THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2010 Arm Lake 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 and Lakewatch Chairs, Al Sosiak and Ron Zurawell. We would like to thank Mike Haines, Al Marchand, Roland Marchand, and Ken White for their 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.

ARM LAKE:

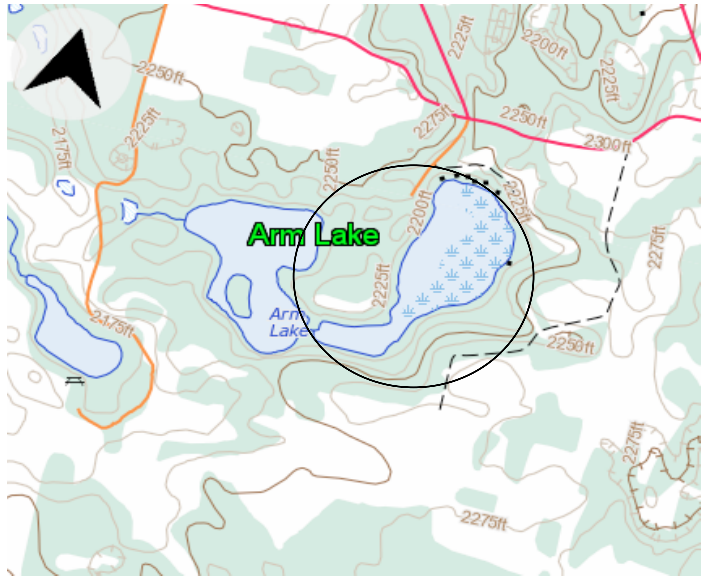

Figure 1 - Two distinct arms of Arm Lake, Alberta. Atlas of Canada, 2010.

Arm Lake (Figure 1, Figure 2) is situated in the North Saskatchewan River drainage basin in east-central Alberta, near the Battle River valley. The lake consists of two distinct arms, though the East arm, which has buildings along the northern shore, is the site of sampling. In the mid 1970's, the narrows joining the two arms was dug out, allowing water to flow from the west arm into the east arm. After lobbying by the Arm Lake Cabin Owners Association, the narrows were restored, now allowing no water to flow between the two arms. The eastern arm is marshy, with large amounts of small-leaf pondweed (*Potamogeton pusillus L.*) observed in 2010. This plant may have been noticed in recent years due to reduced water levels, but is non-invasive and provides cover for fish and waterfowl.

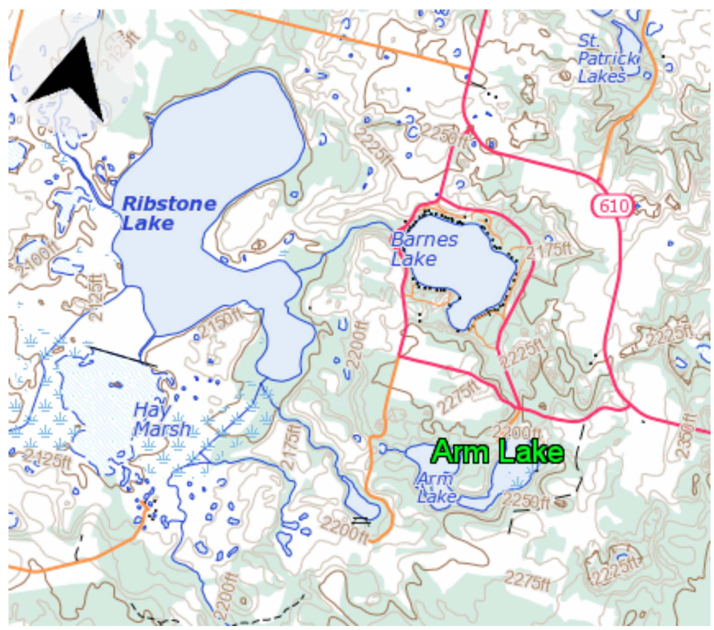

Figure 2 - Topographic map of Arm lake, Alberta and its surroundings. Atlas of Canada, 2010.

The town of Wainwright, with a population of 5,775, and the Canadian Forces Base Wainwright are located approximately 20 km northwest of Arm Lake. Arm Lake, along with its larger neighbour Clear (Barnes) Lake, together make up a popular recreation area for the region. Arm Lake hosts a campground, golf course, public beach, and picnic area. Popular activities on the lake include swimming, boating, and fishing for northern pike and yellow perch.

