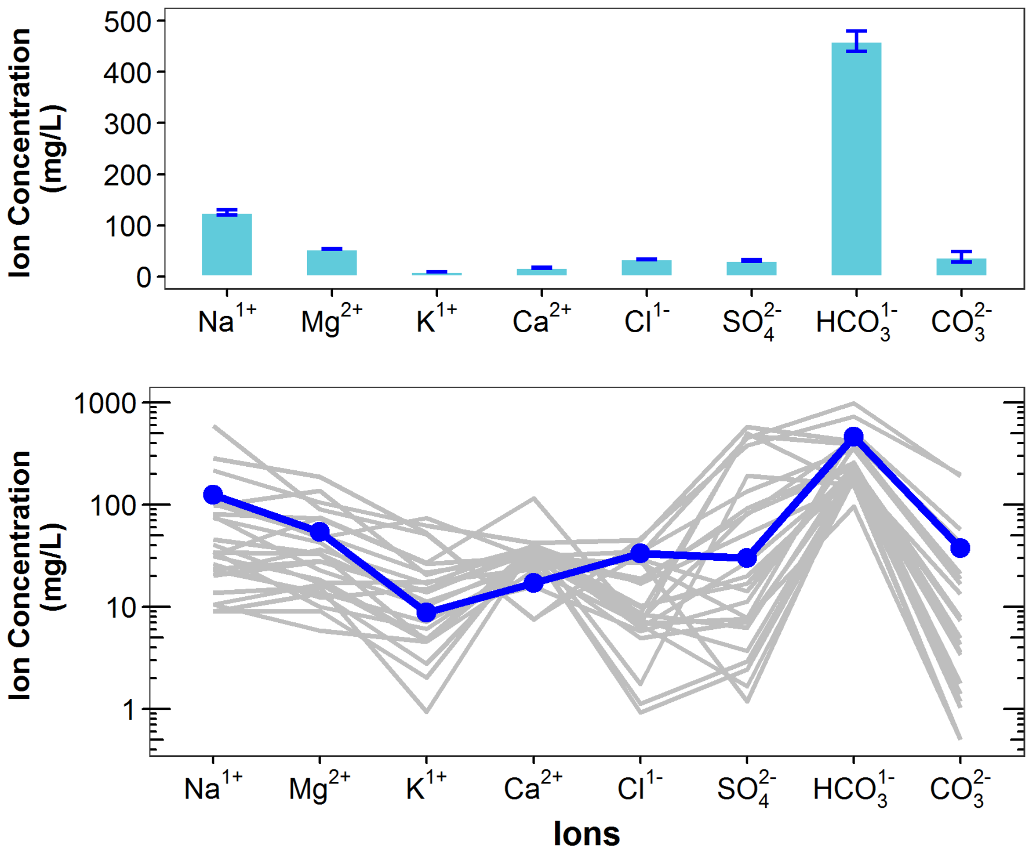


Figure 2. Average levels of cations (sodium = Na^{1+}, magnesium = Mg^{2+}, potassium = K^{1+}, calcium = Ca^{2+}) and anions (chloride = Cl^{1-}, sulphate = SO_4^{2-}, bicarbonate = HCO_3^{1-}, carbonate = CO_3^{2-}) from four measurements over the course of the summer at Crane Lake. Top) bars indicate range of values measured, and bottom) Schoeller diagram of average ion levels at Crane 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 Crane Lake in 2022, and no metal exceeds CCME guidelines (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 Crane Lake in 2022 was 5.80 m, corresponding to an average Secchi depth of 2.90 m (Table 2). Euphotic depth varied over the season, ranging from as deep as 8.10 m on July 15th, to 3.70 m on September 12th (Figure 3). Secchi depth and chlorophyll-*a* were significantly negatively correlated (r = -0.99, p = 0.01), indicating that water clarity was closely associated to the amount of algae and cyanobacteria within the lake during each sampling event.

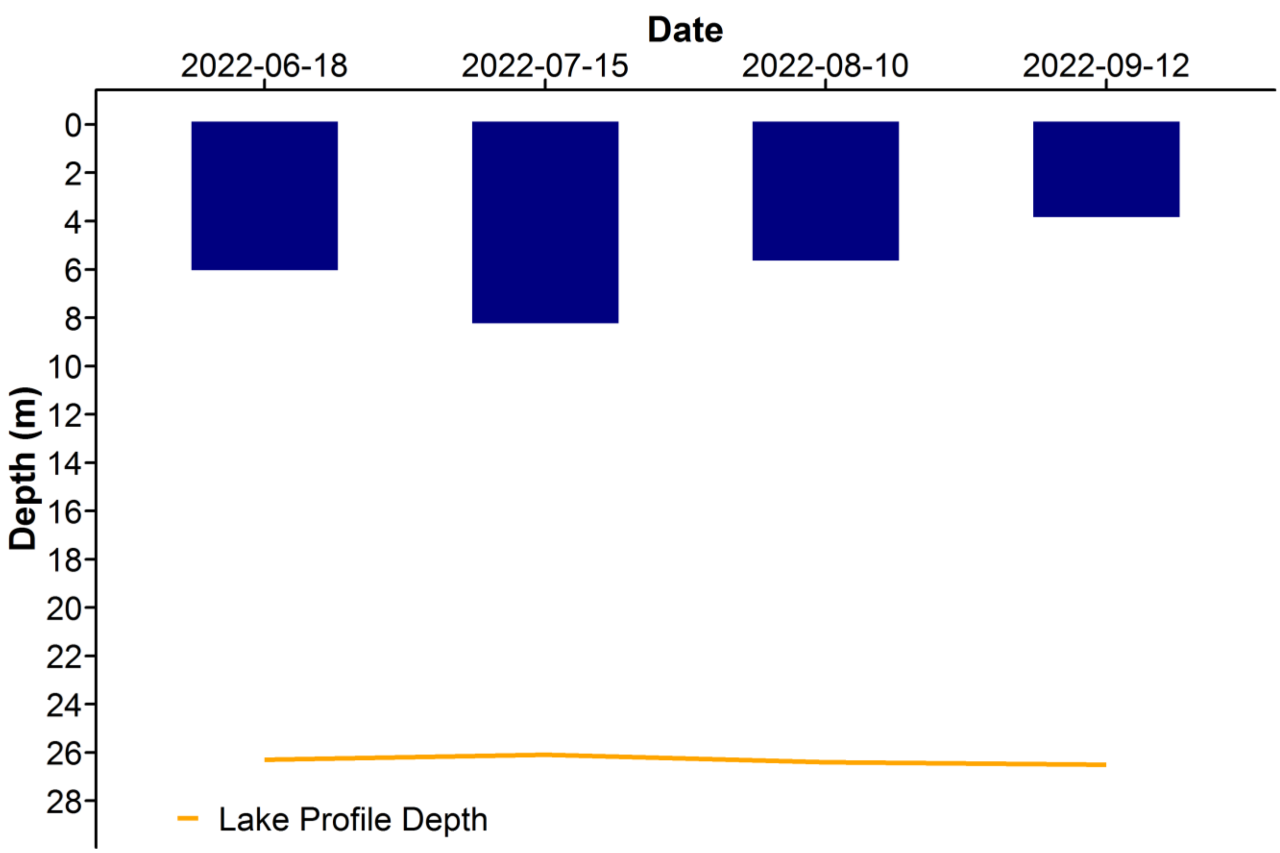


Figure 3. Euphotic depth values measured four times over the course of the summer at Crane Lake in 2022.

