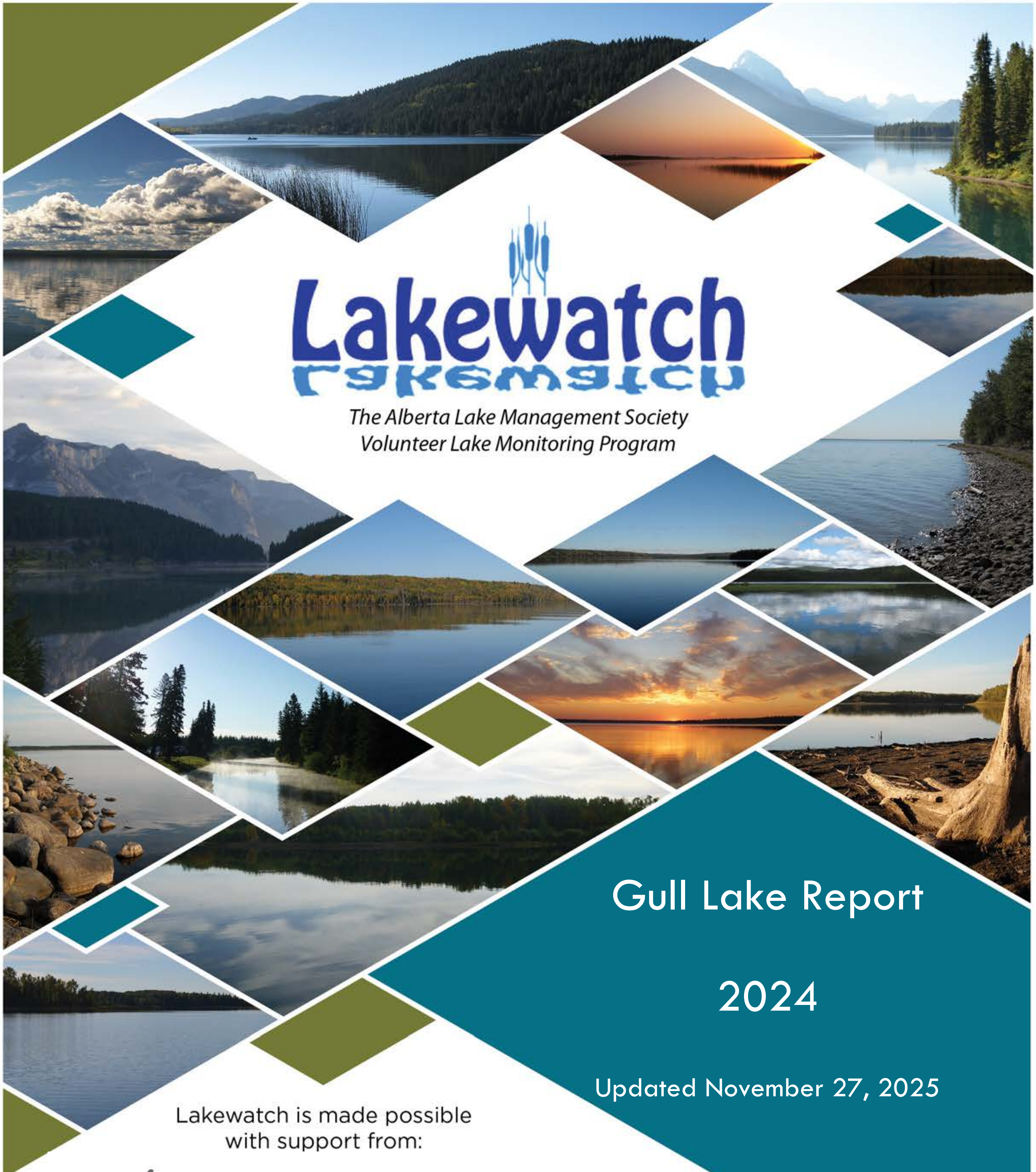


Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Gull Lake Report

2024

Updated November 27, 2025

Lakewatch is made possible with support from:

Alberta

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

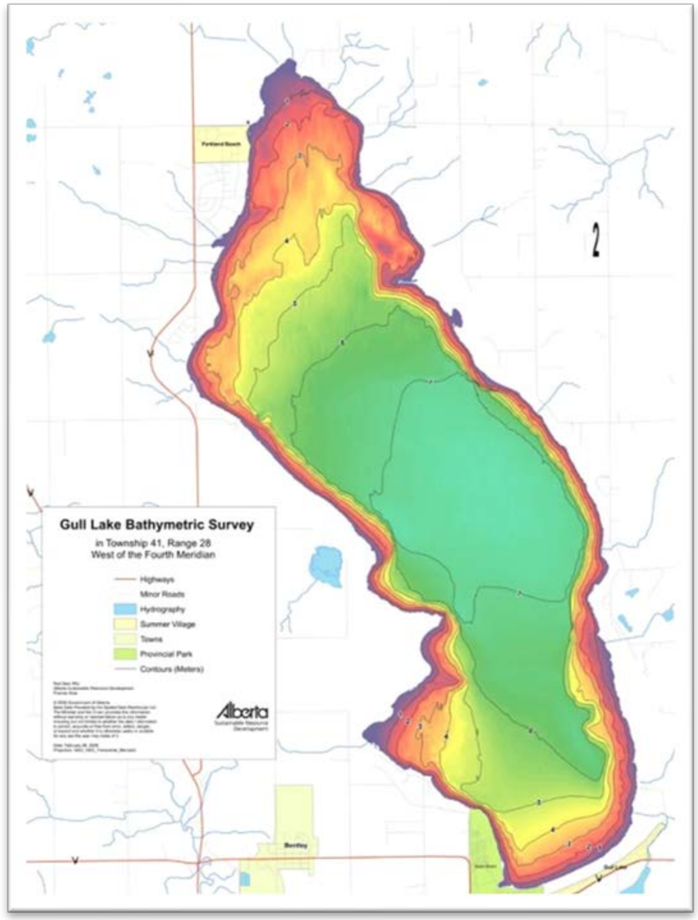
The LakeWatch program is made possible through the dedication of its volunteers. A special thanks to Lon Kasha for their commitment to collecting data at Gull Lake. We would also like to thank Katherine Cundict and Jordyn Lajeunesse, who were summer technicians in 2024. Executive Director Bradley Peter and Program Manager Brittany Onysyk were instrumental in planning and organizing the field program. This report was prepared by Brittany Onysyk and Bradley Peter.

BEFORE READING THIS REPORT, CHECK OUT **A BRIEF INTRODUCTION TO LIMNOLOGY**

GULL LAKE

Known for its clear water and sandy beaches, Gull Lake is a very popular lake located approximately 17 km east of the Town of Lacombe and 136 km south of the City of Edmonton. As this lake is situated between two large cities (Edmonton and Calgary), it is heavily populated and visited frequently throughout the summer months. Gull Lake supports many recreational activities such as boating, swimming, fishing, and sailing.

Gull Lake is shallow, with an average depth of 5.4 m and a maximum depth of 8 m.[1] Gull Lake water levels have been steadily decreasing since at least the 1920s (water levels dropped (~6 cm/yr from 1924 to 1968).[1] A dam installed in 1921 near the south of the lake is located approximately 1.6 km from shore, showing just how far the water has receded. For a time, water was diverted from the Blindman River to the southwest of the lake.[1] In 2018, this diversion ceased due to invasive Prussian carp found in the Blindman River.[2]



Bathymetric map of Gull Lake obtained from the Government of Alberta.

The shoreline is heavily developed, with numerous subdivisions and cottages along the lake's shore, campgrounds, marinas, boat launches, and the Aspen Beach Provincial Park on the southwest shore of the lake. Aspen Beach Provincial Park was established in 1932, making it one of the first parks of the Alberta park system.[1]

Gull Lake lies within the Blindman River sub-basin of the Red Deer River watershed.[3] The lake's watershed is approximately 211 km^2 and the lake itself has a surface area of 79 km^2. The lake to watershed ratio of Gull Lake is roughly 2:1. Most of the watershed is used for agricultural activities and cattle production.

---

[1] Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes.
[2] Government of Alberta. 2024. Gull Lake Stabilization Project.
[3] Red Deer River Watershed Alliance. 2025. Planning & Analysis – Maps.

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 Gull Lake was 21 µg/L (Table 2), falling into the mesotrophic, or moderately productive trophic classification. This value falls on the lower range of historical averages. TP ranged from a minimum of 14 µg/L on September 10 to a maximum of 34 µg/L on June 13 (Figure 1).

The average chlorophyll-*a* concentration in 2024 was 6.6 µg/L (Table 2), similarly falling into the mesotrophic classification. Chlorophyll-*a* values in 2024 also fall within the lower range of historical averages. Chlorophyll-*a* was lowest at 2.7 µg/L on July 18 and peaked at 9.1 µg/L on September 10 (Figure 1).

