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Lakewatch

Moose Lake

The Alberta Lake Management Society
Volunteer Lake Monitoring Report

> *And you really live by the river? What a jolly life!"*
>
> *"By it and with it and on it and in it," said the Rat. "It's brother and sister to me. What it hasn't got is not worth having, and what it doesn't know is not worth knowing." Kenneth Grahame The Wind in the Willows*
>
> *"The world's supply of fresh water is running out. Already one person in five has no access to safe drinking water." BBC World Water Crisis Homepage*

A note from the Lakewatch Coordinator

Preston McEachern

Lakewatch has several important objectives, one of which is to document and interpret water quality in Alberta Lakes. Equally important are the objectives of educating lake users about their aquatic environment; enhancing public involvement in lake management; and facilitating a link between aquatic scientists and lake users. The 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. Substantial additional information is generally available on the lakes that have participated in Lakewatch and readers requiring more information are encouraged to seek these sources.

The 2002 Lakewatch Report has undergone a substantial change in format from previous years. I am no longer the author as much as an editor including text and figures from others who have done an excellent job describing lakes throughout Alberta. I have attempted to give due credit to these outstanding people and apologize for blatant plagiarism where it occurs. As editor, feel free to castigate me for errors. I have included easily accessible information that is likely to have been updated in recent years and readers are encouraged to help update these reports by sending new information to me.

I would like to thank all people who share my love for aquatic environments and particularly those who have helped in the Lakewatch program. These people prove that ecological apathy can be overcome and give us hope that water will not be the limiting factor in the health of our planet.

Acknowledgements

The Lakewatch program is made possible through the dedication of its volunteers and Alberta Environment employees. Bob Hornseth made sampling at Moose Lake possible, without his help Moose would not have been included. Mike Bilyk and John Willis from Alberta Environment were instrumental training people. Financial support from the Lakeland Industry and Community Association (LICA) and the Prairie Farm Rehabilitation Association (PFRA) was essential in 2002. Sophie Lewin and Lucille Kowalchuk were our summer field coordinators and were excellent additions to the program. Without the dedication of these people and the interest of cottage owners, Lakewatch would not have occurred.

Fig. 1: Moose Lake, August 2002

Photo: S. Lewin, ALMS

Moose Lake

Moose Lake is located 240 km NE of Edmonton and 3.5 km west of the Town of Bonnyville. The lake was once known by its French name *Lac d'Orignal*, which was inspired by the abundance of moose (Mitchell and Prepas, 1990). In 1789 Angus Shaw established a trading post for the North West Company on the northwest shore of Moose Lake (Mitchell and Prepas 1990), the earliest white settlement known to Alberta (Alberta Recreation, Parks and Wildlife Foundation 1992). Later in the early 1900's, French Canadian settlers began arriving in the area. Soon after, in 1928, the railway was extended from St. Paul to Bonnyville (Mitchell and Prepas 1990). Moose Lake was in high demand for its abundance of natural resources for a rapidly expanding population. Mink farming, agriculture and even three fish-packing plants for commercial fishing were in operation by 1936 (Mitchell and Prepas 1990). Commercial, domestic and recreational fisheries are currently managed in Moose Lake (Bodden 2002). Walleye, northern pike and yellow perch are the most popular sport fish, but the lake also contains cisco, lake whitefish, burbot, suckers and forage fish. Today, the shoreline is intensively developed with cottage subdivisions, camps and summer villages (Mitchell and Prepas 1990).