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 Crane Lake varied throughout the summer, with the July 15th sampling date having the warmest temperatures at 20.9°C (Figure 4a). The lake was stratified during each sampling trip. The depth and strength of the thermocline varied between each depth, ranging between about 8 m on June 18th (a weak thermocline), to as deep as about 12 m on September 12th (a strong thermocline).

Crane 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). Despite high surface oxygen levels on each sampling date, surface levels appeared to decline from the June to September sampling events. While oxygen levels quickly dropped to anoxic levels (<1.0mg/L) below the thermocline during the July, August, and September sampling events, significant oxygen was present in the lake below the thermocline on the June 18th sampling event, where anoxic conditions were not measured until 25.5 m depth.

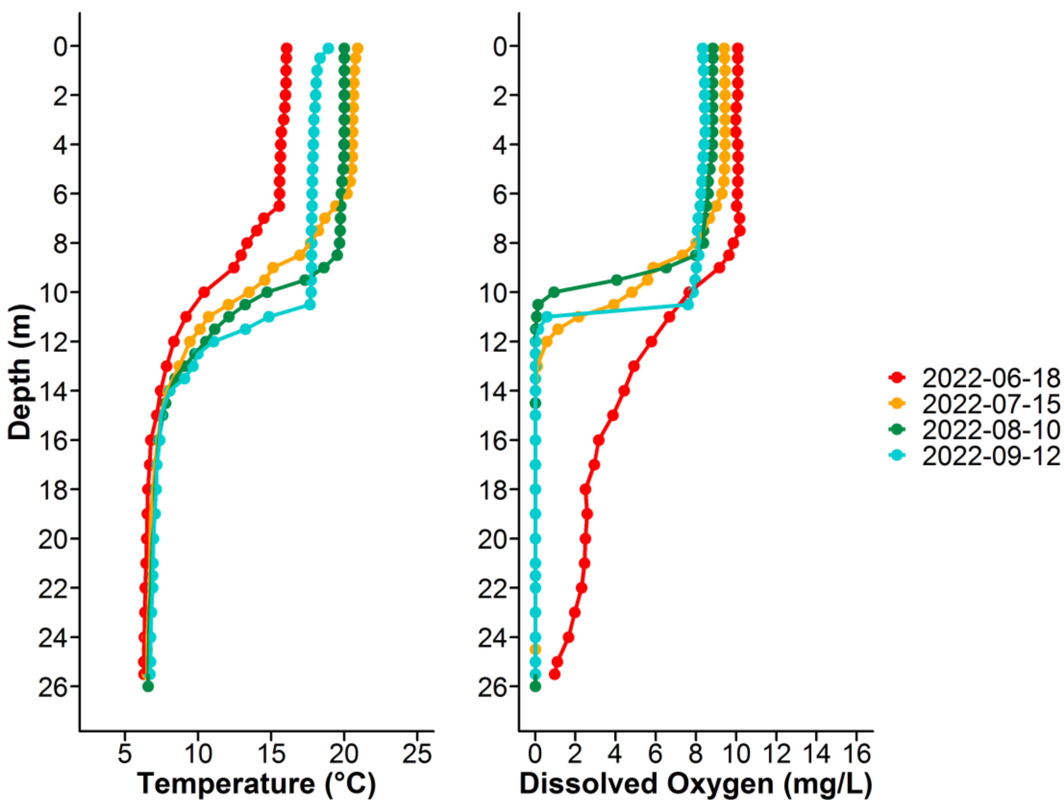


Figure 4. a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Crane Lake measured four times over the course of the summer of 2022.

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 Crane Lake fell below the recreational guideline of 10 μg/L during every sampling event in 2022. In addition, microcystin levels from every sampling event were below the laboratory detection limit of 0.10 μg/L. A value of 0.05 μg/L is assigned to each date that is below detection, in order to calculate an average.

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

Date	Microcystin Concentration (μg/L)
18-Jun-22	<0.1
15-Jul-22	<0.1
10-Aug-22	<0.1
12-Sep-22	<0.1
Average	0.05

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 Crane 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.

A watermilfoil specimen was collected from Crane Lake during the September 12th sampling event, and was confirmed to be the native Northern Watermilfoil.

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 Crane Lake in 2022 were slightly above the historical average during the beginning of the year, and then decreased appreciably. Levels have been relatively stable since measurements began in 1980 (Figure 5).

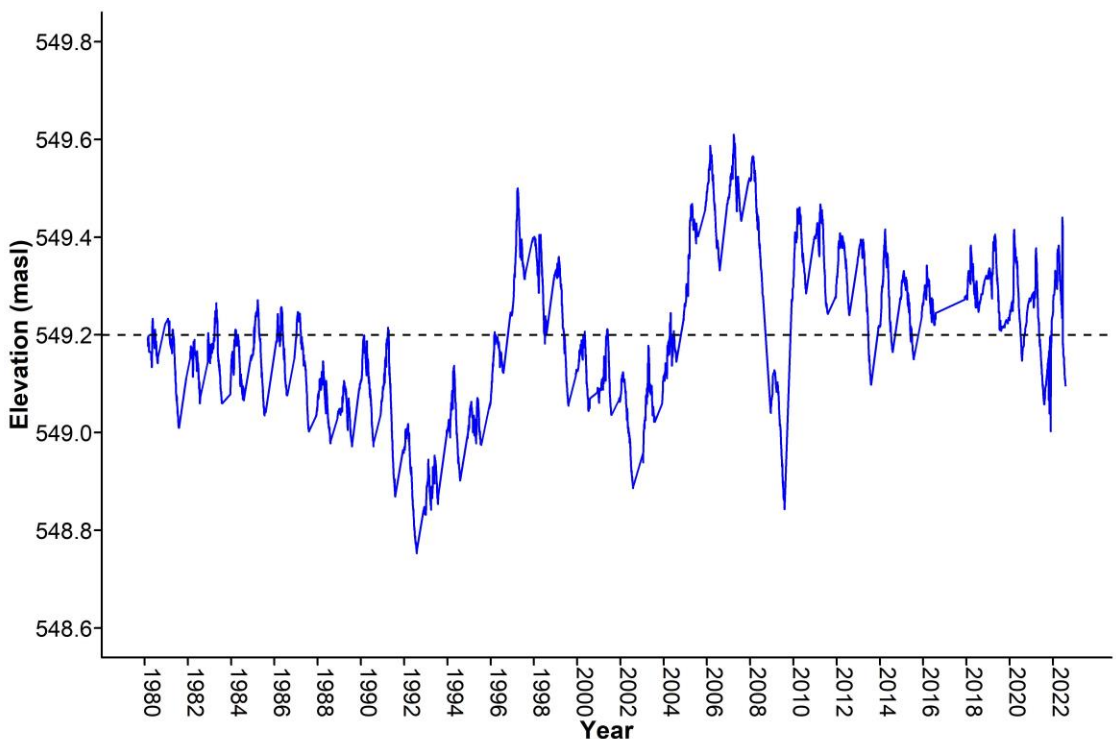


Figure 5. Water levels measured at Crane Lake in metres above sea level (masl) from 1980-2022. Data retrieved from Alberta Environment and Protected Areas and Environment and Climate Change Canada. Black dashed line represents historical yearly average water level.

