Lakewatch

THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2011 Lac La Nonne Report

COMPLETED WITH SUPPORT FROM:

Alberta
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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.

Acknowledgements

The LakeWatch program is made possible through the dedication of its volunteers. We would like to thank Stan and Cathy Dezaeyer for volunteering their time to assist with sampling. We would also like to thank Jessica Davis and Pauline Pozsonyi who were LakeWatch technicians with ALMS in 2011. Program Coordinator Bradley Peter was instrumental in planning and organizing the field program. Technologists Shelley Manchur and Brian Jackson were involved in the training aspects of the program. Doreen LeClair, Chris Rickard, and Lisa Reinbolt were responsible for data management. The 2011 report was updated and prepared by Bradley Peter. Alberta Environment, the Beaver River Watershed Alliance (BRWA), and the Municipal District of Wainwright were major sponsors of the LakeWatch program.

LAC LA NONNE:

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

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.

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 dropped just over one meter since measurements began in 1972.

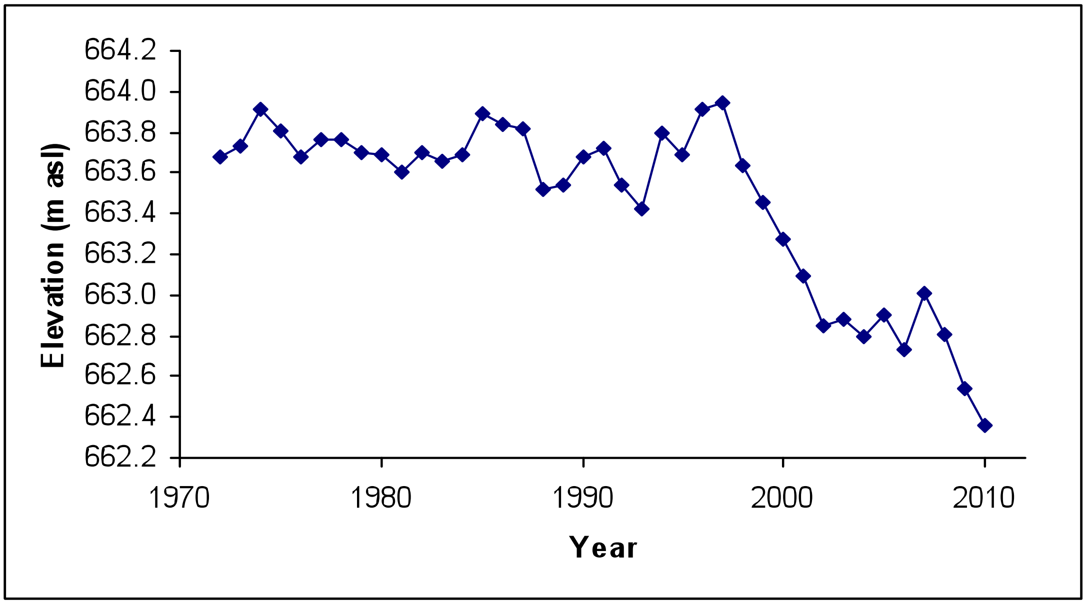

Figure 2 – Water levels at Lac La Nonne measured from 1972-2010. Measurements in meters above sea level (m asl) obtained from Environment Canada.

WATER CLARITY & 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 disk depth measured throughout the summer was 1.98 m, which falls well within the historical variation seen at Lac La Nonne (Table 1). A maximum Secchi disk depth of 4.0 m was measured on June 30th, and a minimum of 1.75 m was measured on July 27th. It is common for Secchi disk depth to decrease throughout the summer in Alberta's lakes, as algae/cyanobacteria densities increase throughout the summer due to increased temperature and nutrients, negatively affecting water transparency.

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 at Lac La Nonne in 2011 changed greatly throughout the summer (Figure 3a). Temperatures ranged from 17.32 °C on June 30th to 21.10 °C on August 14th. Weak thermal stratification was observed only on June 30th and August 28th. Stratification events contribute to the depletion of oxygen observed in the lower portions of the water columns in many lakes throughout Alberta.

