Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Marie Lake

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2004 Report

Completed with support from:

Alberta Lake Management Society
Lakeland Industry & Community Association
Alberta Environment

Alberta Lake Management Society
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> *Water is integral to supporting and maintaining life on this planet as it moderates the climate, creates growth and shapes the living substance of all of Earth's creatures. It is the tide of life itself, the sacred source.* David Suzuki (1997). The Sacred Balance.

Alberta Lake Management Society's Lakewatch Program

Lakewatch has several important objectives, one of which is to collect and interpret water quality 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 these 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 the Lakewatch Chairs, Théo Charette, Preston McEachern, and Ron Zurawell, and the volunteers. Volunteer at Marie Lake made sampling possible through the dedication of their time and of course watercraft. Our summer field technician and volunteer coordinator, Heather Jones, was a valuable addition and contributor to this year's program. Numerous Alberta Environment staff also contributed to successful completion of the 2004 program. Project Technical Coordinator, Shelley Manchur was instrumental in planning and organizing the field program. Technologists, Mike Bilyk, Brian Jackson and John Willis were involved in the logistics planning and training aspects of the program. Doreen LeClair was responsible for data management. Heather Jones and Ron Zurawell (Limnologist, AENV) prepared this report. The Lakewatch program was financially supported by Alberta Environment, Lakeland Industry and Community Association (LICA) and Lakeland County.

Marie Lake

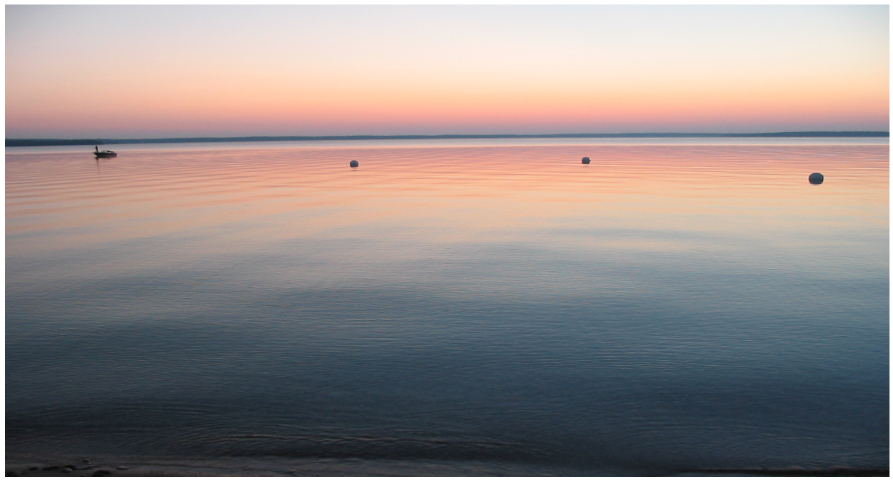

Figure 1. Marie Lake, July 2004. Photo: Theo Charette AB Env

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 peat lands, 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.

In July of 2004 Marie Lake hosted an Ecosystem Discovery Day organized by Theo Charette of Alberta Environment, participating in the event were: Theo Charette, Alan Hingston (Alberta Environment), Kim Dacyk (Living by Water), Wes English (Alberta Sustainable Resource and Development), Francine Forrest (Alberta Agriculture Food and Rural Development), Neal Michelutti (University of Alberta), Heather Jones (Alberta Lake Management Society), Cal Sikstrom (Imperial Oil resources), Crystal Charette (Volunteer), and Tyler Brekko (Volunteer), the activity day was met with great success.

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 (*Coregonus clupeaformis*), tullibee (*Coregonus artedii*), walleye (*Stizostedion vitreum*), ling (*Coregonus artedii*), suckers (*Catostomus spp.*), northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*) (AENV 1983 Main Report).