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.

Crane Lake experienced a warmer, and windier summer than normal (Figure 6). Windy spells leading up to each sampling event likely dictated the depth of mixing, and a warm spell leading up to the July 15th sampling event is the likely cause of the higher surface water temperatures.

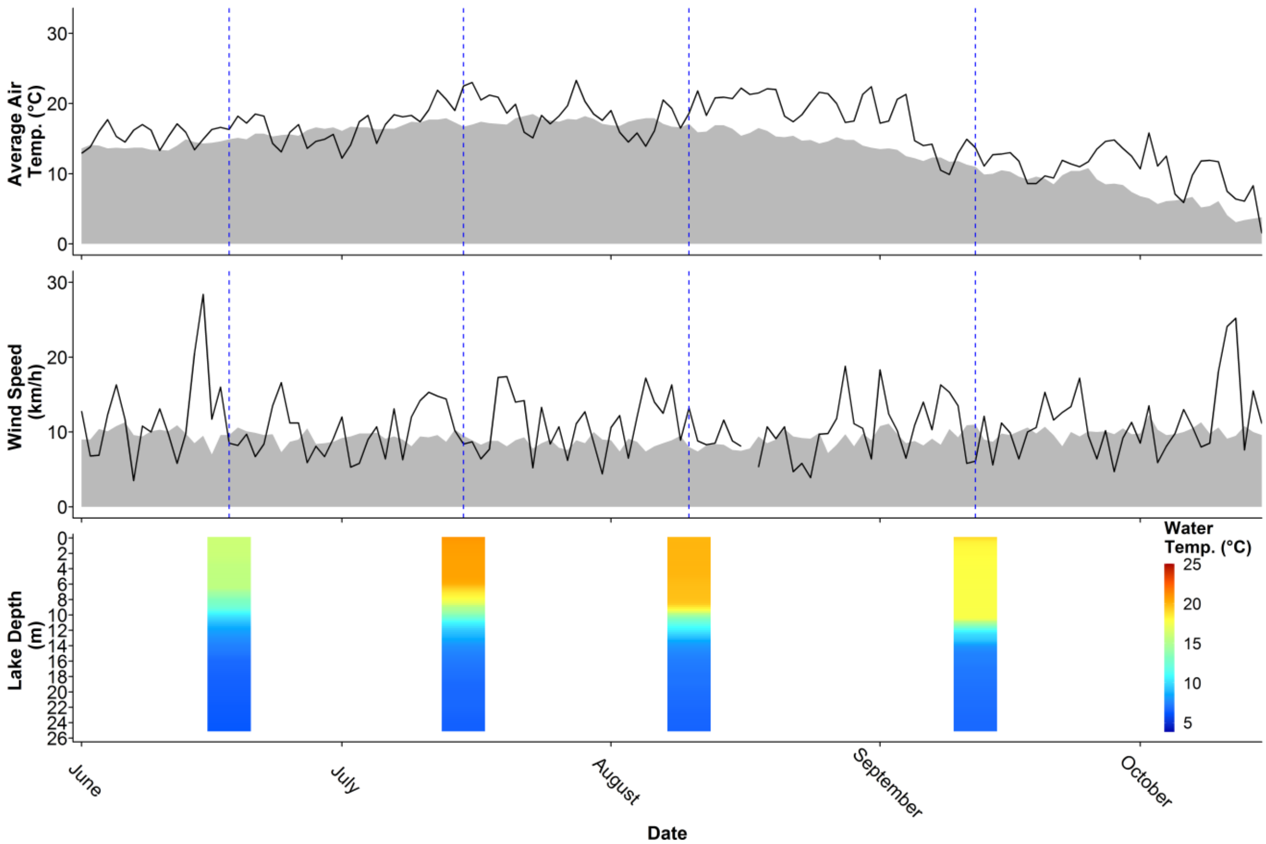


Figure 6. Average air temperature (°C) and wind speed (km/h) measured from 'Cold Lake A' weather station, as well as Crane Lake temperature profiles, interpolated (°C). Black lines indicate 2022 levels, gray indicates long-term normals, and blue lines indicate sampling dates for Crane Lake over the summer. 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 and accumulated precipitation is unavailable for the 'Cold Lake A' weather station.

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

Parameter	1980	1981	1997	2005	2006	2007	2008	2009
TP (µg/L)	/	27	23	24	23	22	23	19
TDP (µg/L)	/	11	10	11	11	10	12	12
Chlorophyll-a (µg/L)	7.9	8.2	7.0	7.1	4.8	3.6	2.5	2.3
Secchi depth (m)	2.70	3.30	3.50	3.22	2.88	3.15	4.00	3.81
TKN (mg/L)	1.2	0.9	1.0	1.0	1.0	0.9	0.9	0.8
NO2 and NO3 (µg/L)	5	3	8	6	6	3	3	5
NH3 (µg/L)	29	22	7	10	14	13	10	15
DOC (mg/L)	15	14	/	14	14	14	13	14
Ca (mg/L)	17	17	16	14	15	15	15	15
Mg (mg/L)	41	40	48	42	48	49	50	47
Na (mg/L)	89	81	116	125	112	124	124	125
K (mg/L)	7	8	8	8	8	8	8	8
SO42- (mg/L)	18	21	28	24	28	26	30	35
Cl- (mg/L)	21	21	26	29	30	30	30	31
CO3 (mg/L)	0.2	/	39	41	41	43	43	42
HCO3 (mg/L)	/	/	415	457	459	461	469	467
pH	/	/	8.90	8.92	8.94	8.88	8.89	8.94
Conductivity (µS/cm)	9	9	822	842	873	862	870	867
Hardness (mg/L)	724	704	233	207	234	241	246	231
TDS (mg/L)	/	/	482	509	507	523	532	533
Microcystin (µg/L)	/	/	/	0.16	0.39	0.14	0.10	0.13
Total Alkalinity (mg/L CaCO3)	354	356	400	443	444	450	456	454

