THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2011 Lac Santé Report

COMPLETED WITH SUPPORT FROM:

Alberta Lake Management Society's LakeWatch Program

LakeWatch has several important objectives, one of which is to collect and interpret water quality data 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 Terry Noble for his assistance with sampling and his commitment to the LakeWatch Program. We would also like to thank Jessica Davis and Pauline Pozsonyi who were summer interns 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. Théo Charette, Ron Zurawell, Lori Neufeld, and Sarah Lord prepared the original report, which was updated for 2011 by Bradley Peter and Arin Dyer. Alberta Environment, the Beaver River Watershed Alliance (BRWA), and the Municipal District of Wainwright were major sponsors of the LakeWatch program.

Lac Santé:

Figure 1 – A view of the shoreline at Lac Santé. Photo by Pauline Pozsonyi.

Lac Santé is a relatively large lake located northeast of the Town of Two Hills. It is a multi-basin lake, and the maximum depth of the deepest basin is ~25 m. Lac Santé's catchment is largely devoted to agricultural practices, and its shoreline is well developed. The southern-most basin is the largest and deepest of four basins. The three other basins (to the northeast) are smaller and all of similar depth (15-19 m; Figure 2). Lac Santé is a dimictic lake, undergoing thermal stratification during the open water season.

The lake is located approximately 140 km northeast of Edmonton. To get to this lake, take Hwy 16 east for 86 km, turn left onto Hwy 63 for 29 km, followed by a left on Hwy 46 (past the town of Two Hills), crossing the North Saskatchewan River. Turn east on the first paved road north of the river and continue for 13 km to the lake. The boat launch is situated amongst a cluster of private lots. All campgrounds along the shores of this lake are privately owned; however, boats may be launched at the county boat launch.

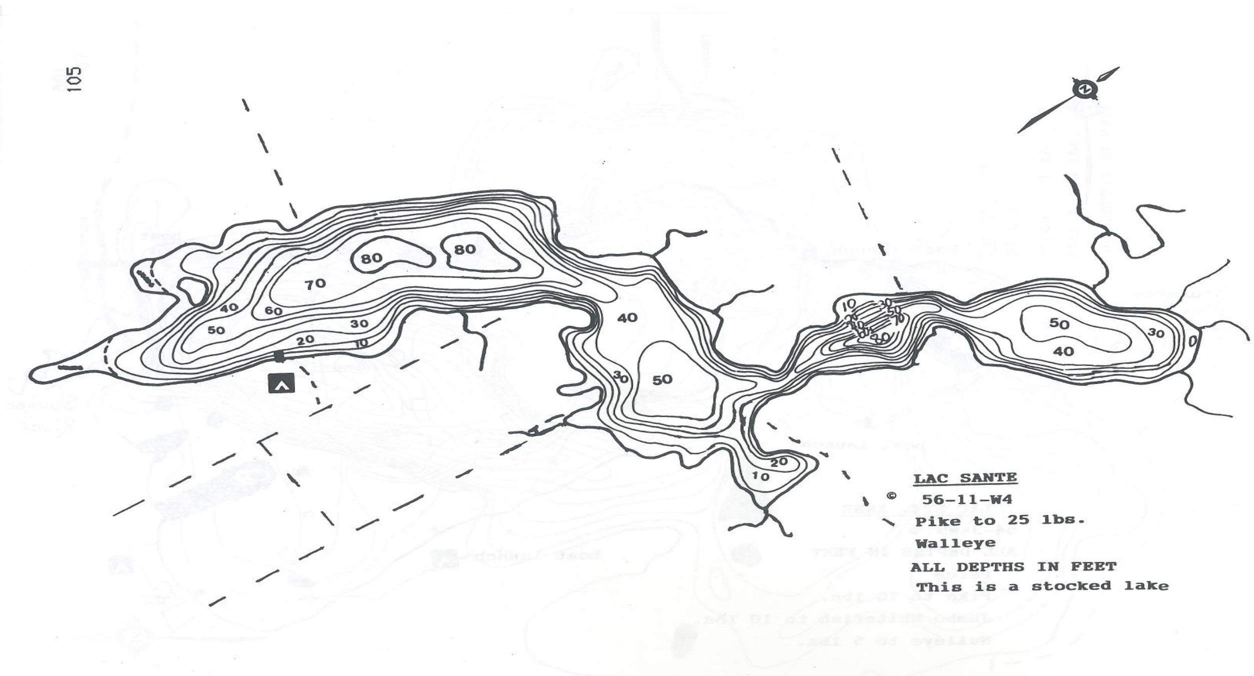

Figure 2 – Bathymetric chart of Lac Santé. Contour intervals are measured in feet.

