Lakewatch

The Alberta Lake Management Society Volunteer Lake monitoring report

Lac La Nonne

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2008 Report

Completed with support from:

Alberta Environment

Alberta Lake Management Society

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> *And you really live by the river? What a jolly life!"*
> *"By it and with it and on it and in it," said the Rat. "It's brother and sister to me. What it hasn't got is not worth having, and what it doesn't know is not worth knowing." Kenneth Grahame The Wind in the Willows*
> *"The world's supply of fresh water is running out. Already one person in five has no access to safe drinking water."*
> *BBC World Water Crisis Homepage*

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 these 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.

Acknowledgements

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Lac La Nonne

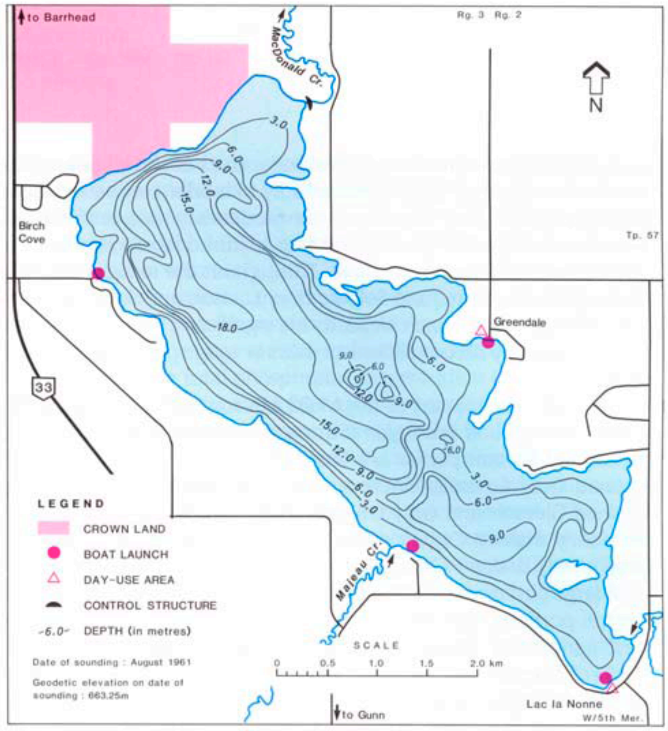

Figure 1. Bathymetry of Lac La Nonne. From Mitchell and Prepas (1990).

Lac La Nonne is 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. This is a highly developed and popular recreational lake. The closest large population centre is the town of Barrhead located 20 km to the north. The name of the lake, "the nun" in French, has an uncertain origin. In 1827, Edward Ermatinger recorded the lake's name in his journal as Lac La Nane. It has been suggested that the name comes from the White-winged Scoter, a duck with features similar to ducks in England known as "the nun". The Hudsons's Bay Company established a trading post at the lake in the early 1800s, and by the 1830s there were many Métis and by the 1870s a Catholic mission had been established. In the 1890s several families had settled around the lake, and by 1912 most of the available land had been homesteaded. Killdeer Beach Resort and Elksbeach Campground are the two commercial facilities at the lake. No commercial fisheries exist on the lake although sport fishery, with the main catches being walleye (*Sander vitreus*) and northern pike (*Esox lucius*), is very popular in the summer.

Land acquisition around this lake and cottage development on the shoreline increased through to the 1970s until most of the shoreline became privately owned. Many cottages have been winterized and general lake use has intensified over the last half of the 1900s. Due to concerns about the quality of the lake, further development around the lake was halted through regulations enforced by Alberta Environment.

Earlier studies showed that nutrients in Lac La Nonne were highly abundant (309 µg TP/L) and that 97% of the summer algal biomass was made up of blue-greens (Mitchell and Prepas 1990). Phosphorus loading—a major determinant of blue-green algal blooms—has been determined to come from surface runoff and Majeau Creek, but the internal loading rate, likely to be very significant, has not yet been determined (Mitchell and Prepas 1990).