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

Parameter	2010	2011	2013	2014	2015	2016	2017	2018	2019	2020	2022
TP (µg/L)	29	25	26	20	12	14	13	13	17	13	9
TDP (µg/L)	11	14	13	9	7	6	5	4	6	5	3
Chlorophyll-*a* (µg/L)	2.3	6.3	3.2	2.5	3.1	4.2	3.7	4.7	5.3	6.8	5.0
Secchi depth (m)	3.75	3.69	3.55	3.65	3.65	3.65	3.86	4.02	4.01	3.0	2.9
TKN (mg/L)	1.0	1.0	1.3	0.9	1.0	0.9	0.9	0.9	0.9	1.0	0.9
NO_2-N and NO_3-N (µg/L)	4	5	4	22	3	3	2	4	2	2	4
NH_3-N (µg/L)	15	11	13	23	25	25	15	15	12	25	8
DOC (mg/L)	13	13	21	14	13	12	13	13	15	12	13
Ca (mg/L)	13	14	14	16	12	12	14	15	16	18	17
Mg (mg/L)	51	50	54	40	55	57	53	54	52	53	54
Na (mg/L)	133	121	129	135	125	136	128	128	123	130	125
K (mg/L)	8	6	8	8	8	9	9	9	8	9	9
SO_4^{2-} (mg/L)	27	21	22	26	30	29	30	29	27	28	30
Cl^- (mg/L)	31	30	30	31	34	34	33	33	36	33	33
CO_3 (mg/L)	37	41	41	45	42	48	43	42	53	60	37
HCO_3 (mg/L)	480	471	413	549	480	466	458	468	445	410	460
pH	8.89	8.95	9.08	8.80	8.91	8.96	8.93	8.87	8.92	8.84	8.80
Conductivity (µS/cm)	893	890	819	914	916	924	906	900	908	905	898
Hardness (mg/L)	243	243	256	205	254	264	254	260	255	265	265
TDS (mg/L)	536	515	543	556	540	550	536	544	535	533	535
Microcystin (µg/L)	0.09	0.09	0.07	0.08	0.06	0.14	0.13	0.12	0.12	0.06	0.05
Total Alkalinity (mg/L $CaCO_3$)	456	454	407	450	460	464	446	454	453	438	440

Table 3a. Concentrations of metals measured in Crane 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)	2005	2006	2007	2008	2009	2010	Guidelines
Aluminum µg/L	2.10	9.07	5.36	8.86	7.95	4.37	100[a]
Antimony µg/L	0.03	0.03	0.03	0.04	0.03	0.03	/
Arsenic µg/L	4.27	3.02	3.66	4.48	3.67	3.06	5
Barium µg/L	13.4	14.4	14.4	13.8	14.0	13.3	/
Beryllium µg/L	0.003	0.003	<0.003	<0.003	<0.003	0.005	100[c,d]
Bismuth µg/L	0.0005	0.001	0.002	0.004	0.0019	0.0005	/
Boron µg/L	255	327	276	289	311	301	1500
Cadmium µg/L	0.010	0.005	0.010	0.013	0.012	0.013	0.36[b]
Chromium µg/L	0.24	0.36	0.22	0.41	0.47	0.18	/
Cobalt µg/L	0.010	0.025	0.013	0.015	0.020	0.009	50,1000[c,d]
Copper µg/L	0.25	0.38	0.24	1.31	0.29	0.24	4[b]
Iron µg/L	6.5	6.0	6.8	8.8	19.9	5.2	300
Lead µg/L	0.050	0.066	0.100	0.035	0.013	0.014	7[b]
Lithium µg/L	65.7	72.5	61.8	62.1	73.1	66.1	2500[d]
Manganese µg/L	1.8	1.7	2.5	1.9	1.3	1.4	130[e]
Molybdenum µg/L	3.19	3.59	3.15	3.23	3.00	2.90	73
Nickel µg/L	0.01	0.09	0.06	<0.005	0.13	0.06	150[b]
Selenium µg/L	0.2	0.5	0.4	0.7	0.4	0.4	1
Silver µg/L	0.001	0.001	<0.0005	0.0014	0.0038	0.000875	0.25
Strontium µg/L	68	75.2	73.8	69	69.9	69.2	/
Thallium µg/L	0	0.01	0.002	0.0018	0.0031	0.0013	0.8
Thorium µg/L	0.004	0.006	0.018	0.020	0.001	0.005	/
Tin µg/L	0.02	0.03	<0.03	<0.03	<0.03	0.015	/
Titanium µg/L	0.61	0.79	0.07	0.74	0.57	0.59	/
Uranium µg/L	0.19	0.21	0.21	0.21	0.18	0.18	15
Vanadium µg/L	0.15	0.25	0.21	0.235	0.268	0.181	100[c,d]
Zinc µg/L	2.08	2.5	0.751	0.362	0.329	0.66	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 Crane 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)	2018	2019	2020	2022	Guidelines
Aluminum µg/L	1.70	3.7	3.4	7	100[a]
Antimony µg/L	0.03	0.024	0.03	0.027	/
Arsenic µg/L	4.08	4.61	4.61	4.27	5
Barium µg/L	13.8	15.4	16.6	15.4	/
Beryllium µg/L	0	0.0015	0.0015	0.0015	100[c,d]
Bismuth µg/L	0	0.0015	0.0015	0.0015	/
Boron µg/L	289	288	270	321	1500
Cadmium µg/L	0.010	0.005	0.005	0.02	0.36[b]
Chromium µg/L	0.10	0.05	0.05	0.05	/
Cobalt µg/L	0.020	0.021	0.016	0.052	50,1000[c,d]
Copper µg/L	0.08	0.14	0.004	0.11	4[b]
Iron µg/L	7.0	8	8.9	7.1	300
Lead µg/L	0.000	0.004	0.008	0.023	7[b]
Lithium µg/L	67.9	63.9	61.3	66	2500[d]
Manganese µg/L	1.4	2.42	3.11	3.34	130[e]
Molybdenum µg/L	2.29	2.16	1.99	1.83	73
Nickel µg/L	0.05	0.07	0.07	0.08	150[b]
Selenium µg/L	0.8	0.4	0.6	0.1	1
Silver µg/L	<0.0005	<0.1	0.0005	0.0005	0.25
Strontium µg/L	70.9	80.4	83.9	72.1	/
Thallium µg/L	<0.001	0.001	0.001	0.001	0.8
Thorium µg/L	<0.001	0.002	0.001	0.003	/
Tin µg/L	0.06	0.03	0.03	0.03	/
Titanium µg/L	0.36	0.35	0.32	0.18	/
Uranium µg/L	0.17	0.151	0.15	0.136	15
Vanadium µg/L	0.11	0.097	0.637	0.104	100[c,d]
Zinc µg/L	0.5	0.4	0.7	1.2	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 Crane Lake. In sum, a significant decreasing trend was observed in TP, significant increasing trends were observed in chlorophyll-*a* and TDS, and no significant trend was detected for Secchi depth. 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 Crane Lake data from 2005 to 2022.

Parameter	Date Range	Direction of Significant Trend
Total Phosphorus	2005-2022	Decreasing
Chlorophyll-*a*	2005-2022	Increasing
Total Dissolved Solids	2005-2022	Increasing
Secchi Depth	2005-2022	No Change

Definitions:

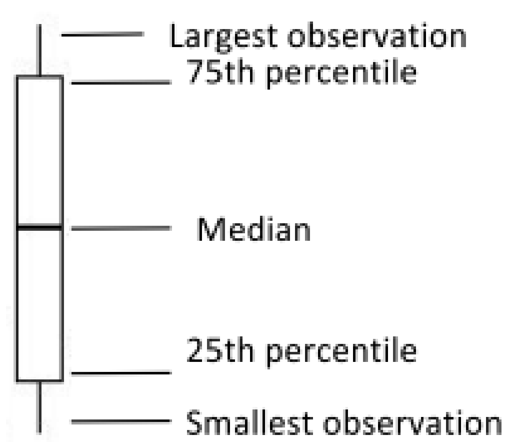
Median: the value in a range of ordered numbers that falls in the middle.

Trend: a general direction in which something is changing.

Monotonic trend: a gradual change in a single direction.

