Lakewatch

THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2010 Gull Lake Report

COMPLETED WITH SUPPORT FROM:

Government of Alberta

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 and Lakewatch Chairs, Al Sosiak and Ron Zurawell. We would like to thank Rick Connery for his efforts in collecting data in 2010. We would also like to thank Bradley Peter and Emily Port who were summer interns with ALMS in 2010. Project Technical Coordinator Jill Anderson was instrumental in planning and organizing the field program. Technologists Shelley Manchur, Mike Bilyk, Brian Jackson, and John Willis were involved in the training aspects of the program. Doreen LeClair and Chris Rickard were responsible for data management. Jill Anderson (Program Manager) was responsible for program administration and planning. Théo Charette, Ron Zurawell, Lori Neufeld, and Sarah Lord prepared the original report, which was updated for 2010 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.

GULL LAKE:

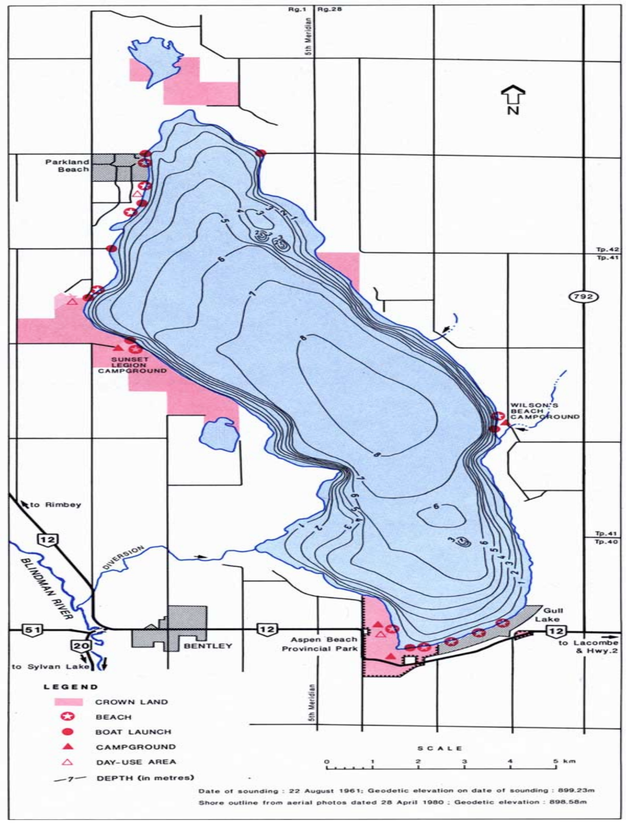

Figure 1 – Bathymetric map of Gull Lake obtained from Alberta Environment.

Gull Lake has a large surface area (80.6 km^2) and is considered to be a shallow lake (mean depth = 5.4 meters). The lake is situated approximately 17 km east of the town of Lacombe and 136 km south from the city of Edmonton. As this lake is situated between two large cities (Edmonton and Calgary), it is heavily populated and visited frequently.

The surrounding region of Gull Lake was settled in 1805. At the turn of the 20th century, a lumber industry was established at the lake. A steamboat was used for the sawmill operation as well as for the transportation of passengers. By 1908, the lake served as a hydroelectric reservoir; however, in 1910, the dam was destroyed. Following the destruction of the dam, Gull Lake water levels continually decreased and were a cause for concern. Although the community of Gull Lake had a dam built at the outlet in 1921, the water level nonetheless continued to decrease. The dam is now located approximately 1.6 km from shore, and the water level dropped, on average, ~6 cm/yr from 1924 to 1968. By 1977, a pipeline and canal was built, diverting water from the Blindman River to increase water levels when they fell below a specified target. The diversion pumps were operated in 2010 and water was transferred into Gull Lake.

The lake is renowned for its clear water and sandy beaches. It also supports moderate sport fishing of predominantly northern pike, walleye, and whitefish. It supports many recreational activities such as boating, swimming, fishing, and sailing. There are many cottages along the lake's shoreline and new subdivisions and commercial campgrounds are being proposed in upland areas within the watershed. Aspen Beach Provincial Park lies on the southwest shore of the lake, which was established in 1932, making it one of the first parks of the Alberta park system. The Provincial Park contains two campgrounds, a boat launch, beaches, and day use areas. There are marinas and boat launches located in various subdivisions around the lakeshore. The remaining majority of the watershed is used for agricultural activities and cattle production.

