Lakewatch

THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2015 Pigeon Lake Report

LAKEWATCH IS MADE POSSIBLE WITH SUPPORT FROM:

Beaver River Watershed Alliance

aemera.org

LICA
Lakeland Industry & Community Association

PIGEON LAKE WATERSHED ASSOCIATION

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LakeWatch has several important objectives, one of which is to collect and interpret water quality data on Alberta Lakes. Equally important is educating lake users about their aquatic environment, 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 a lay 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 people prove that ecological apathy can be overcome and give us hope that our water resources will not be the limiting factor in the health of our environment.

Data in this report is still in the validation process.

Acknowledgements

The LakeWatch program is made possible through the dedication of its volunteers. We would like to thank Richard McCardia and Colin McQueen for volunteering to sample Pigeon Lake in 2015. In addition, we would like to thank the Pigeon Lake Watershed Association and its contributing members and Summer Villages for their assistance in program coordination and financial support. We would also like to thank Laticia McDonald, Ageleky Bouzetos, and Mohamad Youssef who were summer technicians with ALMS in 2015. Executive Director Bradley Peter was instrumental in planning and organizing the field program. Mike Bilyk was involved in the training aspects of the program. Lisa Reinbolt was responsible for data management. This report was prepared by Bradley Peter and Alicia Kennedy. The Beaver River Watershed Alliance (BRWA), the Lakeland Industry and Community Association (LICA), the Alberta Environmental Monitoring Evaluation and Reporting Agency (AEMERA), and Environment Canada, were major sponsors of the program.

PIGEON LAKE:

Pigeon Lake is a large (96.7 km^2), shallow (average depth = 6m) lake located in the counties of Wetaskiwin and Leduc. It is a very popular recreational lake within easy driving distance from the cities of Edmonton, Leduc, and Wetaskiwin.

Pigeon Lake lies within the Battle River watershed. Water flows into the lake through intermittent streams draining the west and northwest portions of the watershed. The outlet, Pigeon Lake Creek, at the southeast margin of the lake, drains toward the Battle River.[1] The lake's drainage basin is small (187 km^2) but heavily developed with agriculture, oil and gas, as well as recreational development throughout the watershed.

The lake name is a translation from the Cree Mehmew Sâkâhikan, which means 'Dove Lake', but by 1858 the name Pigeon Lake was in use.[2] It has been suggested that the name Pigeon Lake refers to the huge flocks of Passenger Pigeons that once ranged in the area.[1] The lake was also previously known as Woodpecker Lake, and the Stoney name is recorded as Ke-gemni-wap-ta.[2]

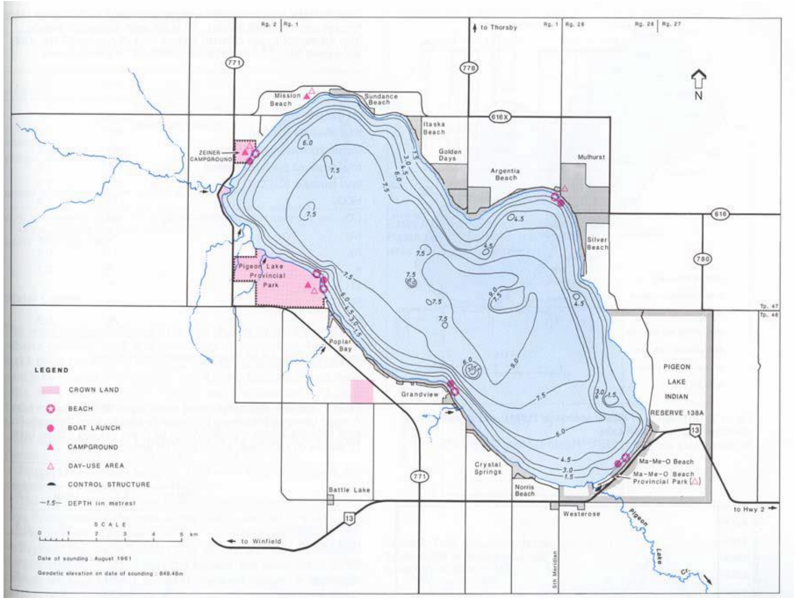

Figure 1 – Bathymetric map of Pigeon Lake.[1]

The water quality of Pigeon Lake is typical of large, productive, shallow lakes in Alberta, with water remaining quite green for most of the summer. However, residents have recently expressed concern over perceptions of deteriorating water quality as a result of recurring toxic blue-green algal blooms, fish kills, and beach advisories[3]. Due to these concerns, there has been a demand to examine ways to reduce the frequency and intensity of cyanobacteria blooms. In 2013, data was collected to prepare a nutrient budget for Pigeon Lake, this report was later released in 2014 and it outlines areas of interest when considering watershed and in-lake management options [4]. Out of the total phosphorus entering

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[1] Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes, University of Alberta Press. Retrieved from http://sunsite.ualberta.ca/projects/alberta-lakes/ Aubrey, M. K. 2006.

[2] Aubrey, M. K. 2006. Concise place names of Alberta. Retrieved from http://www.albertasource.ca/placenames/resources/searchcontent.php?book=1

[3] Aquality Environmental Consulting. 2008. Pigeon Lake State of Watershed Report. Prepared for Pigeon Lake Watershed Alliance. Retrieved from: www.plwa.ca.

[4] Teichreb, C.2014. Pigeon Lake Phosphorus Budget. Alberta Environment and Sustainable Resource Development. 28 pp.

the lake, 56% comes from internal loading and 43% coming from external watershed sources. The major contributors to external loading were dust fall and precipitation (43%), and diffuse inflows (48%). The remaining external sources of phosphorus come from streams (6%), sewage (2%), and groundwater (1%)[4].

