Lakewatch

THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2015 Lac la Nonne Report

LAKEWATCH IS MADE POSSIBLE WITH SUPPORT FROM:

Beaver River Watershed Alliance

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LICA
Lakeland Industry &
Community Association

Alberta
Government

Alberta Lake Management Society's LakeWatch Program

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.

This report has been published before the completion of the data validation process.

Acknowledgements

LAC LA NONNE:

Lac La Nonne is a fairly large (11.8 km^2) and deep (maximum depth 19.8 m) lake located about 90 km northwest of Edmonton in the counties of Barrhead and Lac Ste. Anne.[1] The closest large population centre is the town of Barrhead located 20 km to the north. It is within the Athabasca River Watershed.

This is a highly developed and popular recreational lake. It has one summer village, twelve residential subdivisions, and five campgrounds/resorts and is surrounded by agricultural land. A severe toxic cyanobacteria bloom in August 2002 prompted public concern over water quality and the formation of two local watershed stewardship groups, Lac La Nonne Enhancement and Protection Association and the Lac La Nonne Watershed Stewardship Society. They have been very active in implementing beneficial management practices, educating the watershed community, and organizing data collection in preparation of undertaking a watershed management plan.

Figure 1 – Map of Lac la Nonne obtained from Lac La Nonne Enhancement and Protection Association (LEPA) 2012.

Lac La Nonne Watershed is large (299 km^2) and includes Lake Nakamun and Majeau Lake. In 2006, the Lac La Nonne Watershed Society undertook a State of the Watershed Report. This report summarizes available information for the historical and current condition of the watershed and makes recommendations for maintaining and improving lake and watershed health.[2]

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.

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[1] Michell, P and E. Prepas. 1990. Atlas of Alberta Lakes, University of Alberta Press. Available at: http://sunsite.ualberta.ca/Projects/Alberta-Lakes/

[2] Aquality. 2006. Lac La Nonne State of the Watershed Report. Lac La Nonne Watershed Society. Available at: http://www.laclanonnewatershed.com/LLN_SoW_Report.pdf

Water levels have been measured at Lac La Nonne since 1972 by Environment Canada (Figure 2). There has been a general trend towards decline at Lac La Nonne since 1997, which was the maximum historical water elevation, measuring an average of 663.941 meters above sea level (m asl) that year. Since then, water levels have dropped sharply, reaching a historical minimum of 662.361 m asl. Overall, water levels have fluctuated ~1.7 m since observations began. Since the historical minimum in 2010, water levels have recovered nearly one meter.
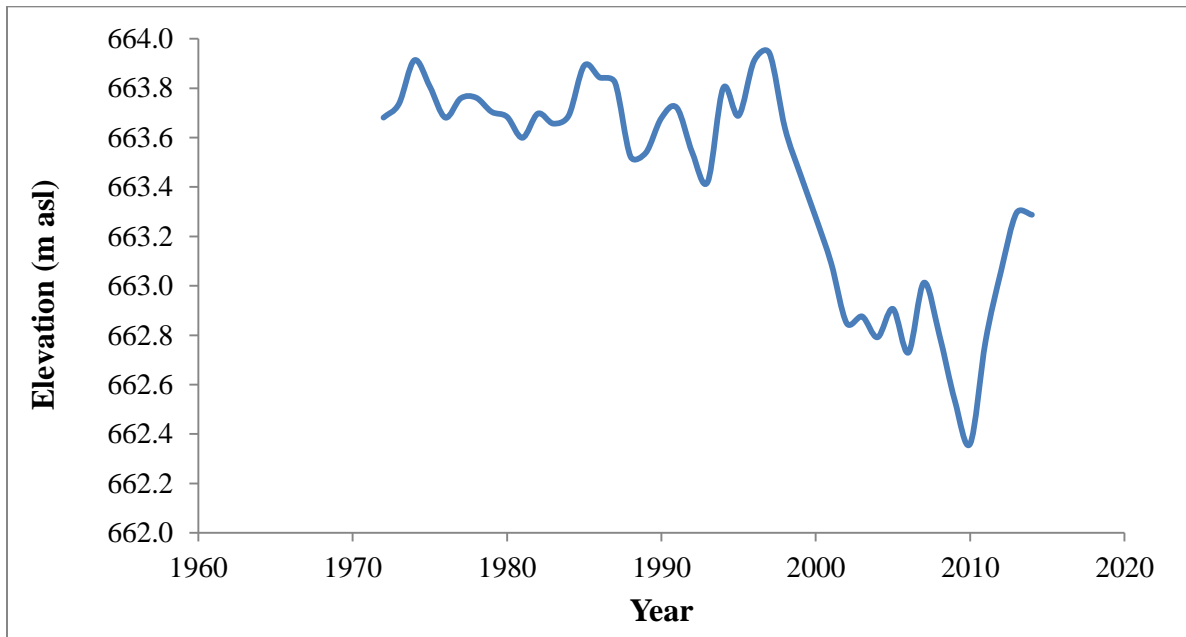