Gull Lake lies within two of Alberta's natural subregions: the Boreal Forest natural region on the northern half and the Parkland natural region on the southern half, they are within the Dry Mixedwood and Central Parkland sub-regions respectively. The dominant trees are trembling aspen, balsam poplar, white spruce, and willow in between large cultivated areas.

WATER LEVELS:

The drainage basin of Gull Lake is approximately two-times the lake's surface area. There are presently only minor inlet and no outlet streams (the outlet has been completely dry for decades), which in part explains why Gull Lake is prone to decreasing lake levels. The pumping from Blindman Creek adds water to the lake in order to reach a target elevation of 899.16 metres above sea level (m asl), and since 1999, Gull Lake has only decreased 0.36 m to 898.8 m asl although fluctuations have been as great as 0.6 meters (Figure 2).

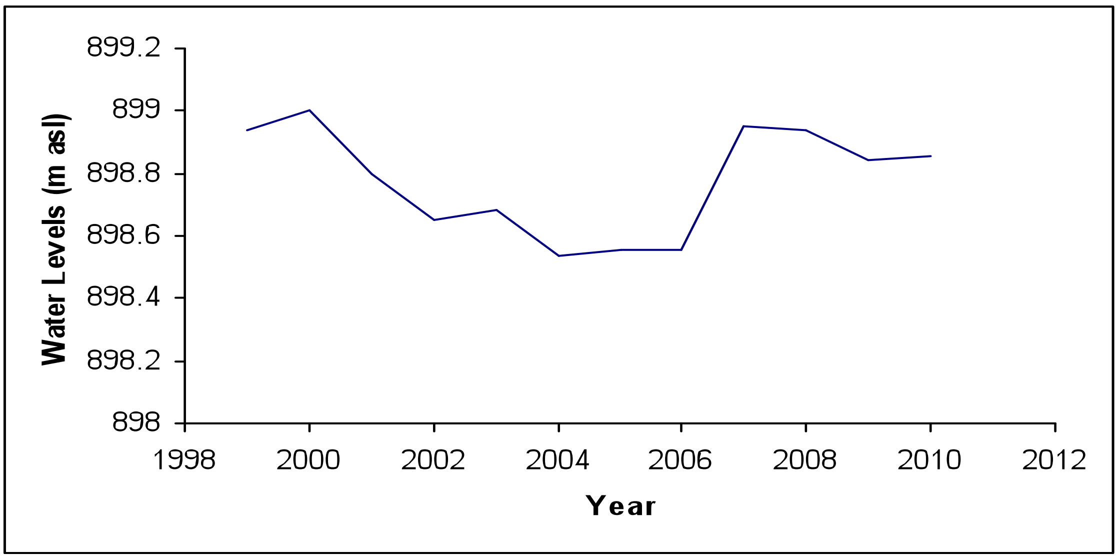

Figure 2 – Historical water levels for Gull Lake given in meters above sea level. Data retrieved from Environment Canada.

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.

Secchi depth in Gull Lake was measured three times over the course of the summer and was, on average, 2.83 meters (Table 1). Maximum secchi depth at Gull Lake was recorded on June 28th and measured 4.50 meters. On July 20th, secchi depth had decreased to 1.75 meters, likely due to algal blooms typical of July. In August, secchi depth had begun to increase again, measuring 2.25 meters. Compared to secchi depth measurements from 2006 and 2008, Gull Lake was slightly clearer in 2010. One contributing factor may be the temperatures in 2010 which were mild and not conducive of large algae blooms.

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.

Water temperature was measured three times over the course of the summer (Figure 3a). In late-June, water temperature was 17.84 °C at the surface and decreased steadily to 16.45°C at the lakebed. In late-July, water temperature had become more uniform, measuring 17.04 °C at the surface and 16.94 °C at the lakebed. In mid-September, water temperature had decreased to 11.44 °C at the surface and increased to 12.61 °C at the lakebed. Because the lake is so large and shallow, Gull Lake is considered polymictic, mixing periodically throughout the spring and summer months. As shown by the temperature profiles, no true thermocline exists in Gull Lake; however, weak thermal stratification may occasionally occur on warm, calm summer days. Temporary stratification events are important if they last several days because they allow the reduction of dissolved oxygen concentrations in deeper water and the release of phosphorous from the sediments into the water column when the temporary stratification breaks down.