WATER QUANTITY:

There are many factors influencing water quantity. Some of these factors include the size of the lakes 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 Science and Monitoring division or through Environment Canada. Visit https://wateroffice.ec.gc.ca and www.rivers.alberta.ca for more information.

Water levels in Pigeon Lake tend to fluctuate within a one-meter interval (Figure 2). Because the watershed of Pigeon Lake is relatively small, only twice the size of the lake area, water levels in Pigeon Lake are likely influenced by ground water input. There has been a general trend towards decline in water quantity since the early 1980's.

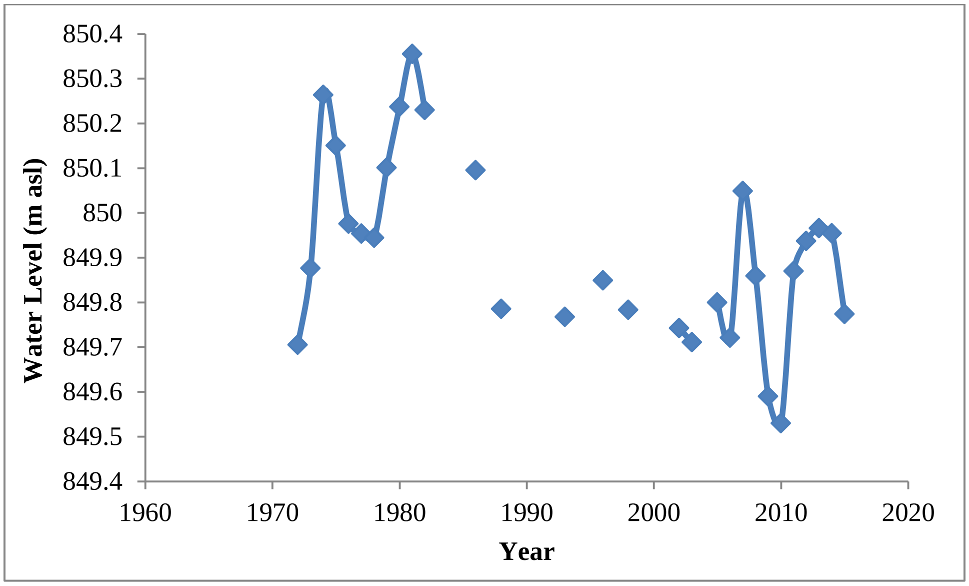

Figure 2 – Averages of historical monthly mean water levels (m asl) available through Environment Canada at https://wateroffice.ec.gc.ca via station code 05FA013. Data available until 2015.

WATER CLARITY AND SECCHI 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 disk depth.*

Average Secchi depth measured 1.65 m in 2015 (Table 2). This average fall on the low end of the historical variation observed at Pigeon Lake (1.38 m–4.42 m). Throughout the summer, Secchi depth closely tracked the concentration of chlorophyll-*a*, highlighting the impact the phytoplankton blooms have on water clarity (Figure 3). A maximum Secchi depth of 2.70 m was observed on June 23rd while a minimum Secchi disk depth of 0.60 m was observed on August 19th.

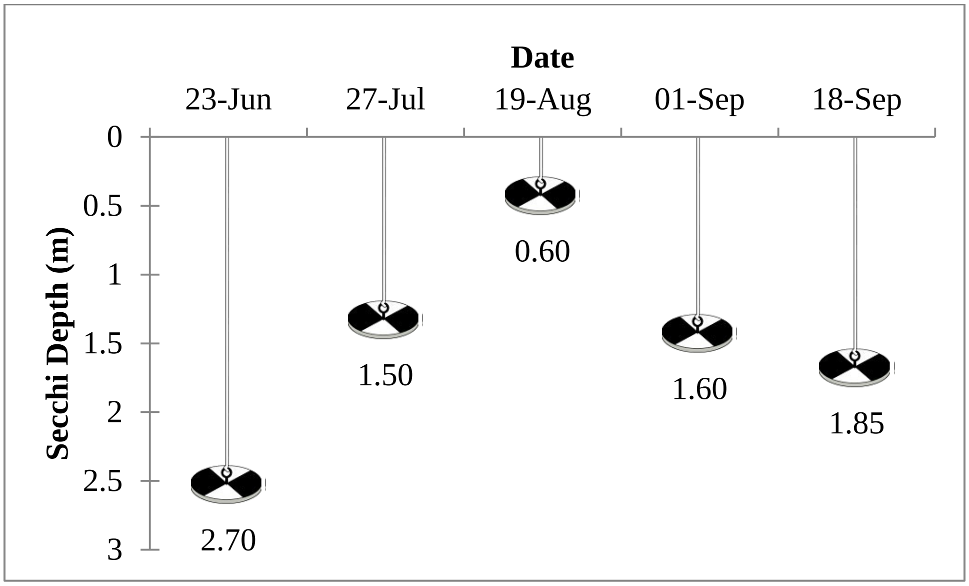

Figure 3 – Secchi disk depth measured five times over the course of the Summer at Pigeon Lake.

WATER TEMPERATURE AND DISSOLVED OXYGEN:

Water temperature and dissolved oxygen 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 temperature measured a maximum of 20.70 °C (Figure 4a). Throughout the water column, temperature remained un-stratified – this has important implications for dissolved oxygen concentrations. Deep waters often act as refuge for fish from warm temperatures – in 2015, the maximum observed temperature at the lake sediment measured 18.69 °C on July 27th. By September 18th, the temperature of the water column had dropped significantly, measuring only 13.75 °C at the lake surface.

