



# Lakewatch

The Alberta Lake Management Society  
Volunteer Lake Monitoring Program

## Pigeon Lake Report

### 2024

Updated November 27, 2025

Lakewatch is made possible  
with support from:



# 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 Daren Lorentz for their commitment to collecting data at Pigeon 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 Onsyk were instrumental in planning and organizing the field program. This report was prepared by Brittany Onsyk and Bradley Peter.

BEFORE READING THIS REPORT,  
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INTRODUCTION TO LIMNOLOGY](#)

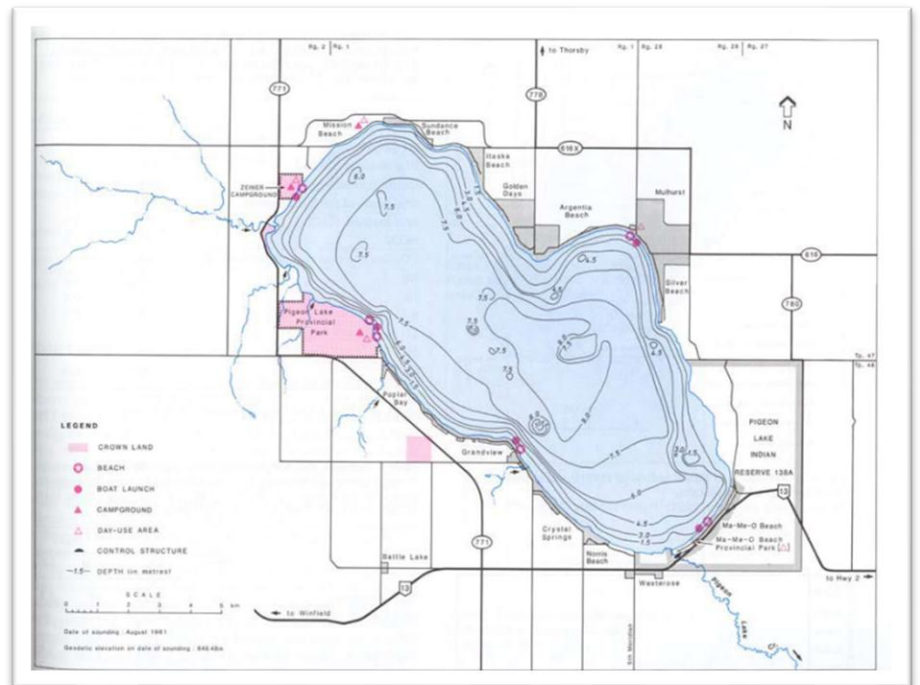
## PIGEON LAKE

Pigeon Lake is a very popular recreational lake located within the counties of Wetaskiwin and Leduc, and within easy driving distance from the City of Edmonton. Pigeon Lake lies within the Battle River watershed, a subbasin of the North Saskatchewan River watershed.<sup>1</sup>

Pigeon Lake is large and shallow, with a surface area of nearly 100 km<sup>2</sup> and an average depth of 6 m. The maximum depth is 9 m. At about 180 km<sup>2</sup>, the watershed is considered quite small compared to the lake, resulting in a watershed to lake ratio of 2:1. The watershed is highly developed by human footprint, with agriculture composing about 75% of the watershed.<sup>2</sup> Surrounding the lake, there are 10 summer villages, two provincial parks, and the Maskwacis Cree reserve on the southeastern shore, which includes the Samson Cree Nation, Ermineskin Cree Nation, Louis Bull Tribe, and Montana First Nation.<sup>3</sup>

Water flows into the lake through intermittent streams from the west and northwest portions of the watershed.<sup>4</sup> The outlet, Pigeon Lake Creek, flows from the southeast end of the lake and drains southeast to the Battle River.<sup>4</sup> In 1914, a wooden weir was installed at the outlet of the lake, and has a sill elevation of 850 masl.<sup>4</sup> Over time, the weir has been rebuilt, but it's sill level remained around at about 850 masl.

The water quality of Pigeon Lake is typical of a large, shallow, productive prairie lake in Alberta, with lake water mixing over the open water season, and remaining quite green through the summer. However, algal blooms were once considered rare on the lake, although concentrations of nutrients (phosphorus and chlorophyll-*a*) have been steady since the lake has been monitored (Table 2).<sup>4</sup>

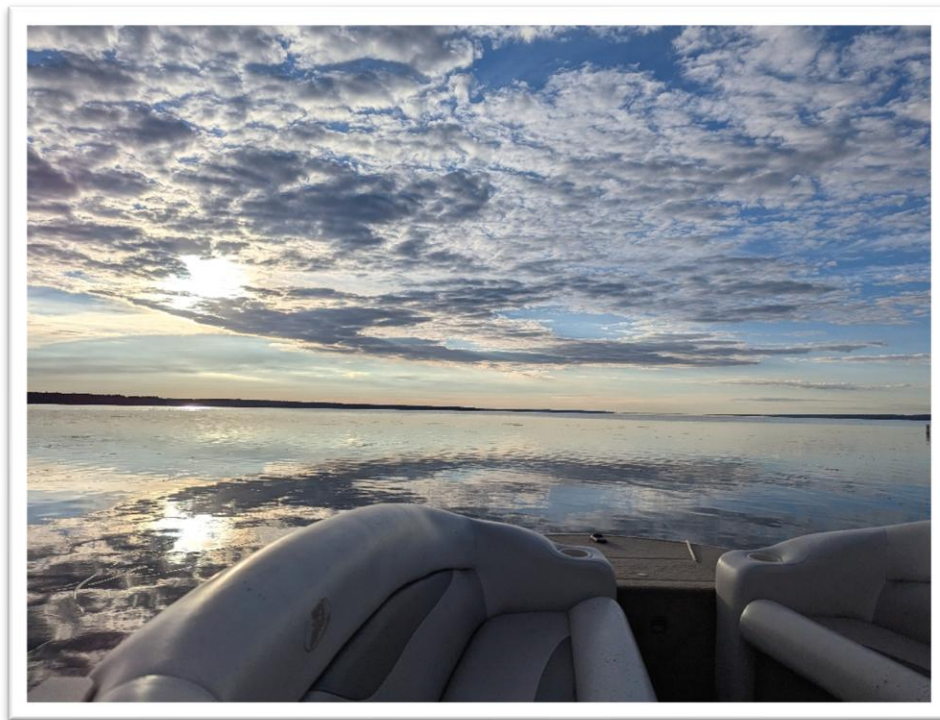


Bathymetric map of Pigeon Lake obtained from the Atlas of Alberta Lakes.

Since the early 2000s, residents have raised concerns regarding perceptions of deteriorating water quality due to recurring planktonic algae and cyanobacteria blooms, fish kills, and beach advisories.<sup>5</sup> Due to these concerns, there has been a drive to examine ways to reduce the frequency and intensity of cyanobacteria blooms.

In 2014, the [Pigeon Lake Phosphorus Budget](#) was released, outlining areas of interest when considering watershed and in-lake management options. The report also highlighted the importance of reducing external phosphorus loads to the lake.<sup>6</sup>

In 2018, the Pigeon Lake Watershed Association released their [Pigeon Lake Watershed Management Plan](#) with strategies to coordinate action for the protection and improvement of Pigeon Lake, its shore, and its watershed.<sup>3</sup>



Early morning sampling at Pigeon Lake on September 17, 2024.

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<sup>1</sup> Battle River Watershed Alliance. 2025. Our Watersheds.

<sup>2</sup> Battle River Watershed Alliance. 2025. Land Use Practices.

<sup>3</sup> Pigeon Lake Watershed Management Plan Steering Committee. 2018. Pigeon Lake Watershed Management Plan 2018.

<sup>4</sup> Mitchell, P. and Prepas, E. 1990. Atlas of Alberta Lakes.

<sup>5</sup> Aquality Environmental Consulting. 2008. Pigeon Lake State of the Watershed Report.

<sup>6</sup> Government of Alberta. 2014. Pigeon Lake Phosphorus Budget.



## 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 Pigeon Lake was 45 µg/L (Table 2), falling into the eutrophic, or highly productivity trophic classification. TP ranged from a minimum of 15 µg/L on June 21 and peaked at 95 µg/L on August 16 (Figure 1). A phosphorus budget conducted at Pigeon Lake suggests that the lake has a high internal total phosphorus load (about 50%), suggesting phosphorus released from the sediments is a significant contributor to summer phosphorus levels.<sup>6</sup>

Average chlorophyll-*a* concentration in 2024 was 19.9 µg/L (Table 2), similarly falling into the eutrophic classification. Chlorophyll-*a* was lowest at 4.1 µg/L on June 21 and peaked at 44.5 µg/L on August 16 (Figure 1).

