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Lakewatch

Marie 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. Volunteers on Marie Lake were Donna, Marlene and Mr. Savard, R. Bibeau, D. Wood, M. Martin, R. Sobey and Cal & Patti Sikstrom. Lakewatch would not have occurred without the dedication of their time and of course watercraft. Mike Bilyk and John Willis from Alberta Environment were instrumental in 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.

Fig. 1: Marie Lake, October 2002	Photo: Lucille Kowalchuk, ALMS

Marie Lake

Marie Lake is located in the Beaver River Drainage Basin. It lies about 26 km north of the Town of Cold Lake. Marie Lake is named after the Cree word *Methae* or *Merai* meaning a fish and may refer specifically to the burbot (*Lota lota*) prevalent throughout most of Alberta. The Cree arrived in the late eighteenth century displacing Beaver, Blackfoot, and Slavey tribes that were common in the area. The Cree arrived during the growth of the fur trade along a popular route from Waterhen, Saskatchewan by way of the Beaver River (Mitchell and Prepas 1990). Oil and gas, agriculture are the primary industries. Orthic Grey Luvisols are found in the upper to mid slopes of the Marie Lake watershed. Poorly drained organic soils associated with moist areas known as fibrisols and meisols are found in depressions and flat areas making peatlands, bogs, fens, and marshes an important component of the Marie Lake watershed (Mitchell and Prepas 1990). A newly formed Marie Lake Air & Watershed Society is spearheading the protection and enhancement of the Marie Lake watershed.

Marie Lake has individual private cottages along the southern shore and a subdivision on the eastern shore on private land. Private recreation areas, such as a Canadian Forces Base tent camping facility and an Alberta Fish and Game Wilderness Camp are situated on leased Crown land (Mitchell and Prepas 1990). The latter camp no longer exists (R. Sobey pers. comm.) Additional private property and a campground are located at Shelter Bay on the north shore. Marie Lake remains largely undeveloped compared with other Alberta lakes of similar size. The most popular recreational activities in order of use include: swimming, fishing, camping, sightseeing, and relaxing. Also, popular are power boating, waterskiing, canoeing, hiking and photography (AENV 1983 Vol.6).

Currently, Marie Lake supports a domestic fishery; commercial licenses have not been issued in the last decade (Bodden 2002). Sport fish include lake whitefish, tullibee, walleye, ling, suckers, northern pike and yellow perch (AENV 1983 Main Report). The sport fishery is believed by locals to be degraded (R. Sobey pers. Comm.)