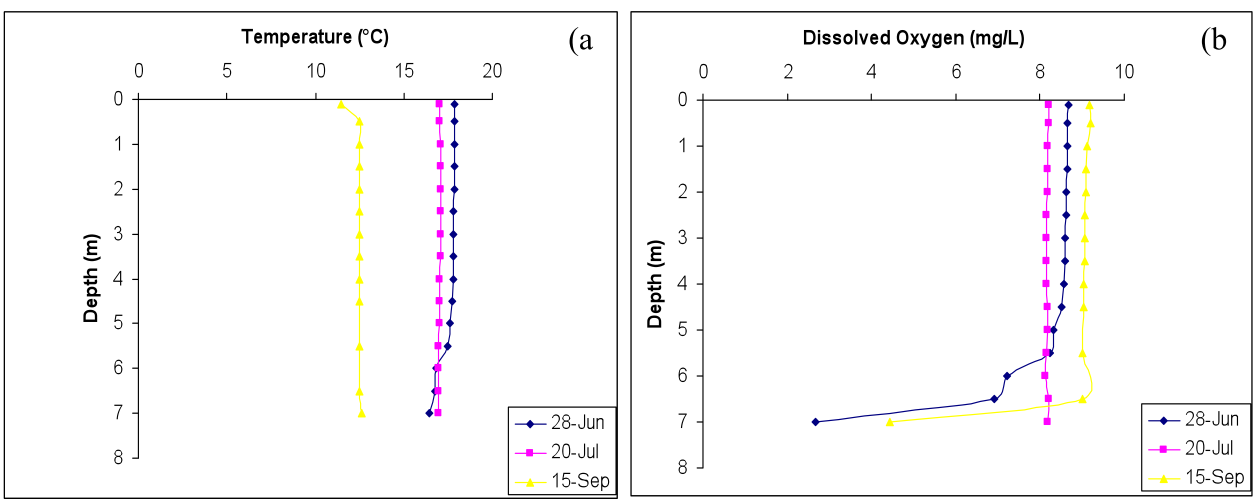

Figure 3 – a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles measured three times over the course of the summer of 2010.

Because of the lake's polymictic nature, dissolved oxygen in Gull Lake remains relatively uniform throughout the water column (Figure 3b). In late-June, dissolved oxygen in Gull Lake was 8.67 mg/L at the surface and decreased to 2.66 mg/L at the lakebed. In late-July, oxygen levels were uniform throughout the water column, measuring 8.20 mg/L at the surface and 8.18 mg/L at the lakebed. Finally, in mid-September, oxygen measured 9.16 mg/L at the surface and decreased suddenly between 6.5 and 7.0 meters to 4.44 mg/L at the lakebed. Because decomposition, an oxygen-consuming process, occurs at the sediment-lake interface, it is typical for oxygen to decrease dramatically at the lakebed. Most of the water column at Gull Lake remained above the Canadian Council for Ministers of the Environment (CCME) guideline for the Protection of Aquatic Life 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.

Gull Lake is considered eutrophic based on nutrient criteria. Average total phosphorous at Gull Lake measured 41.67 µg/L in 2010 (Table 1). This is much lower than the 2008 average of 56.75 µg/L and slightly above the 2006 average of 40.25 µg/L. Total phosphorous increased steadily over the course of the summer, measuring 37 µg/L on June 28, 43 µg/L on July 20th, and 45 µg/L on September 15th (Figure 4)   Nitrogen at Gull Lake changed little over the course of the season. Total nitrogen measured 1.61 mg/L on June 28th, 1.76 mg/L on July 20th, and 1.67 mg/L on September 15th (Figure 4) Similar to phosphorous, average total nitrogen in 2010 was lower than the 2008 average of 1.80 µg/L and slightly higher than the 2006 average of 1.668 µg/L.