The average Total Kjeldahl Nitrogen (TKN) concentration was 0.8 mg/L (Table 2) and displayed consistent levels throughout the season (Figure 1).

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<sup>6</sup> Government of Alberta. 2014. Pigeon Lake Phosphorus Budget.

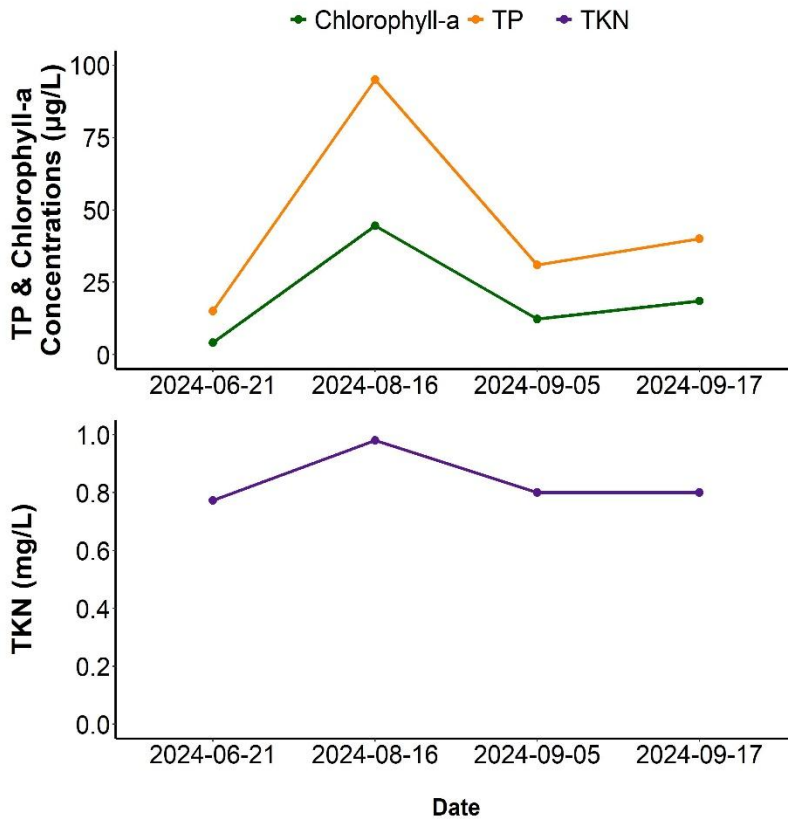


Figure 1. Total Phosphorus, Chlorophyll- $\alpha$ , and Total Kjeldahl Nitrogen concentrations measured over the course of the summer at Pigeon Lake in 2024.

Average pH was measured as 8.48 in 2024, buffered by moderate alkalinity (182 mg/L CaCO<sub>3</sub>) and bicarbonate (202 mg/L HCO<sub>3</sub>). Aside from bicarbonate, calcium and sodium were highest in abundance and contributed to an average conductivity of 322 μS/cm (Figure 2, top; Table 2). Pigeon Lake is in the mid-range of ion levels compared to other LakeWatch lakes sampled in 2024 (Figure 2, bottom).

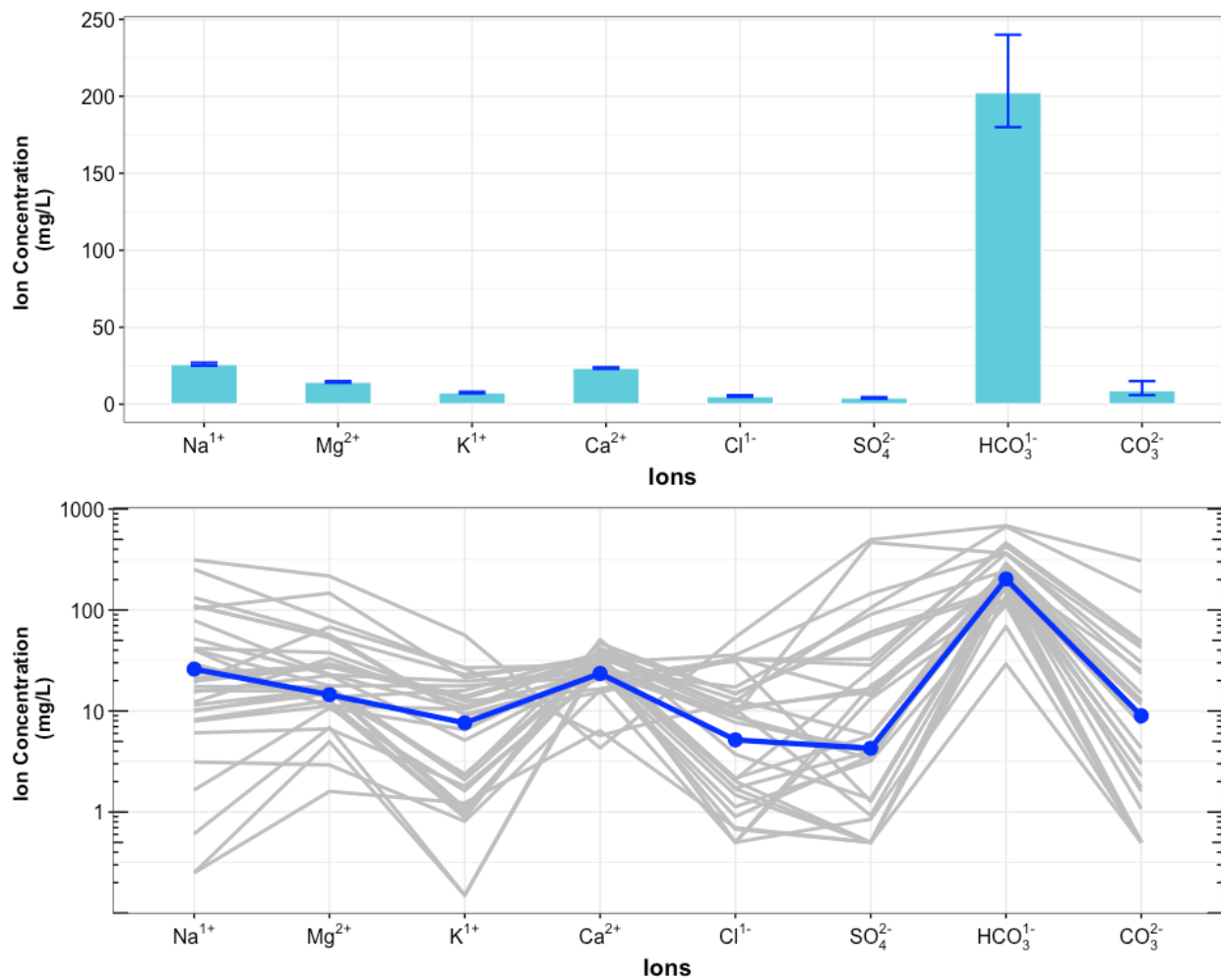


Figure 2. Average levels of cations (sodium = Na<sup>1+</sup>, magnesium = Mg<sup>2+</sup>, potassium = K<sup>1+</sup>, calcium = Ca<sup>2+</sup>) and anions (chloride = Cl<sup>1-</sup>, sulphate = SO<sub>4</sub><sup>2-</sup>, bicarbonate = HCO<sub>3</sub><sup>1-</sup>, carbonate = CO<sub>3</sub><sup>2-</sup>) from 4 measurements over the course of the summer at Pigeon Lake. Top) bars indicate range of values measured, and bottom) Schoeller diagram of average ion levels at Pigeon Lake (blue line) compared to 26 lake basins (gray lines) sampled through the LakeWatch program in 2024 (note log<sub>10</sub> 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 Pigeon Lake in 2024. Historical metal data can be found 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 Pigeon Lake in 2024 was 4.5 m, corresponding to an average Secchi depth of 2.25 m (Table 2). Euphotic depth varied over the season, ranging from as deep as 6.6 m on June 21 to as shallow as 2.6 m on August 16 (Figure 3).

The decrease in euphotic depth on August 16 lines up with the increased concentrations of TP and chlorophyll-*a* on the same day (Figure 1), indicating that an algal bloom was likely occurring and resulted in a reduction in water clarity.