Water Level

The water levels of Lac La Nonne have been recorded regularly since 1972. The maximum recorded lake level was 664.4 m in the spring of 1974. The minimum lake level occurred recently on October 28, 2003 when it reached 662.741 m. Declining water levels have occurred throughout Alberta in recent years due to below-average precipitation. Lac LaNonne is no exception: water levels in 2003 were about 1 m lower than in 1998, and in 2009 were 0.05 m (5 cm) below 2003 levels. If dry conditions persist, low water levels in Lac La Nonne may continue.

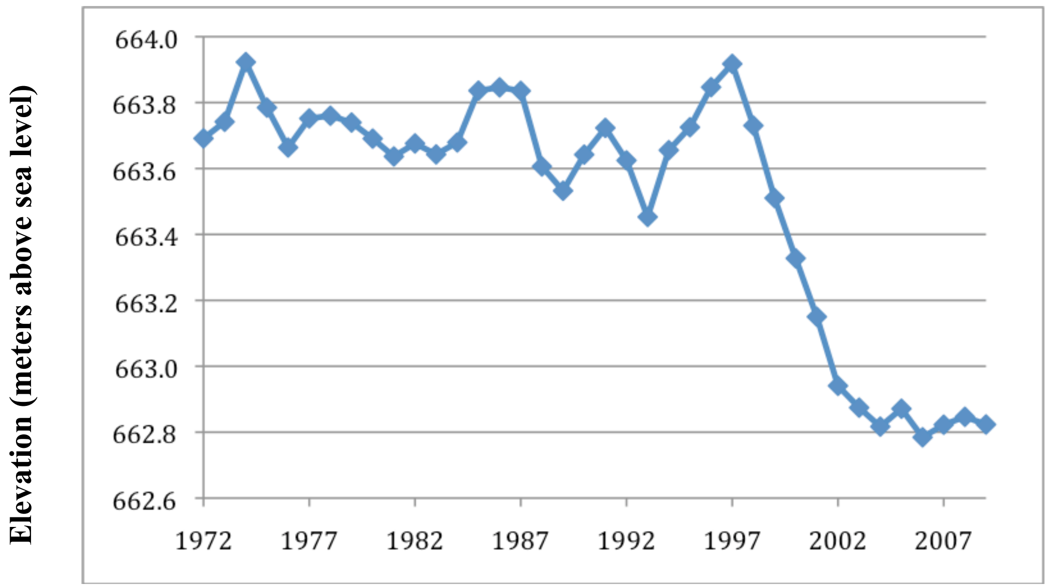

Figure 2. Historical mean annual water levels (meters above sea level (asl)) in Lac La Nonne, Alberta 1972 – 2009.

Results

Water temperature and dissolved oxygen

Thermal stratification in Lac La Nonne was observed during the summer 2008 (**Figure 3**). On 12 June, a weak thermocline was present at 7 m depth, and water temperature decreased from 16.2°C at the surface to 11.0°C in the hypolimnion. By 4 July, the thermocline depth had risen to 3 m, and surface waters had warmed to 22.8°C. On 25 July, the surface water temperature remained similar but the thermocline intensity weakened and dropped to 7 m depth. Surface waters cooled to 21.4°C by 18 August, and the thermocline increased in intensity while dropping to 8 m depth. By 12 September, surface waters cooled significantly to 15.6°C and no thermocline was evident; the isothermic lake waters indicate that fall turnover had occurred prior to the final sampling date.

Dissolved oxygen (DO) concentrations in upper layers of surface waters of Lac La Nonne were ≥ 5 mg/L on all sampling dates through the summer, within the acceptable range for surface water quality (DO ≥ 5.0 mg/L) (**Figure 3**). DO concentrations declined at a depth of 7 m in June and 3 m in July. The weak chemocline remained at 3 m through August, and then dropped to 14 m depth after fall turnover in September. On all sample dates except 14 September, DO was near zero (e.g. anoxic) from the 11 m depth down to the lakebed. Fall turnover reduced oxygen in surface waters to near the 5.0 mg/L guideline. Deep-water anoxia is common in summer, and the decomposition of organic matter produced during the open water season continues on into the winter months, which in turn, leads to low winter oxygen concentrations (as decomposition consumes oxygen).