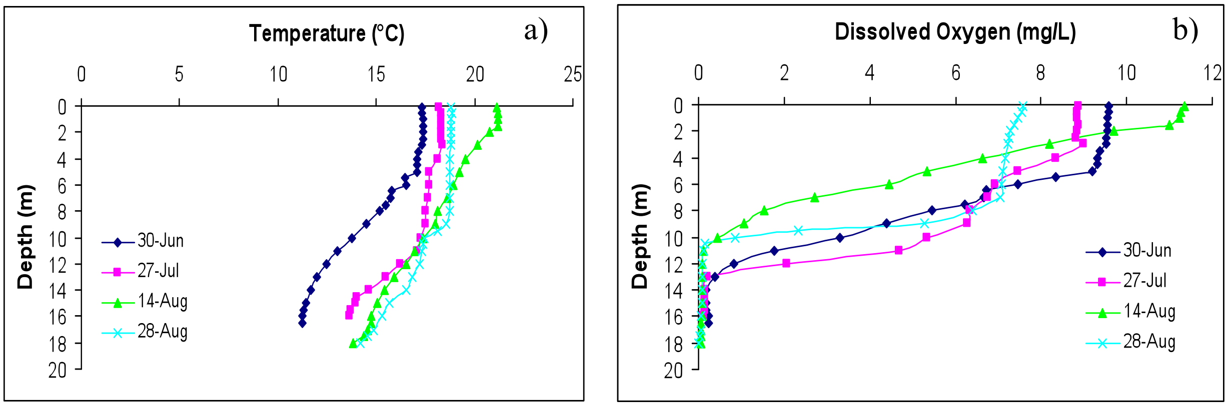

Figure 3 - a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Lac La Nonne in 2011.

Surface dissolved oxygen changed greatly throughout the summer at Lac La Nonne (Figure 3b). On August 28th, surface dissolved oxygen was at a seasonal minimum of 7.57 mg/L. This is in contrast to August 14th, when dissolved oxygen was at a seasonal maximum of 11.36 mg/L. Based on the pattern of dissolved oxygen and temperature depletion measured on August 28th, it appears the lake was beginning to mix, though no September sample was obtained in order to confirm this. During all of the sampling trips dissolved oxygen proceeded to anoxia in the bottom 3/4ths of the water column. This pattern is typical in Alberta lakes as decomposition of organic matter, such as algae/cyanobacteria, on the lake bed is an oxygen-consuming process.

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 Phosphorous (TP) measured in Lac La Nonne in 2011 was 212.8 µg/L, which falls into the hypereutrophic, or extremely productive, classification. 212.8 µg/L is the highest average measured in recent years (Table 1). TP increased throughout the summer, measuring 144 µg/L on June 30th and 266 µg/L on August 14th (Figure 5). An increase in total phosphorous throughout the summer is suggestive either of internal loading from the lake sediments or of an external source. Given that 2011 was a high run-off year, it is possible that this caused an increase in nutrients. Earlier studies showed that nutrients in Lac La Nonne were highly abundant (Table 1) and that 97% of the summer algal biomass was made up of blue-greens.[1] Phosphorous loading 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.[2]

Figure 4 – Cyanobacterial bloom on the surface of Lac La Nonne. Photo by Jessica Davis

Similarly, Total Kjeldahl Nitrogen (TKN) measured an average of 1780 µg/L, which also falls into the hypereutrophic classification. TKN steadily increased throughout the summer, measuring 1580 µg/L on June 30th and 1920 µg/L on August 28th (Figure 5).

Finally, average chlorophyll-*a* concentration, an indirect measure of algal/cyanobacterial biomass, measured 30.38 µg/L, which also falls into the hypereutrophic classification. Chlorophyll-*a* was low in June, measuring only 10.8 µg/L, though by August 14th had increased to a seasonal maximum of 41.0 µg/L (Figure 5). An average of 30.38 µg/L falls well within the historical variation seen at Lac La Nonne.

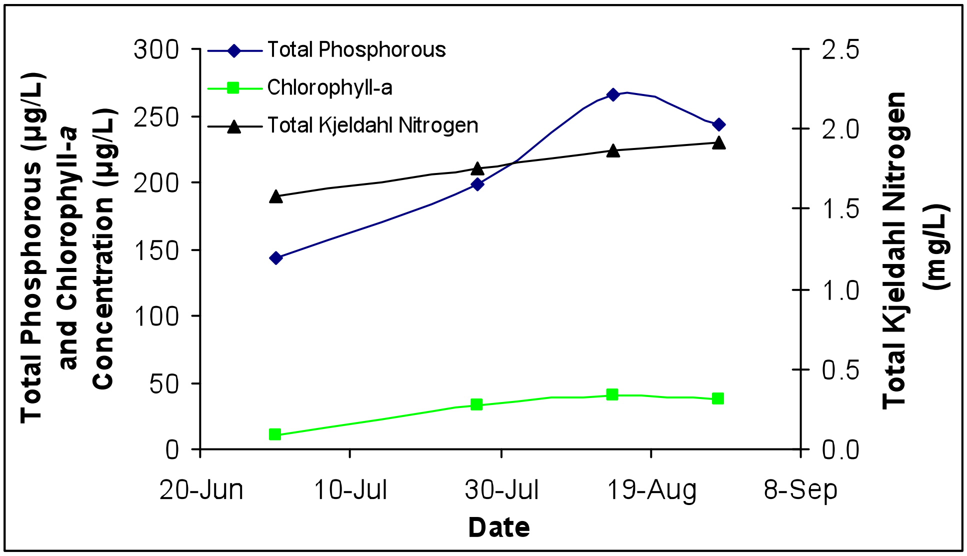

Figure 5 – Chlorophyll-*a* (µg/L), total phosphorous (µg/L), and total Kjeldahl nitrogen (mg/L) measured over the course of the summer in 2011.