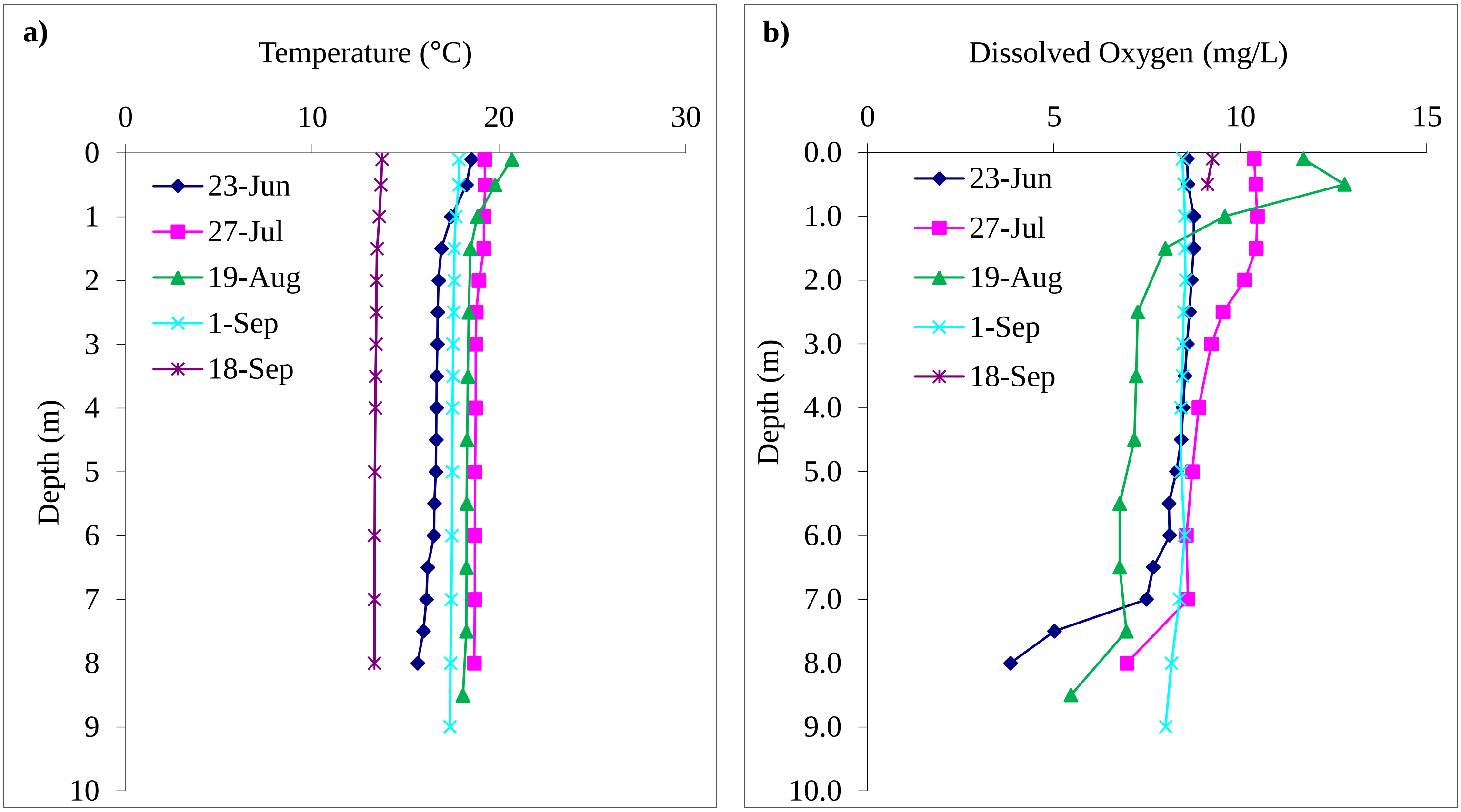

Figure 4 – a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles measured five times over the course of the summer of 2015.

Dissolved oxygen concentrations remained well above the Canadian Council for Ministers of the Environment guidelines for the Protection of Aquatic Life of 6.5 mg/L for much of the water column throughout 2015 (Figure 4b). Concentrations at the surface appeared slightly elevated due to phytosynthetic activity on August 19th Due to probe malfunction, oxygen data was not obtained on September 18th. Anoxia was not observed, though sharp decreases in oxygen concentration were observed near the sediment. In contrast, in 2014 thermal stratification resulted in a dramatic decline in oxygen concentration. Anoxia near the lake sediment can result in the release of phosphorus from lake sediments.

WATER CHEMISTRY:

ALMS measures a suite of water chemistry parameters. Phosphorous, 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 1 for a complete list of parameters.

Average Total Phosphorus (TP) measured 61 µg/L in 2015 (Table 2). This value falls toward the high end of the historical variation observed in Pigeon Lake (23 µg/L-75 µg/L) and falls into the eutrophic, or nutrient rich, classification (Table 1; Figure 6). Because the lake was well mixed throughout the summer, total phosphorus concentrations increased steadily throughout the sample season, from a minimum of 19 µg/L on June 23rd to a maximum of 81 µg/L on September 1st (Figure 5). Fluctuations in TP concentration appear closely correlated with changes in chlorophyll-*a* concentration (Figure 6).

Average Total Kjeldahl Nitrogen (TKN) measured 1.3 mg/L – similar to TP, this value falls on the high end of the historical variation observed at Pigeon Lake (0.6 mg/L-1.5 mg/L; table 2).TKN increased from a minimum of 0.8 mg/L on June 23rd to a maximum of 1.6 mg/L on August 19th.