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 at Arm Lake (**Table 1**) reached a maximum of 4.50 meters on June 14th. On July 12th, the secchi depth decreased to a minimum of 3.25 meters likely due to increased algal growth as a result of July temperatures. In August and September, the secchi depth began to increase as algae died off, reaching 3.50 meters on August 9th, 3.75 meters on August 24th, and 4.25 meters on September 7th. On average, the secchi depth at Arm Lake was 3.85 meters in 2010. In comparison to the 2009 average of 3.56 meters, the average secchi depth was only slightly higher in 2010.

WATER LEVELS:

Currently there is no water level data available for Arm Lake.

WATER TEMPERATURE AND DISSOLVED OXYGEN:

Water temperature and dissolved oxygen profiles in the water column can provide information on water quality and fish habitat. The depth of the thermocline is important in determining the depth to which dissolved oxygen from the surface can be mixed. Please refer to the end of this report for descriptions of technical terms.

Thermal stratification was observed in Arm Lake in 2010 (**Figure 3a)**. In June, surface-water temperature was 15.92 °C and remained relatively constant until thermal stratification was observed between 3.0 meters (15.42 °C) and 6.0 meters (10.82 °C). After 6.0 meters, temperature steadily declined to a minimum of 7.81 °C. In July, surface water temperature had increased to 20.03 °C and a thermocline was present between 4.0 meters (19.84 °C) and 7.0 meters (10.28 °C). Beyond 7.0 meters, the temperature dropped steadily to a seasonal minimum of 7.44 °C. On August 9th, the surface temperature had increased to a seasonal maximum of 21.39 °C and the thermocline became larger, stretching between 4.5 meters (20.81 °C) and 8.5 meters (10.28 °C). At the bottom, temperature had dropped to 8.49 °C. On August 24th, surface temperature began to decline, dropping to 17.06 °C and the thermocline began to weaken, present only between 6.5 (15.82 °C) and 8.5 meters (10.45 °C). At the bottom, temperature reached a minimum of 8.35 °C. Finally, in early-September, surface temperature was 15.00 °C and a weak thermocline was present between 7.5 (14.41 °C) and 9.5 meters (9.83 °C). Temperature increased from previous months to 8.60 °C on the lakebed. Due to a mild summer in 2010, surface temperatures were cooler than those seen in 2009.

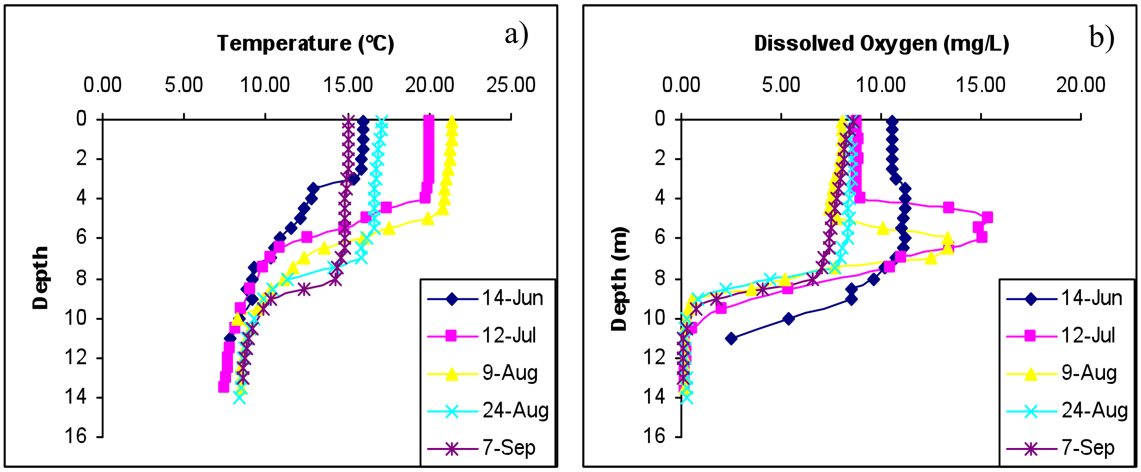

Figure 3. A) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Arm Lake in 2010.

Surface dissolved oxygen concentration (**Figure 3b)** ranged from a maximum of 10.53 mg/L on June 14th to a minimum of 8.02 mg/L on August 9th. These concentrations were well within the acceptable range for surface water quality (DO> 5.0 mg/L). Of note, on June 14th, July 12th, and August 9th, oxygen showed a marked increase between 4.0 and 6.0 meters. This was most pronounced on July 12th when oxygen increased from 8.96 mg/L at 4.0 meters to 15.35 mg/L at 5.0 meters. These patterns are indicative of a metalimnetic algal bloom, which produce oxygen, and discrete samples were collected and archived for analysis. Anoxia at Arm Lake was consistently observed below 9.0 meters, except for on June 14th, when no anoxia was observed. This is likely due to uniform water temperatures in early June which allow for oxygen to be mixed throughout the entire water column before there was strong thermal stratification.