Figure 2 – Historical water levels measured as water quantity in meters above sea level (m asl) for Lac la Nonne from 1972-2014. Data retrieved from Environment Canada. Values obtained by averaging monthly elevations for each year.

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 water clarity measured 2.80 m in 2015 (Table 2). This value is the highest water clarity measured since observations began in 1983. This average was comprised of a maximum water clarity of 6.50 m observed on June 23rd, and a minimum water clarity of 1.75 m observed on both August 18th and September 8th (Figure 3). Water clarity measurements appear closely correlated with the concentration of chlorophyll-*a* in the water column, suggesting phytoplankton blooms are the primary factor affecting water clarity in Lac la Nonne.
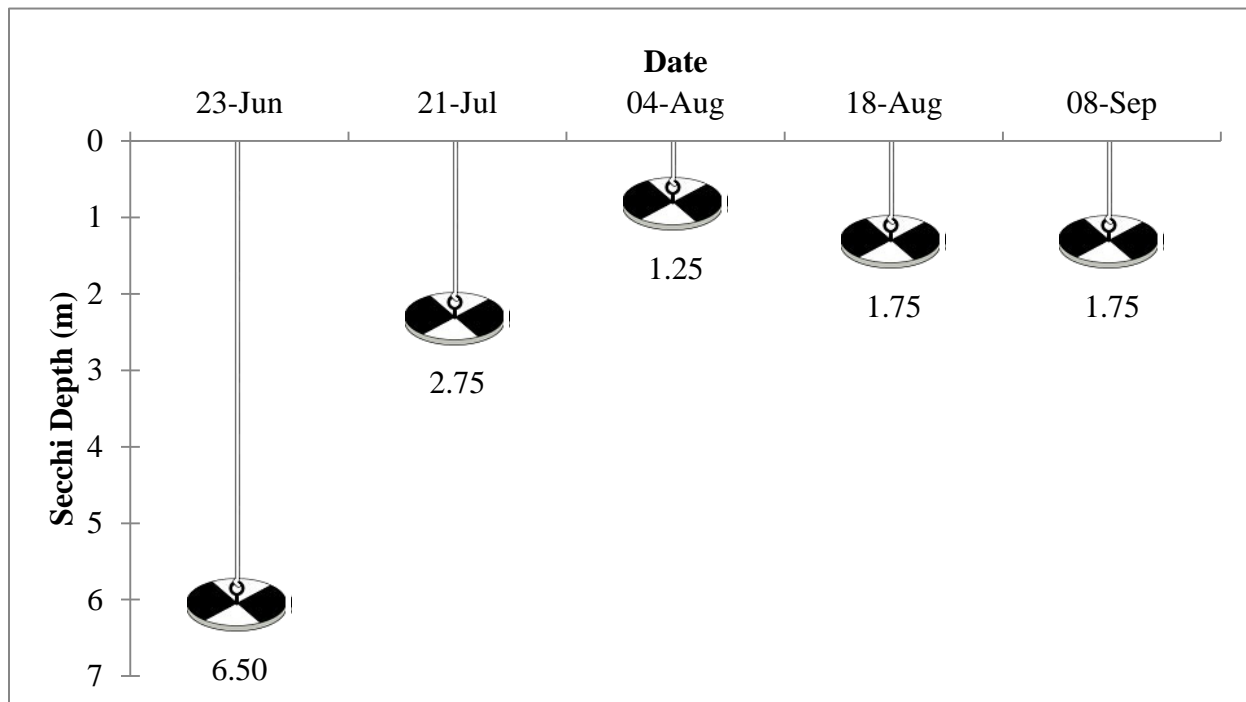
Figure 3 – Secchi depth values measured five times over the course of the summer at Lac la Nonne in 2015.

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.