WATER LEVELS:

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.

Water levels at Lac Santé have shown a general trend towards decline since 1981 (Figure 3). A historical maximum of 608.006 meters above sea level (m asl) was measured in 1974, and a historical minimum of 603.448 m asl was measured in 2010. Since the historical maximum, water levels have dropped approximately 4.0 m.

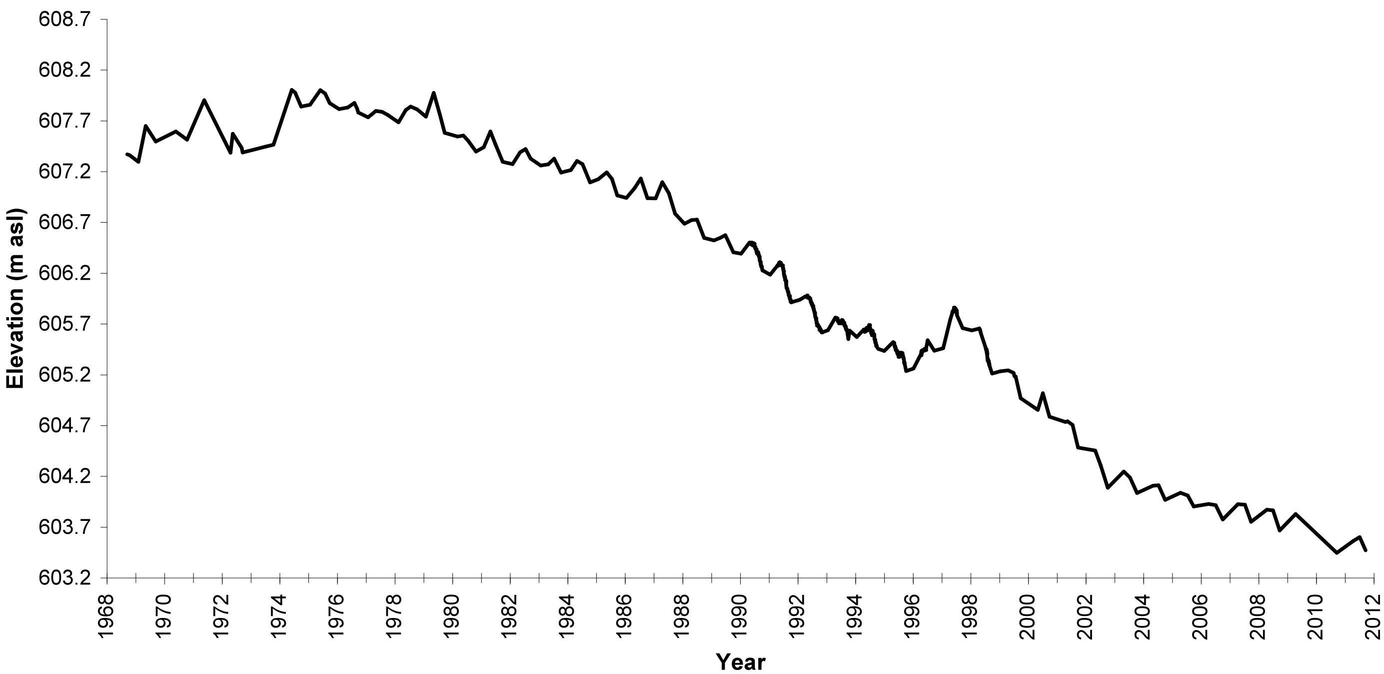

Figure 3– Water levels from 1968-2011 for Lac Santé measured in meters above sea level (m asl). Data obtained from Alberta Environment.

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.