The average Total Kjeldahl Nitrogen (TKN) concentration in 2024 was 1.8 mg/L (Table 2) and was steady through the season (Figure 1).

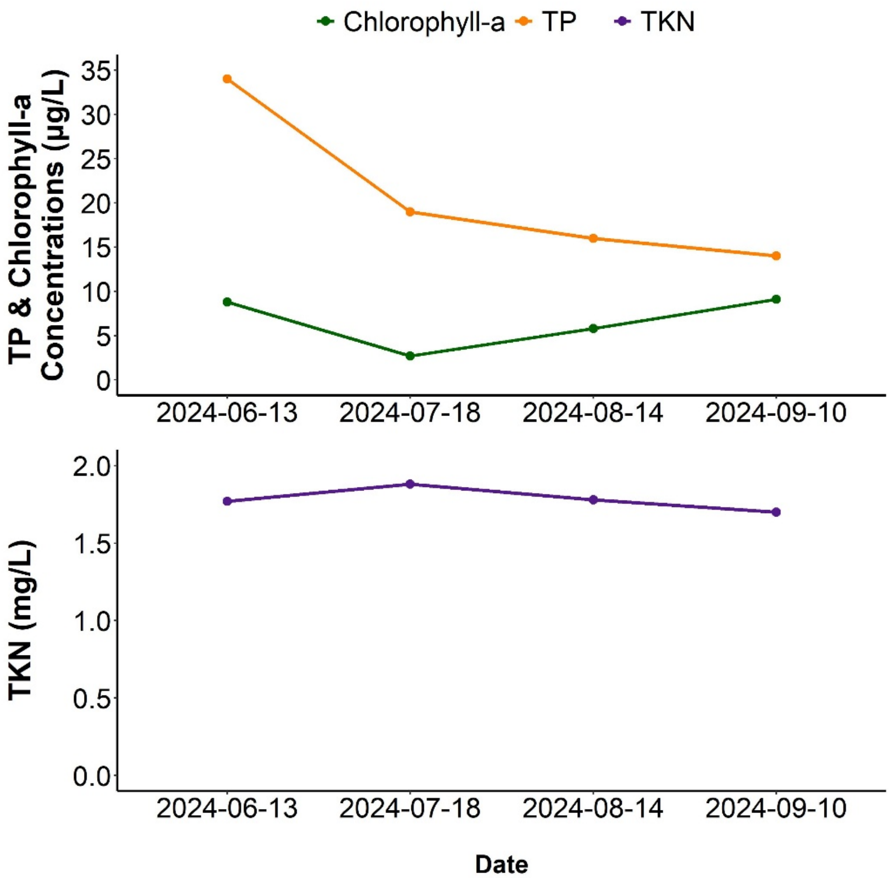
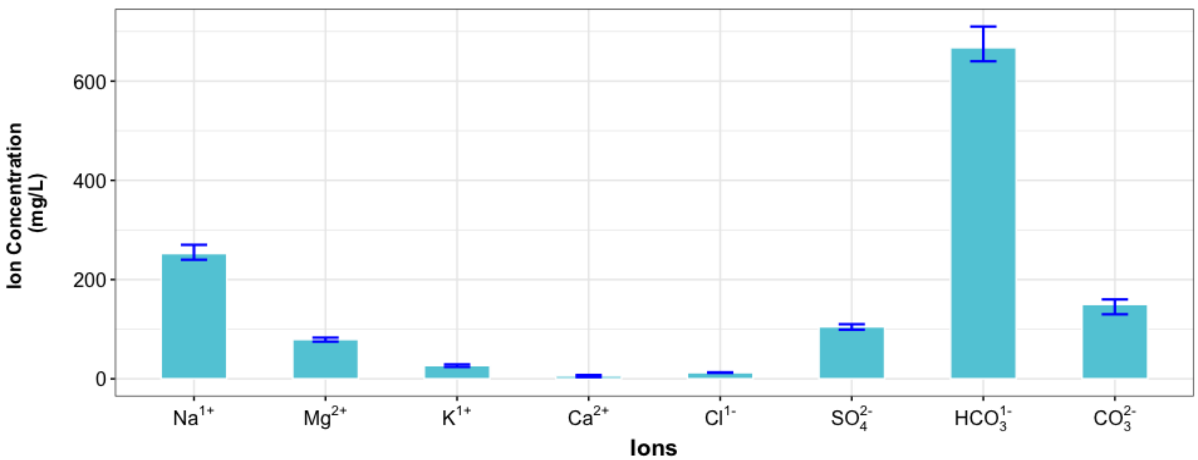


Figure 1. Total Phosphorus, Chlorophyll-*a*, and Total Kjeldahl Nitrogen concentrations measured over the course of the summer at Gull Lake in 2024.

Average pH was measured as 9.2 in 2024, buffered by high alkalinity (mg/L $CaCO_3$) and bicarbonate (668 mg/L HCO_3). Aside from bicarbonate, major ions with higher relative abundance were sodium, carbonate, and sulphate, together contributing to a high conductivity of 1525 µS/cm (Figure 2, top; Table 2). Gull Lake displayed moderate to higher ion levels compared to other LakeWatch lakes sampled in 2024, with the exception of calcium, where Gull Lake displayed near the lowest level of any lake in 2024 (Figure 2, bottom). Low calcium levels were likely due to a 'whiting' event which caused calcium to precipitate out of the water column.[4]



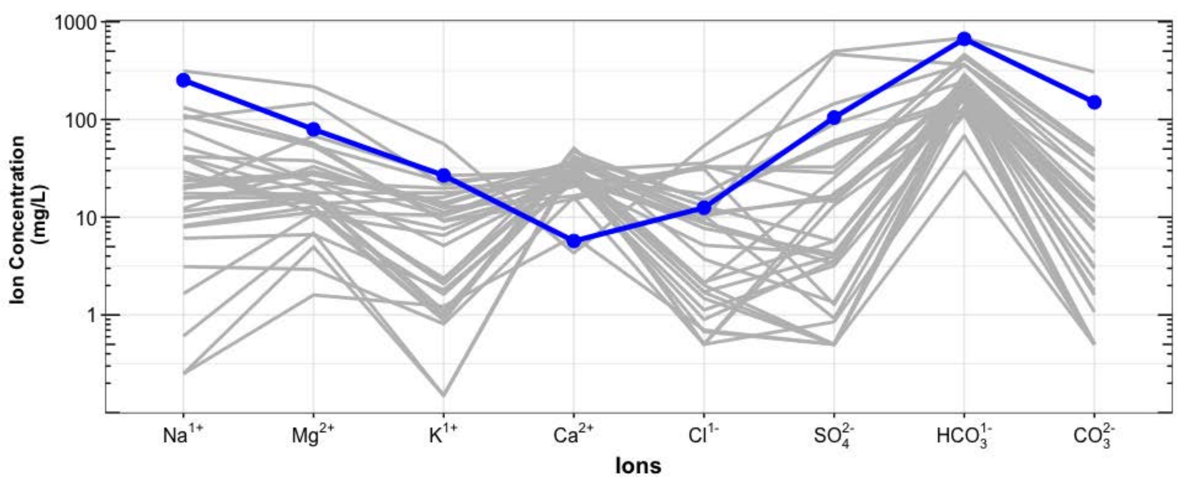


Figure 2. Average levels of cations (sodium = Na^{1+}, magnesium = Mg^{2+}, potassium = K^{1+}, calcium = Ca^{2+}) and anions (chloride = Cl^{1-}, sulphate = SO_4^{2-}, bicarbonate = HCO_3^{1-}, carbonate = CO_3^{2-}) from 4 measurements over the course of the summer at Gull Lake. Top) bars indicate range of values measured, and bottom) Schoeller diagram of average ion levels at Gull Lake (blue line) compared to 26 lake basins (gray lines) sampled through the LakeWatch program in 2024 (note log10 scale on y-axis of bottom figure).

---

[4] The Earth Observatory. 2013. Whiting Event, Lake Ontario.

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 Gull Lake in 2024 (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 Gull Lake in 2024 was 3.5 m, corresponding to an average Secchi depth of 1.75 m (Table 2). Euphotic depth showed great variation over the season, ranging from as deep as 6.2 m on July 18 to 1.8 m on August 14 (Figure 3).

Generally, lower water clarity levels, as such seen at Gull Lake in 2024, would indicate significant algal growth. However, chlorophyll-*a* levels at Gull Lake are very low (Figure 1). Rather than algal growth impacting the water quality, the low water clarity can be attributed to the presence of a 'whiting event'[4] noted on the August 14 sampling trip. When a whiting event occurs, the water chemistry is altered such that calcium carbonate forms in high abundance, and precipitates out of the water column, giving the change in water colour and clarity. See Photos 1-3 below to see what whiting event looks like on the water, and from space.

[4] The Earth Observatory. 2013. Whiting Event, Lake Ontario.

