



*THE ALBERTA LAKE MANAGEMENT SOCIETY  
VOLUNTEER LAKE MONITORING PROGRAM*

## **2011 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**

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## ARM LAKE:

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 food for waterfowl.

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.

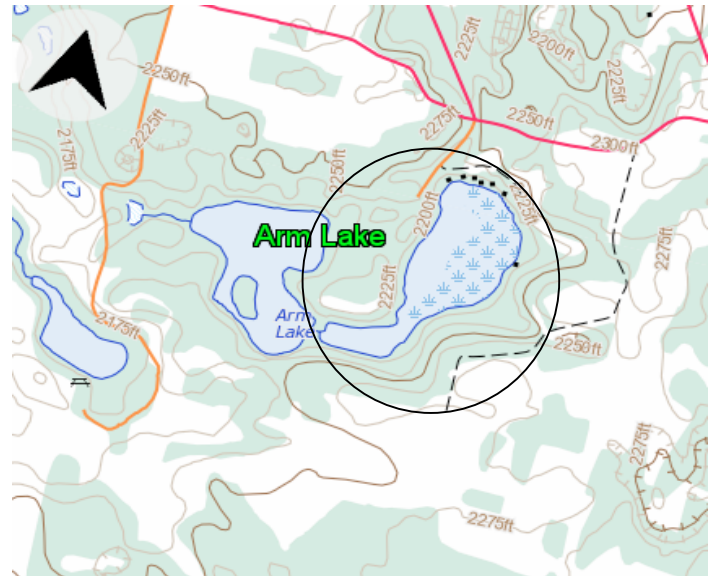


Figure 1 - Two distinct arms of Arm Lake, Alberta. Atlas of Canada, 2010.

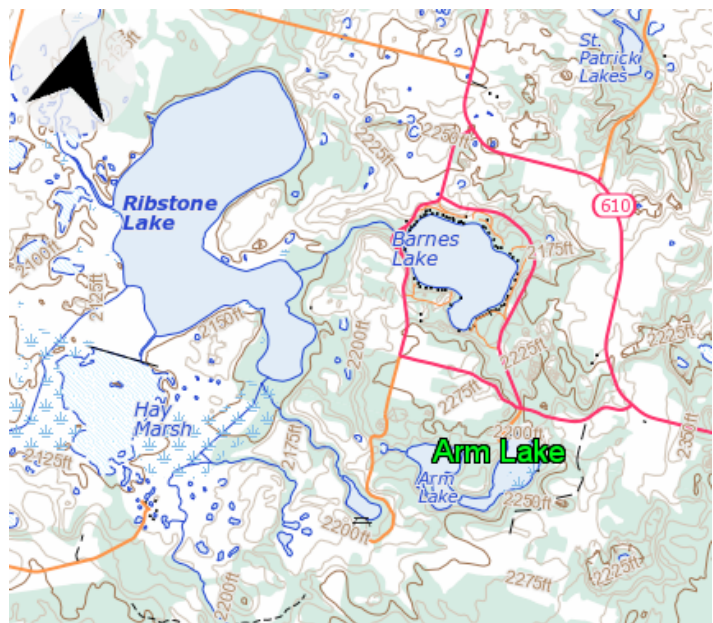


Figure 2 - Topographic map of Arm Lake, Alberta and its surroundings. Atlas of Canada, 2010.

## **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.*

Currently no water level data exists for Arm Lake. Requests for water level monitoring should go through Environment and Sustainable Resource Development's Monitoring and Science Division.

## **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.*

Average Secchi disk depth measured at Arm Lake in 2011 was 4.55 m (Table 1). Throughout the summer, Secchi depth ranged from a minimum of 3.50 m on July 11<sup>th</sup> to a maximum of 5.25 m on June 8<sup>th</sup>. Compared to 2009 (3.56 m) and 2010 (3.85 m), the 2011 average is ~1.0 m deeper. The cause of this increased clarity is unknown, though many factors such as ambient light conditions, human error, total dissolved solids, and changes in the phytoplankton community can affect Secchi disk depth.