Average chlorophyll-*a* concentration (40.8 µg/L) also fell at the high end of the historical variation observed at Pigeon Lake (7.98 µg/L-66.2 µg/L; table 2). An average value of 40.8 µg/L falls into the hypereutrophic (extremely productive) classification. Chlorophyll-*a* concentration peaked on August 19th (59.2 µg/L) which coincided with the minimum observed water clarity.

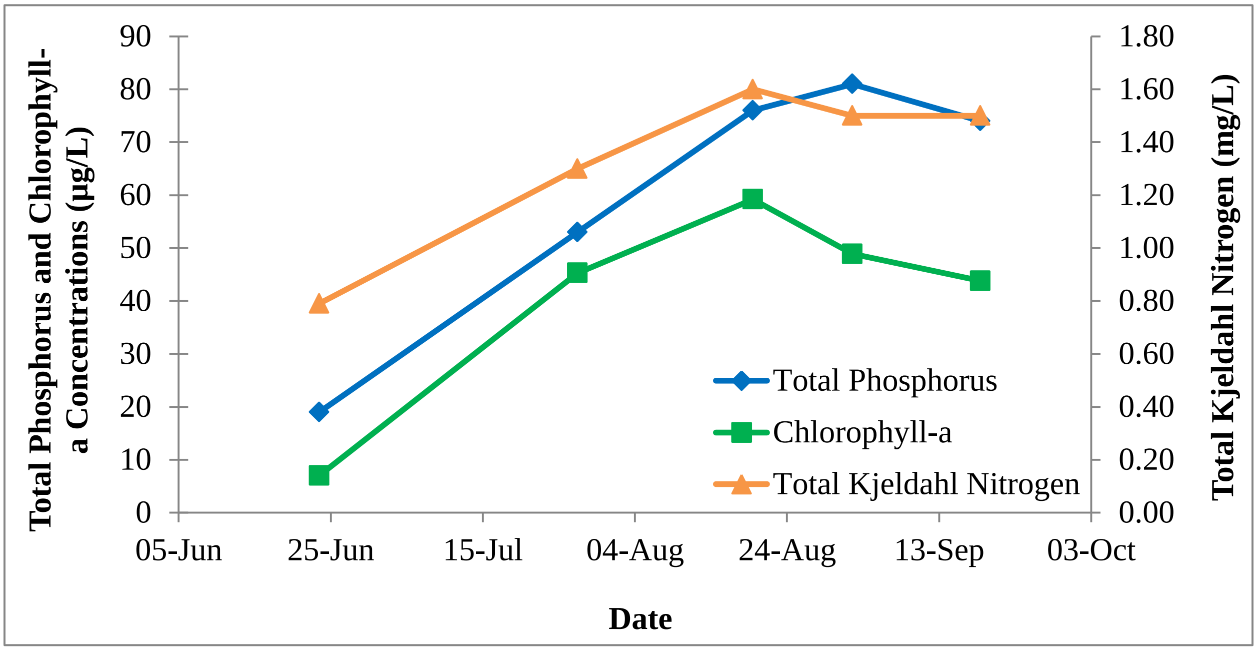

Figure 5 – Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentration measured five times over the course of the summer at Pigeon Lake.