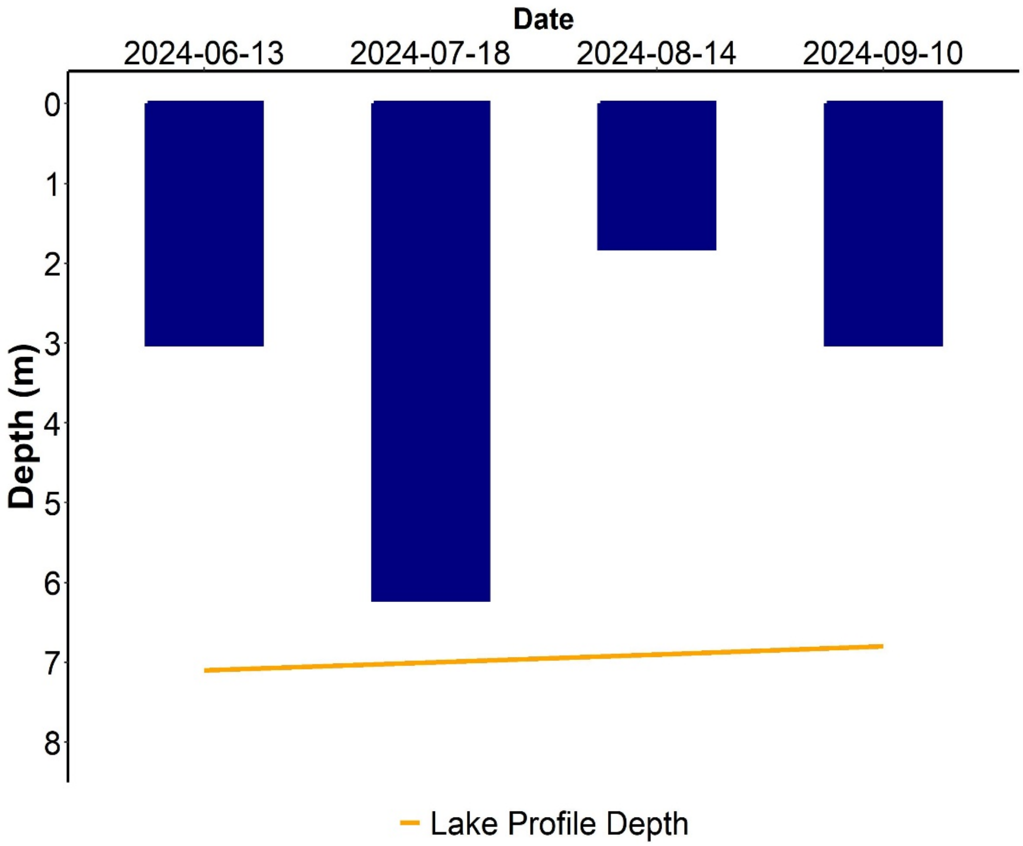


Figure 3. Euphotic depth values measured over the course of the summer at Gull Lake in 2024.

Photo 1: Gull Lake June 13, 2024 sampling trip.

Photo 2: Gull Lake August 14, 2024 sampling trip.

Photo 3: ‘Whiting event’ at Gull Lake (top right) compared to Sylvan Lake (bottom left) on August 29th, 2021. Satellite imagery from the European Space Agency’s Sentinel 2 satellites.

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 Gull Lake varied throughout the summer, with the July 18 sampling trip having the warmest temperatures at 23.35°C (Figure 4). The lake was mixed during all sampling trips.

Gull Lake was well oxygenated in all sampling dates, measuring above the CCME guidelines of 6.5 mg/L dissolved oxygen[5] (Figure 4). Due to the lack of thermal stratification, the lake was able to mix throughout the summer and remained well oxygenated to the bottom of the lake on each sampling event.

---

[5] Canadian Council of Ministers of the Environment. 1999. Canadian water quality guidelines for the protection of aquatic life: Dissolved oxygen (freshwater).

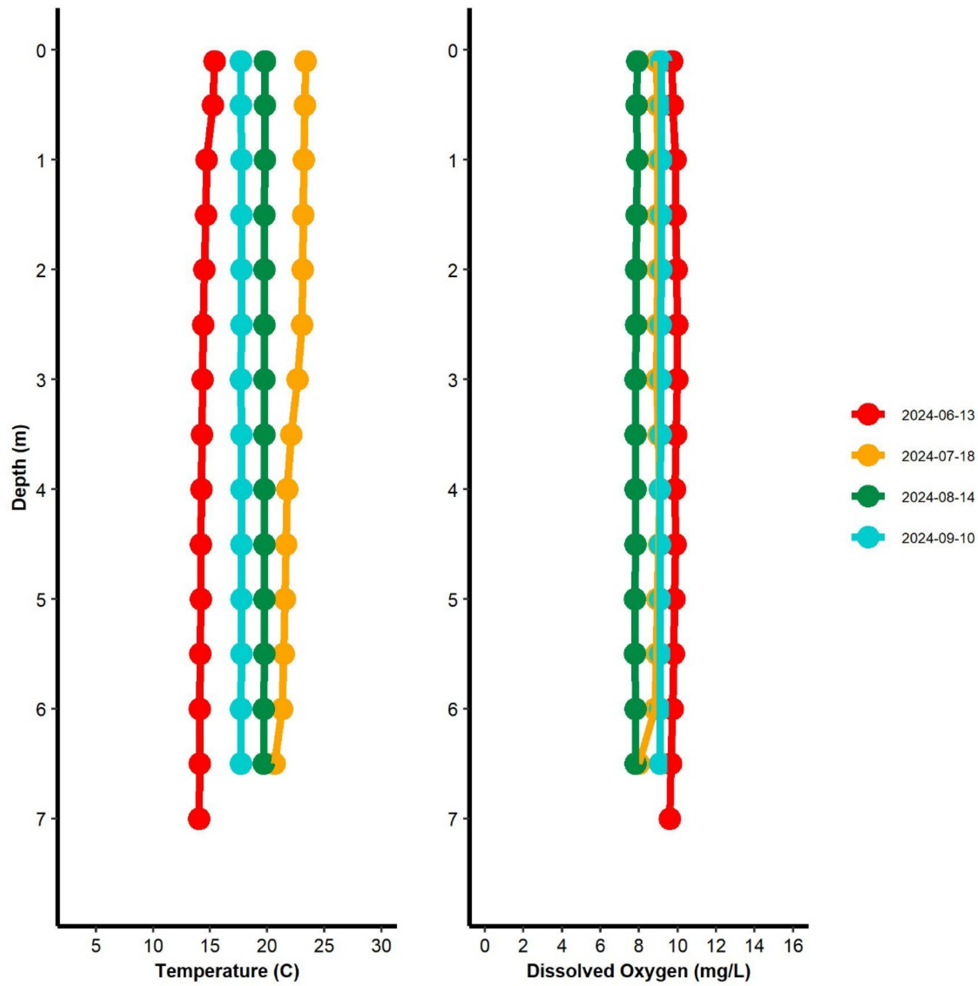


Figure 4. Temperature (°C) and dissolved oxygen (mg/L) profiles for Gull Lake measured over the course of the summer of 2024.

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 Gull Lake fell below the recreational guideline of 10 µg/L[6] during every sampling event in 2024. Despite low levels of microcystin detected during the sampling events, caution should be observed in areas of the lake where significant cyanobacteria accumulation occurs. during every sampling event in 2024.

Table 1. Microcystin concentrations measured four times at Gull Lake in 2024.

Date	Microcystin Concentration (µg/L)
06/13/2024	0.24
07/18/2024	0.14
08/14/2024	0.15
09/10/2024	0.24
Average	**0.19**

[6] Health Canada. 2022. Guidelines for Canadian Recreational Water Quality.

INVASIVE SPECIES

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. This monitoring is designed to detect juvenile Dreissenid mussel veligers and spiny water flea. No mussels or spiny water flea were detected at Gull Lake in 2024.

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.

Watermilfoil was not collected from Gull Lake in 2024.