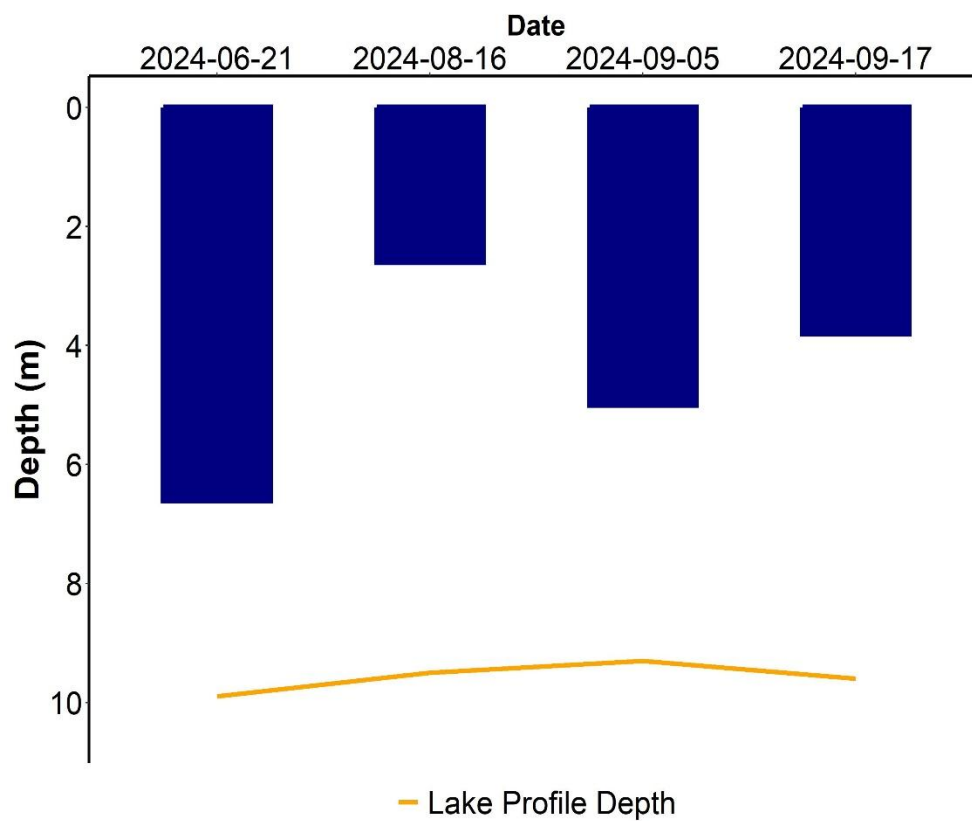


Figure 3. Euphotic depth values measured over the course of the summer at Pigeon Lake in 2024.



## 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 water temperatures at Pigeon Lake varied throughout the summer, with the August 16 sampling event having the warmest temperature of 19.88°C (Figure 4). The lake was completely mixed during each sampling event, with consistent temperatures throughout the water column on each sampling date.

Pigeon Lake was well oxygenated in the surface waters on all sampling dates, measuring above the CCME guidelines of 6.5 mg/L dissolved oxygen<sup>7</sup> (Figure 4). Due to the lack of thermal stratification, the lake was able to mix throughout the summer and remained well oxygenated throughout the water column on each sampling event, dropping slightly during the September sampling events. Dissolved oxygen dropped to near 0 mg/L at the bottom sediments at 9 m on September 5.

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<sup>7</sup> Canadian Council of Ministers of the Environment. 1999. Canadian water quality guidelines for the protection of aquatic life: Dissolved oxygen (freshwater).

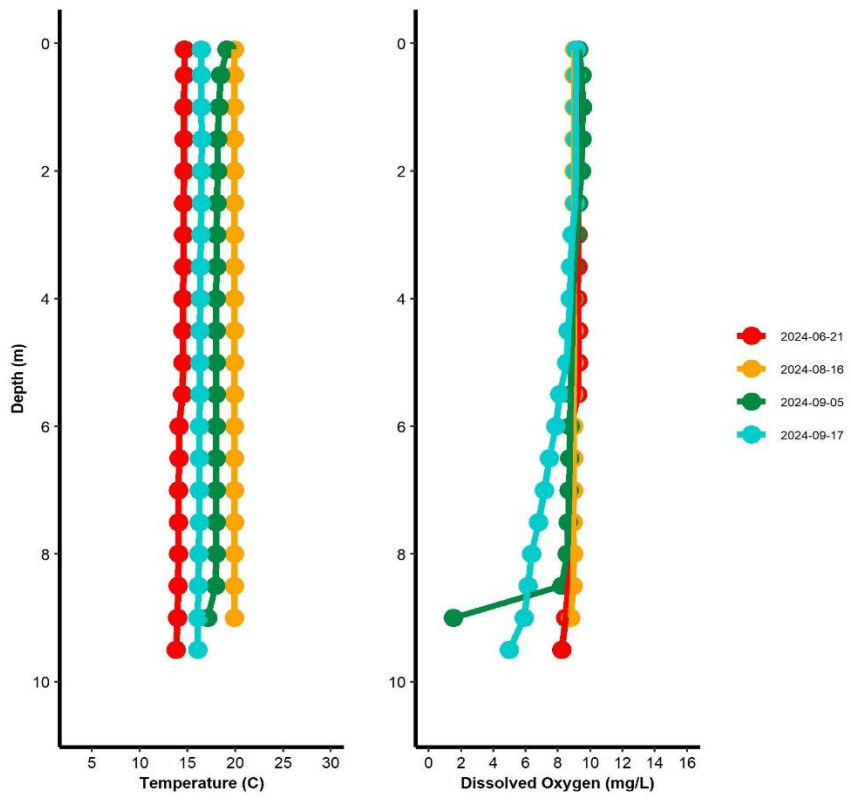


Figure 4. Temperature (°C) and dissolved oxygen (mg/L) profiles for Pigeon Lake measured over the course of the summer of 2024.



## 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 Pigeon Lake fell below the recreational guideline of 10 µg/L<sup>8</sup> 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.

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

Date	Microcystin Concentration (µg/L)
06/21/2024	< 0.1
08/16/2024	0.66
09/05/2024	0.24
09/17/2024	0.61
<b>Average</b>	<b>0.39</b>

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<sup>8</sup> 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 Pigeon 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 collected from Pigeon Lake on August 16. The specimen was confirmed to be Northern Watermilfoil (*Myriophyllum sibiricum*).

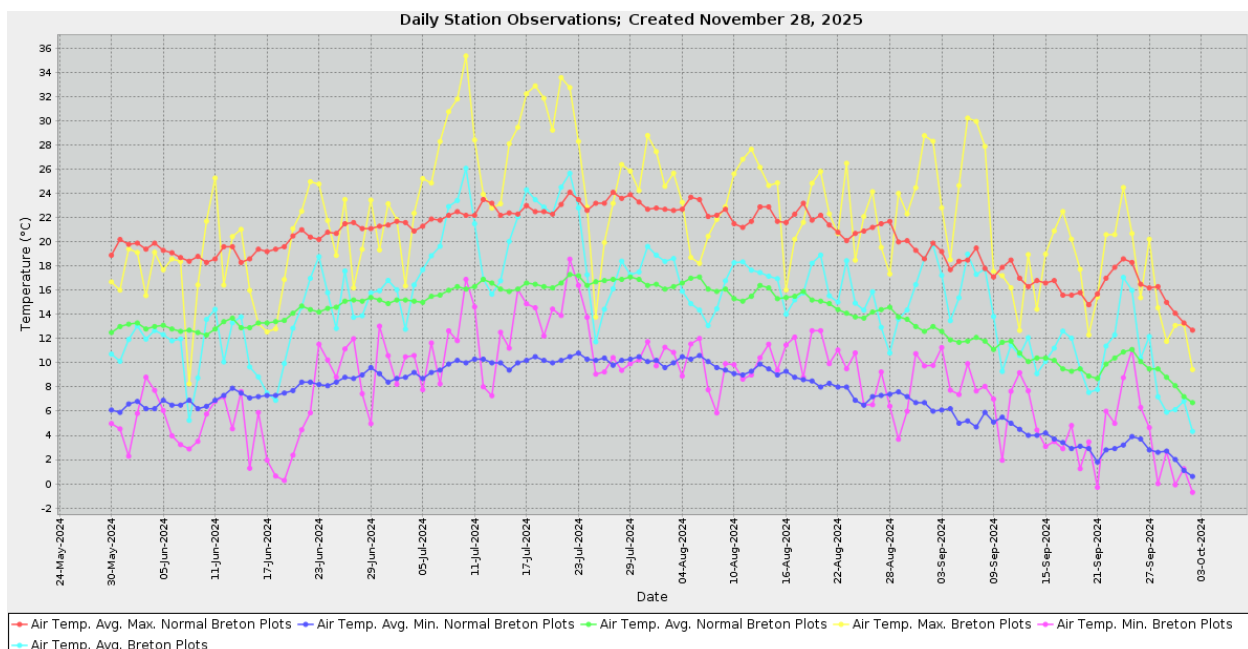
## WEATHER AND LAKE STRATIFICATION

*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, Pigeon Lake experienced a warmer and windier summer compared to normal, with 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 lowest temperature records on numerous days, including the coldest temperature recorded on June 19 at 0.2°C. July was the warmest month, with the average temperature being 19.4°C. 2024 also broke heat records on numerous days in July and September, including the hottest day recorded on July 10 at 35.4°C. September was also a warmer than average month, with the average temperature being 12.5°C.