Thermal stratification was present in Lac la Nonne on each of the five sampling trips in 2015 (Figure 4a). Thermal stratification began as early as 6.5 m on August 4th and was weak in both June and September. Water temperatures were not overly warm at the surface – on August 4th a maximum seasonal surface water temperature of 21.48°C was observed. However, water temperatures did not decrease dramatically with depth. At the lakebed, a minimum seasonal water temperature of 10.14 °C was observed.

Dissolved oxygen concentrations were greatly impacted by the thermal stratification present in Lac la Nonne. Up until September, dissolved oxygen concentrations above the thermocline remained above the Canadian Council for Ministers of the Environment guidelines of 6.5 mg/L for the Protection of Aquatic Life (Figure 4b). Below the thermocline, however, dissolved oxygen concentrations regularly proceeded toward anoxia. On September 8th, the entire water column fell below the CCME PAL guidelines. A decrease in dissolved oxygen concentrations throughout the water column is not uncommon as thermal stratification begins to break down and surface waters are mixed with anoxic bottom waters.
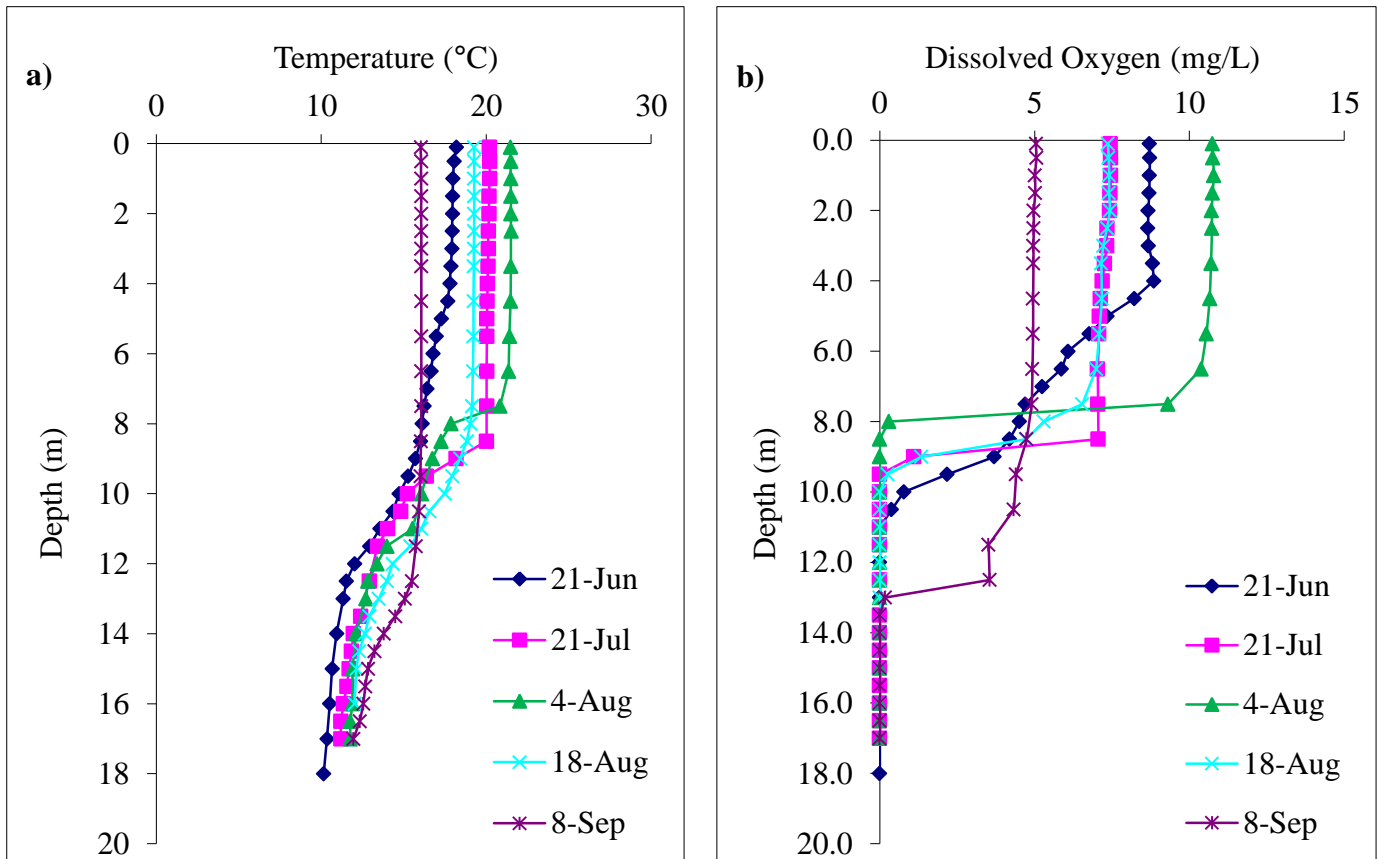
Figure 4 – a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Lac la Nonne measured five times over the course of the summer of 2015.