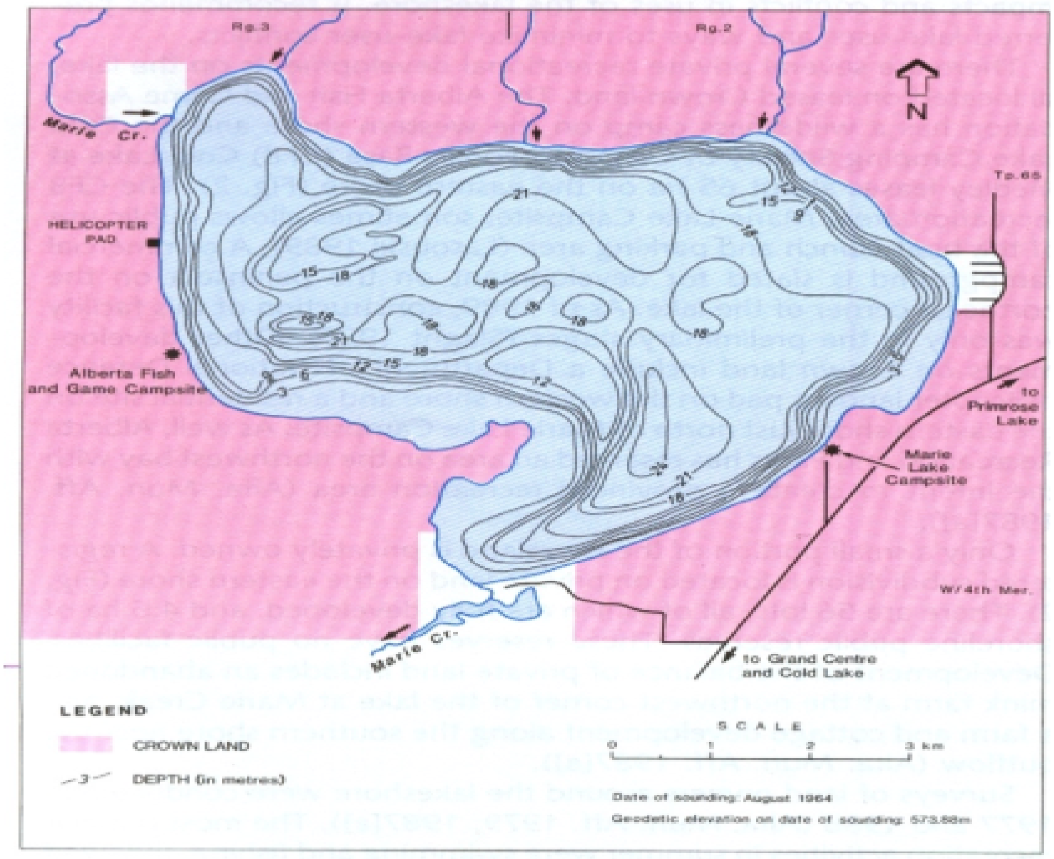

Figure 2. Bathymetry of Marie Lake. From Mitchell and Prepas 1990

Marie Lake is over 26 m deep (**Figure 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 (*Scirpus spp.*), pondweed (*Potamogeton spp.*), and northern watermilfoil (*Myriophyllum exalbescens*) (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.

Water Levels

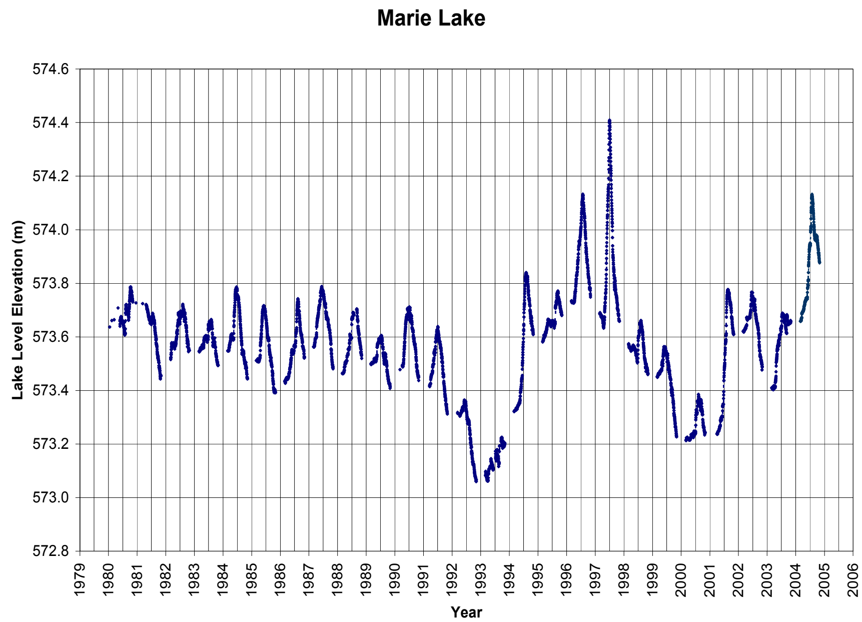

Figure 3. Historical water levels of Marie Lake.

Water levels in Marie Lake have been monitored between the years 1979 – 2004 (**Figure 3**). 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 had 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. Water levels have been steadily increasing to a level of 574.1 m in 2004 (**Figure 3**).

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.