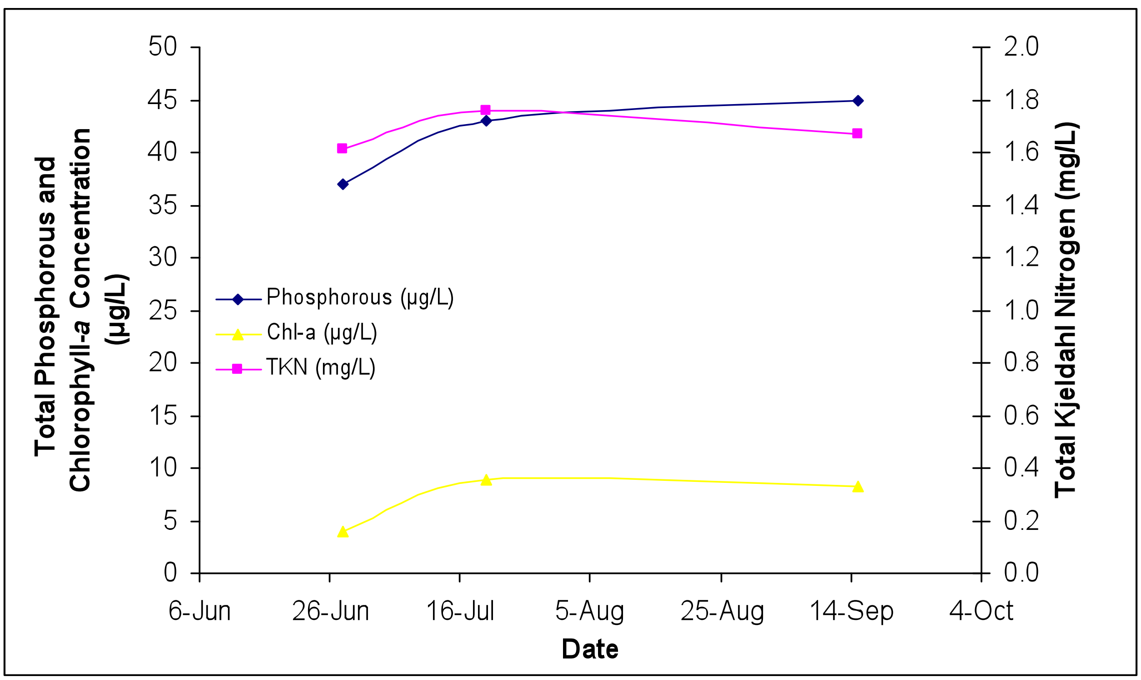

Figure 4 – Total phosphorous (µg/L), chlorophyll-*a* (µg/L), and total Kjeldahl nitrogen (mg/L) measured during the summer of 2010 at Gull Lake.

Based on chlorophyll-a criteria, Gull Lake would be considered mesotrophic, or moderately productive. Average chlorophyll-*a* was 6.99 µg/L in 2010, in contrast with 9.81 µg/L in 2008, and 9.39 µg/L in 2006 (Table 1; Figure 4). Chlorophyll-*a* levels in Gull Lake in 2010 were lower than previous years, this may be because temperatures in 2010 were mild resulting in reduced algae levels. Both total phosphorous and chlorophyll-*a* fell below their respective historical averages (Figure 5).

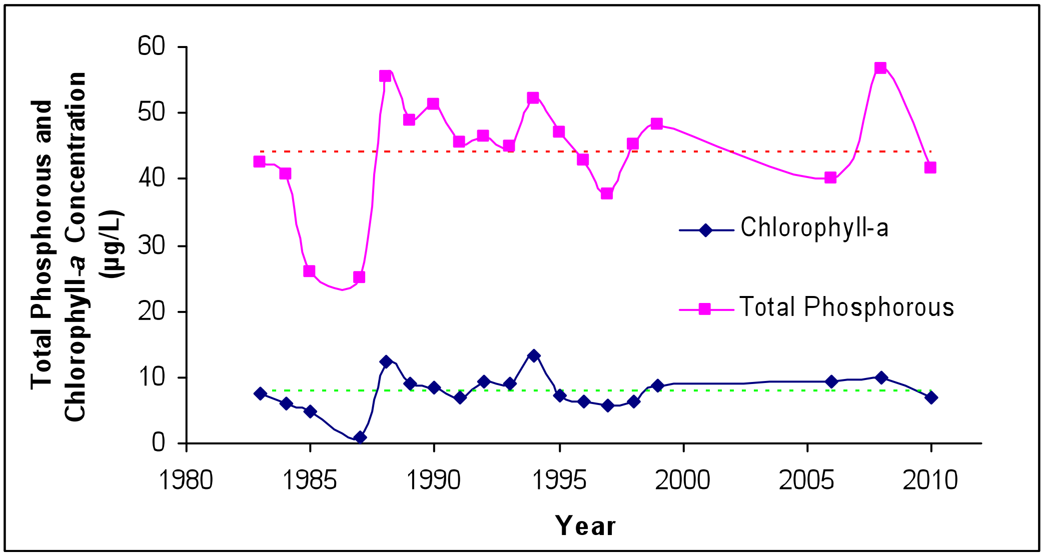

Figure 5 – Historical total phosphorous (µg/L) and chlorophyll-*a* (µg/L) concentrations for Gull Lake. Historical averages are presented for

Average pH in Gull Lake was 9.005, well above neutral (Table 1). Dominant ions in Gull Lake include magnesium (63.95 mg/L), sodium (228.5 mg/L), and bicarbonate (688.5 mg/L). A high alkalinity (691 mg/L CaCO3) helps to buffer the lake against changes to pH. Gull Lake is also considered slightly saline based on its concentration of Total Dissolved Solids (TDS) (Table 1). Due to the Gull Lake's somewhat saline conditions, it is possible that algal biomass is depressed somewhat relative to the nutrient (phosphorous) concentrations.