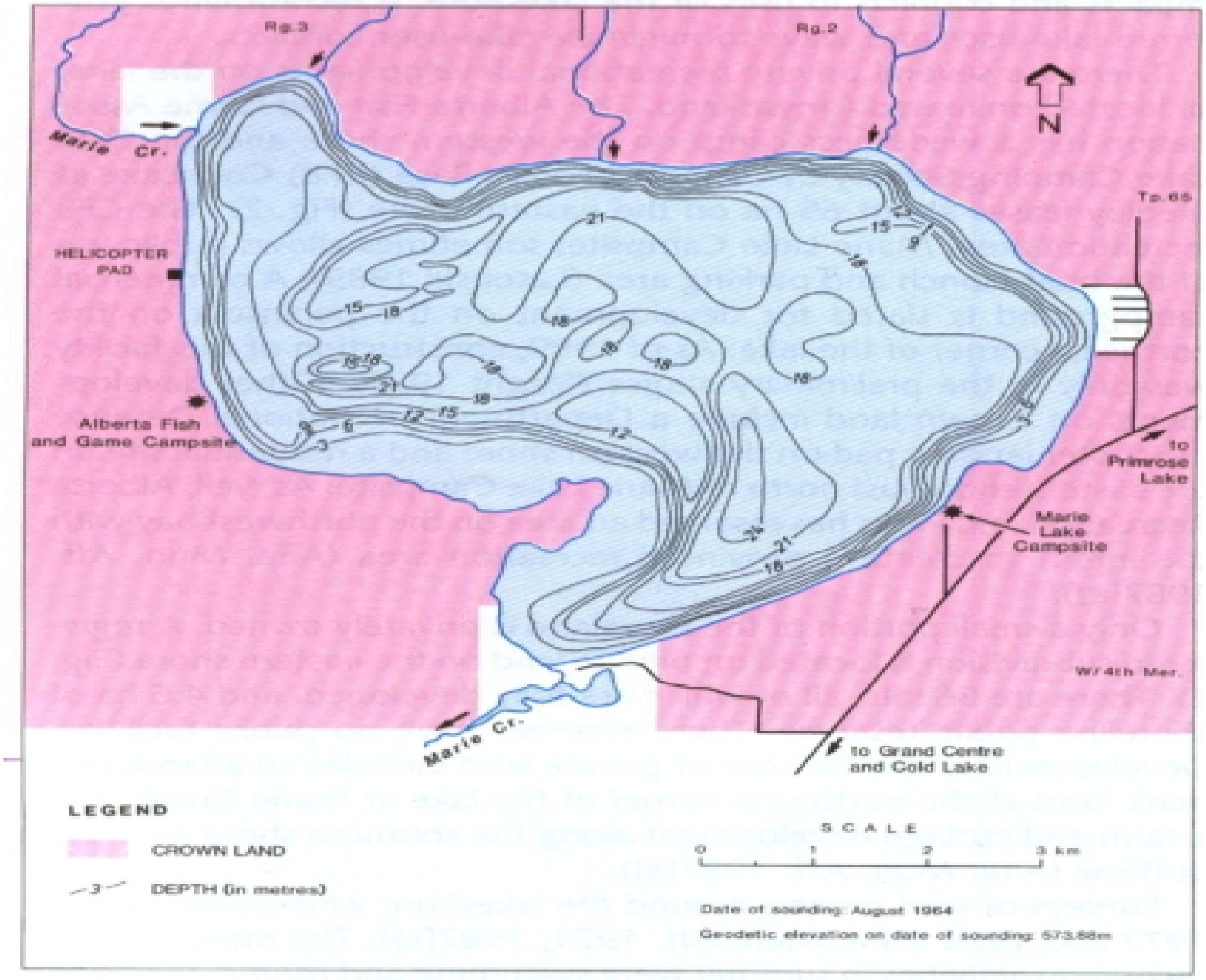

Fig. 2: Bathymetry of Marie Lake. From Mitchell and Prepas 1990.

Marie Lake is over 26 m deep (Fig. 2) with a slow flushing rate (a residence time of 14.5 years). It is mesotrophic and has a small littoral zone for its surface area of 36 km^2 (AENV, 1983). The shoreline is primarily sandy with macrophytes limited to a couple areas. A large macrophyte bed is located along the west shore stretching toward the north, and another lies on the western edge of the south bay. Macrophyte beds are dominated by bulrush, pondweed, stonewart, and northern watermilfoil (Mitchell and Prepas 1990). The low productivity of the shoreline does not provide suitable habitat for semi - aquatic wildlife (AENV1983 Main Report). However, the macrophyte beds present are very important for maintaining a productive fishery.

The water in Marie Lake is clear with little algal growth. Phytoplankton (algae) have been identified in previous studies. Six species of Cyanophyta (Blue-green algae) were present but comprised a low proportion of total algal biomass throughout the open water season. Bacillariophyta (Diatoms), Chrysophyta (Golden-brown algae), and Pyrrhophyta (Dinoflagellates) were abundant in late summer through fall.