Pigeon Lake received less than normal precipitation in the summer of 2024 (230 mm vs 320 mm). Precipitation fell periodically over the summer months. Little precipitation fell during the month of September (Figure 5).

Strong winds were also observed throughout the sampling season.



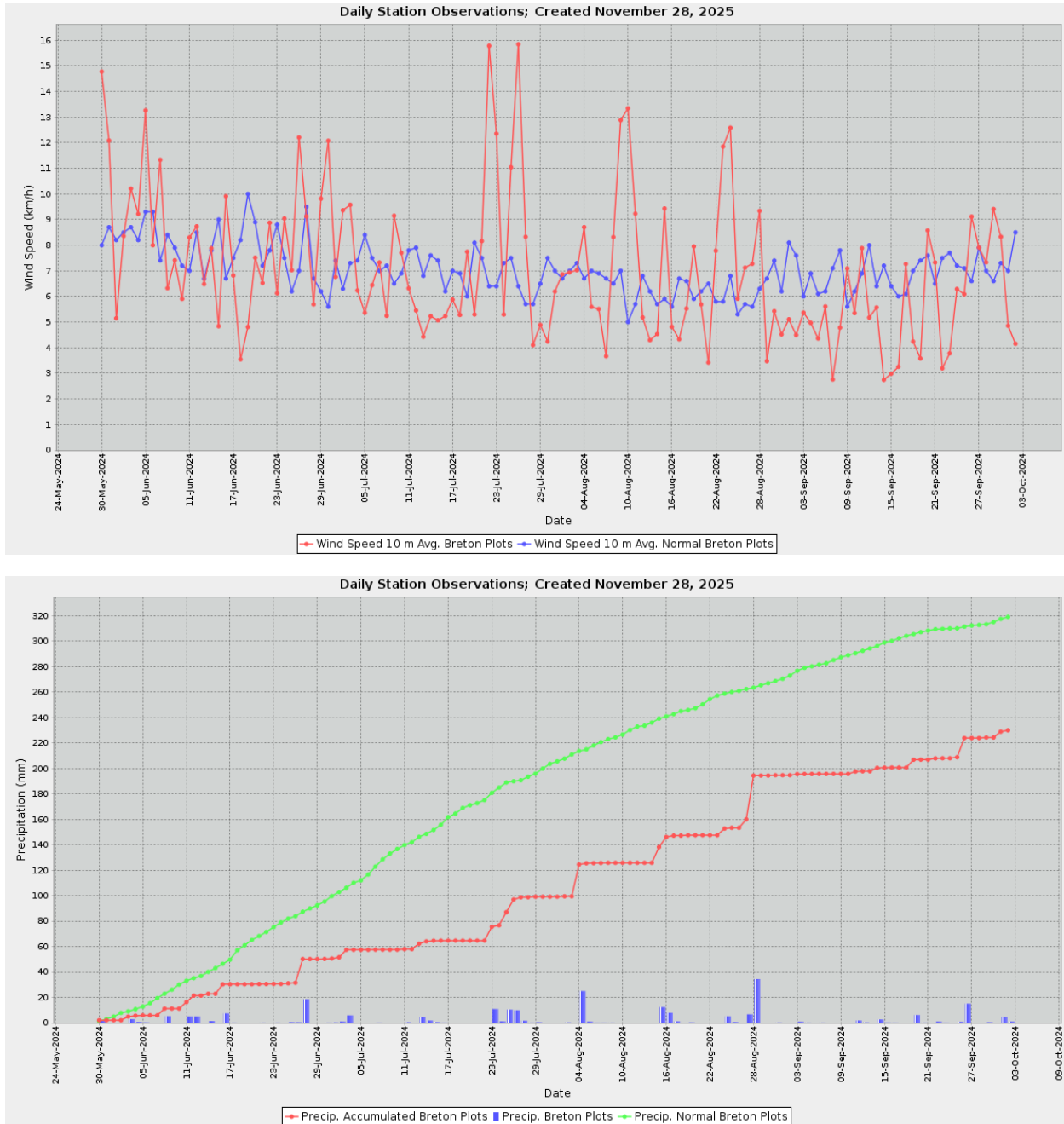


Figure 5. Air temperature (°C), wind speed (km/h), and precipitation (mm) measured from Breton Plots weather station northwest of Pigeon Lake. Weather data provided by Agriculture, Forestry and Rural Economic Development, Alberta Climate Information Service (ACIS) <https://acis.alberta.ca>.

## 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.*

As mentioned, water levels at Pigeon Lake are controlled by a weir on the southeast end of the lake.<sup>4</sup> Its sill level has sat around 850 masl. Water levels at Pigeon Lake in 2024 were slightly below the historical average (849.9 masl; Figure 6, Figure 7). Historical data indicates that since the beginning of the record in 1972, lake levels have experienced a very slight downward trajectory. Despite this downward trend, there has been considerable variability over the 50 year record.

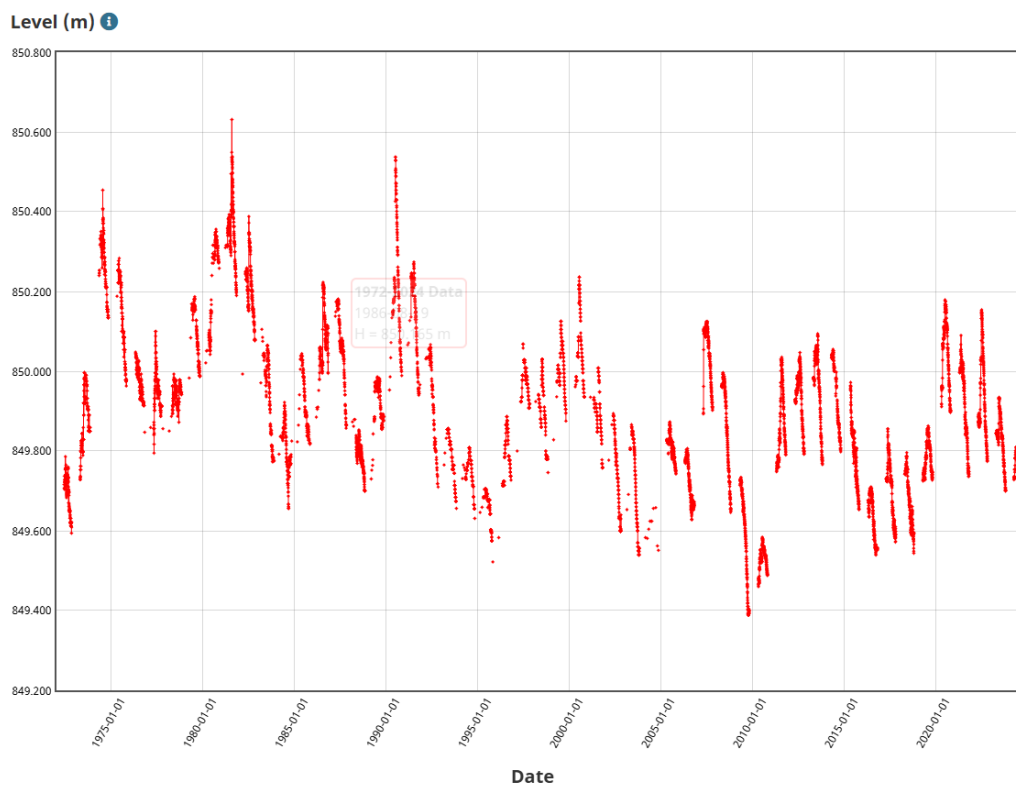


Figure 6. Historical water levels measured at Pigeon Lake in metres above sea level (masl) from 1972-2024. Obtained from <https://wateroffice.ec.gc.ca/report/>.

<sup>4</sup> Mitchell, P. and Prepas, E. 1990. Atlas of Alberta Lakes.

Water Level for 05FA013  
Pigeon Lake at Pigeon Lake Provincial Park - WSC



Generated at: 2025-11-19 05:08:33



Figure 7. Water levels measured at Pigeon Lake in metres above sea level (masl) from 2022-2025. Obtained from Environment and Climate Change Canada.