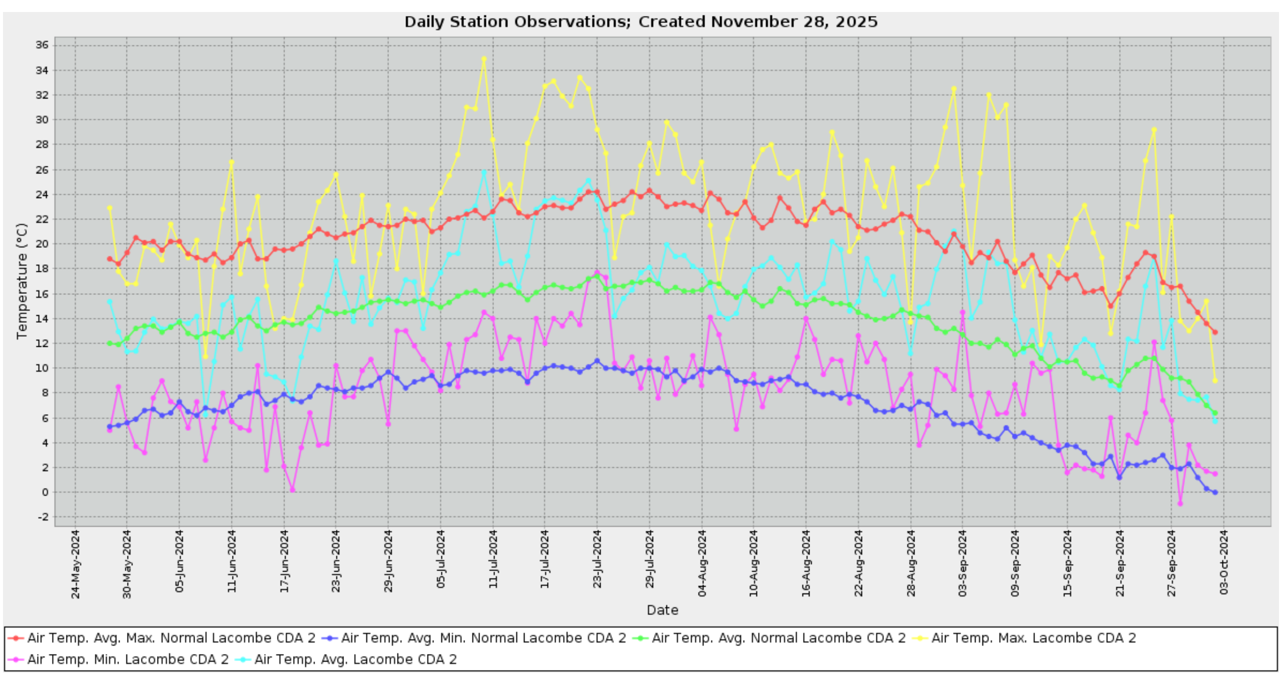
WEATHER AND LAKE STRATIFICATION

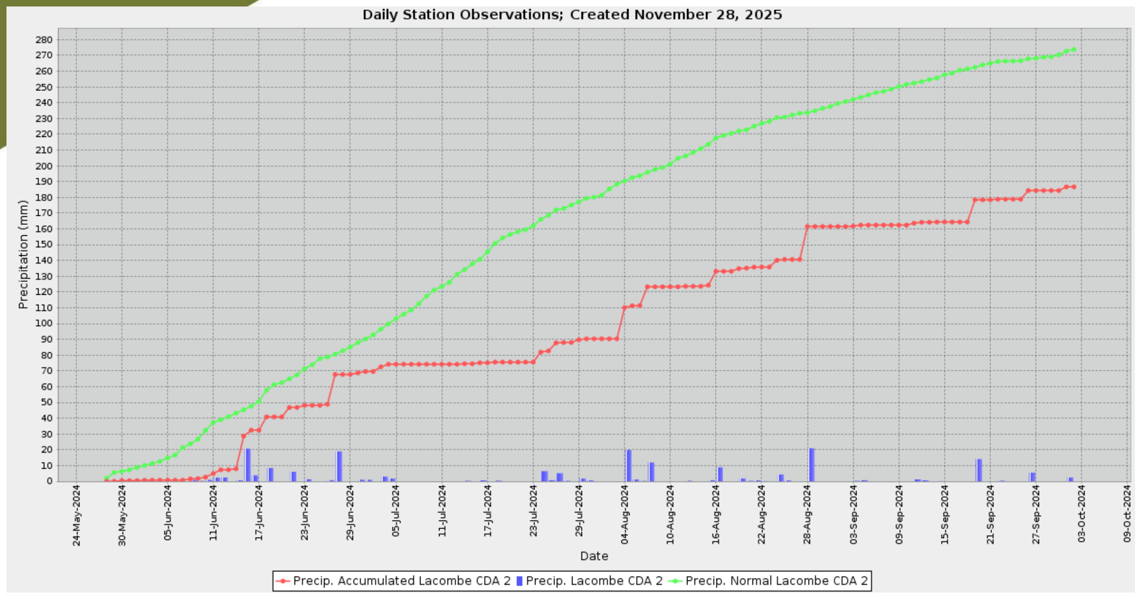
Air temperature will directly impact lake temperatures, and result in different temperature layers (stratification) throughout the lake, depending on its depth. Wind will also impact the degree to which a lake mixes, and how it will stratify. The amount of precipitation that falls within a lake's watershed 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.

In 2024, Gull Lake experienced a warmer and windier summer compared to normal, with substantially less than normal accumulated precipitation (Figure 5). Although it was warmer overall, the beginning of the sampling season was unseasonably cool, with the month of June falling below average temperatures and breaking the lowest temperature record on June 18 at 0.2°C. July was the warmest month, with the average temperature being 19.9°C. 2024 also broke heat records on numerous days in July and September, including the hottest day recorded on July 10 at 34.9°C. August and September were warmer than average months, with the average temperature being 16.8°C and 13.3°C, respectfully.

Gull Lake received much less precipitation than it normally receives throughout the summer months (over 100 mm difference). The actual precipitation in 2024 was 186 mm total, versus a normal amount of 273 mm. Precipitation was sporadic over the summer months (Figure 5).

Strong winds were also observed throughout the sampling season.





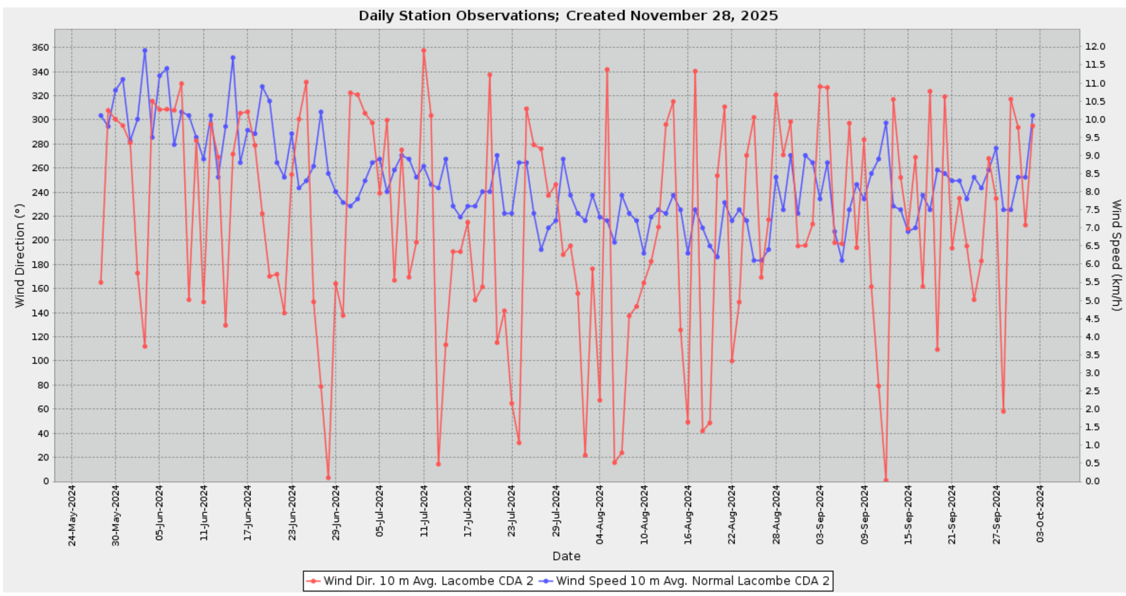


Figure 5. Air temperature (°C), wind speed (km/h), and precipitation (mm) measured from Lacombe CDA 2 weather station east of Gull Lake. Weather data provided by Agriculture, Forestry and Rural Economic Development, Alberta Climate Information Service (ACIS) https://acis.alberta.ca.

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 at Gull Lake have decreased significantly since the beginning of the historical record in 1922 (Figure 6). In 2024, water levels reached their lowest at about 898.2 masl (Figure 7), well below the historical average of 899.3 masl.