WATER CHEMISTRY:

Based on total phosphorous measured in 2010 Arm Lake is classified as mesotrophic, or moderately productive (**Table 1**). Total phosphorous peaked at 21 µg/L on July 12th and reached a minimum of 15 µg/L on both August 24th and September 15th (**Figure 4**). On average, total phosphorous was 17.4 µg/L in 2010, lower than the 2009 average of 21.8 µg/L. Nitrogen followed a similar pattern, reaching a maximum on July 12th of 1.19 mg/L and a minimum on August 24th of 1.08 mg/L. Average nitrogen concentration for the summer was 1.11 mg/L, slightly higher than the 2009 average of 1.05 mg/L. Finally, chlorophyll-*a* was at a minimum of 2.80 µg/L on June 14th and reached a maximum of 3.36 µg/L on July 12th. On average, chlorophyll-*a* was 3.02 µg/L in 2010, lower than the 2009 average of 3.24 µg/L. The trophic status of the lake has not changed since 2009 based on phosphorous, nitrogen, or chlorophyll-*a.*

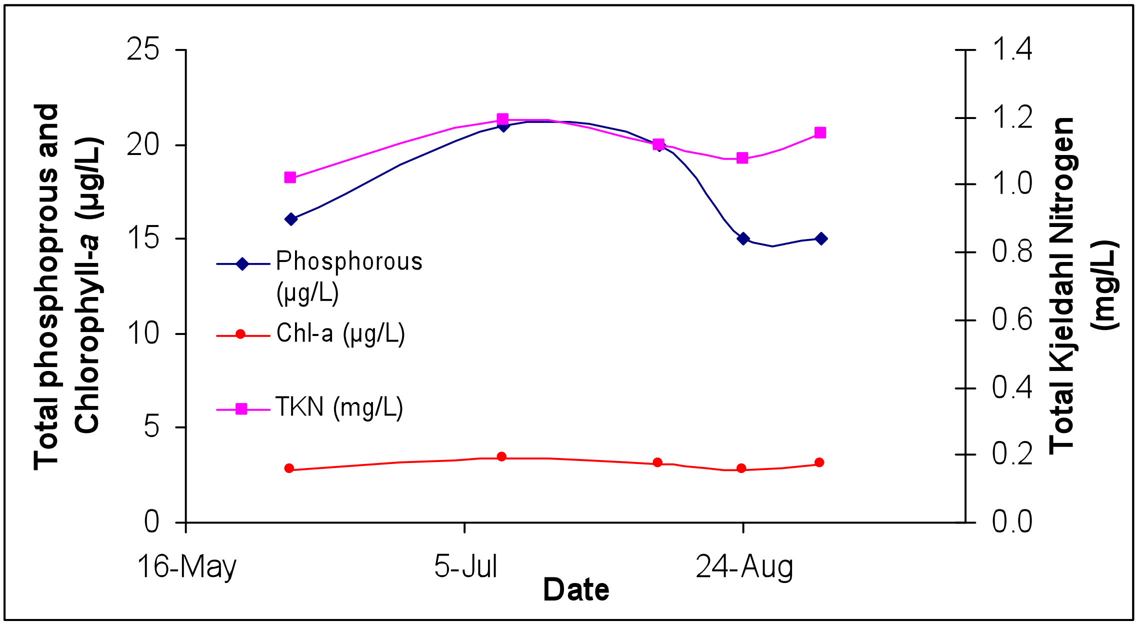

Figure 4 – Chlorophyll-*a* (µg/L), total phosphorous (µg/L), and total Kjeldahl nitrogen (mg/L) measured over the course of the summer in 2010.

Arm Lake's pH changed little from 2009 (8.53) to 2010 (8.51) (**Table 1)**. Higher than neutral, this pH level is common in Alberta due to large amounts of carbonate rich soils and falls within the Canadian Council of Ministers of the Environment (CCME) guideline for the protection of aquatic life (6.5-9.0). Dominant ions remained bicarbonate, magnesium, and calcium, which commonly make up a large portion of the total ions present in Alberta lakes. The large amounts of bicarbonate and calcium contribute to a high alkalinity in Arm Lake (190 mg/L $CaCO_3$), which helps to buffer the lake from changes in pH.