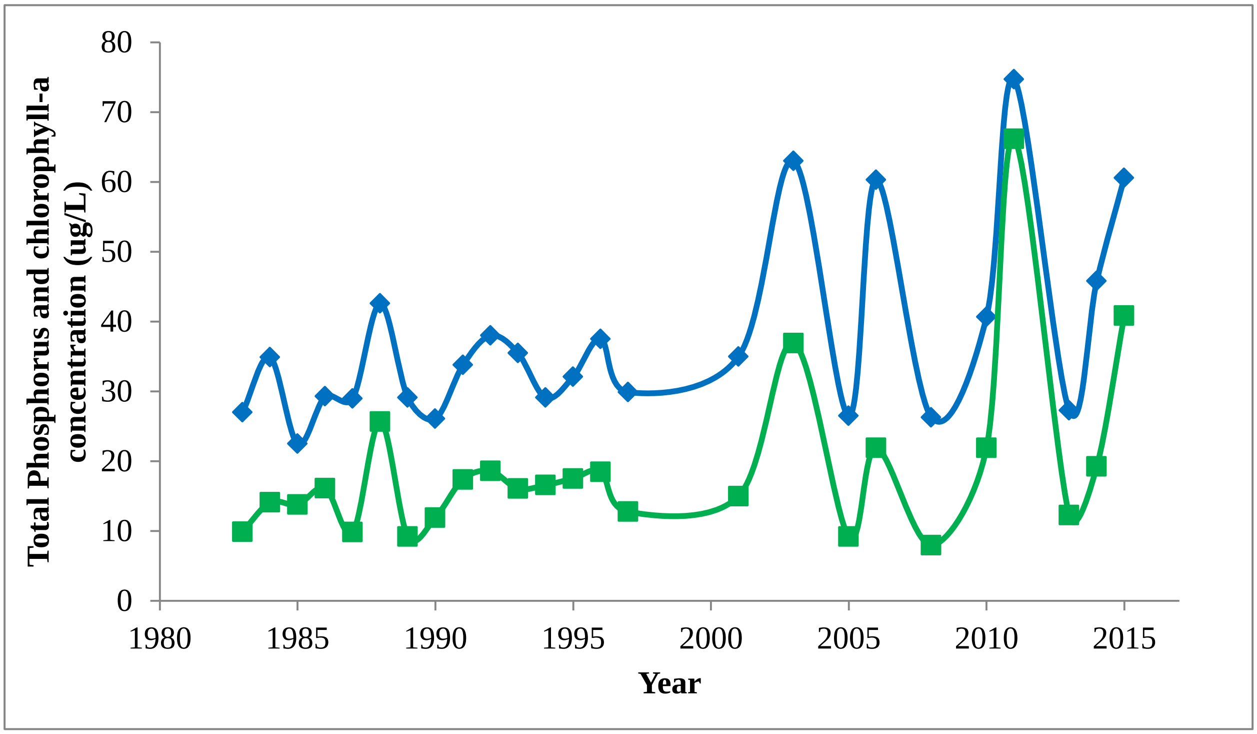

Figure 6 – Historical total phosphorus (µg/L) and chlorophyll-*a* (µg/L) concentrations measured at Pigeon Lake from 1983-2015.

Average pH in Pigeon Lake has changed little since monitoring began in 1983. In 2015, pH measured an average of 8.48 – this value is well above neutral. pH has moderate alkalinity and bicarbonate concentrations which help to buffer the lake against changes to pH. Pigeon Lake has low conductivity (298 uS/cm) with dominant contributing ions including calcium (20 mg/L) and sodium (21 mg/L).

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 the one of the most common cyanobacteria toxins. In Alberta, recreational guidelines for microcystin are set at 20 µg/L.

Microcystin was detected on each sampling trip to Pigeon Lake, though all concentrations fell below the recommended recreational guideline of 20 ug/L. Phytoplankton community shifts in Pigeon Lake may be responsible for the higher microcystin concentrations observed later in the summer, as the frequently dominant *Aphanizomenon* spp. is unable to produce microcystin. Caution should always be observed when recreating in waters containing cyanobacteria.

Table 1 - Microcystin concentrations measured at Pigeon Lake over the course of the summer of 2015.

Date	Microcystin (μg/L)
23-Jun	0.13
27-Jul	0.51
19-Aug	1.92
01-Sep	4.18
18-Sep	4.85

INVASIVE SPECIES:

Quagga and Zebra mussels are invasive species which, if introduced to our lakes, will have significant negative ecological, economical, and recreational impacts. ALMS collects water samples which are analyzed for mussel veligers (juveniles) and monitors substrates for adult mussels. In order to prevent the spread of invasive mussels, always clean, drain, and dry your boat between lakes. To report mussel sightings or mussel-fouled boats, call the confidential Alberta hotline at 1-855-336-BOAT.

In 2015, no zebra or quagga mussels were detected in Pigeon Lake.

Table 2 - Average Secchi disk depth and water chemistry values for Pigeon Lake. Previous years averages are provided for comparison. Table continued onto the next page.

Parameter	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
TP (μg/L)	27	34.9	22.5	29.3	29	42.6	29.1	26.1	33.8	38	35.5	29.1
TDP (μg/L)	/	/	/	/	/	/	/	/	/	/	/	/
Chlorophyll-*a* (μg/L)	9.91	14.1	13.8	16.13	9.85	25.7	9.2	11.94	17.4	18.6	16.08	16.6
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	2.13
TKN (mg/L)	0.9	/	0.6	/	/	/	/	/	/	/	/	/
NO_2 and NO_3 (μg/L)	/	/	/	/	/	/	/	/	/	/	/	/
NH_3 (μg/L)	/	/	/	/	/	/	/	/	/	/	/	/
DOC (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/
Ca (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/
Mg (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/
Na (mg/L)	15	15.3	16.3	15	15	17.1	16.12	14.33	14	17	17	17
K (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/
SO_4^{2-} (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/
Cl^- (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/
CO_3 (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/
HCO_3 (mg/L)	180.5	178.2	184	168.62	176.15	170.52	187.3	175.3	176.7	174	174.7	176.5
pH	8.37	8.43	8.35	8.57	8.5	8.36	8.32	8.5	8.46	8.45	8.56	8.6
Conductivity (μS/cm)	283.25	288	292.25	280.3	293	279	302.2	293.7	292.7	285.7	286.7	290
Hardness (mg/L)	112.13	103.25	113	109.7	111	109.25	119.95	122	120.7	110.7	113.3	113.5
TDS (mg/L)	156.7	153.7	157.9	151.21	157.41	151.1	163	157.7	155.7	152.3	154	154.5
Microcystin (μg/L)	/	/	/	/	/	/	/	/	/	/	/	/
Total Alkalinity (mg/L $CaCO_3$)	151.75	152.95	152.58	147	153.5	144.9	155.8	152.7	150	146	148	149.5

Note: TP = total phosphorus, TDP = total dissolved phosphorus, Chl-*a* = chlorophyll-*a*, TKN = total Kjeldahl nitrogen. NO_{2+3} = nitrate+nitrite, NH_3 = ammonia, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulphate, Cl = chloride, CO_3 = carbonate, HCO_3 = bicarbonate. A forward slash (/) indicates an absence of data.

Table 2 continued.