Moose Lake has over 64 km of irregular shoreline within a 40 km^2 lake surface area. The lake is comprised of four main bays with a maximum depth of 19 m and a mean depth of 5.6 m (Fig. 2, AENV 1989) Moose Lake is eutrophic, and turbid periodically throughout the summer. Dense blue-green algal blooms occur during the late summer or fall (Mitchell and

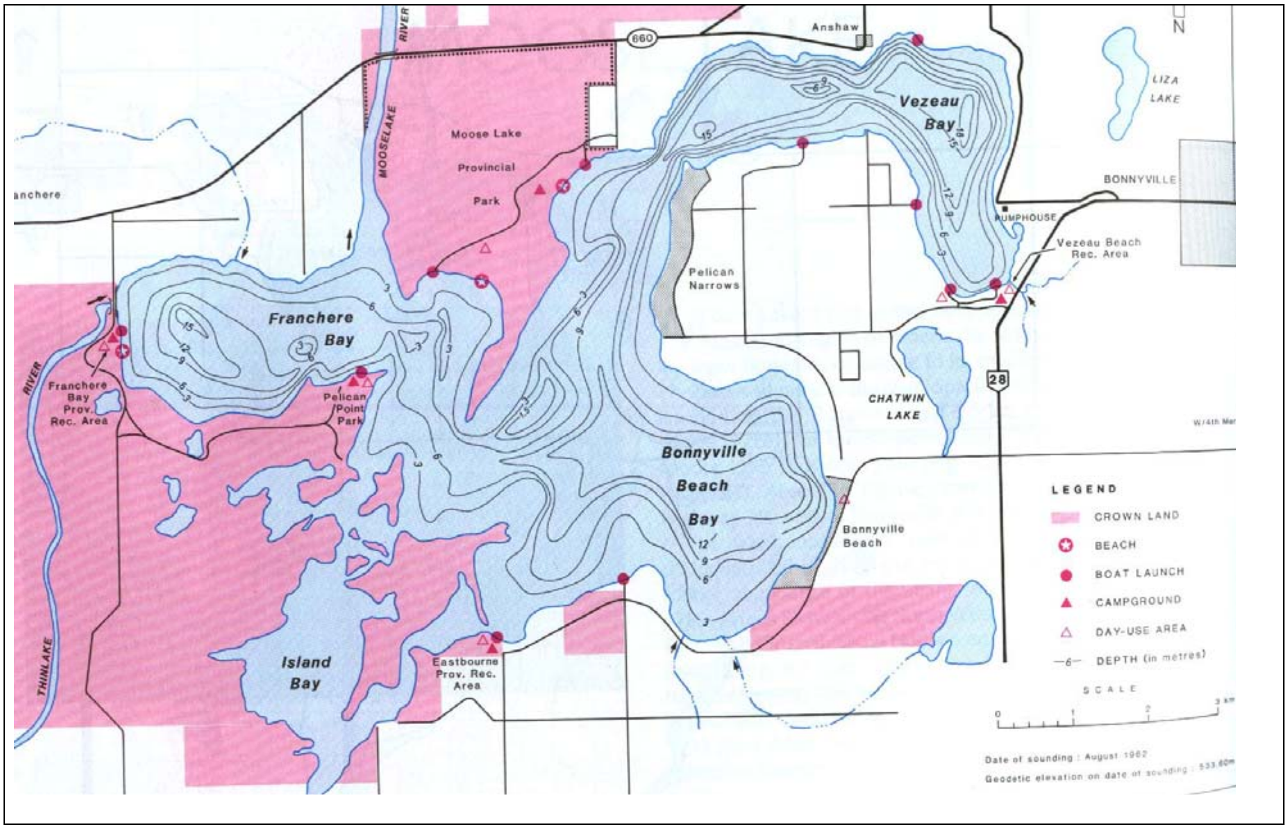

Fig. 2: Bathymetry of Moose Lake from Mitchell and Prepas (1990).