Table 1 – Average secchi disc depth and water chemistry values for 2009 and 2010 at Arm Lake.

Parameter	2009	2010
TP (µg/L)	21.8	17.4
TDP (µg/L)	8.75	9.60
Chlorophyll-*a* (µg/L)	3.24	3.02
Secchi depth (m)	3.56	3.85
TKN (µg/L)	1042.5	1112.0
NO_2 and NO_3 (µg/L)	6.5	7.6
NH_3 (µg/L)	21.75	14.40
DOC (mg/L)	12.7	12.6
Ca (mg/L)	28.3	24.1
Mg (mg/L)	27.3	28.3
Na (mg/L)	10.3	10.0
K (mg/L)	3.48	4.47
SO_4^{2-} (mg/L)	15.8	17.0
Cl^- (mg/L)	1.53	1.50
CO_3 (mg/L)	8.0	3.17
HCO_3 (mg/L)	214.5	225.3
pH	8.53	8.51
Conductivity (µS/cm)	366.5	363.0
Hardness (mg/L)	183	176
TDS (mg/L)	200.3	199.3
Microcustin (µg/L)	/	0.08
Total Alkalinity (mg/L $CaCO_3$)	189	190

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 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:

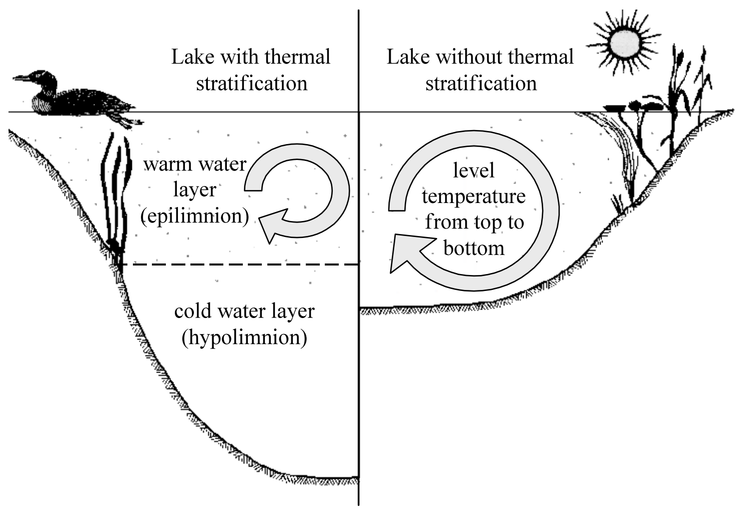

Figure A: Difference in the circulation of the water column depending on thermal stratification.

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 $mg•L^{-1}$ and should not average less than 6.5 $mg•L^{-1}$ over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 $mg•L^{-1}$ in areas where early life stages of aquatic biota, particularly fish, are present.

GENERAL WATER CHEMISTRY:

Water in lakes always contains substances that have been transported by rain and snow or have entered the lake in groundwater and inflow streams. These substances may be dissolved in the water or suspended as particles. Some of these substances are familiar minerals, such as sodium and chloride, which when combined form table salt, but when dissolved in water separate into the two electrically charged components called **ions**. Most dissolved substances in water are in ionic forms and are held in solution due to the polar nature of the water molecule. **Hydrophobic** (water-fearing) compounds such as oils contain little or no ionic character, are non-polar and for this reason do not readily dissolve in water. Although hydrophobic compounds do not readily dissolve, they can still be transported to lakes by flowing water. Within individual lakes, ion concentrations vary from year to year depending on the amount and mineral content of the water entering the lake. This mineral content can be influenced by the amount of precipitation and other climate variables as well as human activities such as fertilizer and road salt application.

PHOSPHORUS AND NITROGEN:

Phosphorus and nitrogen are important nutrients limiting the growth of algae in Alberta lakes. While nitrogen usually limits agricultural plants, phosphorus is usually in shortest supply in lakes. Even a slight increase of phosphorus in a lake can, given the right conditions, promote algal blooms causing the water to turn green in the summer and impair recreational uses. When pollution originating from livestock manure and human sewage enters lakes not only are the concentrations of phosphorus and nitrogen increased but nitrogen can become a limiting nutrient which is thought to cause blooms of toxic algae belonging to the cyanobacteria. Not all cyanobacteria are toxic, however, the blooms can form decomposing mats that smell and impair dissolved oxygen concentrations in the lake.