Parameter	1995	1996	1997	2001	2003	2005	2006	2008	2010	2011	2013	2014	2015
TP (µg/L)	32.1	37.5	29.9	35	63	26.5	60.3	26.3	40.7	74.7	27.3	45.8	61
TDP (µg/L)	/	/	/	/	/	6	38	9	13	19.1	7.69	16.4	11
Chlorophyll-*a* (µg/L)	17.53	18.5	12.77	15	36.9	9.2	21.9	7.98	21.92	66.2	12.28	19.24	40.8
Secchi depth (m)	2.2	1.8	2.5	1.5	1.38	1.9	2.7	4.42	2.75	1.25	3.23	2.31	1.7
TKN (µg/L)	0.9	/	/	0.6	1.1	0.7	1.1	0.7	1.0	1.5	0.8	0.7	1.3
NO_2 and NO_3 (µg/L)	/	/	/	1	/	3	29	13	7.67	15.9	5.91	26	2.5
NH_3 (µg/L)	/	/	/	3	/	2.5	124	16	72.3	108.9	28.39	24.6	31
DOC (mg/L)	/	/	/	/	/	/	7	/	7.35	/	/	8.3	7.8
Ca (mg/L)	/	/	/	/	/	28.85	21.13	27.2	23.75	19.5	27.62	22.83	20
Mg (mg/L)	/	/	/	/	/	12.65	14.12	12.87	13.85	12.5	12.84	11.43	13
Na (mg/L)	17.5	14.6	18.6	/	18.7	20	21	20.33	21.95	20.1	20.57	23.6	21
K (mg/L)	/	/	/	/	/	6.1	6.63	6.17	6.3	6.2	6.59	6.6	6.1
SO_4^{2-} (mg/L)	/	/	/	/	/	7.3	10.2	5.47	9	3.38	6.38	5.03	4.5
Cl^- (mg/L)	/	/	/	/	/	4	3.33	3.33	3.05	3.03	3.19	3.5	3.8
CO_3 (mg/L)	/	/	/	/	/	8	4.67	3.33	0.5	8.7	3.27	5.92	3.6
HCO_3 (mg/L)	167.5	163	190	/	168.5	183	180	198	195	161	194.53	191.6	178
pH	8.61	8.66	8.17	/	8.56	8.6	8.5	8.37	8.57	8.74	8.34	8.59	8.48
Conductivity (µS/cm)	281.5	293	304	/	/	313	287	321.7	309.5	286.7	164	314	298
Hardness (mg/L)	110.5	106	130	/	103	125	119	121	116	100.2	122	103.9	101
TDS (mg/L)	156	151	169	/	/	176.5	173	175.33	173.5	153	176	182.3333	166
Microcystin (µg/L)	/	/	/	/	/	/	/	/	0.087	0.173	0.1354	0.972	2.32
Total Alkalinity (mg/L $CaCO_3$)	148.5	149	156	/	151	163	155.3	165.7	160	146.7	164	156.8	154

Note: TP = total phosphorus, TDP = total dissolved phosphorus, Chl-*a* = chlorophyll-*a*, TKN = total Kjeldahl nitrogen. NO_{2+3} = nitrate+nitrite, NH_3 = ammonia, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulphate, Cl = chloride, CO_3 = carbonate, HCO_3 = bicarbonate. A forward slash (/) indicates an absence of data.

Table 2 - Concentrations of metals measured in Pigeon Lake on August 19th and September 18th 2015. Values shown for 2015 are an average of those dates. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference.

Metals (Total Recoverable)	**2003**	**2012**	**2014**	**2015**	**Guidelines**
Aluminum µg/L	14.9	5.13	10.55	14.3	100[a]
Antimony µg/L	0.05	0.06685	0.089	0.0785	6[e]
Arsenic µg/L	1.67	1.375	2.285	2.145	5
Barium µg/L	78.5	89.75	77.35	74.1	1000[e]
Beryllium µg/L	0.02	0.00675	0.004	0.004	100[d,f]
Bismuth µg/L	0.0025	0.00125	0.0005	0.00325	/
Boron µg/L	27.9	29.85	27.4	28.5	5000[ef]
Cadmium µg/L	0.01	0.00325	0.002	0.004	0.085[b]
Chromium µg/L	0.27	0.015	0.5235	0.09	/
Cobalt µg/L	0.11	0.00605	0.006565	0.018	1000[f]
Copper µg/L	1.08	0.2255	0.4155	0.235	4[c]
Iron µg/L	39	2.04	15.75	144.2	300
Lead µg/L	0.145	0.0167	0.245	0.0595	7[c]
Lithium µg/L	8.6	9.09	8.29	9.175	2500[g]
Manganese µg/L	54.1	16.9	15.75	49.65	200[g]
Molybdenum µg/L	0.62	0.704	0.731	0.728	73[d]
Nickel µg/L	0.16	0.0025	0.3465	0.0205	150[c]
Selenium µg/L	0.25	0.103	0.35	0.03	1
Silver µg/L	0.0025	0.0015	0.00681	0.002	0.1
Strontium µg/L	245	234	261	233	/
Thallium µg/L	0.0015	0.00105	0.00291	0.000875	0.8
Thorium µg/L	0.0015	0.008725	0.003575	0.011425	/
Tin µg/L	0.05	0.0549	0.0231	0.0355	/
Titanium µg/L	1.5	0.8925	1.4355	3.125	/
Uranium µg/L	0.086	0.1805	0.1945	0.167	100[e]
Vanadium µg/L	0.26	0.1545	0.456	0.14	100[f,g]
Zinc µg/L	1.5	0.899	1.56	0.65	30

Values represent means of total recoverable metal concentrations.

[a] Based on pH ≥ 6.5; calcium ion concentrations [Ca^{+2}] ≥ 4 mg/L; and dissolved organic carbon concentration [DOC] ≥ 2 mg/L.

[b] Based on water Hardness of 300 mg/L (as $CaCO_3$)

[c] Based on water hardness > 180mg/L (as $CaCO_3$)

[d] CCME interim value.

[e] Based on Canadian Drinking Water Quality guideline values.