Prepas 1990), while May and June tend to have better water clarity (Mitchell 1999). Phosphorus concentrations are mostly received through run-off and bottom sediments (Mitchell and Prepas 1990), which have accumulated since the lake formed about 10 000 years ago (AENV 1989). Nutrient concentrations increase through the summer and may peak as late as September with an associated peak biomass for phytoplankton. Blue-green algae (*Anabaena* sp.) and green algae are the most abundant phytoplankton. Aquatic reeds fringe the areas that are more sheltered. Dominant emergent plants include bulrush (*Scirpus validus)* and cattail *(Typha latifolia).* Common subemergent plants are pondweeds *(Potamogeton* sp.*)* and northern watermilfoil *(Myriophyllum exalbescens).*

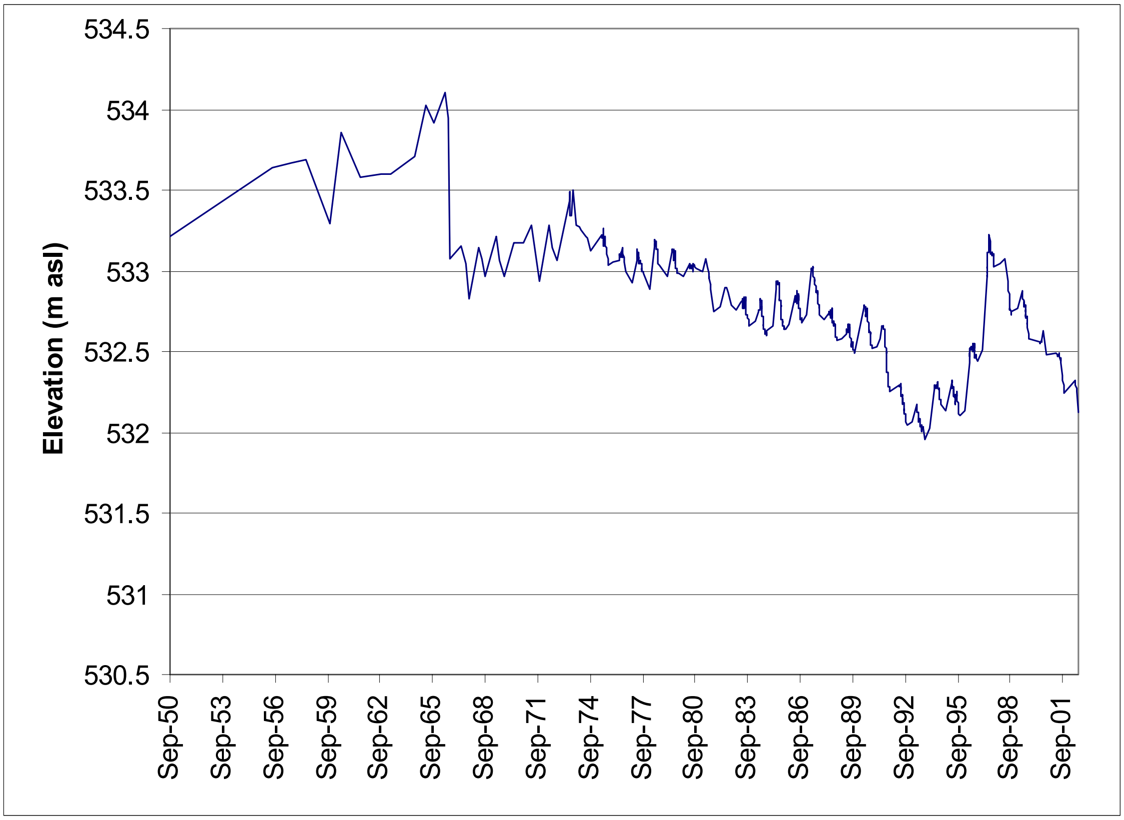

Fig. 3: Water level data for Moose Lake from 1950 to 2002.

Water levels

Water levels in Moose Lake have been monitored since 1950 and concern over low water levels at the time resulted in the construction of a weir in 1951. Water levels then rose steadily to 534.10 m by 1966. The weir deteriorated and water levels dropped to a low of 532.60 m. A new weir with a target elevation of 533.23 m was installed in 1986 to ensure habitat for fish and waterfowl, recreational enjoyment and drinking water (Mitchell and Prepas, 1990). The new weir was ineffective as water levels continued to drop to the lowest recorded level of 531.95 m in Oct. 1993. The two wet years 1996 and 1997 restored water levels to the weir crest of 533.23 m by July 1997. In 2002, the average water level was 532.26 m, down 0.42m from the long term average calculated since 1950. The water withdrawl limit for the Town of Bonnyville is 3 million m^3/year, approximately 8 cm of depth if the town extracted water to the limit and there were no runoff from the watershed (Mitchell and Prepas 1990).