## **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 at Arm Lake showed strong thermal stratification throughout the summer (Figure 3). This is the same pattern observed in both 2009 and 2010. Surface water temperature ranged from a minimum of 16.09 degC on June 8<sup>th</sup> to a maximum of 20.5 degC on August 16<sup>th</sup>. For the first four samples, thermal stratification began between 6.0-7.0 m. However, by September, thermal stratification began to weaken and moved lower to 8.0 m. The establishment of strong thermal stratification contributes to the depletion of oxygen in the hypolimnetic zone.

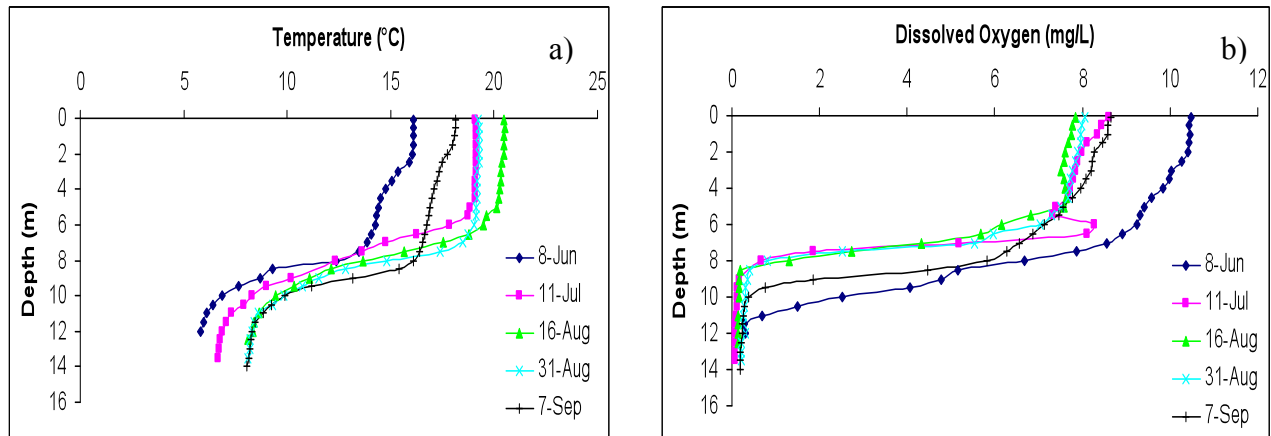


Figure 3 - a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Arm Lake in 2010.

At the surface, dissolved oxygen at Arm Lake fell well within the Canadian Council for Ministers of the Environment (CCME) recommendation of 6.5 mg/L. Below the thermocline, however, dissolved oxygen dropped dramatically, reaching anoxia by 9.0 m during each sampling trip. Dramatic drops in oxygen are often a result of decomposition occurring at the lakebed and the separation of bottom waters from oxygen-rich surface waters by the thermocline. Similar to both 2009 and 2010, a spike in dissolved oxygen was observed at 6.0 m on July 11<sup>th</sup>. A spike in oxygen at this depth is indicative of a metalimnetic algal bloom which grows best at deeper depths and produces oxygen via photosynthesis.

#### **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.

Based on average Total Phosphorous collected in 2011 (18.8 µg/L), Arm Lake is classified as mesotrophic, or moderately productive (Table 1). This is the same classification as both 2009 (21.8 µg/L) and 2010 (17.4 µg/L). Total Phosphorous reached a maximum of 27.0 µg/L on August 16<sup>th</sup>, and a minimum of 16.0 µg/L on both June 8<sup>th</sup> and September 7<sup>th</sup>. Similar to both 2009 and 2010, average chlorophyll-*a* concentration in 2012 fell into the oligotrophic, or low nutrient, classification. Chlorophyll-*a* concentration fluctuated little throughout the summer, measuring a minimum of 2.15 µg/L on June 8<sup>th</sup> and a maximum of 4.55 µg/L on July 11<sup>th</sup>. Finally, Total Kjeldahl Nitrogen (TKN) also showed little fluctuation throughout the summer. Measuring an average of 1034 µg/L, TKN was at a minimum of 980 µg/L on June 8<sup>th</sup> and a maximum of 1080 µg/L on August 16<sup>th</sup>.