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 1 for a complete list of parameters.

Average total phosphorus (TP) measured 204 µg/L in 2015 (Table 2). This average falls well into the hypereutrophic, or very productive, classification. In addition, this average falls on the high end of the historical variation previously recorded at Lac la Nonne. Throughout the summer, TP peaked in mid-August, reaching 230 µg/L on August 4th (Figure 5).

Average chlorophyll-*a* concentration measured 24.8 µg/L in 2015. This value falls on the low end of the historical variation previously observed at Lac la Nonne and falls into the eutrophic, or productive, classification. This lower concentration of chlorophyll-*a* is likely responsible for the higher water clarity values observed in 2015. Throughout the summer, chlorophyll-*a*

measured a minimum of 3.50 µg/L on June 23rd and a maximum of 41.4 µg/L on August 18th (Figure 5).

Finally, total Kjeldahl nitrogen (TKN) measured an average of 1.8 mg/L in 2015. This value falls on the low end of the historical variation previously observed at Lac la Nonne.
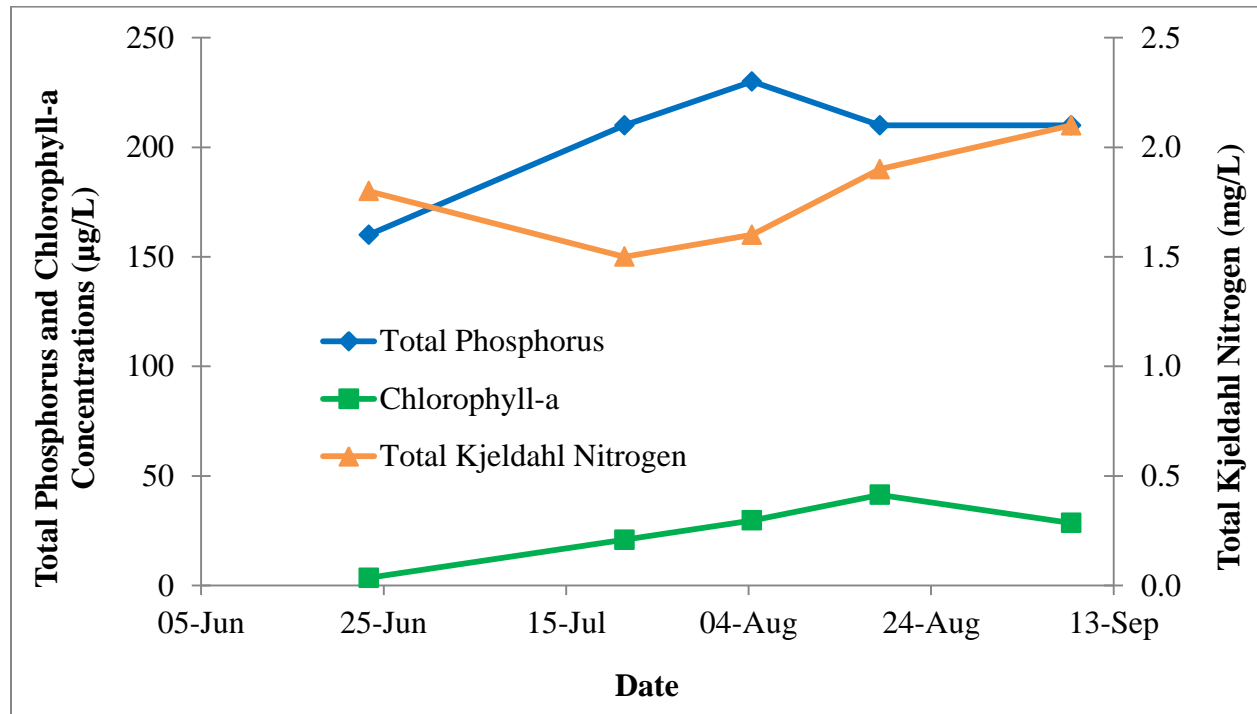
Figure 5 – Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentration measured five times over the course of the summer at Lac la Nonne.