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

Parameter	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
TP ( $\mu\text{g/L}$ )	26	32	22	29	29	43	29	26	34	38	35
TDP ( $\mu\text{g/L}$ )	11	-	-	-	-	-	-	-	-	-	-
Chlorophyll-a ( $\mu\text{g/L}$ )	9.9	12.3	13.8	16.1	9.8	25.7	9.2	11.9	17.4	18.6	16.1
Secchi depth (m)	3.19	1.94	2.19	3.08	2.25	1.63	2.35	2.32	2.14	1.72	1.98
TKN (mg/L)	0.9	-	0.6	-	-	-	-	-	-	-	-
NO <sub>2</sub> -N and NO <sub>3</sub> -N ( $\mu\text{g/L}$ )	21	25	44	25	10	12	6	13	2	8	2
NH <sub>3</sub> -N ( $\mu\text{g/L}$ )	-	-	-	-	-	-	-	-	-	-	-
DOC (mg/L)	-	-	-	-	-	-	-	-	-	-	-
Ca <sup>2+</sup> (mg/L)	29	25	28	26	28	24	30	29	29	26	26
Mg <sup>2+</sup> (mg/L)	10	10	11	11	10	12	11	12	12	11	11
Na <sup>+</sup> (mg/L)	15	15	16	15	15	17	16	14	14	17	17
K <sup>+</sup> (mg/L)	6	5	5	5	5	5	5	5	5	5	5
SO <sub>4</sub> <sup>2-</sup> (mg/L)	4	3	2	2	2	3	6	4	5	4	3
Cl <sup>-</sup> (mg/L)	1	0	1	0	2	1	2	1	1	2	2
CO <sub>3</sub> <sup>2-</sup> (mg/L)	-	-	-	-	-	-	-	-	-	-	-
HCO <sub>3</sub> <sup>2-</sup> (mg/L)	-	-	-	-	-	-	-	-	-	-	-
pH	8.37	8.43	8.35	8.57	8.50	8.36	8.32	8.50	8.46	8.45	8.56
Conductivity ( $\mu\text{S/cm}$ )	283	288	292	280	293	279	302	294	293	286	287
Hardness (mg/L)	112	103	113	110	111	109	120	122	121	111	113
TDS (mg/L)	157	154	158	151	157	151	163	158	156	152	154
Microcystin ( $\mu\text{g/L}$ )	-	-	-	-	-	-	-	-	-	-	-
Total Alkalinity (mg/L CaCO <sub>3</sub> )	152	153	153	147	154	145	156	153	150	146	148

<b>Parameter</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>2003</b>	<b>2005</b>	<b>2006</b>	<b>2008</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>
TP (µg/L)	32	29	38	30	63	28	60	26	41	75	28
TDP (µg/L)	-	9	-	-	10	6	38	8	13	19	7
Chlorophyll-a (µg/L)	21.4	13.6	18.5	12.8	36.8	9.2	21.9	9.2	21.9	66.2	24.0
Secchi depth (m)	1.83	2.40	1.80	2.50	1.38	2.43	2.70	4.42	2.75	1.25	3.15
TKN (mg/L)	-	0.8	-	-	1.1	0.7	1.1	0.7	1	1.5	0.9
NO <sub>2</sub> -N and NO <sub>3</sub> -N (µg/L)	9	5	-	-	10	3	29	13	8	16	4
NH <sub>3</sub> -N (µg/L)	-	-	-	-	14	-	124	-	-	-	-
DOC (mg/L)	-	7	-	-	-	-	7	-	7	-	-
Ca <sup>2+</sup> (mg/L)	26	24	22	31	-	30	24	27	-	-	-
Mg <sup>2+</sup> (mg/L)	12	12	12	13	-	13	14	13	-	-	-
Na <sup>+</sup> (mg/L)	17	18	15	19	19	20	21	20	22	-	-
K <sup>+</sup> (mg/L)	5	5	4	6	6	6	7	6	6	-	-
SO <sub>4</sub> <sup>2-</sup> (mg/L)	3	6	5	6	5	8	10	5	9	3	6
Cl <sup>-</sup> (mg/L)	2	2	2	0	2	4	3	3	3	3	4
CO <sub>3</sub> <sup>2-</sup> (mg/L)	-	-	9	0.2	7.5	7	4.7	3.3	0.5	8.7	5.5
HCO <sub>3</sub> <sup>2-</sup> (mg/L)	-	-	163	190	168.5	184	180.33	198.33	195	161	189.5
pH	8.59	8.61	8.66	8.17	8.55	8.50	8.50	8.37	8.57	8.74	8.53
Conductivity (µS/cm)	290	282	293	304	-	314	287	322	310	287	318
Hardness (mg/L)	114	110	-	-	-	-	-	-	-	-	-
TDS (mg/L)	154	156	151	169	156	178	173	175	174	153	173
Microcystin (µg/L)	-	-	-	-	-	-	1.18	0.41	0.09	0.17	0.3
Total Alkalinity (mg/L CaCO <sub>3</sub> )	150	148	149	156	151	163	155	166	160	147	165

<b>Secchi depth (m)</b>	<b>2014</b>	<b>2015</b>	<b>2016</b>	<b>2017</b>	<b>2018</b>	<b>2019</b>	<b>2020</b>	<b>2021</b>	<b>2022</b>	<b>2023</b>	<b>2024</b>
TP (µg/L)	46	61	26	47	33	22	44	29	27	56	45
TDP (µg/L)	16	11	6	4	5	6	10	5	6	10	10
Chlorophyll-a (µg/L)	19.2	40.8	27.9	57.7	39.2	14.8	38.6	30.3	21.8	56.3	19.9
Secchi depth (m)	2.31	1.65	3.36	1.85	2.29	2.94	2.16	2.59	2.44	2.74	2.25
TKN (mg/L)	0.7	1.3	0.8	1.3	1	0.8	1.2	1.1	1	1.4	0.8
NO <sub>2</sub> -N and NO <sub>3</sub> -N (µg/L)	26	-	2	2	7	6	9	7	9	11	20
NH <sub>3</sub> -N (µg/L)	25	-	25	21	12	11	34	15	8	32	12
DOC (mg/L)	8	8	7	8	8	8	7	8	7	7	8
Ca <sup>2+</sup> (mg/L)	-	20	26	25	25	26	25	25	26	23	24
Mg <sup>2+</sup> (mg/L)	-	13	14	15	14	14	14	13	14	14	14
Na <sup>+</sup> (mg/L)	24	21	24	24	24	24	24	23	23	24	26
K <sup>+</sup> (mg/L)	7	6	7	7	7	7	7	7	7	8	8
SO <sub>4</sub> <sup>2-</sup> (mg/L)	5	4	6	5	7	7	5	5	7	7	4
Cl <sup>-</sup> (mg/L)	4	4	4	4	5	5	5	4	5	6	5
CO <sub>3</sub> <sup>2-</sup> (mg/L)	6.1	3.6	5.6	7.6	6.6	3.7	1.8	4.2	1	4.8	9
HCO <sub>3</sub> <sup>2-</sup> (mg/L)	179.8	178	184	178	188	195	182.5	217.5	200	207.5	202.5
pH	8.59	8.48	8.61	8.63	8.56	8.51	8.39	8.47	8.24	8.33	8.48
Conductivity (µS/cm)	314	298	320	316	328	332	318	332	328	318	322
Hardness (mg/L)	-	-	124	120	124	125	120	118	122	115	120
TDS (mg/L)	182	166	190	182	196	195	170	195	195	190	195
Microcystin (µg/L)	0.97	2.32	0.13	0.47	0.57	0.06	0.24	0.22	0.12	0.91	0.39
Total Alkalinity (mg/L CaCO <sub>3</sub> )	157	154	160	160	164	168	150	182	162	175	182