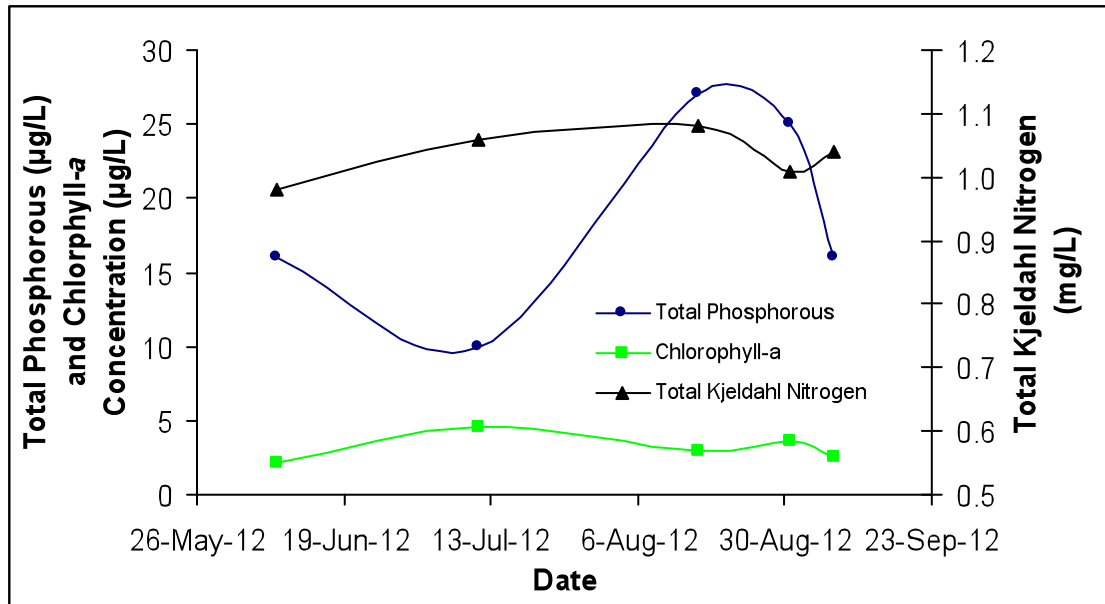


Figure 4 – Chlorophyll-*a* (µg/L), total phosphorous (µg/L), and total Kjeldahl nitrogen (mg/L) measured over the course of the summer in 2011.

Average pH at Arm Lake in 2012 was 8.41, well above neutral. As seen in previous years, dominant ions include calcium, magnesium, and bicarbonate. These ions contribute to a high alkalinity (190.6 mg/L CaCO<sub>3</sub>) which helps buffer Arm Lake against changes to pH. Over the past three years of sampling, none of the ions at Arm Lake have changed appreciably. The data collected during the past three years creates a valuable baseline, and monitoring should continue at regular intervals in the future to monitor for changes to the water quality at Arm Lake.

Table 1 – Average Secchi disk depth and water chemistry values for 2009, 2010, and 2011 at Arm Lake.

<b>Parameter</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>
TP (µg/L)	21.8	17.4	18.8
TDP (µg/L)	8.75	9.60	8.3
Chlorophyll-a (µg/L)	3.24	3.02	3.16
Secchi depth (m)	3.56	3.85	4.55
TKN (µg/L)	1042.5	1112.0	1034
NO <sub>2</sub> and NO <sub>3</sub> (µg/L)	6.5	7.6	4.9
NH <sub>3</sub> (µg/L)	21.75	14.40	23.6
DOC (mg/L)	12.7	12.6	11.6
Ca (mg/L)	28.3	24.1	29.2
Mg (mg/L)	27.3	28.3	29.2
Na (mg/L)	10.3	10.0	9.3
K (mg/L)	3.48	4.47	3.53
SO <sub>4</sub> <sup>2-</sup> (mg/L)	15.8	17.0	14.3
Cl <sup>-</sup> (mg/L)	1.53	1.50	1.37
CO <sub>3</sub> (mg/L)	8.0	3.17	3.2
HCO <sub>3</sub> (mg/L)	214.5	225.3	225.8
pH	8.53	8.51	8.41
Conductivity (µS/cm)	366.5	363.0	375
Hardness (mg/L)	183	176	193.3
TDS (mg/L)	200.3	199.3	221.3
Microcystin (µg/L)	/	0.08	0.055
Total Alkalinity (mg/L CaCO <sub>3</sub> )	189	190	190.6