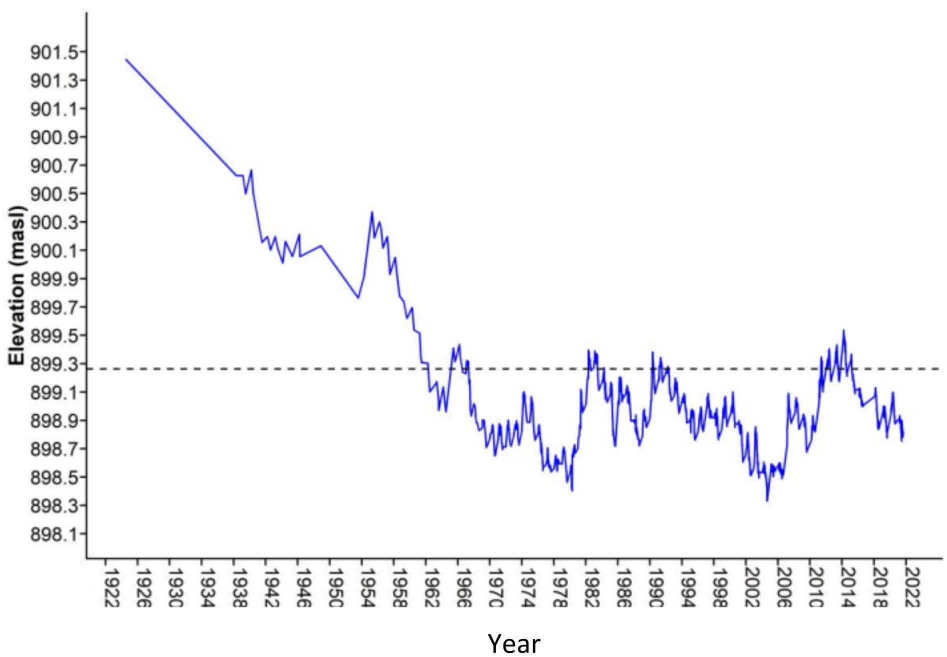


Figure 6. Historical water levels measured at Gull Lake in metres above sea level (masl) from 1922-2022. Obtained from Environment Canada (https://wateroffice.ec.gc.ca/).

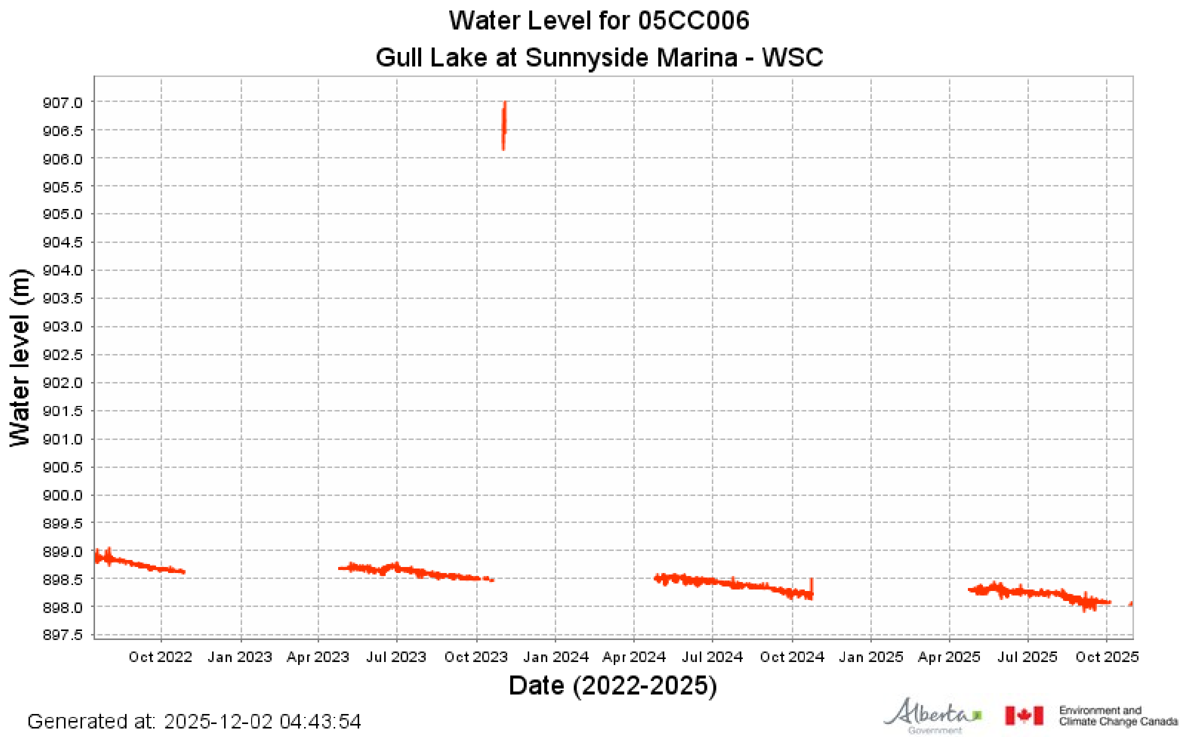


Figure 7. Water levels measured at Gull Lake in metres above sea level (masl) from 2022-2025. Note that the recording in November 2023 is likely an error and should be excluded. Obtained from Alberta Environment and Parks Real-Time Hydrometric Data (https://rivers.alberta.ca/).

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

Parameter	1983	1984	1985	1987	1988	1989	1990	1991	1992	1993
TP (µg/L)	42	41	26	25	55	49	47	46	46	45
TDP (µg/L)	-	-	-	-	-	22	-	-	-	-
Chlorophyll-a (µg/L)	7.4	6.0	4.7	1.0	12.3	9.0	8.4	7.0	9.5	9.0
Secchi depth (m)	2.94	3.12	3.25	6.00	2.35	2.43	2.30	2.83	2.50	2.43
TKN (mg/L)	-	-	2.1	-	-	1.7	-	-	-	-
NO_2-N and NO_3-N (µg/L)	25	25	28	10	9	2	10	2	746	6
NH_3-N (µg/L)	-	-	-	-	-	-	-	-	-	-
DOC (mg/L)	-	-	-	-	-	22	-	-	-	-
Ca^{2+} (mg/L)	9	9	8	9	10	11	12	12	12	12
Mg^{2+}(mg/L)	55	61	66	63	70	67	66	67	66	63
Na^{+} (mg/L)	174	187	201	187	202	199	181	184	190	188
K^{+} (mg/L)	18	18	20	18	17	19	17	17	18	18
SO_4^{2-} (mg/L)	69	64	71	90	77	75	75	72	75	75
Cl^{-} (mg/L)	3	3	4	4	3	4	4	10	4	4
$CO\sim_3^{2-}$ (mg/L)	-	-	-	-	-	-	-	-	-	-
HCO_3^{2-} (mg/L)	-	-	-	-	-	-	-	-	-	-
pH	9.17	9.13	9.07	9.00	9.09	9.06	9.14	9.11	9.11	9.09
Conductivity (µS/cm)	1137	1128	1236	1177	1238	1214	1150	1158	1186	1195
Hardness (mg/L)	251	273	291	281	312	304	298	307	304	290
TDS (mg/L)	694	720	768	746	781	764	726	738	752	746
Microcystin (µg/L)	-	-	-	-	-	-	-	-	-	-
Total Alkalinity (mg/L CaCO3)	609	630	664	626	669	655	620	624	638	642

Parameter	1994	1995	1996	1997	1998	1999	2006	2008	2010	2011
TP (µg/L)	52	47	43	38	45	47	36	47	42	38
TDP (µg/L)	-	21	-	-	18	18	16	17	14	14
Chlorophyll-a (µg/L)	13.4	7.4	6.4	5.8	6.3	8.9	8.5	9.7	7.0	7.8
Secchi depth (m)	1.97	2.42	2.00	1.88	2.27	1.89	1.84	2.00	2.83	2.17
TKN (mg/L)	-	1.4	-	-	1.5	1.5	1.6	1.7	1.7	1.5
NO_2-N and NO_3-N (µg/L)	2	2	-	-	2	5	3	3	8	3
NH_3-N (µg/L)	-	-	-	-	-	-	24	-	-	-
DOC (mg/L)	-	20	-	-	20	-	23	-	20	-
Ca^{2+} (mg/L)	12	11	12	12	10	11	6	10	-	-
Mg^{2+}(mg/L)	66	67	61	65	66	65	74	67	-	-
Na^{+} (mg/L)	195	198	191	199	206	205	228	208	228	-
K^{+} (mg/L)	19	19	19	20	20	20	22	20	22	-
SO_4^{2-} (mg/L)	79	84	79	79	78	83	89	80	95	78
Cl^{-} (mg/L)	4	4	4	4	6	5	7	7	7	7
$CO{\sim}_3^{2-}$ (mg/L)	-	-	85.2	66.1	86.9	83.8	112	99	76	97.7
HCO_3^{2-} (mg/L)	-	-	630	650	626.33	630.2	642.6	616.67	688.5	596.67
pH	9.05	9.08	9.00	8.82	9.00	9.02	9.17	9.07	9.01	9.16
Conductivity (µS/cm)	1203	1213	1242	1190	1250	1188	1320	1273	1298	1240
Hardness (mg/L)	302	304	-	-	-	-	-	-	-	-
TDS (mg/L)	769	779	766	770	786	782	853	795	842	754
Microcystin (µg/L)	-	-	-	-	-	-	0.22	0.24	0.14	0.14
Total Alkalinity (mg/L CaCO3)	655	659	658	643	658	654	713	670	691	652