Table 3. Concentrations of metals measured in Pigeon 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	2013	2014	2015	2016	2017	Guidelines
Aluminum (µg/L)	5.13	6.14	10.55	14.3	7.2	5.1	100 <sup>a</sup>
Antimony (µg/L)	0.067	0.075	0.089	0.078	0.066	0.064	/
Arsenic (µg/L)	1.38	1.58	2.29	2.14	2.06	1.87	5
Barium (µg/L)	89.8	92.8	77.3	74.1	73.5	78.1	/
Beryllium (µg/L)	0.0068	0.0033	0.004	0.004	0.004	0.0015	100 <sup>c,d</sup>
Bismuth (µg/L)	0.0013	5e-04	5e-04	0.0033	0.001	0.0015	/
Boron (µg/L)	29.9	31.4	27.4	28.5	31.1	27.3	1500
Cadmium (µg/L)	0.003	0.005	0.002	0.004	0.005	0.005	0.36 <sup>b</sup>
Chromium (µg/L)	0.015	0.183	0.5235	0.09	0.04	0.05	/
Cobalt (µg/L)	0.00605	0.0073	0.006565	0.018	0.005	0.021	500, 1000 <sup>c,d</sup>
Copper (µg/L)	0.226	0.937	0.416	0.235	0.5	0.22	4 <sup>b</sup>
Iron (µg/L)	2.04	1	15.75	144.2	20.6	14.3	300
Lead (µg/L)	0.017	0.029	0.245	0.06	0.028	0.032	7 <sup>b</sup>
Lithium (µg/L)	9.09	11.05	8.29	9.18	11.2	9.47	2500 <sup>d</sup>
Manganese (µg/L)	16.9	40.49	15.75	49.65	6.48	27.5	130 <sup>e</sup>
Molybdenum (µg/L)	0.704	0.754	0.731	0.728	0.907	0.711	73
Nickel (µg/L)	0.002	0.023	0.346	0.02	0.219	0.88	150 <sup>b</sup>
Selenium (µg/L)	0.103	0.05	0.35	0.03	0.21	0.1	1
Silver (µg/L)	0.0015	0.0278	0.0068	0.002	0.003	5e-04	0.25
Strontium (µg/L)	234	329	261	233	249	231	/
Thallium (µg/L)	0.001	0.0018	0.0029	9e-04	0.0075	0.003	0.8
Thorium (µg/L)	0.009	0	0.004	0.011	0.01	0.005	/
Tin (µg/L)	0.05	0.08	0.02	0.04	0.03	0.03	/
Titanium (µg/L)	0.892	1.8	1.436	3.125	1	1.37	/
Uranium (µg/L)	0.18	0.234	0.194	0.167	0.161	0.144	15
Vanadium (µg/L)	0.154	0.226	0.456	0.14	0.26	0.189	100 <sup>c,d</sup>
Zinc (µg/L)	0.9	1.5	1.56	0.65	0.9	0.3	30 <sup>f</sup>

Values represent means of total recoverable metal concentrations.

<sup>a</sup> Based on pH ≥ 6.5

<sup>b</sup> Based on 2016 avg. water hardness (as CaCO<sub>3</sub>) with CCME equation

<sup>c</sup> Based on CCME Guidelines for Agricultural use (Livestock).

<sup>d</sup> Based on CCME Guidelines for Agricultural Use (Irrigation).

<sup>e</sup> Based on CCME Manganese variable calculation ([https://ccme.ca/en/chemical/129#\\_aq\\_fresh\\_concentration](https://ccme.ca/en/chemical/129#_aq_fresh_concentration)) using 2016 avg. water hardness (as CaCO<sub>3</sub>) and avg. pH

<sup>f</sup> Based on 2016 avg. water hardness (as CaCO<sub>3</sub>), 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 Pigeon Lake. In sum, significant increasing trends were detected in chlorophyll-*a*, TDS, and Secchi depth. No significant trend was detected for TP. 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 Pigeon Lake data from 1983 to 2024.

Parameter	Date Range	Direction of Significant Change
Total Phosphorus	1983-2024	No Change
Chlorophyll- <i>a</i>	1983-2024	Increasing
Total Dissolved Solids	1983-2024	Increasing
Secchi Depth	1983-2024	Increasing

## Definitions

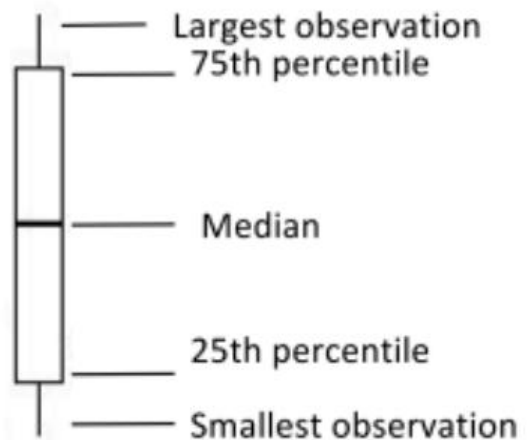
**Median:** the value in a range of ordered numbers that falls in the middle.

**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 no significant upward or downward trend in Pigeon Lake since 1983 (Tau = -0.022,  $p = 0.97$ ). Note, variation within a particular year in TP concentrations appears significantly different in recent years compared to historical data.

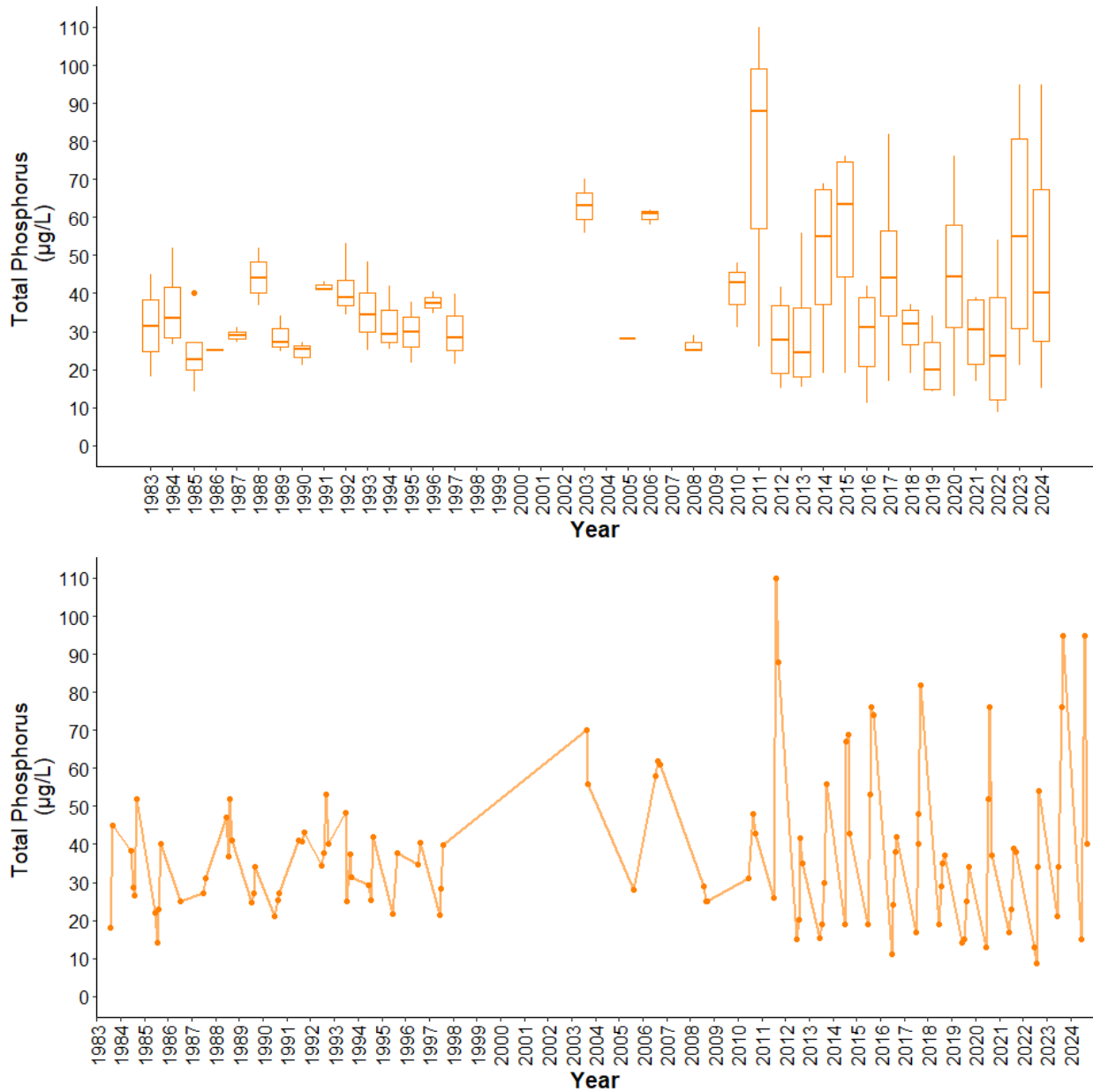


Figure 8. Monthly total phosphorus (TP) concentrations measured between June and September over the long term sampling dates between 1983 and 2024 ( $n = 110$ ). The value closest to the 15<sup>th</sup> day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

## Chlorophyll-a

Trend analysis of chlorophyll-a showed it has significantly increased over time at Pigeon Lake from 1983 to 2024 (Tau = 0.1403,  $p = 0.03$ ).