Note: TP = total phosphorous, TDP = total dissolved phosphorous, Chl-*a* = chlorophyll-*a*, TKN = total Kjeldahl nitrogen. NO<sub>2+3</sub> = nitrate+nitrite, NH<sub>4</sub> = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO<sub>4</sub> = sulphate, Cl = chloride, CO<sub>3</sub> = carbonate, HCO<sub>3</sub> = 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:

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

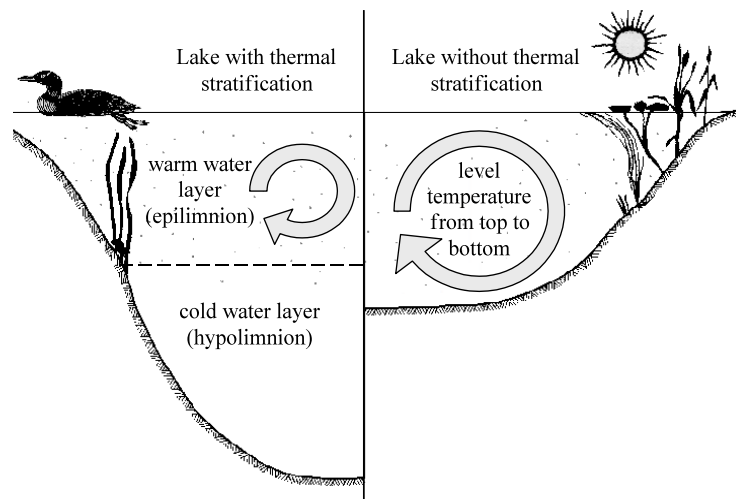


Figure A: Difference in the circulation of the water column depending on thermal stratification.



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<sup>-1</sup> and should not average less than 6.5 mg•L<sup>-1</sup> over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 mg•L<sup>-1</sup> 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.

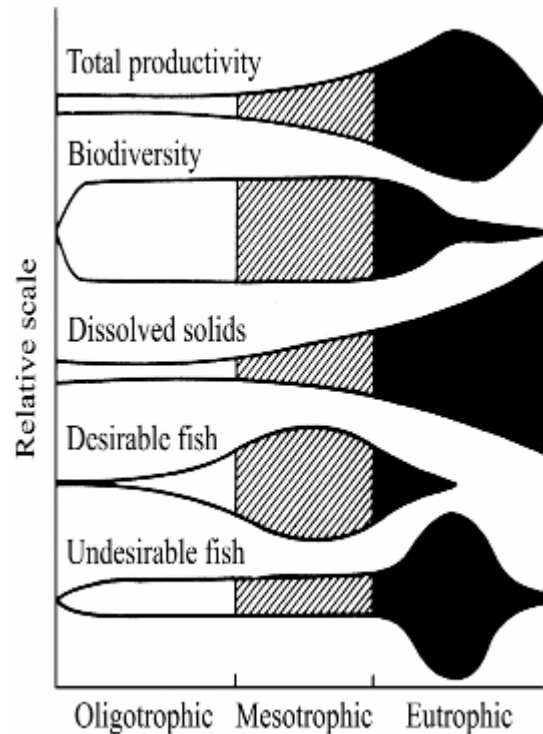


Figure B: Suggested changes in various lake characteristics with eutrophication.

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

Trophic state	Total Phosphorus (µg•L <sup>-1</sup> )	Total Nitrogen (µg•L <sup>-1</sup> )	Chlorophyll a (µg•L <sup>-1</sup> )	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