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

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

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

A BRIEF INTRODUCTION TO LIMNOLOGY

INDICATORS OF WATER QUALITY:

Water samples are collected in LakeWatch to determine the chemical characteristics that characterize general water quality. Though not all encompassing, the variables collected in LakeWatch are sensitive to human activities in watersheds that can cause degraded water quality. For example, nutrients such as phosphorus and nitrogen are important determinants of lake productivity. The concentrations of these nutrients in a lake are impacted (typically elevated) by land use changes such as increased crop production or livestock grazing. Elevated nutrient concentrations can cause increases in undesirable algae blooms resulting in low dissolved oxygen concentrations, degraded habitat for fish and noxious smells. A large increase in nutrients over time may also indicate sewage inputs which in turn may result in other human health concerns associated with bacteria or the protozoan *Cryptosporidium*.

TEMPERATURE AND MIXING:

Water temperature in a lake dictates the behavior of many chemical parameters responsible for water quality. Heat is transferred to a lake at its surface and slowly moves downward depending on water circulation in the lake. Lakes with a large surface area or a small volume tend to have greater mixing due to wind. In deeper lakes, circulation is not strong enough to move warm water to depths typically greater than 4 or 5 m and as a result cooler denser water remains at the bottom of the lake. As the difference in temperature between warm surface and cold deeper water increases, two distinct layers are formed. Limnologists call these layers of water the **epilimnion** at the surface and the **hypolimnion** at the bottom. The layers are separated by a transition layer known as the **metalimnion** which contains the effective wall separating top and bottom waters called a **thermocline**. A thermocline typically occurs when water temperature changes by more than one degree within one meter depth. The hypolimnion and epilimnion do not mix, nor do elements such as oxygen supplied at the surface move downward into the hypolimnion. In the fall, surface waters begin to cool and eventually reach the same temperature as hypolimnetic water. At this point the water mixes from top to bottom in what is often called a **turnover** event. Surface water cools further as ice forms and again a thermocline develops this time with 4° C water at the bottom and near 0° C water on the top.

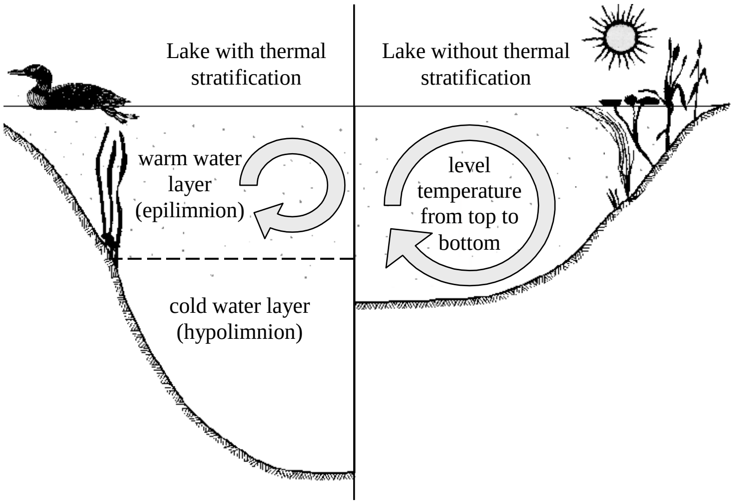

Figure A: Difference in the circulation of the water column depending on thermal stratification.

In spring another turnover event occurs when surface waters warm to 4° C. Lakes with this mixing pattern of two stratification periods and two turnover events are called **dimictic** lakes. In shallower lakes, the water column may mix from top to bottom most of the ice-free season with occasional stratification during periods of calm warm conditions. Lakes that mix frequently are **termed polymictic** lakes. In our cold climate, many shallow lakes are **cold monomictic meaning a thermocline develops every winter, there is one turnover event in spring but the remainder of the ice free season the lake is polymictic.**

DISSOLVED OXYGEN:

Oxygen enters a lake at the lake surface and throughout the water column when produced by photosynthesizing plants, including algae, in the lake. Oxygen is consumed within the lake by respiration of living organisms and decomposition of organic material in the lake sediments. In lakes that stratify (see temperature above), oxygen that dissolves into the lake at the surface cannot mix downward into the hypolimnion. At the same time oxygen is depleted in the hypolimnion by decomposition. The result is that the hypolimnion of a lake can become **anoxic**, meaning it contains little or no dissolved oxygen. When a lake is frozen, the entire water column can become anoxic because the surface is sealed off from the atmosphere. Winter anoxic conditions can result in a fish-kill which is particularly common during harsh winters with extended ice-cover. Alberta Surface Water Quality Guidelines suggest dissolved oxygen concentrations (in the epilimnion) must not decline below 5 $mg \bullet L^{-1}$ and should not average less than 6.5 $mg \bullet L^{-1}$ over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 $mg \bullet L^{-1}$ in areas where early life stages of aquatic biota, particularly fish, are present.

GENERAL WATER CHEMISTRY:

Water in lakes always contains substances that have been transported by rain and snow or have entered the lake in groundwater and inflow streams. These substances may be dissolved in the water or suspended as particles. Some of these substances are familiar minerals, such as sodium and chloride, which when combined form table salt, but when dissolved in water separate into the two electrically charged components called **ions**. Most dissolved substances in water are in ionic forms and are held in solution due to the polar nature of the water molecule. **Hydrophobic** (water-fearing) compounds such as oils contain little or no ionic character, are non-polar and for this reason do not readily dissolve in water. Although hydrophobic compounds do not readily dissolve, they can still be transported to lakes by flowing water. Within individual lakes, ion concentrations vary from year to year depending on the amount and mineral content of the water entering the lake. This mineral content can be influenced by the amount of precipitation and other climate variables as well as human activities such as fertilizer and road salt application.