Parameter	2012	2015	2016	2021	2024
TP (µg/L)	43	26	16	17	21
TDP (µg/L)	17	9	6	7	10
Chlorophyll-a (µg/L)	10.0	8.5	8.8	7.3	6.6
Secchi depth (m)	1.95	1.68	2.00	1.41	1.75
TKN (mg/L)	1.5	1.4	1.5	1.9	1.8
NO_2-N and NO_3-N (µg/L)	2	-	2	8	3
NH_3-N (µg/L)	18	-	25	43	32
DOC (mg/L)	20	21	21	22	24
Ca^{2+} (mg/L)	-	9	8	7	6
Mg^{2+}(mg/L)	-	64	68	76	79
Na^{+} (mg/L)	194	194	210	235	252
K^{+} (mg/L)	21	21	23	26	27
SO_4^{2-} (mg/L)	95	82	65	88	105
Cl^{-} (mg/L)	8	9	9	12	12
$CO\sim_3^{2-}$ (mg/L)	77.6	92.6	101.5	125	150
HCO_3^{2-} (mg/L)	630.4	624	637.5	600	667.5
pH	9.09	9.08	9.16	9.16	9.20
Conductivity (µS/cm)	1227	1280	1300	1400	1525
Hardness (mg/L)	-	-	300	330	340
TDS (mg/L)	775	788	808	878	968
Microcystin (µg/L)	0.21	0.21	0.27	0.16	0.19
Total Alkalinity (mg/L CaCO3)	647	666	695	702	800

Table 3. Concentrations of metals measured in Gull 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	2012	2015	2016	Guidelines
Aluminum (µg/L)	45.2	84	17.3	100[a]
Antimony (µg/L)	0.273	0.3	0.308	/
Arsenic (µg/L)	7.08	7.05	6.31	5
Barium (µg/L)	48.3	35	36.6	/
Beryllium (µg/L)	0.0015	0.004	0.004	100[c,d]
Bismuth (µg/L)	0.0021	5e-04	0.001	/
Boron (µg/L)	161.5	156	155	1500
Cadmium (µg/L)	0.018	0.009	0.005	0.36[b]
Chromium (µg/L)	0.2445	0.205	0.06	/
Cobalt (µg/L)	0.07665	0.0895	0.066	500, 1000[c,d]
Copper (µg/L)	0.881	0.84	0.96	4[b]
Iron (µg/L)	32.6	59.7	28.1	300
Lead (µg/L)	0.105	0.132	0.113	7[b]
Lithium (µg/L)	42.95	42.35	45.5	2500[d]
Manganese (µg/L)	2.54	3.42	2.48	130[e]
Molybdenum (µg/L)	4.065	3.965	3.65	73
Nickel (µg/L)	0.28	0.5	0.428	150[b]
Selenium (µg/L)	0.146	0.03	0.24	1
Silver (µg/L)	0.0034	0.002	0.001	0.25
Strontium (µg/L)	109	65.7	60.4	/
Thallium (µg/L)	8e-04	0.0018	0.0012	0.8
Thorium (µg/L)	0.006	0.01	0.003	/
Tin (µg/L)	0.04	0.01	0.02	/
Titanium (µg/L)	1.415	2.94	1.26	/
Uranium (µg/L)	2.61	2.74	2.59	15
Vanadium (µg/L)	1.49	1.12	1.42	100[c,d]
Zinc (µg/L)	0.99	0.85	2.9	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 guidelines.

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 Gull Lake. In sum, a decreasing trend was detected in TP and Secchi depth, while an increasing trend was detected in TDS. No significant trend was detected in chlorophyll-*a*. 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 Gull Lake data from 1983 to 2024.

Parameter	Date Range	Direction of Significant Change
Total Phosphorus	1983-2024	Decreasing
Chlorophyll-*a*	1983-2024	No Change
Total Dissolved Solids	1983-2024	Increasing
Secchi Depth	1983-2024	Decreasing

Definitions

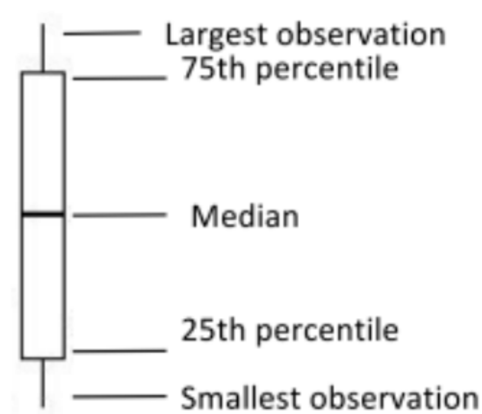
Median: the value in a range of ordered numbers that falls in the middle.

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 it has significantly decreased in Gull Lake since 1983 (Tau = -0.504, $p < 0.001$).

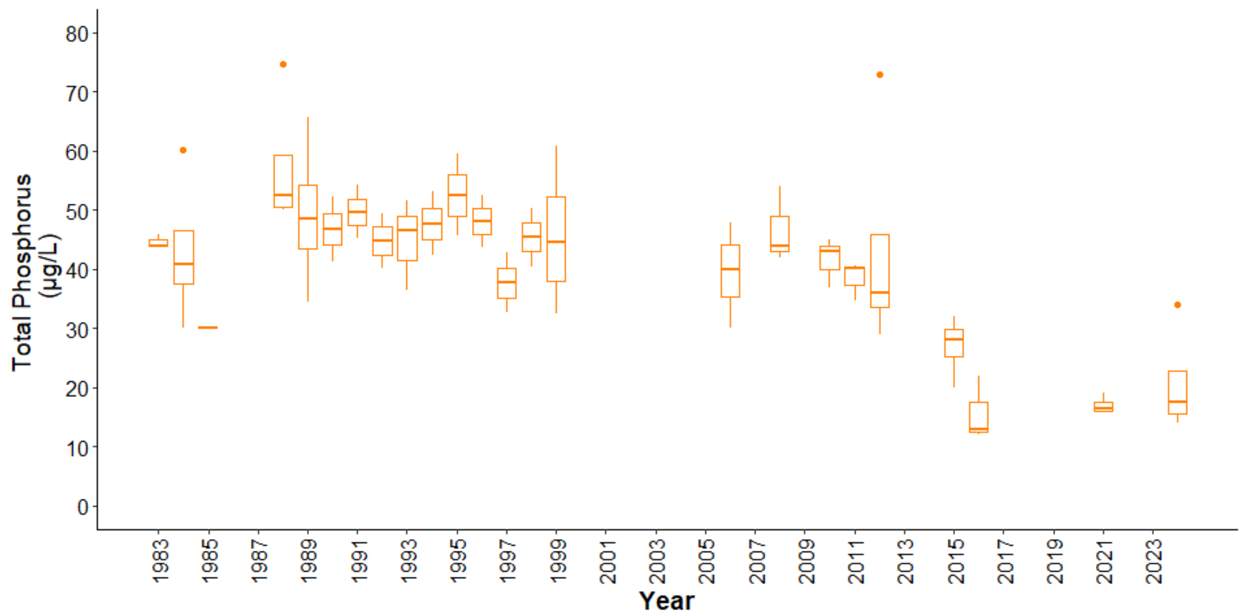


Figure 8. Monthly total phosphorus (TP) concentrations measured between June and September over the long term sampling dates between 1983 and 2024 (n = 71). The value closest to the 15^{th} day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Chlorophyll-*a*

Trend analysis of chlorophyll-*a* showed no significant change at Gull Lake from 1983-2024 (Tau = -0.0717, p = 0.3270).