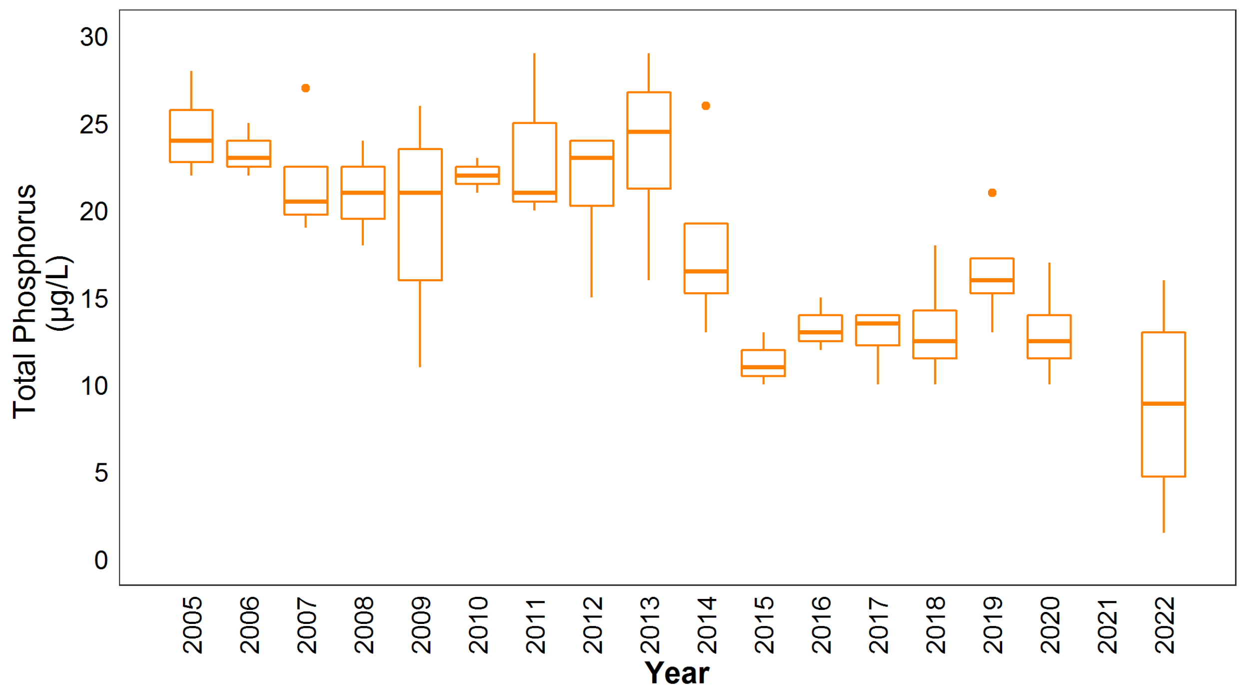
Statistically significant: The likelihood that a relationship between variables is caused by something other than random chance. This is indicated by a p-value of <0.05. Variability: the extent by which data is inconsistent or scattered.

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 Crane Lake since 20025 (Tau = -0.53, *p* = <0.001).



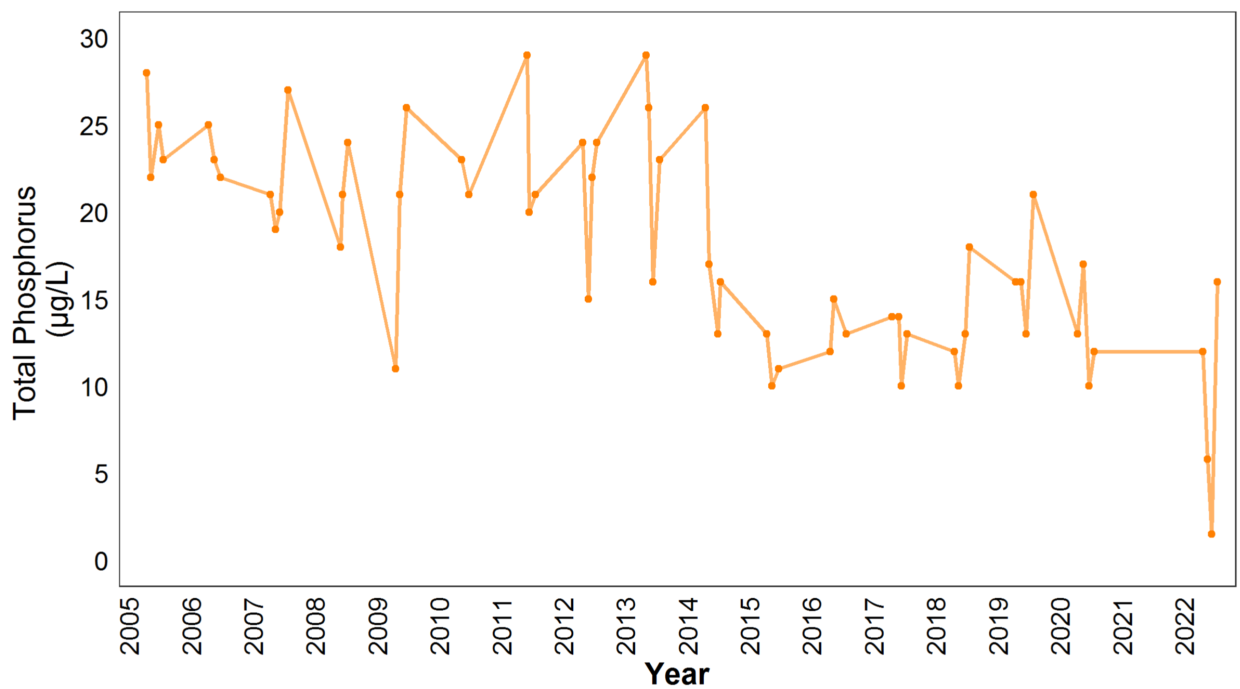
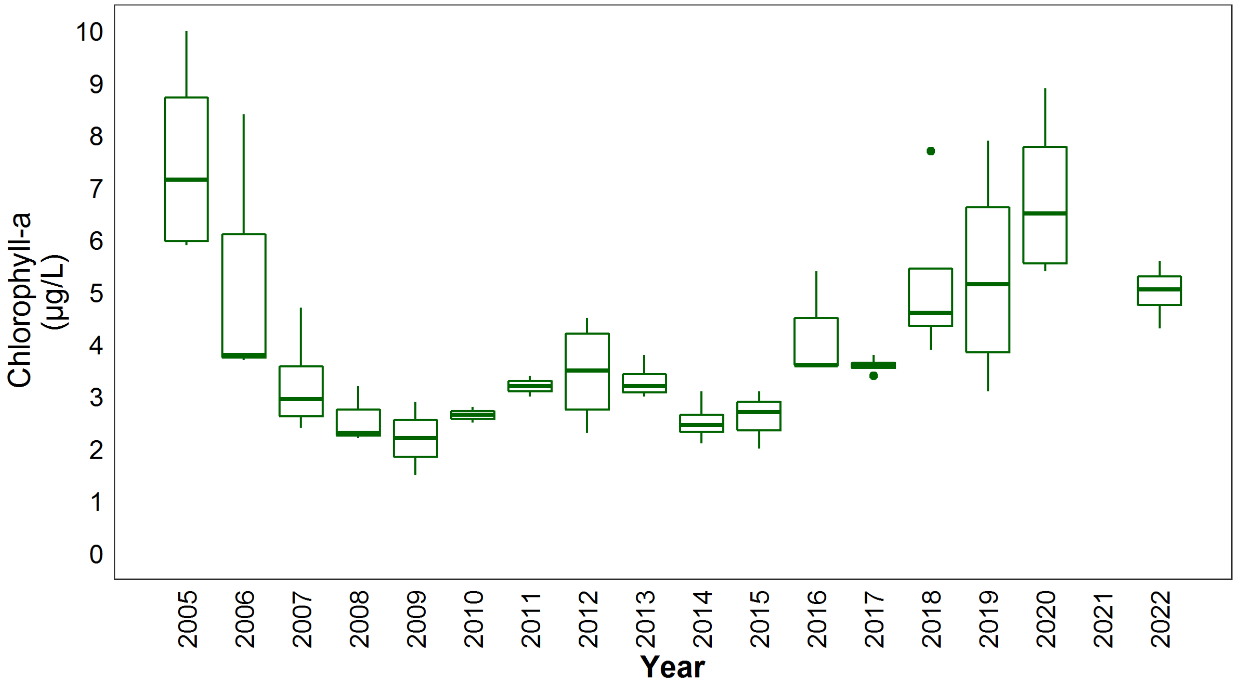