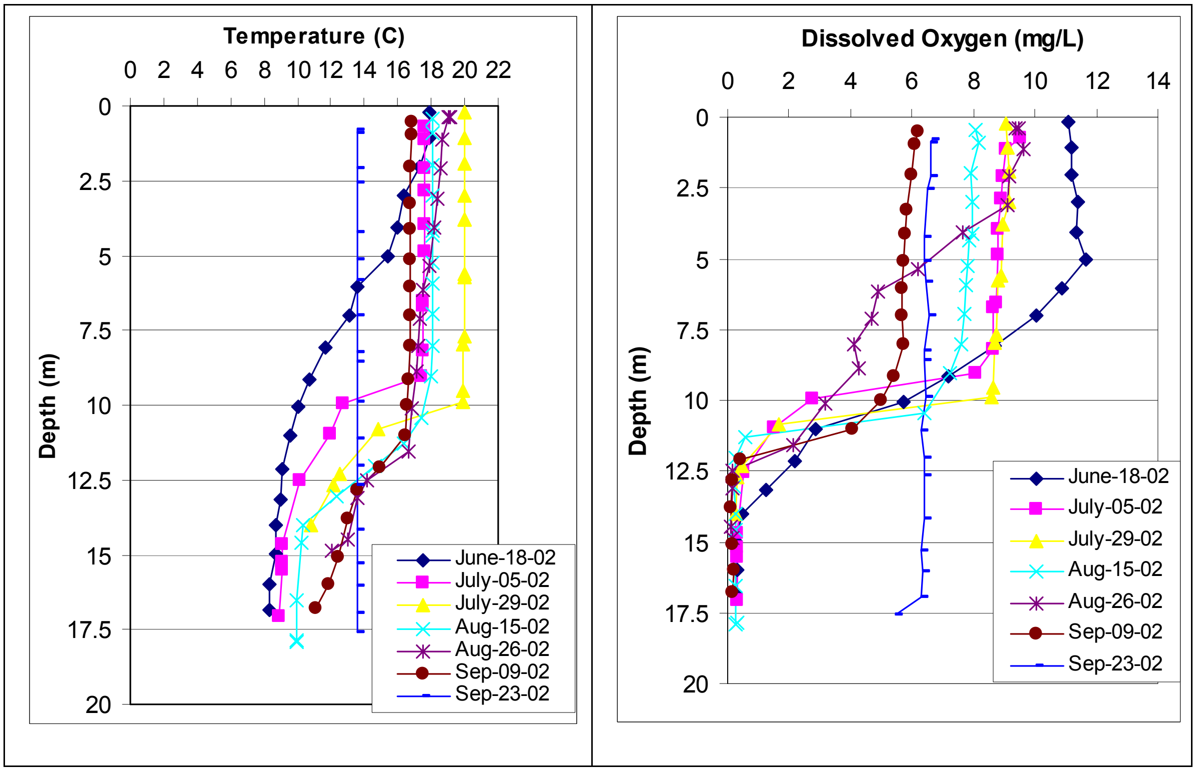

Fig. 4: Temperature and dissolved oxygen profiles for Moose Lake during 2002 sampling season.