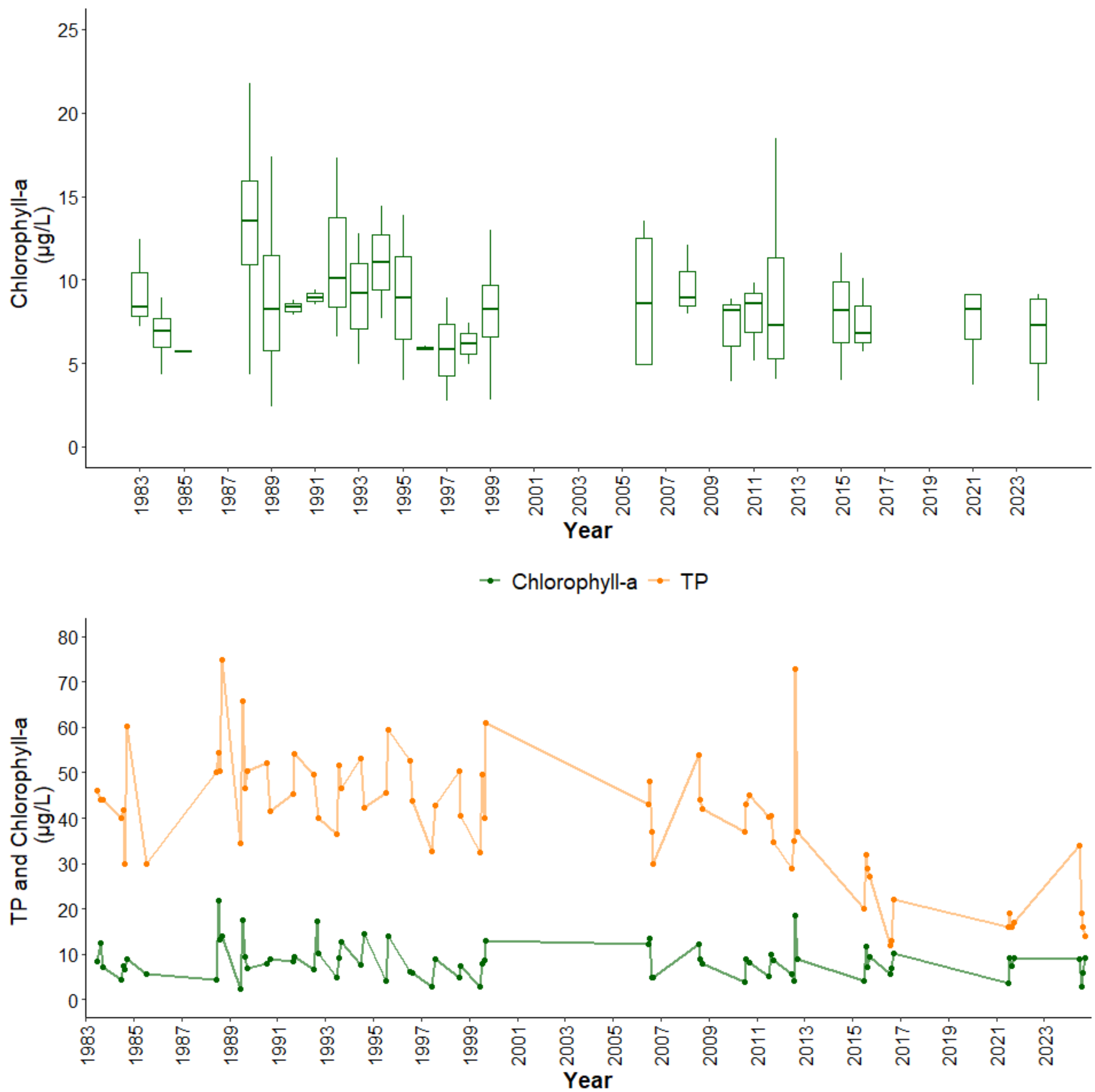
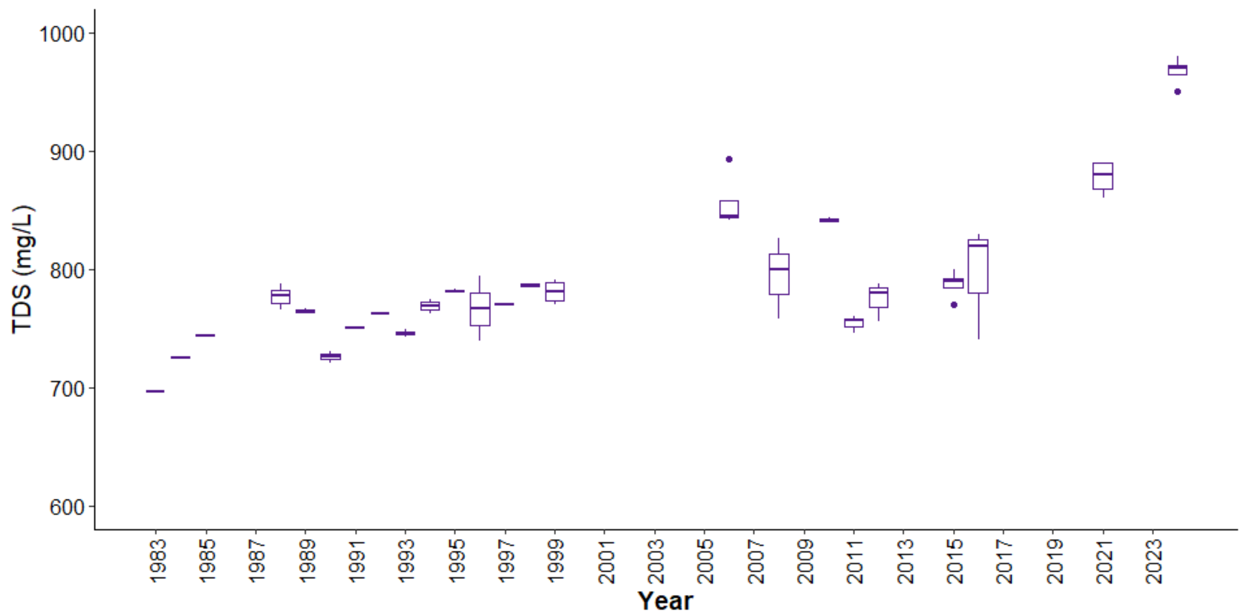


Figure 9. Monthly chlorophyll-*a* concentrations measured between June and September over the long term sampling dates between 1983 and 2024 (n = 72). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

Total Dissolved Solids (TDS)

Trend analysis of TDS showed a significantly increasing trend in TDS in Gull Lake since 1983 (Tau = 0.5504, $p < 0.001$).



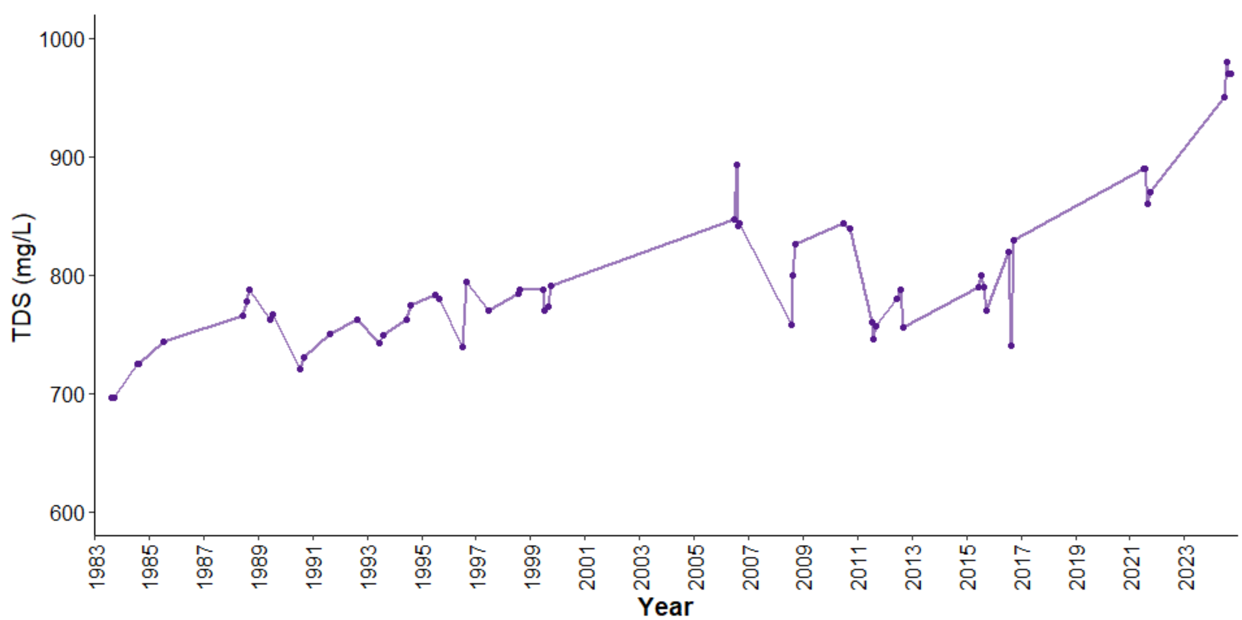


Figure 10. Monthly TDS values measured between June and September over the long term sampling dates between 1983 and 2024 (n = 59). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Trend analysis of major ions at Gull Lake indicates that all ions with the exception of calcium are significantly increasing (Figure 11). Precipitation of calcium from the water column may be occurring as pH increases at Gull Lake. As many ions are moving in the same direction, it is likely that evaporative loss is driving the change in total dissolved solids in Gull Lake.