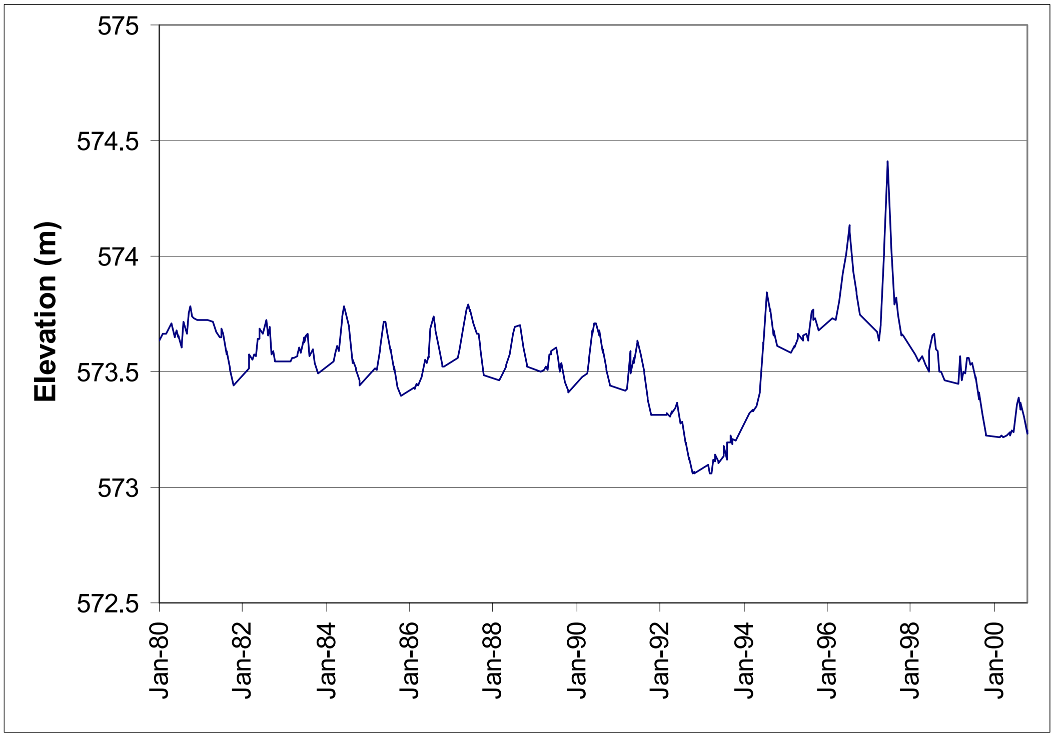

Fig. 3: Water levels in Marie Lake for the period of record from 1980 through November 2000.

Water Levels

Water levels in Marie Lake have been monitored between the years 1980 - 2000. Water levels declined to a minimum 573.060 in 1992; and subsequently increased to a maximum 574.409 m in 1997, a difference of 1.35 m. Water levels have declined since 1997 but have remained within historical ranges compared to the long-term low of 1993. Declining water levels appear to be a response to the generally dry climate and reduced runoff that has occurred in Alberta over recent years. In the last four years, average annual precipitation has been 26% lower than the long-term mean at Cold Lake with all four years below the long-term mean. The driest year on record was 2002 with only 236 mm or 55% of the long-term mean precipitation.

The water management plan implemented in 1985 indicates as much as 0.425 x 10^6 m^3 /year could be allocated from Marie Lake (Mitchell and Prepas 1990). However, there are currently no industrial water withdrawals taken from Marie Lake directly. Local residents are concerned that sustained industrial withdrawals from groundwater are contributing to reduced runoff in the region. Recently, a regulatory application has been filed for an oil expansion project on the north leases of Marie Lake. The water volumes currently licensed for industry are not expected to increase according to the Environmental Impact Assessment report for this project (Imperial Oil Resources 2002).