Figure 7. Monthly total phosphorus (TP) concentrations measured between June and September over the long term sampling dates between 2005 and 2022 (n = 60). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Chlorophyll-*a*

Chlorophyll-*a* has significantly increased over time at Crane Lake (Tau = 0.26, p = 0.006). While the trend is diven primarily by an increasing between 2009 and the present, levels mesuresed within the previous 3 years are within the range of values measursed at the start of the record between 2005 and 2007 (Figure 8).



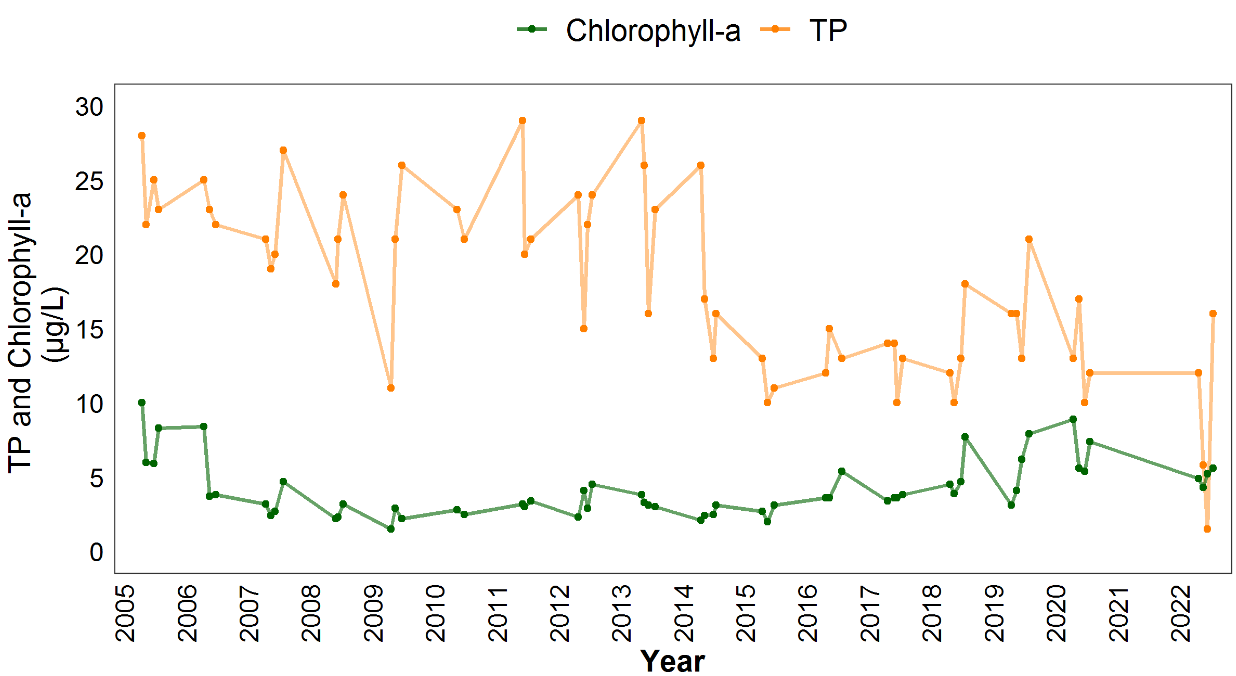
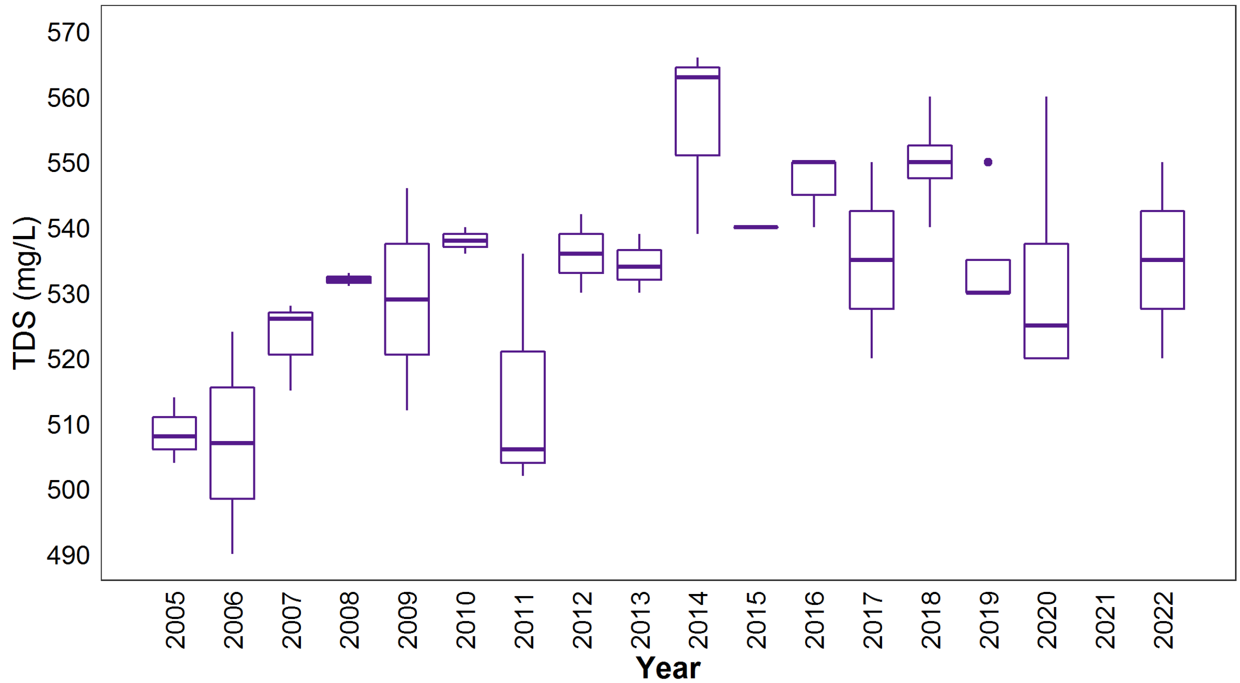


Figure 8. Monthly chlorophyll-*a* concentrations measured between June and September over the long term sampling dates between 2005 and 2022 (n = 60). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

Total Dissolved Solids (TDS)

Trend analysis showed a significant increasing trend in TDS between 2005 and 2022 (Tau = 0.31, p = 0.002) in Crane Lake.