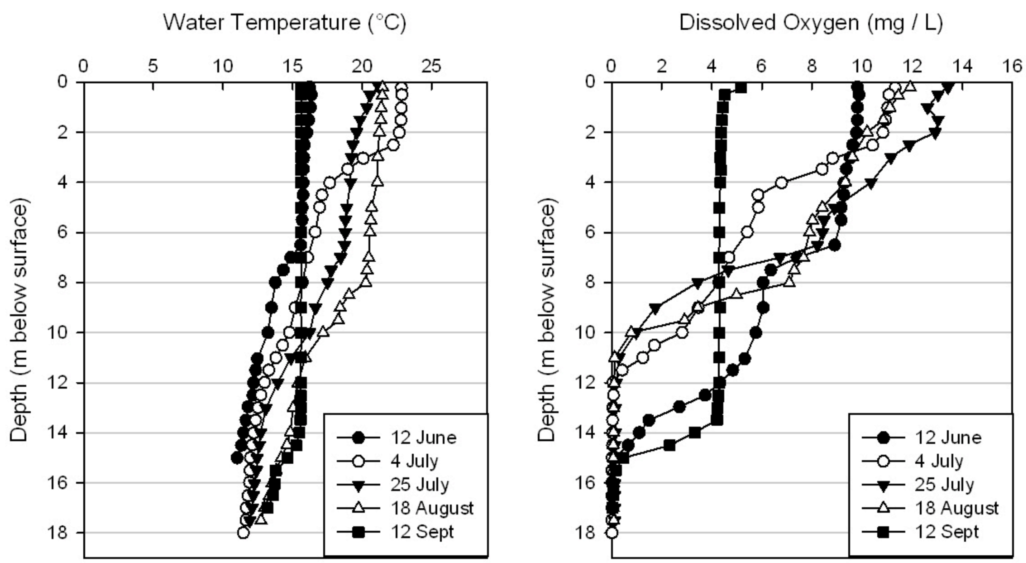

Figure 3. Water temperature (°C) and dissolved oxygen (mg/L) profiles for Lac La Nonne during the summer of 2008.

Water clarity and Secchi Disk Depth

Water clarity is influenced by suspended material, both living and dead, as well as some coloured dissolved compounds in the water column. The most widely used measure of lake water clarity is the Secchi disk depth. Following the period of ice and snowmelt, a lake can have low clarity due to spring runoff and the inflow of suspended sediments into the lake. Lake water usually clears in the spring but then becomes more turbid due to algal growth taking place throughout the summer open water season.

Water clarity on Lac La Nonne was measured five times during the summer of 2008. Lac La Nonne was neither exceptionally turbid nor exceptionally clear compared to other lakes in Alberta, with average Secchi disk depth = 1.8 m (**Table 1**). In June, light penetrated 2.75 m or ~16% of the total lake depth, which allowed for algal growth in the top 5.5 m of the lake. By 4 July, Secchi disk depth had decreased to 2 m, and dropped further to 1.4 m on 25 July and reached a minimum of 0.75 m on 18 August. Water clarity increased more than two-fold from this minimum in mid-September, recovering to a Secchi disk depth of 2 m. This pattern of water clarity dynamics is typical of highly productive Alberta lakes, when algal growth during July and August causes reduced water clarity. Water clarity recovers in September as lower temperatures limit growth, and dying algae fall out of the water column and settle on the lakebed where they are decomposed by anaerobic bacteria.

Water chemistry

Based on lake water characteristics, Lac La Nonne is considered hypereutrophic (see *A Brief Introduction to Limnology* at the end of this report). Average total phosphorus (TP = 154.8 μg/L) and total Kjeldahl nitrogen (TN = 1840 μg/L) concentrations were within the hypereutrophic range in 2008 (**Table 1**). Chlorophyll *a* (chl *a* = 35.8 μg/L) was also within the hypereutrophic range.