Results

Water Temperature and Dissolved Oxygen

Thermal stratification formed early at 5 m depth in June. As surface waters continued to heat the thermocline strengthened and the mixed zone (epilimnion) extended down to between 9 and 12 m depths throughout the summer (Fig. 4). The lake mixed during mid-September creating uniform water temperature (14° C) throughout the water column. Dissolved oxygen concentrations in the epilimnion were highest (11mg•L^{-1}) in June (Fig. 4). As the thermocline deepened, surface waters remained well oxygenated with concentrations above 8 mg•L^{-1} through early August. Dissolved oxygen concentrations below the thermocline (>11 m depth) were generally lower than 1 mg•L^{-1} throughout the summer. When the thermocline broke down in September, the dissolved oxygen concentrations became uniform with depth (6.5 mg•L^{-1}) to the lake bottom (17.5 m). These patterns are a textbook example of oxygen and temperature profiles for a dimictic lake – a typical deep lake in a temperate climate.

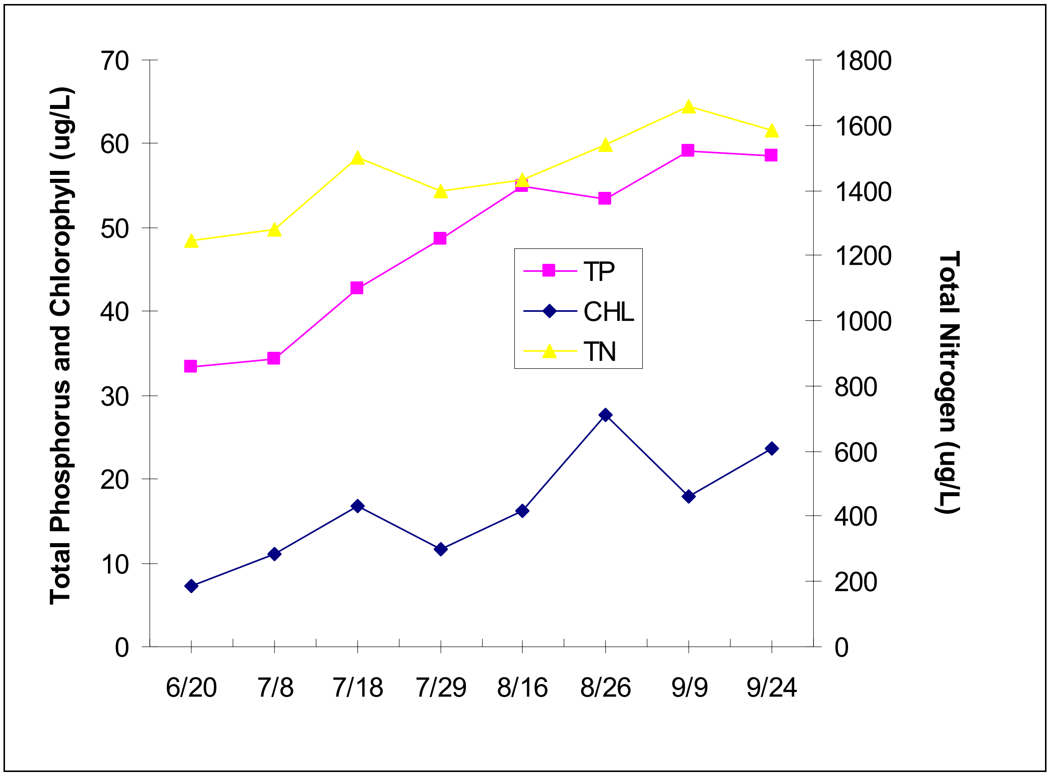

Fig. 5: Total phosphorus, chlorophyll *a* and Kjeldahl nitrogen for Moose Lake, summer 2002.

Water clarity and Secchi Depth

Water clarity is influenced by suspended material, both living and dead, as well as some coloured dissolved compounds in the water column. The most widely used measure of lake water clarity is the Secchi depth. After ice and snowmelt a lake can have low clarity due to spring runoff and suspended sediments in the lake. Lake water usually clears in the spring but then becomes less clear as algae grow through the summer. In Moose Lake, the Secchi depth demonstrated little change throughout the spring and summer. June Secchi depths of 1.7 m temporarily rose to 2.5 m in early July but returned to values between 1 and 1.75 m through the rest of the summer.