Total average Secchi disk depth was 3.87 m during the summer of 2011. Secchi disk depth changed greatly throughout the summer, measuring a maximum of 6.75 m on June 29th and a minimum of 3.0 m on August 22nd. Decreasing transparency throughout the summer is typical in Alberta's lakes, and often reflects increasing algae/cyanobacteria concentration. The 2011 Secchi disk depth average is less than that measured from 2006-2008, likely due to higher concentrations of algae/cyanobacteria.

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 at Lac Santé changed little throughout the course of the summer, measuring a maximum of 20.66 °C on July 25th and a minimum of 15.27 °C on September 19th (Figure 4a). Due to the lakes depth, stratification was observed on each sampling date. By September, surface water temperatures became more uniform and stratification began to weaken and move deeper.

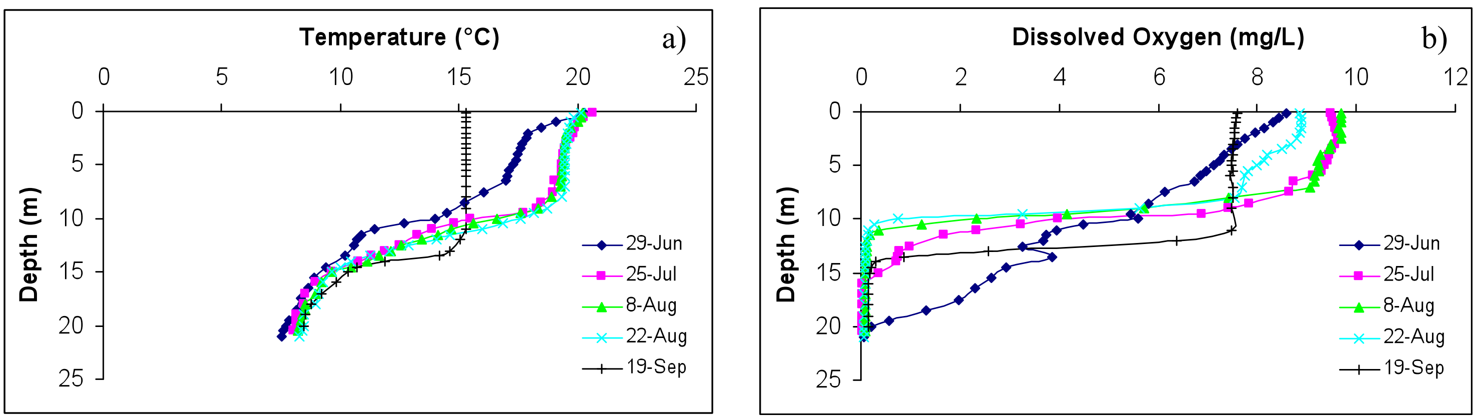

Figure 4 - a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Lac Santé in 2011.

Dissolved oxygen concentration showed dramatic declines below the thermocline at Lac Santé (Figure 4b). With the exception of June, oxygen decreased to anoxia often below 10.0 m. Decreased oxygen in the hypolimnion is common throughout the summer as decomposition of algae on the lakebed, coupled with the separation of bottom and surface waters by the thermocline, contributes to the depletion of oxygen. Above the thermocline, surface waters were well oxygenated, and remained well above the Canadian Council of Ministers of the Environment Protection of Aquatic Life guideline of 6.5 mg/L.

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) during the summer of 2011 was 61.2 μg/L, which falls into the eutrophic, or nutrient rich, classification (Figure 5). Phosphorous is an important nutrient, and often the limiting nutrient which contributes to the growth of algae and cyanobacteria. While only a few measurements of TP exist for Lac Santé, an average value of 61.2 μg/L falls above the historical average. Throughout the summer, measurements ranged from 43 μg/L on July 25th to 82 μg/L on August 8th.

Average chlorophyll-*a* concentration*,* an indirect measure of algae/cyanobacteria biomass, was 7.19 μg/L in 2011. A concentration of 7.19 μg/L falls into the mesotrophic, or moderately productive, classification. A maximum chlorophyll-*a* concentration of 12.8 μg/L was measured on July 25th which corresponds with the highest surface water temperature. A minimum chlorophyll-*a* concentration of 2.09 μg/L was measured on June 29th. Because chlorophyll-*a* concentration measured at Lac Santé is less than one would expect given the concentrations of phosphorous and nitrogen, it is possible that the lakes high salinity and conductivity help to limit algae growth.