Total phosphorous increased over the summer, from 95 μg/L on 12 June to a maximum of 195 μg/L on 18 August (**Figure 4**). The observed pattern is opposite that of most lakes in Alberta (in which total phosphorous typically declines through the summer, as algal growth consumed nutrients in the water column) and indicates internal (e.g. phosphorous release from lake bottom sediments) or external (e.g. phosphorous additions from land-use practices in the watershed) phosphorous loading into the lake throughout the summer.

Total nitrogen followed a similar pattern of increase, from a minimum of 1.24 mg/L on 12 June to a maximum of 2.38 mg/L on 18 August. The decrease in total nitrogen and total phosphorous by 12 September is likely due to fall turnover, which mixes the water column. Chlorophyll *a* (a measure of algal biomass) responded strongly to the high nutrient concentrations, increasing from 7.79 μg/L on 12 June to a maximum of 72.1 μg/L on 25 July. After this bloom, chl *a* concentrations declined to 59.3 μg/L on 18 August (still within the hypereutrophic range) and to 25.4 μg/L after fall turnover in September. It is likely that this late-summer algal bloom resulted from internal loading of phosphorus. In shallow lakes, phosphorus is frequently released from the deeper sediments during calm periods in summer, and from shallow sediments throughout the summer.

During the summer 2008, Lac La Nonne was well buffered from acidification with an average pH = 8.65, which is well above that of pure water (i.e., pH 7). Dominant ions include bicarbonate, carbonate, and ammonium (**Table 1**). No obvious changes in ion concentration in Lac La Nonne are apparent from the four sampling years since 1988. The average concentrations of various heavy metals (as total recoverable concentrations) in Lac La Nonne were not measured in the summer of 2008.