Table 1. Average secchi depth and water chemistry values for Gull Lake measured in 2010. Average values from 2006 and 2008 are shown for comparison.

Parameter	2006	2008	2010
TP (μg/L)	40.25	56.75	41.67
TDP (μg/L)	17.5	17.25	14
Chlorophyll-*a* (μg/L)	9.39	9.805	6.99
Secchi depth (m)	1.65	2	2.83
TKN (μg/L)	1668	1800	1680
NO_2 and NO_3 (μg/L)	<5	3	8.17
NH_3 (μg/L)	28.5	19.75	26
DOC (mg/L)	23.2	/	20.45
Ca (mg/L)	8.33	10.025	10.7
Mg (mg/L)	67.85	66.05	63.95
Na (mg/L)	233.5	205.5	228.5
K (mg/L)	21.7	19.75	21.95
SO_4^{2-} (mg/L)	90	79	95
Cl^- (mg/L)	5.85	7.5	7.2
CO_3 (mg/L)	103.5	98	76
HCO_3 (mg/L)	657.5	614.5	688.5
pH	9.165	9.1	9.005
Conductivity (μS/cm)	1323.3	1270	1297.5
Hardness (mg/L)	310.5	297	290
TDS (mg/L)	844.5	788	841.5
Total Alkalinity (mg/L $CaCO_3$)	712	666.75	691
Microcystin (μg/L)	0.22	0.24	0.14

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.

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:

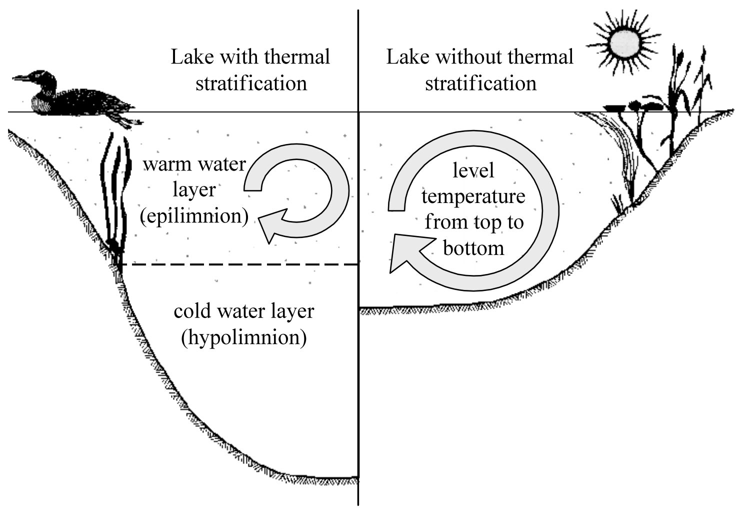

Figure A: Difference in the circulation of the water column depending on thermal stratification.

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.

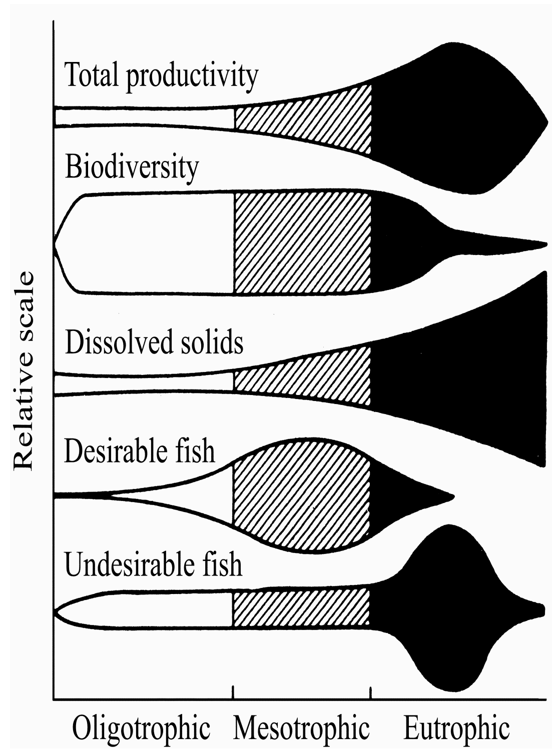

Figure B: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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.