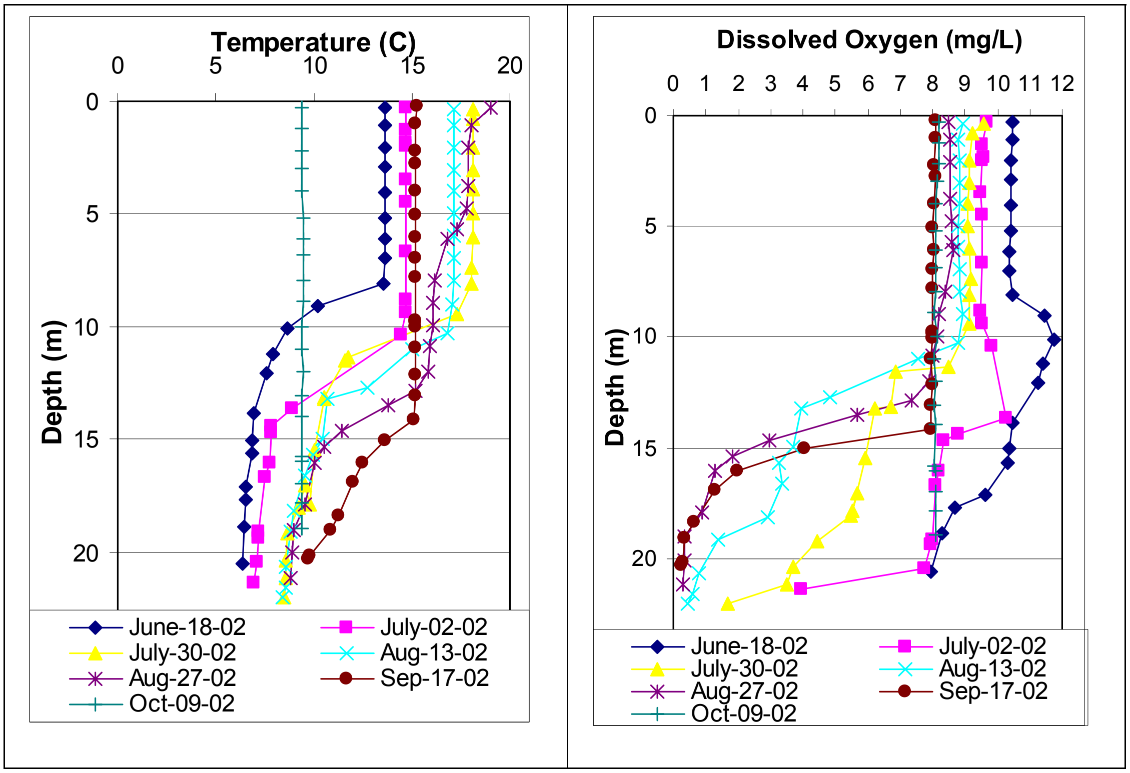

Fig. 4: Temperature and dissolved oxygen profiles for Marie Lake for the summer 2002.

Results

Water Temperature and Dissolved Oxygen

Strong thermal stratification had already formed in Marie Lake by mid-June when sampling began. The depth of the warmer water in the epilimnion moved down from 8 m to a maximum of 14 m by mid-September. Secondary thermoclines developed at 1.5 and 5 m in August likely as a result of calm conditions during the latter part of the month. Fall mixing of the water column was underway by early October when isothermic conditions occurred. During June and early July, oxygen concentrations increased at the thermocline. Subsurface peaks in oxygen concentration often occur in stratified lakes and are indicative of a phytoplankton layer that is concentrated at the thermocline. The concentrated algae use the higher nutrient concentrations that occur at the thermocline and intense photosynthesis generates the oxygen seen in the subsurface peak. Dissolved oxygen concentrations were above 8 mg•L^{-1} in the epilimnion through the entire summer. Dissolved oxygen declined below the thermocline which is typical for a stratified lake.

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. Secchi depths in Marie Lake averaged 4.6 m in 2002. Spring (4.5 m) and early summer (3.75 m) turbidity gave way to exceptional water clarity in mid-July (7.5 m). Secchi depths subsequently declined to a low of

3 m in mid-August then remained between 4 and 5 m for the remainder of the summer and fall.