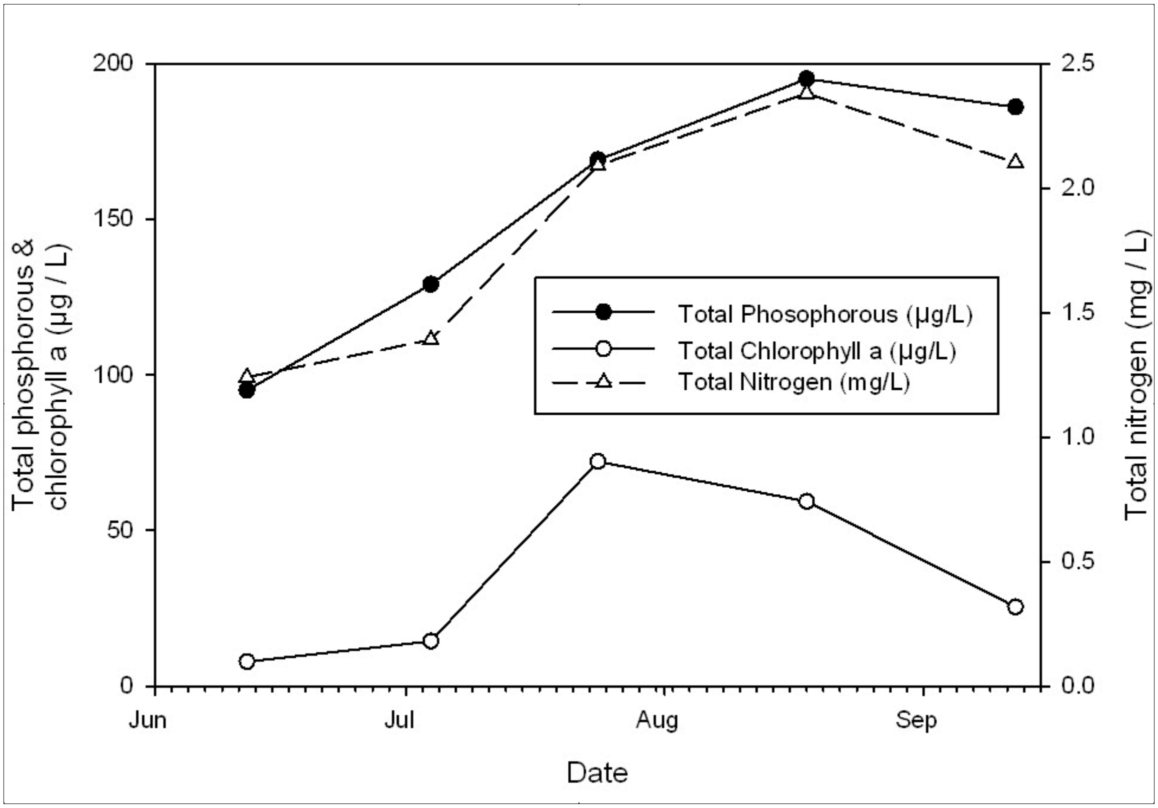

Figure 4. Total phosphorous, chlorophyll a (a measure of algal biomass), and total nitrogen concentrations for Lac La Nonne during the summer of 2008.

Table 1. Water chemistry values for Lac La Nonne, summer 1988 - 2008.

Parameter	1988	2001	2003	2008
TP (μg/L)	168	183	148	155
TDP (μg/L)	104	147	101	95
Chlorophyll-*a* (μg/L)	55.5	22	28	35.8
Secchi disk depth (m)	1.9	2.4	2.1	1.8
TKN (μg/L)	2.23	5.55	1.64	1.84
$NO_{2,3}$ (μg/L)	<8	3	2.3	1.3
NH_4 (μg/L)	43	32	9	79
Dissolved organic C (mg/L)	-	-	-	15.8
Ca (mg/L)	33	31	32	29.8
Mg (mg/L)	10	10	11	11.1
Na (mg/L)	17	18	21	23.4
K (mg/L)	10	11	11	12.0
SO_4^{2-} (mg/L)	14	12	13	8.3
Cl^- (mg/L)	3	5	4	5.4
TDS (mg/L)	-	-	-	184
pH	8.1 – 9.0	9	8.4	8.7
Conductivity (μS/cm)	314	337	333	330
Hardness (mg/L)	-	-	-	120
HCO_3 (mg/L)	164	175	180	173
CO_3 (mg/L)	<9	6	10	13.5
Total Alkalinity (mg/L $CaCO_3$)	149	154	161	157

Note: TP = total phosphorous, TDP = total dissolved phosphorous, Chla = chlorophyll *a*, TKN = total Kjeldahl nitrogen, NO_{2+3} = nitrate+nitrite, NH_4 = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulphate, Cl = chloride, CO_3 = carbonate, HCO_3 = bicarbonate.

*Atlas of Alberta Lakes (Mitchell and Prepas, 1990).

References

Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes. University of Alberta Press.

Vollenweider, R.A., and J. Kerekes, Jr. 1982. Eutrophication of Waters. Monitoring, Assessment and Control. Organization for Economic Co-Operation and Development (OECD), Paris. 156p.

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A brief introduction to Limnology

Indicators of water quality

The goal of **Lakewatch** is to collect water samples necessary to determine the water quality of lakes. Though not all encompassing, the variables measured in **Lakewatch** are sensitive to human activities in watersheds that may cause impacts to 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 affected (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 fish habitat and production of noxious odors. Large increases in nutrients over time may also indicate sewage inputs, which in turn, may result in other human health concerns such as harmful bacteria or protozoans (e.g. *Cryptosporidium*).

Temperature and mixing

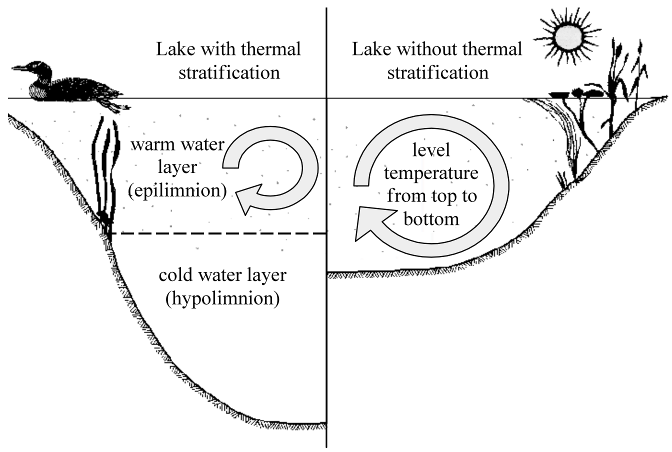

Figure 6: Difference in the circulation of the water column depending on thermal stratification.