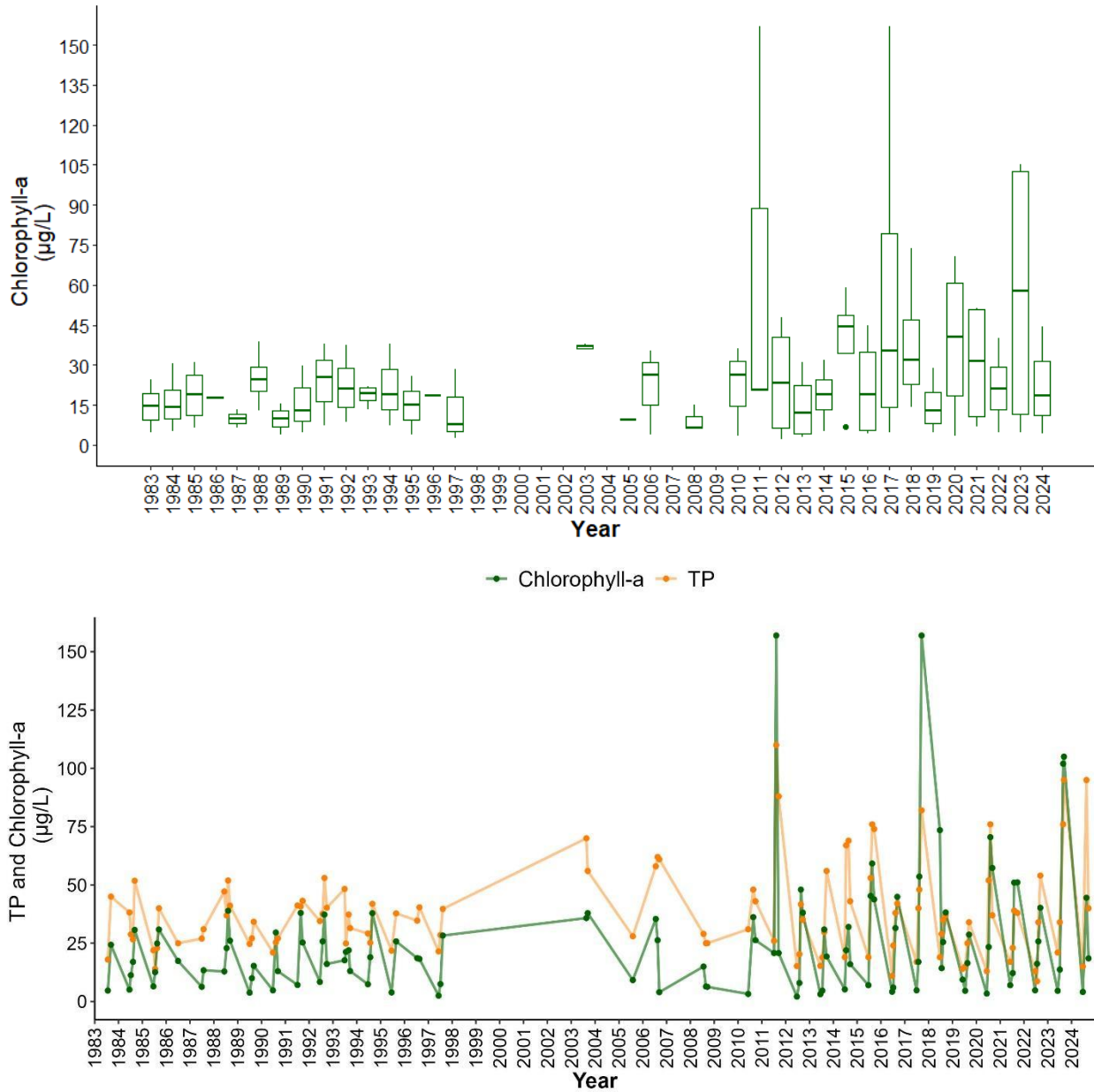


Figure 9. Monthly chlorophyll-a concentrations measured between June and September over the long term sampling dates between 1983 and 2024 ( $n = 110$ ). The value closest to the 15<sup>th</sup> day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

## Total Dissolved Solids (TDS)

Trend analysis showed a significant increasing trend in TDS in Pigeon Lake since 1983 (Tau = 0.5963,  $p < 0.001$ ).

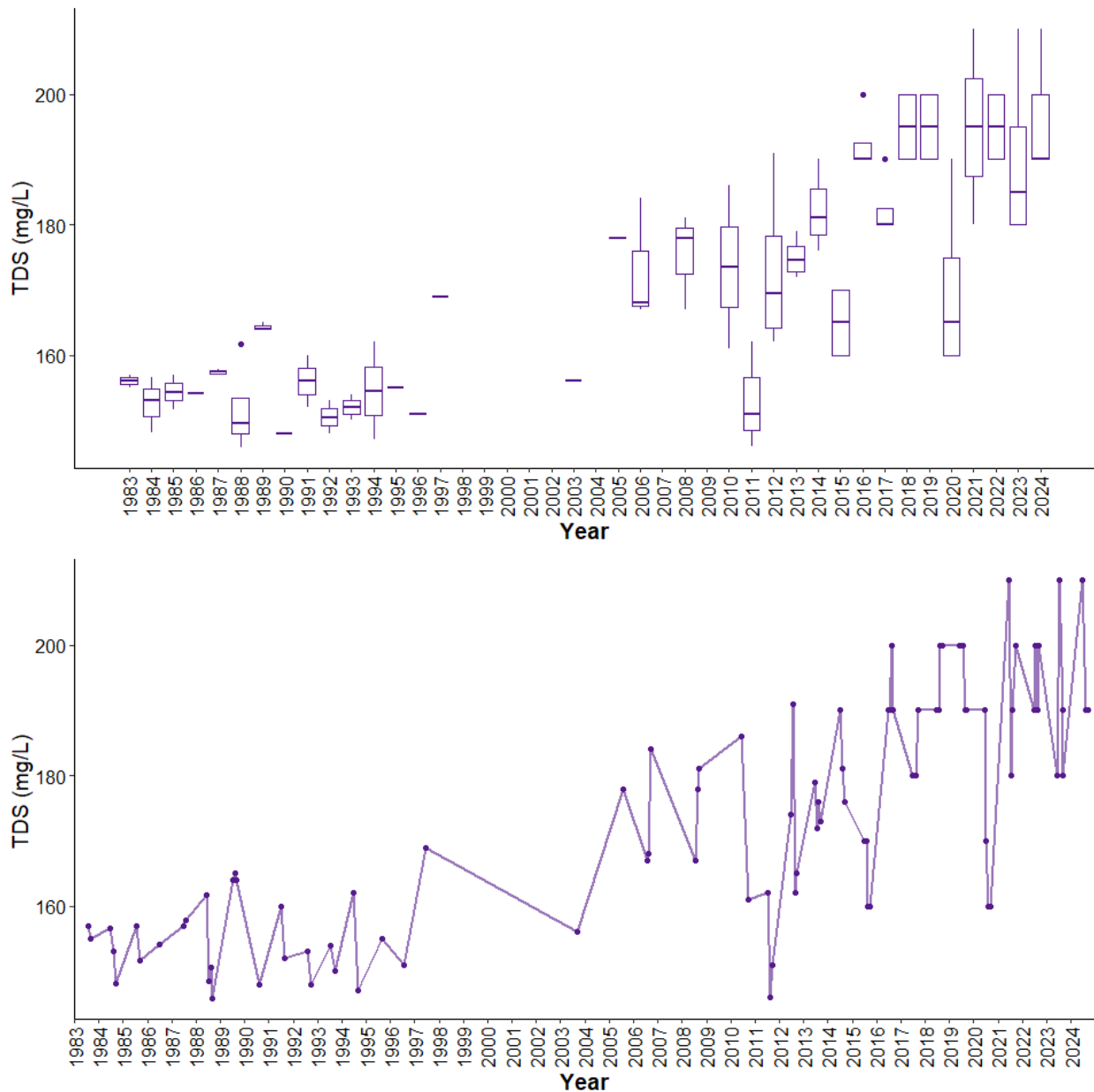



Figure 10. Monthly TDS values measured between June and September over the long term sampling dates between 1983 and 2024 (n = 92). The value closest to the 15<sup>th</sup> day of the month was chosen to represent the monthly value in cases with multiple monthly samples.



Due to the significant increasing trend of TDS in Pigeon Lake, exploring the specific major ions which may be driving this trend is important to determine.

Trend analysis of major ions at Pigeon Lake indicates that sodium, potassium, chloride, and alkalinity are significantly increasing (Figure 11). Sodium and alkalinity (bicarbonate and carbonate) display the greatest magnitude of change over time, increasing at 0.24 mg/L and 0.48 mg/L per year, respectively. No trends were detected in calcium or sulphate. Magnesium had insufficient data for calculating a trend.