Table1: Mean values from summer 2002 samples compared to values from those reported in the Atlas of Alberta Lakes.

Parameter	1986	1988	2002
TP ($\mu g \bullet L^{-1}$)	40	42	48.2
TDP ($\mu g \bullet L^{-1}$)	-	-	13.3
Chl ($\mu g \bullet L^{-1}$)	17.6	16.0	17
Secchi (m)	2.6	2.5	1.6
TKN ($\mu g \bullet L^{-1}$)	-	-	-
TN ($\mu g \bullet L^{-1}$)	-	-	1,455
$NO_{2+3}N$ ($\mu g \bullet L^{-1}$)	-	-	1.5
NH_4^+ N ($\mu g \bullet L^{-1}$)	-	-	4.0
Ca ($mg \bullet L^{-1}$)	25	-	26.7
Mg ($mg \bullet L^{-1}$)	35	-	49.6
Na ($mg \bullet L^{-1}$)	12	-	96.9
K ($mg \bullet L^{-1}$)	13	-	17.7
SO_4^{2-} ($mg \bullet L^{-1}$)	25	-	149
Cl^- ($mg \bullet L^{-1}$)	87	-	22.4
Total Alkalinity ($mg \bullet L^{-1}$ $CaCO_3$)	254	-	319

Water chemistry

The concentrations of sodium and sulfate have increased markedly in Moose Lake since 1986. Like Angling Lake, these increases may reflect changes in hydrology towards reduced inputs from runoff making groundwater a more important source of contributions to the overall water budget. The changing ion concentrations suggest Moose Lake is not in hydrologic equilibrium. The water level graph (Fig. 3) confirms reduced water contributions, however, depth has only declined by 0.5 m since 1982. This alone should not account for the 8-fold increase in sodium concentrations. Increased sodium concentrations from sewage effluent or road salt application are typically associated with increasing chloride concentrations as well. Chloride concentrations have declined in Moose Lake either indicating that sodium sulfate. groundwater is the source of changing ion concentrations or that the 1982 chloride value is in error. Additional data collected by the town of Bonnyville would be helpful in sorting out the ion trends and the reasons behind them.

Moose Lake is eutrophic by phosphorus and chlorophyll criteria and hypereutrophic by nitrogen criteria. Algae are productive in the lake but not excessively so. In the Alberta context, Moose Lake is about average to better than average in these characteristics. Phosphorus concentrations have not increased appreciably since 1986. Historic data for nitrogen were not available for comparison.

Chlorophyll *a* (CHL) concentrations in Moose Lake have not changed since 1986 (17 $\mu g \bullet L^{-1}$). In 2002, chlorophyll *a* concentration peaked at 29 $\mu g \bullet L^{-1}$ in late August and then declined but continued the general increasing pattern that occurred through the summer (Fig. 5). The small increase in algal biomass, as indicated by CHL, that occurred in late August may represent a short period of enhanced growth perhaps induced by warm, sunny and calm weather. It is not indicative of an algal bloom which typically results in CHL concentrations similar to or above total phosphorus concentrations.

Moose Lake does not appear to be impacted by eutrophication problems caused by excessive nutrient loading that are common to other lakes in Alberta. However, ion concentrations have increased markedly, particularly towards sodium and sulfate. The increase in these two ions indicates a possible change in hydrology with greater contributions coming from deeper groundwater sources. This may be a natural result of our recent dry climate cycle. Data from regional groundwater studies should be compared with the water chemistry in this report to determine if these changes are natural. Of particular interest will be changes in water table and results from flow modeling that are likely to come from recent LICA and AENV collaboration on the Beaver River, Cold Lake Water Management Plan update.

Volunteer B. Hornseth getting ready to take a Secchi depth. Photo: Lewin, ALMS

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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 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**. 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.

Trophic status classification based on lake water characteristics.

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