Water temperature in a lake dictates the behavior of many chemical parameters responsible for water quality (Figure 6). 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 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 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 and should not average less than 6.5 mg/L over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 mg/L 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. Larger aquatic plants, known as macrophytes, rather than algae, dominate some highly productive lakes. In these lakes, chlorophyll-*a* and nutrient values taken from water samples do not include productivity from large aquatic plants. As a result, lakes like Chestermere, which are dominated by macrophytes, can exist at 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 Depth

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. Secchi disk depth is the oldest, simplest, and quickest quantitative measure of water clarity. A Secchi disk is a black and white disk that is lowered down through the water column until it can no longer be seen. Secchi disk depth is the midpoint between the depth at which it disappears when lowered and reappears when it is pulled up again. The Secchi disk depth in lakes with high algal biomass will generally be shallow. However, Secchi disk depth is not only affected by algae. 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 shallow Secchi disk depths despite low algal growth and nutrient concentrations.

The euphotic zone, calculated as twice the Secchi disk depth, is the portion of the water column that has sufficient light for aquatic plants to grow. Murky waters, with shallow Secchi depths, can prevent aquatic plants from growing on the lake bottom. Aquatic plants are important because they ensure clear lake water by reducing shoreline erosion and stabilizing lake bottom sediments. Many lakes in Alberta are shallow and have bottom sediments with 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 fish, depend on aquatic plants for food and shelter.

Trophic state

Trophic state is a classification system for lakes that depends on fertility and is a useful index for rating and comparing lakes. From low to high nutrient and algal biomass (as chlorophyll-*a*) concentrations, the trophic states are: **oligotrophic**, **mesotrophic**, **eutrophic** and **hypereutrophic**. The nutrient and algal biomass concentrations that define these categories are shown in table 2 and a graph of Alberta lakes compared by trophic state can be found on the ALMS website. A majority of lakes in Alberta are meso- to eutrophic because they naturally contain high nutrient concentrations due to our deep fertile soils. Thus, lakes in Alberta are susceptible to human impacts because they are already nutrient-rich; any further nutrient increases can bring about undesirable conditions illustrated in Figure. 7.

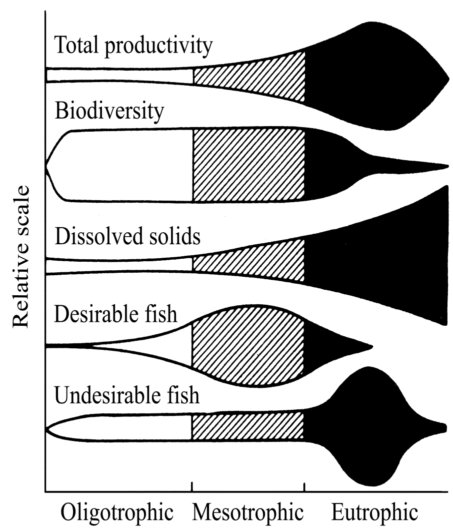

Figure 7: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

Table 2: Trophic status based on lake water characteristics

Trophic state	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll a (µg/L)	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

Note: These values are from a detailed study of global lakes reported in Nurnberg 1996. Alberta Environment uses slightly different values for TP and CHL based on those of the OECD reported by Vollenweider (1982). The AENV and OECD cutoffs for TP are 10, 35 and 100; for CHL are 3, 8 and 25. AENV does not have TN or Secchi depth criteria. The corresponding OECD exists for Secchi depth and the cutoffs are 6, 3 and 1.5 m.