Average pH measured at Lac La Nonne during the summer of 2011 was 8.77 (Table 1). This is well above neutral and common for an Alberta lake, and likely due to the high bicarbonate concentration (174.5 mg/L HCO_3) which helps to buffer the lake against changes to pH. Other ion concentrations in the lake were low – this was also confirmed by the low conductivity readings recorded throughout the summer.

Table 1 – Average Secchi disk depth and water chemistry values for 2011 at Lac La Nonne.

Parameter	**1988**	**2002**	**2003**	**2008**	**2011**
TP (µg/L)	168	183	148	155	213
TDP (µg/L)	104	147	101	95	157
Chlorophyll-*a* (µg/L)	55.5	22	28	35.8	30.4
Secchi depth (m)	1.9	2.4	2.1	1.8	1.98
TKN (µg/L)	2230	5550	1640	1840	1780
NO_2 and NO_3 (µg/L)	<8	3	2.3	1.3	7
NH_3 (µg/L)	43	32	9	79	40
DOC (mg/L)	/	/	/	15.8	15.7
Ca (mg/L)	33	31	9	79	25.5
Mg (mg/L)	10	10	11	11.1	11.5
Na (mg/L)	17	18	21	23.4	23.6
K (mg/L)	10	11	11	12	12.5
SO_4^{2-} (mg/L)	14	12	13	8.3	7
Cl^- (mg/L)	3	5	4	5.4	5.95
CO_3 (mg/L)	/	/	/	/	7.75
HCO_3 (mg/L)	/	/	/	/	174.5
pH	8.1-9.0	9	8.4	8.7	8.8
Conductivity (µS/cm)	314	337	333	330	337
Hardness (mg/L)	/	/	/	120	111
TDS (mg/L)	/	/	/	184	180
Microcystin (µg/L)	/	/	/	/	0.791
Total Alkalinity (mg/L $CaCO_3$)	149	154	161	157	157

Note: TP = total phosphorous, TDP = total dissolved phosphorous, Chl-*a* = 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. A forward slash (/) indicated an absence of data.

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:

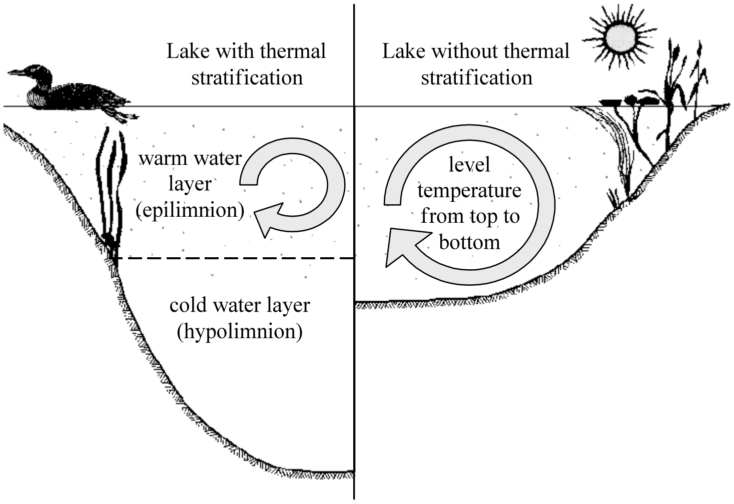

Figure A: Difference in the circulation of the water column depending on thermal stratification.

Water temperature in a lake dictates the behavior of many chemical parameters responsible for water quality. 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.

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.

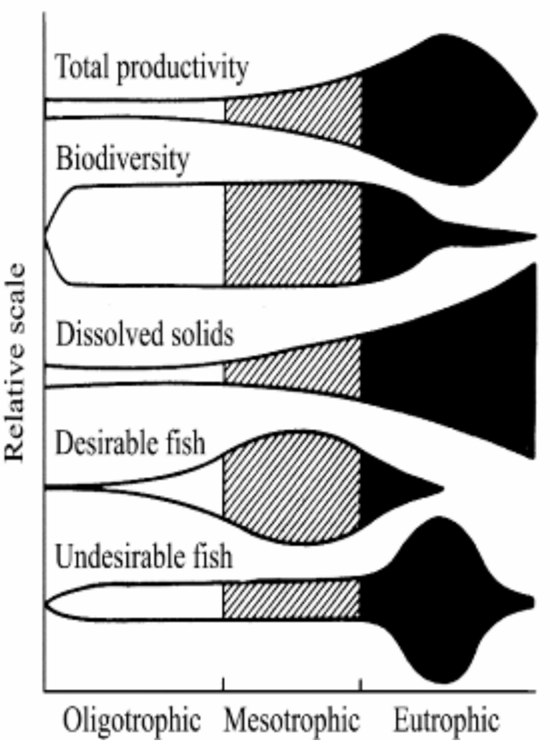

Figure B: Suggested changes in various lake characteristics with eutrophication. From “Ecological Effects of Wastewater”, 1980.

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

Trophic state	Total Phosphorus ($\mu g \cdot L^{-1}$)	Total Nitrogen ($\mu g \cdot L^{-1}$)	Chlorophyll a ($\mu g \cdot L^{-1}$)	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