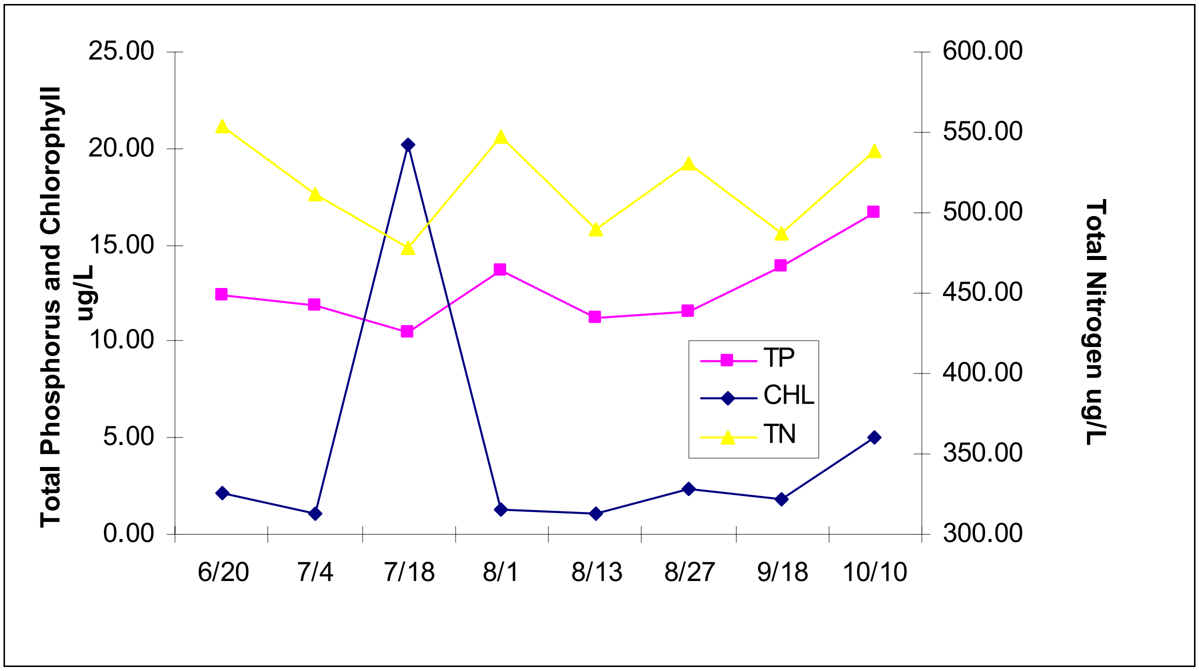

Fig. 5: Total phosphorus, chlorophyll *a* and total nitrogen for Marie Lake, summer 2002.

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

Parameter	1980	1981	2002
TP ($\mu g \bullet L^{-1}$)	-	15	13
TDP ($\mu g \bullet L^{-1}$)	-	8	5
Chl ($\mu g \bullet L^{-1}$)	6.5	4.6	2.1
Secchi (m)	2.5	3.0	4.6
TN ($\mu g \bullet L^{-1}$)	-	-	517
$NO_{2+3}N$ ($\mu g \bullet L^{-1}$)	<1	-	1.8
NH_4^+ N ($\mu g \bullet L^{-1}$)	-	<22	9.3
Ca ($mg \bullet L^{-1}$)	30	-	35
Mg ($mg \bullet L^{-1}$)	12	-	12
Na ($mg \bullet L^{-1}$)	6	-	6
K ($mg \bullet L^{-1}$)	2	-	2
SO_4^{2-} ($mg \bullet L^{-1}$)	< 3	-	0.69
Cl^- ($mg \bullet L^{-1}$)	< 1	-	0.56
Total Alkalinity ($mg \bullet L^{-1}$ $CaCO_3$)	135	-	147

Water chemistry

Ion concentrations have remained virtually unchanged in Marie Lake since data were collected in 1980. Mineral ions such as calcium and sulfate are supplied by weathering in the watershed and from groundwater inflows. The stable ion concentrations suggest Marie Lake has remained in equilibrium with its hydrology over the period of data records. Stable sulfate concentrations also indicate that atmospheric deposition of acidifying pollutants from petroleum activities are not currently influencing runoff chemistry. Excessive evaporation or changes in surface runoff that favor groundwater contributions or even problems with well injections of wastewater all result in changes in base cation concentrations if they impact the lake. Such changes were not observed in Marie Lake indicating that it has not been impacted by these types of development.

Marie Lake is mesotrophic with what is considered medium to low nutrient concentration and algal biomass compared to lakes throughout Canada. In the Alberta context, Marie Lake is one of few lakes with exceptional water quality. Nutrient concentrations remained relatively constant through the ice-free period. A slight rising trend towards the end of summer was apparent for total phosphorus; however, the rise was small when compared to the late summer increases seen in other Alberta lakes. The relatively stable nutrient concentrations are a reflection of both the volume of Marie Lake relative and by association its insensitivity to loading events from the watershed or internal processes. Marie Lake does not appear to have been impacted by nutrient loading associated with human use and land use activities in the watershed.

Chlorophyll *a* (CHL) concentrations in Marie Lake were relatively low in 2002. The apparent decline when compared to 1981 may be an artifact of sampling. We have values covering a wide range of the summer including spring when algal growth was low. An algal bloom occurred in Marie Lake in mid-July with chlorophyll concentrations reaching almost double the concentration of total phosphorus (Fig. 5). After the bloom, algal biomass quickly returned to the low concentrations seen for most of the summer.

Marie Lake does not appear to be impacted by the eutrophication problems common to other lakes in Alberta associated with non-point source discharges of nutrients. Instead its water chemistry has remained relatively pristine. However, if the declining trend in water level continues as it has done with other smaller lakes in the region, changes in water chemistry will eventually occur.

A good day with volunteers, Sikstrom, Sobey, and Savard. photo: Kowalchuk, ALMS

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.