Finally, Total Kjeldahl Nitrogen (TKN) measured 2330 μg/L in 2011, which falls into the hypereutrophic, or extremely productive classification. TKN has changed little compared to measurements taken in 2006, 2007, and 2008.

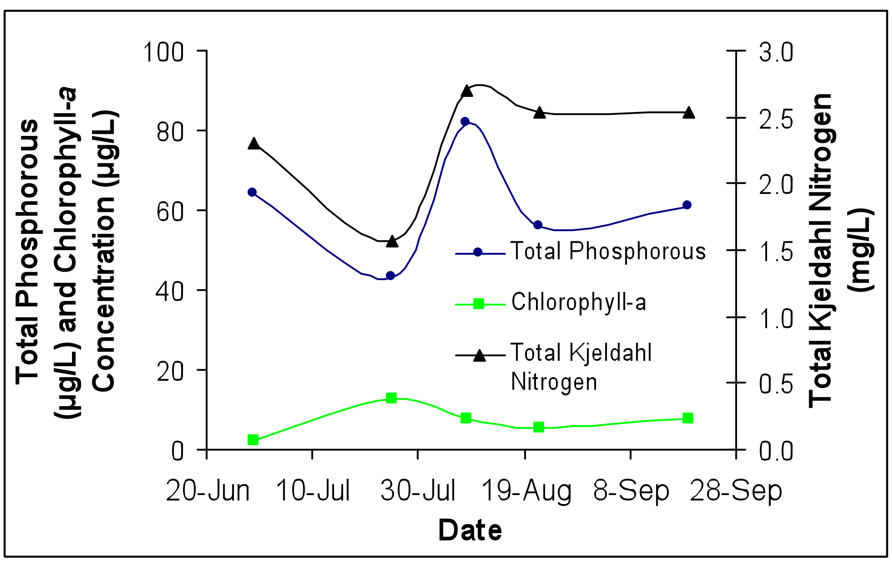

Figure 5 – Chlorophyll-*a* (μg/L), total phosphorous (μg/L), and total Kjeldahl nitrogen (mg/L) measured over the course of the summer of 2011 at Lac Santé.

Average pH measured in 2011 at Lac Santé measured 9.098, well above neutral (Table 1). This is likely maintained by high alkalinity (916.4 mg/L CaCO3) and bicarbonate (826.4 mg/L) concentrations which help to buffer lakes against changes to pH. Other dominant ions include sulphate (294.3 mg/L), sodium (218.3 mg/L), and magnesium (165.0 mg/L). High concentrations of dissolved ions contribute to the high conductivity (1940 uS/cm) seen at Lac Santé.

Metals were measured twice at Lac Santé during the summer of 2011, all metals, with the exception of arsenic, fell within their respective guidelines (Table1). Arsenic concentration in 2011 (5.43 µg/L) was slightly above the 5.0 µg/L guideline recommended by the Canadian Council for Ministers of the Environment for the Protection of Aquatic Life.

Table 1 – Average Secchi disk depth and water chemistry values for 2006, 2007, 2008, and 2011 at Lac Santé.

Parameter	**2006**	**2007**	**2008**	**2011**
TP (µg/L)	61	52	51.7	61.2
TDP (µg/L)	/	37	29	31.6
Chlorophyll-*a* (µg/L)	7.33	5.41	3.51	7.19
Secchi depth (m)	4.75	5	4.8	3.87
TKN (µg/L)	2298	2030	2243	2330
NO_2 and NO_3 (µg/L)	6.5	402	10.5	4.6
NH_3 (µg/L)	151.2	43	33.5	39.6
DOC (mg/L)	/	29.3	26.5	29.3
Ca (mg/L)	8.14	8.6	7.8	8.98
Mg (mg/L)	178.67	181	152.7	165
Na (mg/L)	209.67	212	207	218.3
K (mg/L)	48.97	51.8	49.5	52.5
SO_4^{2-} (mg/L)	295	279	282.7	294.3
Cl^- (mg/L)	16.3	16.2	16.4	17.2
CO_3 (mg/L)	148	138	140.3	143.2
HCO_3 (mg/L)	791	797	808.3	826.4
pH	9.15	9.1	9	9.089
Conductivity (µS/cm)	1873	1871	1887	1940
Hardness (mg/L)	756	/	648	702
TDS (mg/L)	1293	1280	1253	1307
Microcystin (µg/L)	/	/	/	0.169
Total Alkalinity (mg/L $CaCO_3$)	895	883	897.3	916.4