CHLOROPHYLL-*A*:

Chlorophyll *a* is a photosynthetic pigment that green plants, including algae, possess enabling them to convert the sun's energy to living material. Chlorophyll *a* can be easily extracted from algae in the laboratory. Consequently, chlorophyll *a* is a good estimate of the amount of algae in the water. Some highly productive lakes are dominated by larger aquatic plants rather than suspended algae. In these lakes, chlorophyll *a* and nutrient values taken from water samples do not include productivity from large aquatic plants. The result, in lakes like Chestermere which are dominated by larger plants known as macrophytes, can be a lower trophic state than if macrophyte biomass was included. Unfortunately, the productivity and nutrient cycling contributions of macrophytes are difficult to sample accurately and are therefore not typically included in trophic state indices.

SECCHI DISK TRANSPARENCY :

Lakes that are clear are more attractive for recreation, whereas those that are turbid or murky are considered by lake users to have poor water quality. A measure of the transparency or clarity of the water is performed with a Secchi disk with an alternating black and white pattern. To measure the clarity of the water, the Secchi disk is lowered down into the water column and the depth where the disk disappears is recorded. The Secchi depth in lakes with a lot of algal growth will be small while the Secchi depth in lakes with little algal growth can be very deep. However, low Secchi depths are not caused by algal growth alone. High concentrations of suspended sediments, particularly fine clays or glacial till, are common in plains or mountain reservoirs of Alberta. Mountain reservoirs may have exceedingly low Secchi depths despite low algal growth and nutrient concentrations.

The euphotic zone or the maximum depth that light can penetrate into the water column for actively growing plants is calculated as twice the Secchi depth. Murky waters, with shallow Secchi depths, can prevent aquatic plants from growing on the lake bottom. Conversely, aquatic plants can ensure lakes have clear water by reducing shoreline erosion and stabilizing lake bottom sediments. In Alberta, many lakes are shallow and bottom sediments contain high concentrations of nutrients. Without aquatic plants, water quality may decline in these lakes due to murky, sediment laden water and excessive algal blooms. Maintaining aquatic plants in certain areas of a lake is often essential for ensuring good water clarity and a healthy lake as many organisms, like aquatic invertebrates and insects, depend on aquatic plants for food and shelter.

TROPHIC STATE:

Trophic state is classification of lakes into four categories of fertility and is a useful index for rating and comparing lakes. From low to high nutrient and algal biomass (as chlorophyll) concentrations, the trophic states are; **oligotrophic**, **mesotrophic**, **eutrophic** and **hypereutrophic (Table 2)**.

A majority of lakes in Alberta contain naturally high levels of chlorophyll *a* (8 to 25 µg/L) due to our deep fertile soils. These lakes are usually considered fertile and are termed eutrophic. The nutrient and algal biomass concentrations that define these categories are shown in the following table, a figure of Alberta lakes compared by trophic state can be found on the ALMS website.

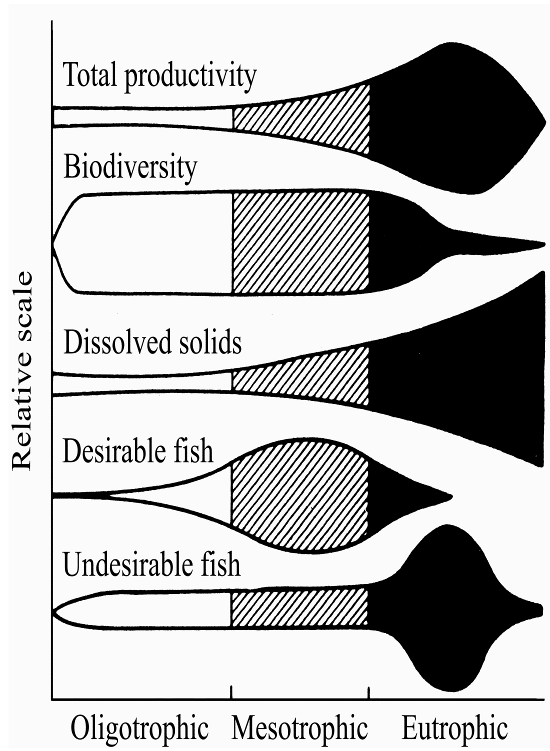

Figure B: Suggested changes in various lake characteristics with eutrophication. From “Ecological Effects of Wastewater”, 1980.

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

Trophic state	Total Phosphorus (µg•L^{-1})	Total Nitrogen (µg•L^{-1})	Chlorophyll a (µg•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.