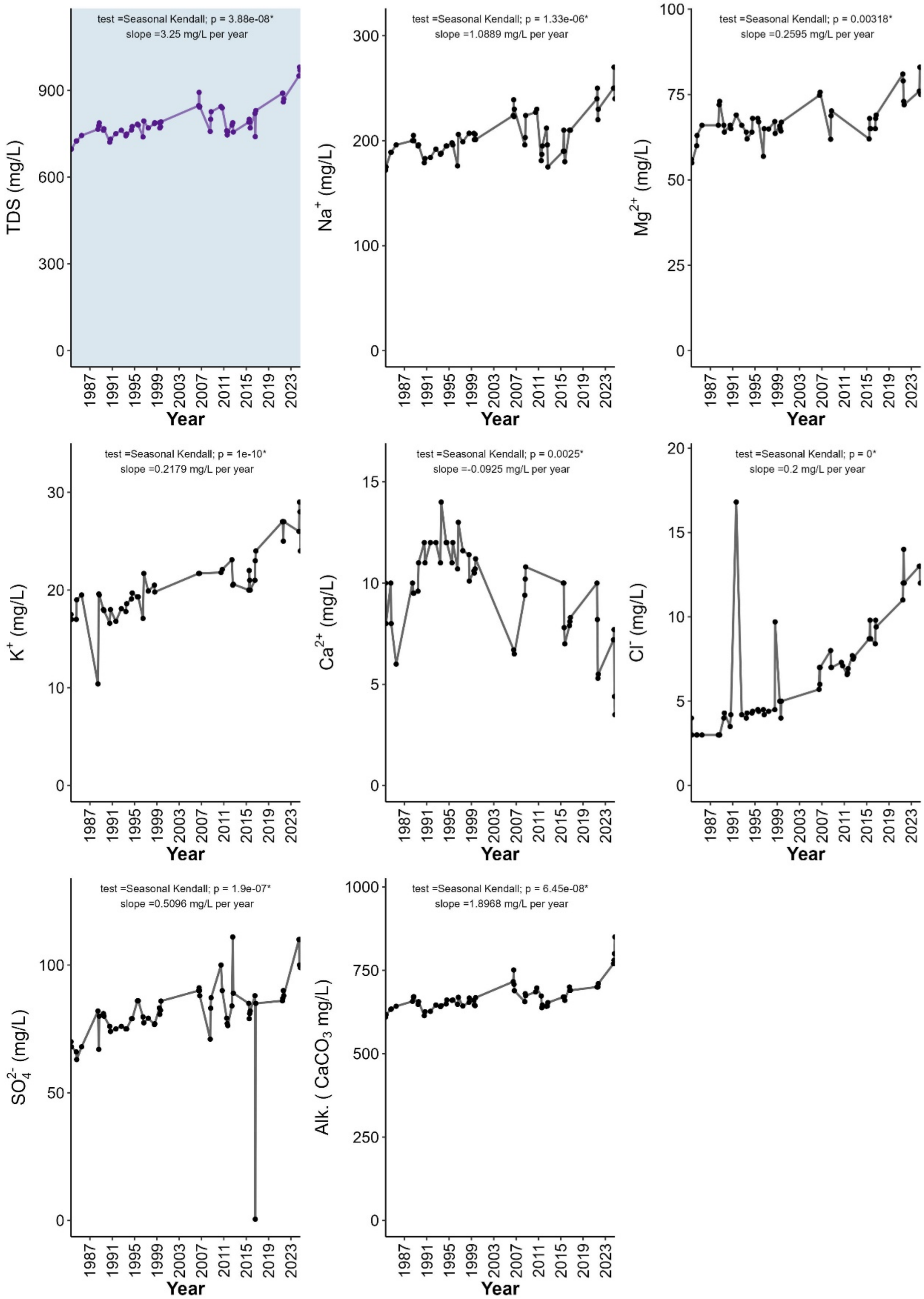
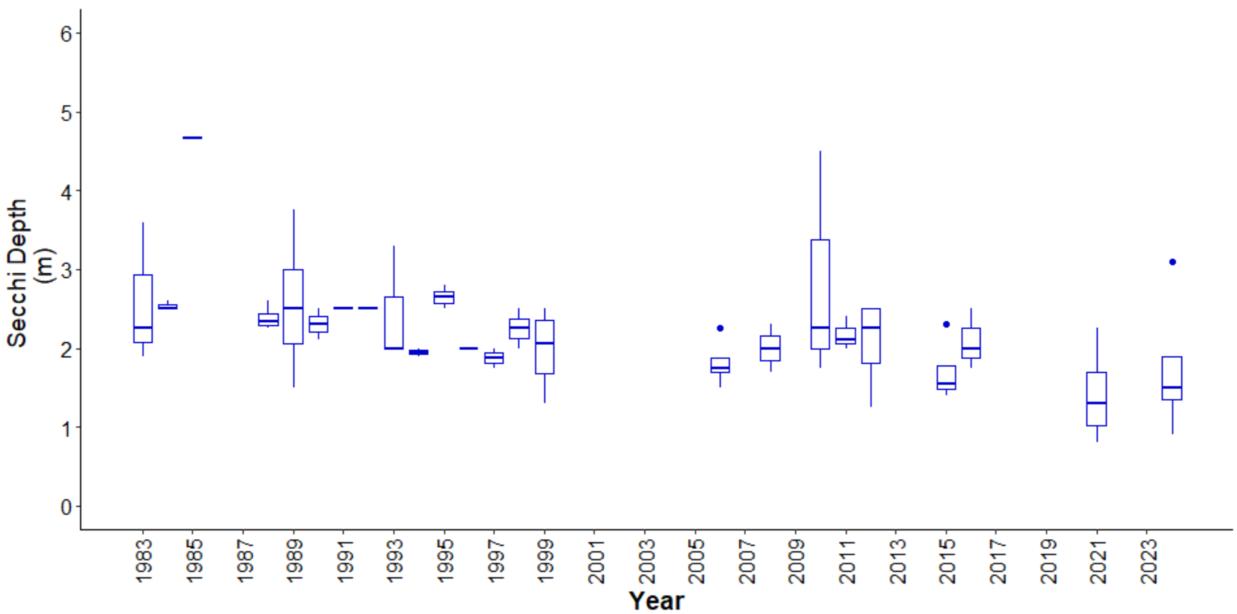


Figure 11. Concentrations of TDS (top left, blue panel), major ions (sodium = Na^+, magnesium = Mg^{2+}, potassium = K^+, calcium = Ca^{2+}, chloride = Cl^-, sulphate = SO_4^{2-}), and total alkalinity (Alk., as mg/L $CaCO_3$) measured monthly between June and September on sampling dates between 1983 and 2024. 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

Trend analysis of Secchi depth over time showed that it has significantly decreased (the lake has become less clear) in Gull Lake since 1983 (Tau = -0.3958, $p < 0.001$).



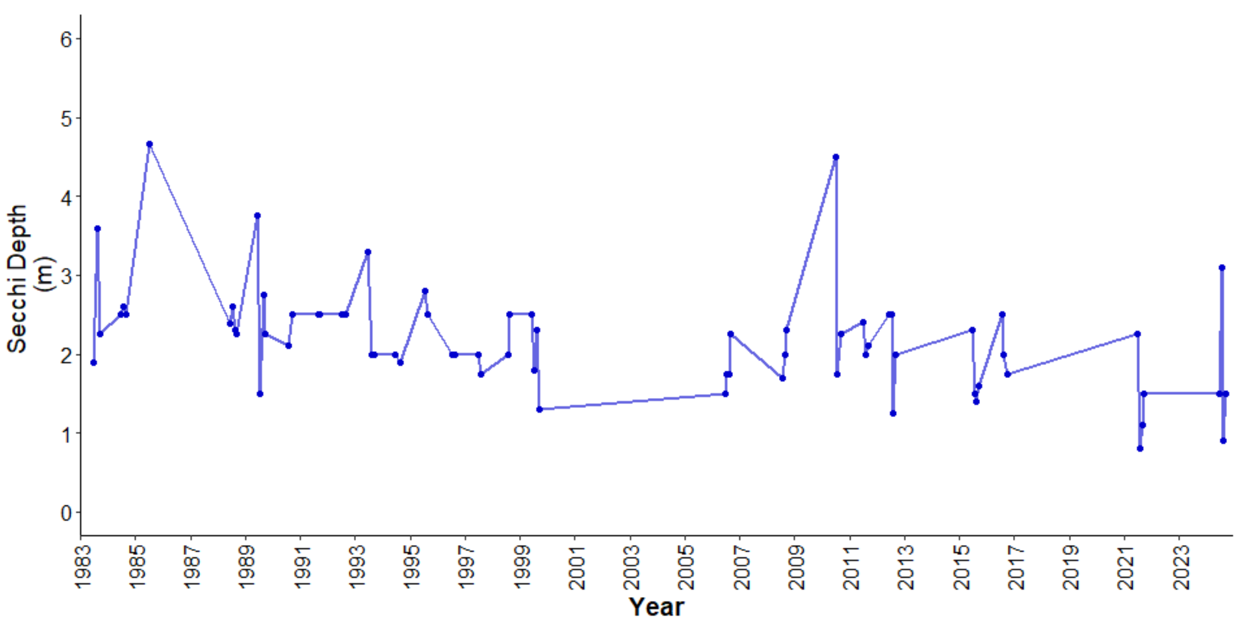


Figure 12. Monthly Secchi depth values measured between June and September over the long term sampling dates between 1983 and 2024 (n = 70). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

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 1983-2024 on Gull 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	-0.504	-0.0717	0.5504	-0.3958
The extent of the trend	Slope (units per Year)	-0.75	-0.0284	3.25	-0.025
The statistic used to find significance of the trend	Z	-5.7326	-0.9802	5.4964	-4.6754
Number of samples included	n	71	72	59	70
The significance of the trend	*p*	< 0.001*	0.3270	< 0.001*	< 0.001*

*$p < 0.05$ is significant within 95%