Average pH measured 8.57 in 2015 – this average is well above neutral. Lac la Nonne is buffered against changes to pH due to its alkalinity (170 mg/L $CaCO_3$) and bicarbonate (190 HCO_3) concentrations. Conductivity in Lac la Nonne measured 364 µS/cm in 2015, with dominant contributing ions as calcium (28 mg/L) and sodium (26 mg/L) (Table 2).

Metals were measured three times at Lac la Nonne and all average concentrations fell within their respective guidelines (Table 3).

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.

In 2015, microcystin concentrations from composite samples fell below the recommended guidelines of 20 µg/L. Microcystin concentration peaked in September, likely due to a shift in the cyanobacteria community composition (Table 1). All cyanobacteria blooms should be treated with caution.

Table 1 – Microcystin concentrations measured five time at Lac la Nonne in 2015.

Date	Microcystin Concentration (µg/L)
June 23	0.30
July 21	3.90
August 4	3.27
August 18	2.76
September 8	5.85
Average	**6.366**

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 Lac la Nonne.

Table 2 - Average Secchi disk depth and water chemistry values for Lac la Nonne. Previous years averages are provided for comparison.

Parameter	1983	1988	1989	1990	2001	2002	2003	2004	2008	2011	2014	2015
TP (µg/L)	320	168	178.62	252.02	183	167	148	153.66	155	213	219	204
TDP (µg/L)	191.2	104	112.65	/	147	98	101	118.17	95	157	20	152
Chlorophyll-a (µg/L)	108	55.5	60.1	120.73	22	43	28	39.98	35.8	30.4	62.75	24.8
Secchi depth (m)	0.60	1.90	1.91	1.47	2.40	0.70	2.10	2.39	1.80	1.98	1.35	2.80
TKN (mg/L)	2.6	2.2	2.1	/	5.6	3.4	1.6	1.9	1.8	1.8	2.1	1.8
NO_2 and NO_3 (µg/L)	12.75	<8	22.83	10	3	3	2.3	61	1.3	7	41.3	40.4
NH_3 (µg/L)	15	43	88.5	/	32	6	9	300.5	79	40	24.5	134
DOC (mg/L)	/	/	16.43	/	/	/	/	16.15	15.8	15.7	18.05	16.8
Ca (mg/L)	30	33	33	30.33	31	/	9	24.35	79	25.5	30.05	28
Mg (mg/L)	9	10	9.75	10	10	/	11	10.10	11.1	11.5	11.4	12
Na (mg/L)	17	17	17.5	15	18	/	21	24.78	23.4	23.6	26.75	26
K (mg/L)	8.7	10	9.75	9.6	11	/	11	11.73	12	12.5	14.95	14
SO_4^{2-} (mg/L)	12	14	13	11.33	12	/	13	13.75	8.3	7	14	16
Cl^- (mg/L)	2	3	2.617	3	5	/	4	4.5	5.4	5.95	6.65	7.1
CO_3 (mg/L)	10	/	13.63	24.67	/	/	/	/	/	7.75	19.75	5.8
HCO_3 (mg/L)	148	/	166.75	133.33	/	/	/	178.5	/	174.5	194.5	190
pH	8.7	8.1-9.0	8.432	9.33	9	/	8.4	8.16	8.7	8.8	8.99	8.57
Conductivity (µS/cm)	292	314	316.33	297.67	337	/	333	317.75	330	337	347.5	364
Hardness (mg/L)	112	/	122.67	117.33	/	/	/	102.48	120	111	122	122
TDS (mg/L)	/	/	175.20	169.67	/	/	/	177.5	184	180	213.5	204
Microcystin (µg/L)	/	/	/	/	/	/	/	/	/	0.79	1.69	3.22
Total Alkalinity (mg/L $CaCO_3$)	138	149	148.83	150.33	154	/	161	146	157	157	159.5	170