PHOSPHORUS AND NITROGEN:

Phosphorus and nitrogen are important nutrients limiting the growth of algae in Alberta lakes. While nitrogen usually limits agricultural plants, phosphorus is usually in shortest supply in lakes. Even a slight increase of phosphorus in a lake can, given the right conditions, promote algal blooms causing the water to turn green in the summer and impair recreational uses. When pollution originating from livestock manure and human sewage enters lakes not only are the concentrations of phosphorus and nitrogen increased but nitrogen can become a limiting nutrient which is thought to cause blooms of toxic algae belonging to the cyanobacteria. Not all cyanobacteria are toxic, however, the blooms can form decomposing mats that smell and impair dissolved oxygen concentrations in the lake.

CHLOROPHYLL-*A*:

Chlorophyll *a* is a photosynthetic pigment that green plants, including algae, possess enabling them to convert the sun's energy to living material. Chlorophyll *a* can be easily extracted from algae in the laboratory. Consequently, chlorophyll *a* is a good estimate of the amount of algae in the water. Some highly productive lakes are dominated by larger aquatic plants rather than suspended algae. In these lakes, chlorophyll *a* and nutrient values taken from water samples do not include productivity from large aquatic plants. The result, in lakes like Chestermere which are dominated by larger plants known as macrophytes, can be a lower trophic state than if macrophyte biomass was included. Unfortunately, the productivity and nutrient cycling contributions of macrophytes are difficult to sample accurately and are therefore not typically included in trophic state indices.

SECCHI DISK TRANSPARENCY:

Lakes that are clear are more attractive for recreation, whereas those that are turbid or murky are considered by lake users to have poor water quality. A measure of the transparency or clarity of the water is performed with a Secchi disk with an alternating black and white pattern. To measure the clarity of the water, the Secchi disk is lowered down into the water column and the depth where the disk disappears is recorded. The Secchi depth in lakes with a lot of algal growth will be small while the Secchi depth in lakes with little algal growth can be very deep. However, low Secchi depths are not caused by algal growth alone. High concentrations of suspended sediments, particularly fine clays or glacial till, are common in plains or mountain reservoirs of Alberta. Mountain reservoirs may have exceedingly low Secchi depths despite low algal growth and nutrient concentrations.

The euphotic zone or the maximum depth that light can penetrate into the water column for actively growing plants is calculated as twice the Secchi depth. Murky waters, with shallow Secchi depths, can prevent aquatic plants from growing on the lake bottom. Conversely, aquatic plants can ensure lakes have clear water by reducing shoreline erosion and stabilizing lake bottom sediments. In Alberta, many lakes are shallow and bottom sediments contain high concentrations of nutrients. Without aquatic plants, water quality may decline in these lakes due to murky, sediment laden water and excessive algal blooms. Maintaining aquatic plants in certain areas of a lake is often essential for ensuring good water clarity and a healthy lake as many organisms, like aquatic invertebrates and insects, depend on aquatic plants for food and shelter.

TROPHIC STATE:

Trophic state is classification of lakes into four categories of fertility and is a useful index for rating and comparing lakes. From low to high nutrient and algal biomass (as chlorophyll) concentrations, the trophic states are; **oligotrophic**, **mesotrophic**, **eutrophic** and **hypereutrophic (Table 2)**.

A majority of lakes in Alberta contain naturally high levels of chlorophyll *a* (8 to 25 µg/L) due to our deep fertile soils. These lakes are usually considered fertile and are termed eutrophic. The nutrient and algal biomass concentrations that define these categories are shown in the following table, a figure of Alberta lakes compared by trophic state can be found on the ALMS website.

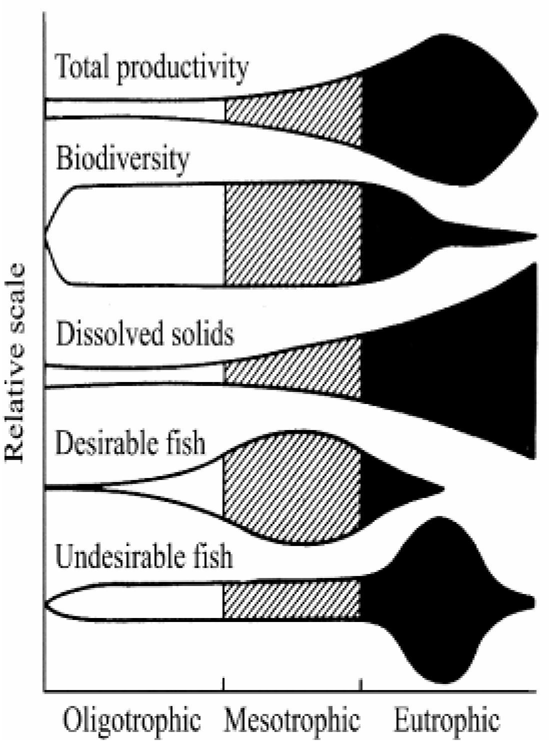

Figure B: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

Table A - Trophic status classification based on lake water characteristics.

Trophic state	Total Phosphorus ($\mu g \bullet L^{-1}$)	Total Nitrogen ($\mu g \bullet L^{-1}$)	Chlorophyll a ($\mu g \bullet L^{-1}$)	Secchi Depth (m)
Oligotrophic	< 10	< 350	< 3.5	> 4
Mesotrophic	10 – 30	350 - 650	3.5 - 9	4 - 2
Eutrophic	30 – 100	650 - 1200	9 - 25	2 - 1
Hypereutrophic	> 100	> 1200	> 25	< 1