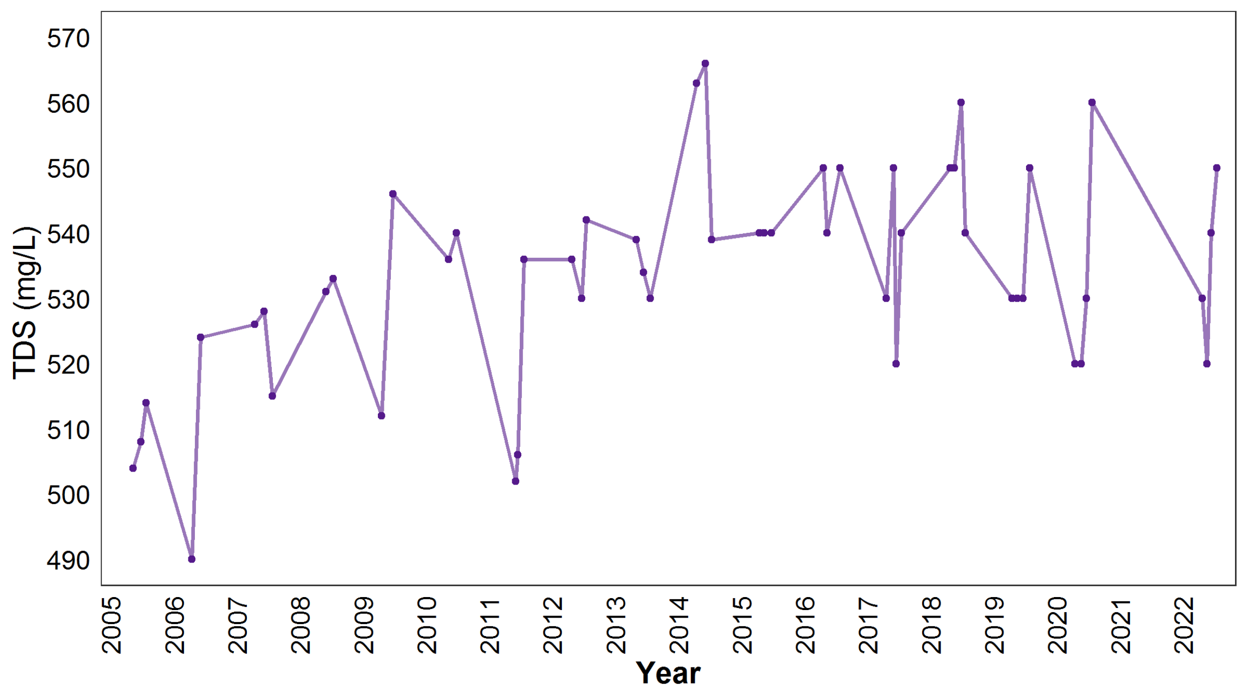


Figure 9. Monthly TDS values measured between June and September over the long term sampling dates between 2005 and 2022 (n = 52). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Due to the significant increasing trend of TDS in Crane Lake, exploring the specific major ions which may be driving this trend is important to determine. Of the major ions where trend analysis was possible, only potassium, chloride, and sulphate showed significant trends. The slopes of each of these trends are positive, indicating they are contributing to the overall positive trend in TDS over time. Note that trend analysis of calcium and magnesium were not possible due to insufficient data (Figure 10).