Note: TP = total phosphorous, TDP = total dissolved phosphorous, 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 at Lac Santé on June 29th and August 22nd. Values shown for 2011 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)	2011	Guidelines
Aluminum µg/L	20.1	100
Antimony µg/L	0.1525	6
Arsenic µg/L	**5.43**	**5**
Barium µg/L	4.36	1000
Beryllium µg/L	0.00435	100
Bismuth µg/L	0.0018	/
Boron µg/L	434	5000
Cadmium µg/L	0.00425	0.085
Chromium µg/L	0.3045	/
Cobalt µg/L	0.09975	1000
Copper µg/L	1.2235	4
Iron µg/L	14.425	300
Lead µg/L	0.02425	7
Lithium µg/L	261.5	2500
Manganese µg/L	5.625	200
Molybdenum µg/L	1.14	73
Nickel µg/L	0.2125	150
Selenium µg/L	0.349	1
Silver µg/L	0.015725	0.1
Strontium µg/L	22.3	/
Thallium µg/L	0.000425	0.8
Thorium µg/L	0.02115	/
Tin µg/L	0.015	/
Titanium µg/L	1.42	/
Uranium µg/L	4.575	100
Vanadium µg/L	1.365	100
Zinc µg/L	1.345	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:

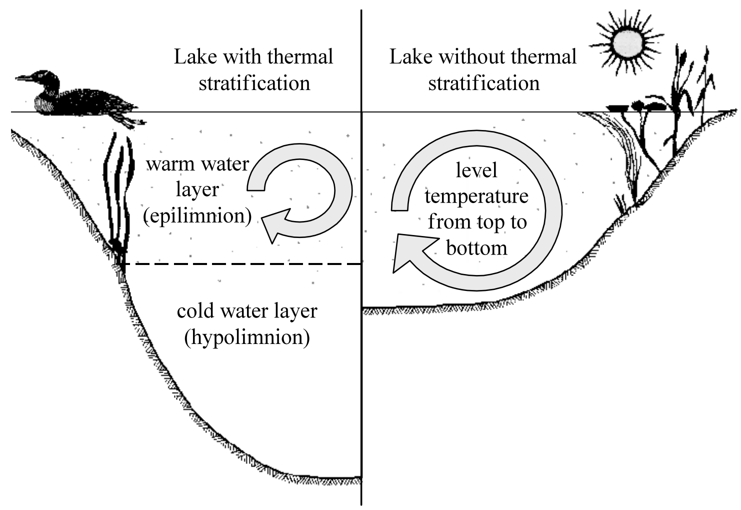

Figure A: Difference in the circulation of the water column depending on thermal stratification.

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.

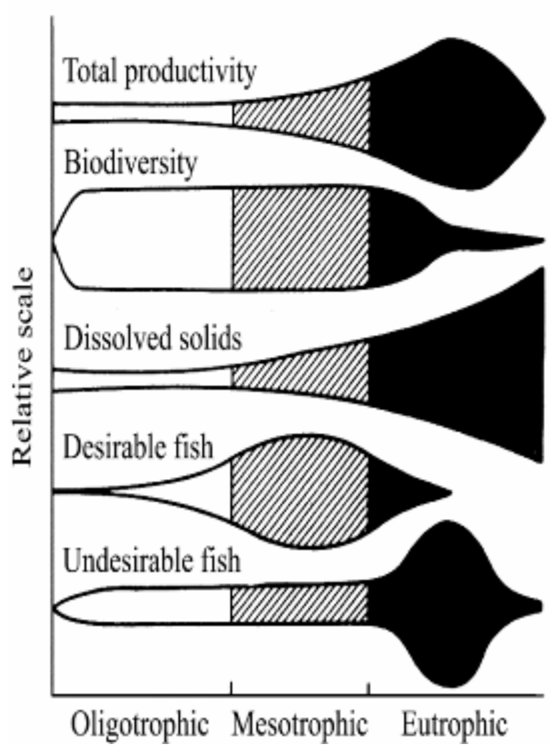

Figure B: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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

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.