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

Table 3 - Average concentrations of metals measured in Lac la Nonne Lake on June 23rd, August 4th, and September 8th. 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)	2004	2014	2015	Guidelines
Aluminum µg/L	16.955	18.8	26.3333	100[a]
Antimony µg/L	3.0335	0.054	0.0587	6[e]
Arsenic µg/L	1.52	0.969	0.9990	5
Barium µg/L	48.65	43.5	62.5333	1000[e]
Beryllium µg/L	0.00825	0.004	0.0040	100[d,f]
Bismuth µg/L	0.0005	0.0005	0.0052	/
Boron µg/L	56.7	50.2	66.2	5000[ef]
Cadmium µg/L	0.017	0.012	0.0013	0.085[b]
Chromium µg/L	0.24	0.45	0.27	/
Cobalt µg/L	0.09605	0.02	0.0370	1000[f]
Copper µg/L	0.53	0.26	0.3033	4[c]
Iron µg/L	5.25	18.1	19.9667	300
Lead µg/L	0.11155	0.041	0.0233	7[c]
Lithium µg/L	13.55	11.6	16.0333	2500[g]
Manganese µg/L	34.1	20.1	79.6	200[g]
Mercury @ Surface ng/L	/	/	0.32	26
Mercury @ Bottom ng/L	/	/	1.06	26
Molybdenum µg/L	0.2355	0.109	0.1213	73[d]
Nickel µg/L	0.165	0.004	0.1827	150[c]
Selenium µg/L	0.8	0.1	0.0300	1
Silver µg/L	0.06512	0.001	0.0017	0.1
Strontium µg/L	153	169	179	/
Thallium µg/L	0.50075	0.0016	0.0013	0.8
Thorium µg/L	0.00215	0.00045	0.0021	/
Tin µg/L	0.051	0.016	0.0253	/
Titanium µg/L	0.97	1.44	2.0600	/
Uranium µg/L	0.164	0.106	0.1137	100[e]
Vanadium µg/L	0.429	0.32	0.2333	100[f,g]
Zinc µg/L	7.35	0.9	0.3167	30

Values represent means of total recoverable metal concentrations.
[a] Based on pH $\geq$ 6.5; calcium ion concentrations $[Ca^{+2}] \geq 4$ mg/L; and dissolved organic carbon concentration $[DOC] \geq 2$ 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
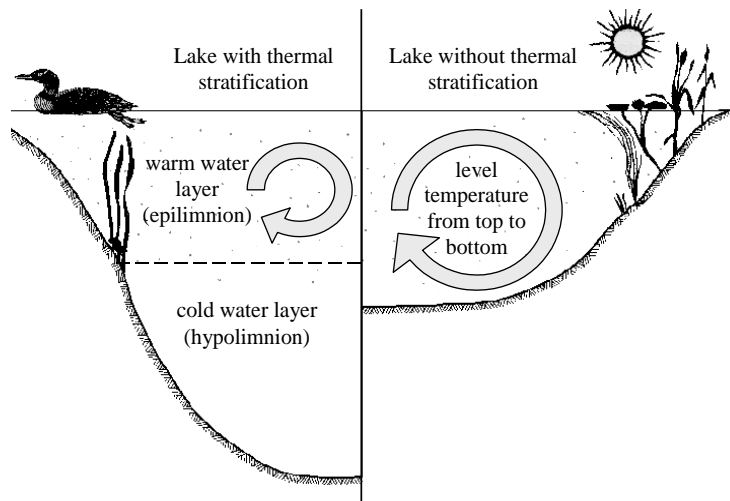

Figure A: Difference in the circulation of the water column depending on thermal stratification.

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.

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•L^{-1} and should not average less than 6.5 mg•L^{-1} over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 mg•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.
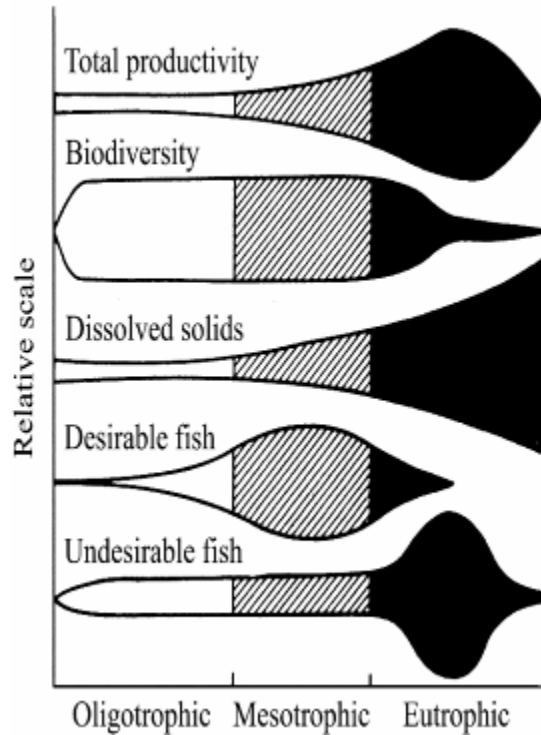

Figure B: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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