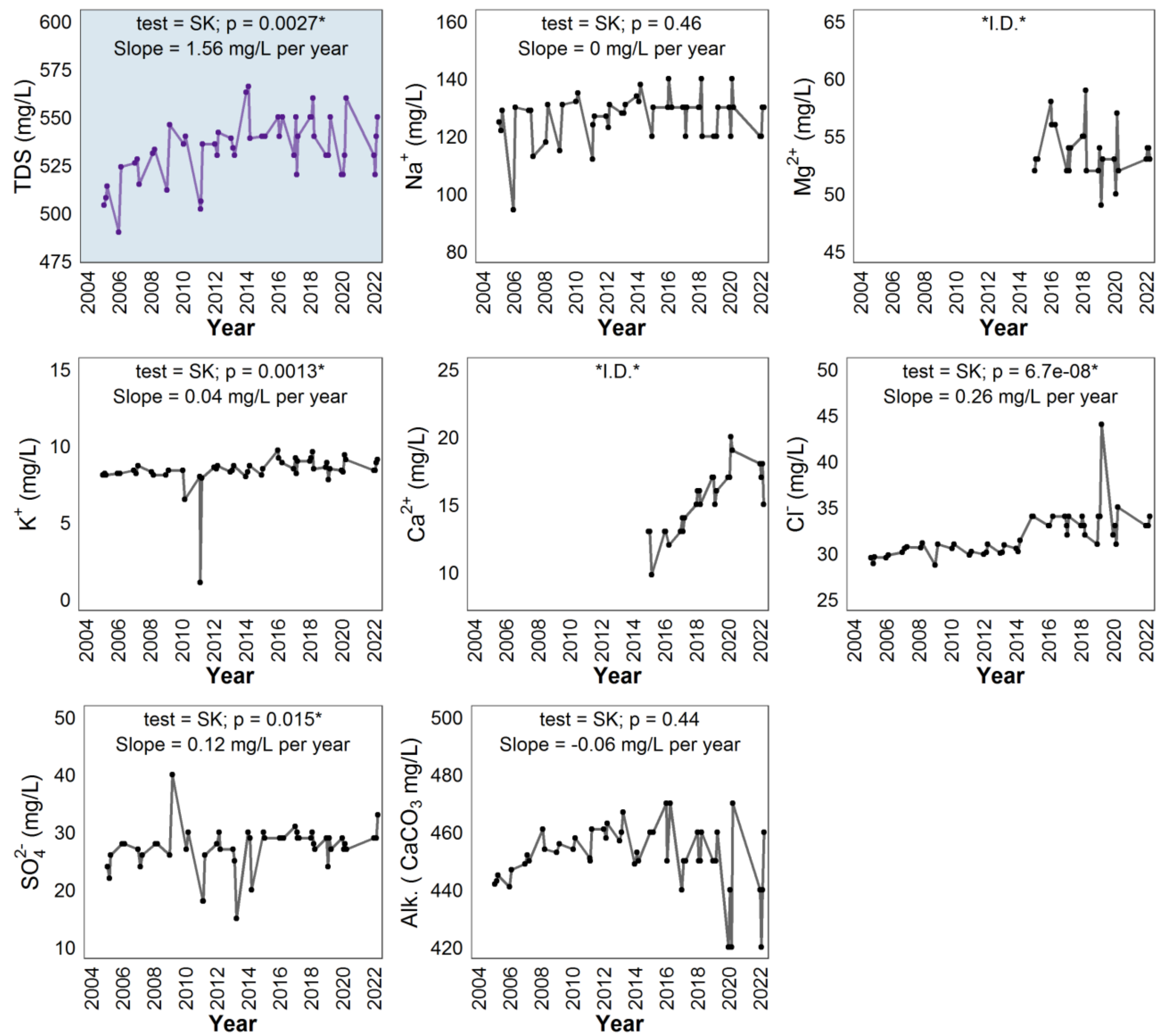
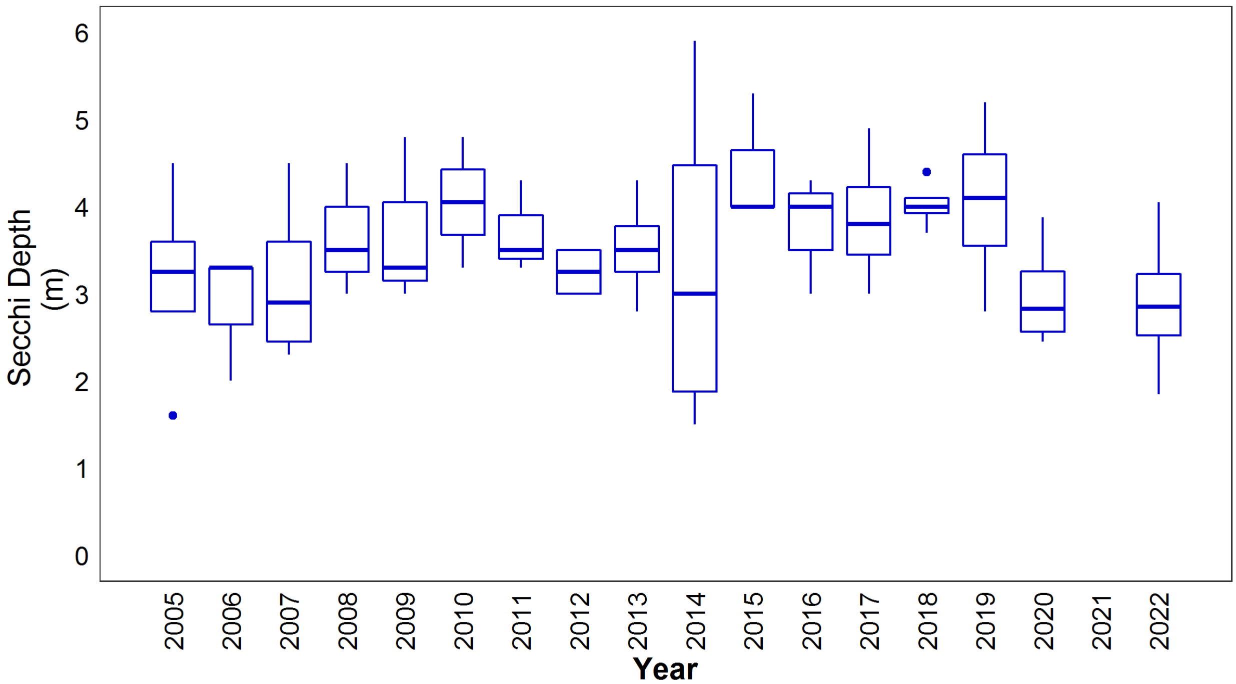


Figure 10. Concentrations of TDS (top left, blue panel), major ions (sodium = Na^+, magnesium = Mg^{2+}, potassium = K^+, calcium = Ca^{2+}, chloride = Cl^-, sulphate = SO_4^{2-}), and total alkalinity (Alk., as mg/L $CaCO_3$) measured monthly between June and September on sampling dates between 2005 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 displayed no significant change over time in Crane Lake since 2005 (Tau = 0.096, $p = 0.34$).



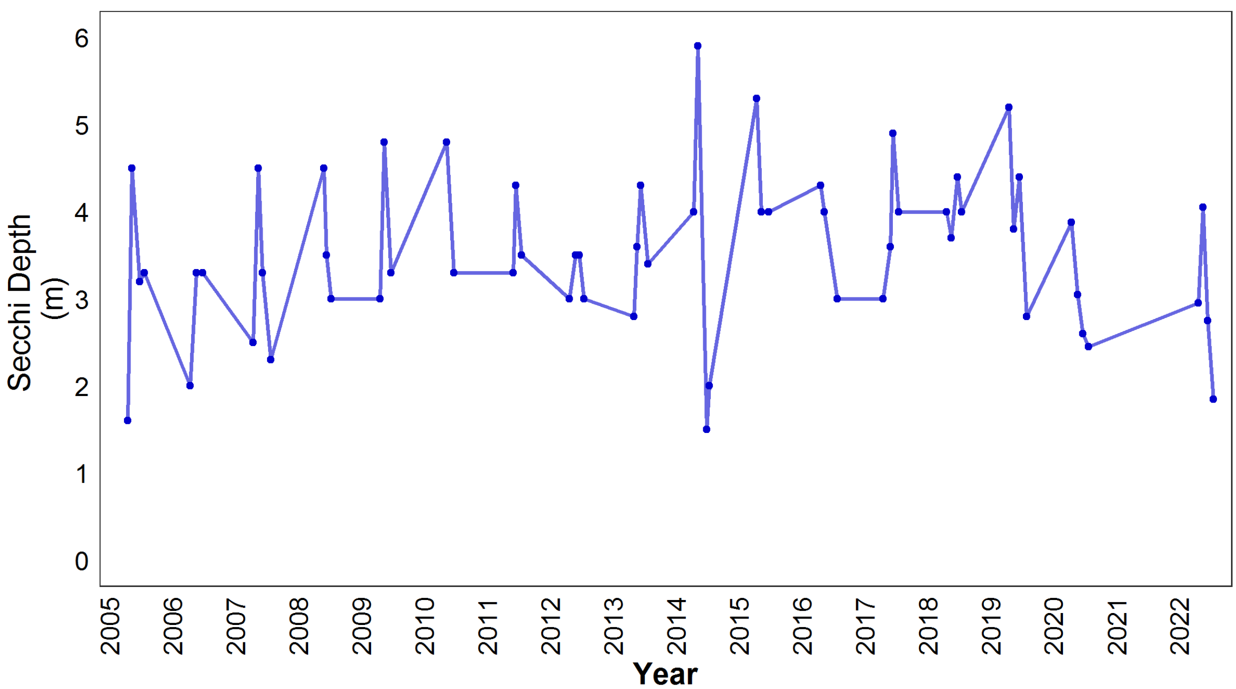


Figure 11. Monthly Secchi depth values measured between June and September over the long term sampling dates between 2005 and 2022 (n = 60). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

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 2005-2022 on Crane 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	-0.53	0.26	0.31	0.10
The extent of the trend	Slope (units per Year)	-0.87	0.11	1.56	0.02
The statistic used to find significance of the trend	Z	-5.57	2.76	3.00	0.96
Number of samples included	n	60	60	52	60
The significance of the trend	*p*	2.62×10^{-8}*	5.84×10^{-3}*	2.66×10^{-3}*	0.34

*$p < 0.05$ is significant within 95%