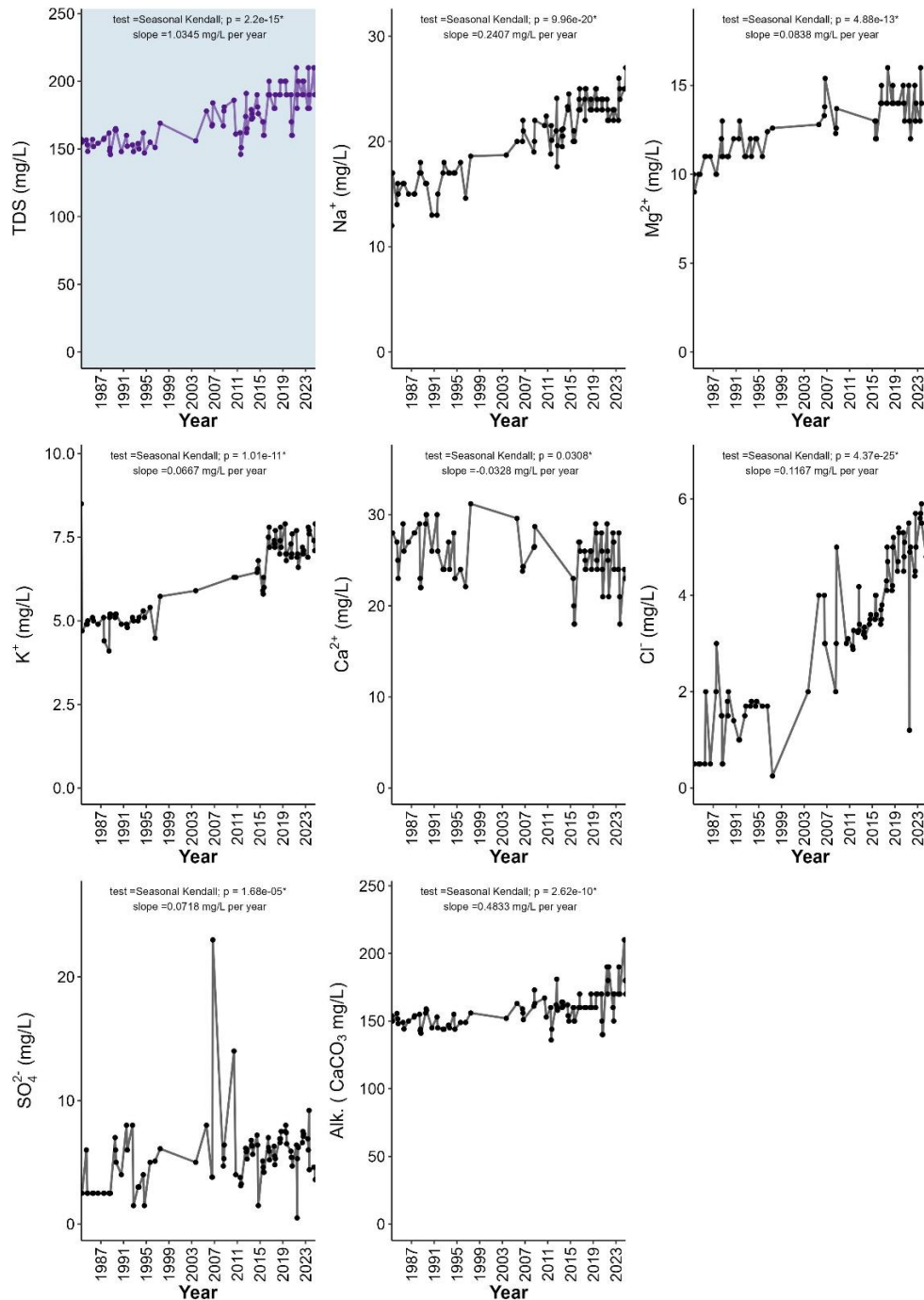


Figure 11. Concentrations of TDS (top left, blue panel), major ions (sodium = Na<sup>+</sup>, magnesium = Mg<sup>2+</sup>, potassium = K<sup>+</sup>, calcium = Ca<sup>2+</sup>, chloride = Cl<sup>-</sup>, sulphate = SO<sub>4</sub><sup>2-</sup>), and total alkalinity (Alk., as mg/L CaCO<sub>3</sub>) measured 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  $p < 0.05$ ) and the slope of the trend. A  $p$ -value of 0\* indicates an extremely low  $p$ -value. 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 15<sup>th</sup> 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 increased (the lake has become more clear) in Pigeon Lake since 1983 (Tau = 0.1622,  $p = 0.02$ ).

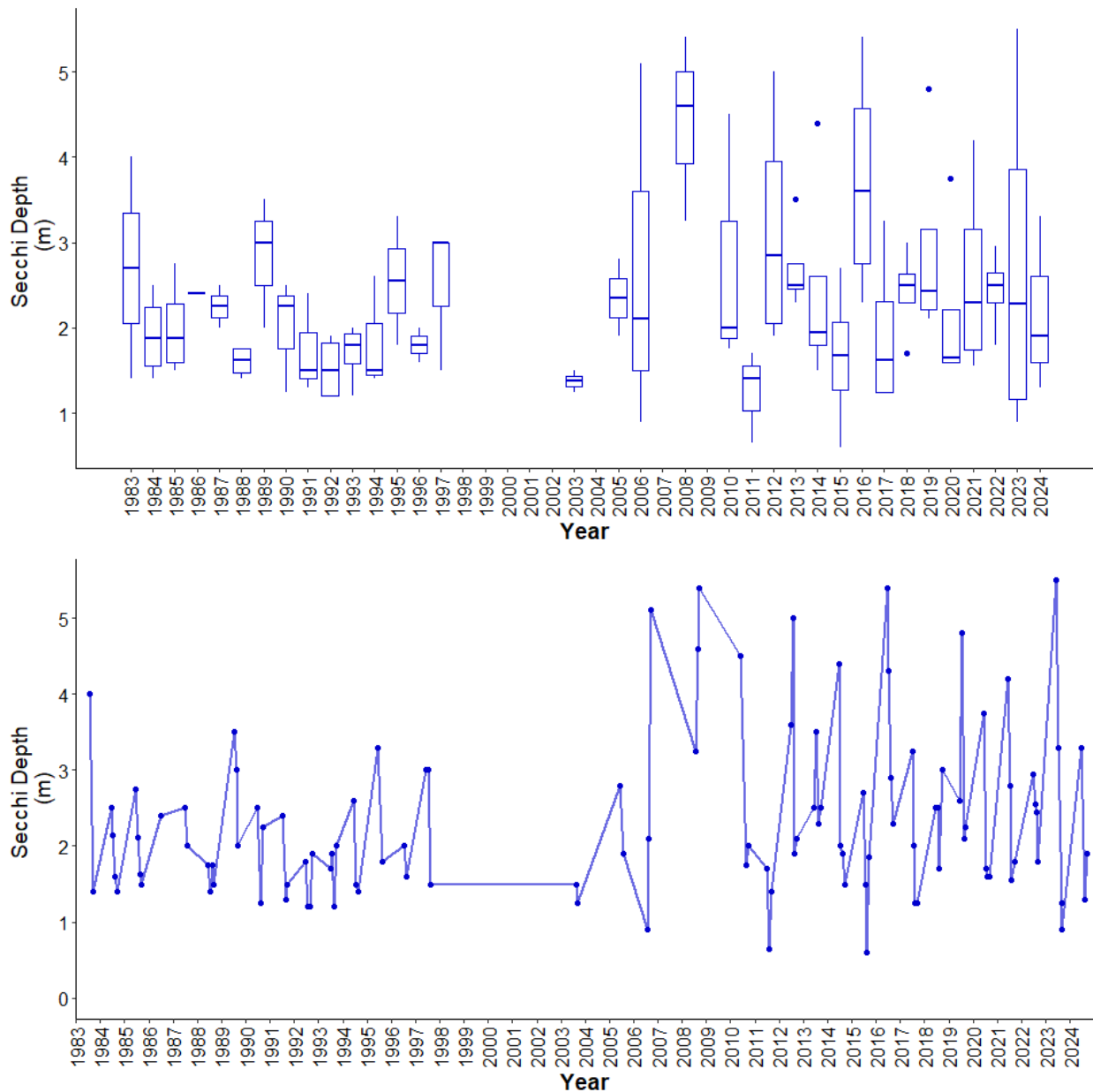


Figure 12. Monthly Secchi depth values measured between June and September over the long term sampling dates between 1983 and 2024 ( $n = 111$ ). The value closest to the 15<sup>th</sup> day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Table 5. Results of trend tests using total phosphorus, chlorophyll-*a*, total dissolved solids, and Secchi depth data from June to September for sampled years from 1983-2024 on Pigeon Lake data.

Definition	Unit	Total Phosphorus (TP)	Chlorophyll- <i>a</i>	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	-0.022	0.1403	0.5963	0.1622
The extent of the trend	Slope (units per Year)	0	0.1587	1.0345	0.0111
The statistic used to find significance of the trend	Z	0.0401	2.2162	7.9296	2.2896
Number of samples included	n	110	110	92	111
The significance of the trend	<i>p</i>	0.968	0.0267*	<0.001*	0.022*

\**p* < 0.05 is significant within 95%