Results

Water Temperature and Dissolved Oxygen

Strong thermal stratification existed in Marie Lake during July and August (**Figure 4)**. The depth of the warmer water in the epilimnion moved down from 8 m to a maximum of 11 m by late August. Fall mixing of the water column was underway by early September when isothermic conditions occurred. During early July, oxygen concentrations increased at the thermocline (**Figure 4**). 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 steady at 9 mg/L in the epilimnion through the entire summer. Dissolved oxygen declined below the thermocline which is typical for a stratified lake.

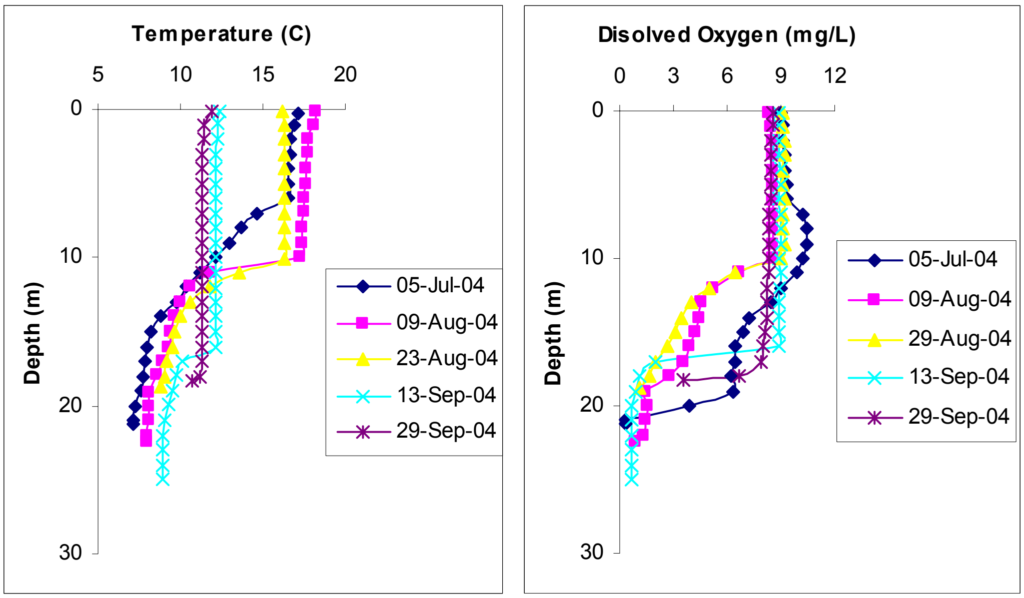

Figure 4. Temperature and dissolved oxygen profiles for Marie Lake, summer 2004.

Water clarity and Secchi Depth

Suspended material, both living and dead, as well as some coloured dissolved compounds in the water column influence water clarity. 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.

During the first sample, in early July the Secchi Disc reading was 5.5 m. Secchi depths in Marie Lake averaged 3.7 m in 2004 (**Table 1**). Secchi depths subsequently declined to a low of 3 m in late August then remained between 3.25 and 3.5 m for the remainder of the summer and fall.

Water chemistry

Ion concentrations have remained virtually unchanged in Marie Lake since data were collected in 1980 (**Table 1**). 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 he lake. Such changes were not observed in Marie Lake indicating that these types of developments have not influenced the lake.

Table1. Mean values from summer 2004. Compared to historic

Parameter	1980	1981	2002	2003	2004
TP ($\mu g \bullet L^{-1}$)	-	15	13	12	19
TDP ($\mu g \bullet L^{-1}$)	-	8	5	4	3
Chl ($\mu g \bullet L^{-1}$)	6.5	4.6	2.1	4	4.8
Secchi (m)	2.5	3.0	4.6	5.75	3.7
TN ($\mu g \bullet L^{-1}$)	-	-	517	495	550
$NO_{2+3}N$ ($\mu g \bullet L^{-1}$)	<1	-	1.8	4.8	5.2
NH_4^+ N ($\mu g \bullet L^{-1}$)	-	<22	9.3	6.5	9.0
Ca ($mg \bullet L^{-1}$)	30	-	35	34	33
Mg ($mg \bullet L^{-1}$)	12	-	12	14	12
Na ($mg \bullet L^{-1}$)	6	-	6	6	6.6
K ($mg \bullet L^{-1}$)	2	-	2	2	2
SO_4^{2-} ($mg \bullet L^{-1}$)	< 3	-	0.69	<3	<3
Cl^- ($mg \bullet L^{-1}$)	< 1	-	0.56	0.47	0.6
Total Alkalinity ($mg \bullet L^{-1}$ $CaCO_3$)	135	-	147	152	171
pH	-	-	-	-	8.44

ote. TDP = total dissolved phosphorus, NO_{2+3} = nitrate+nitrite, NH_4 = mmonium, Ca = calcium, Mg = magnesium, Na = sodium, K = otassium, SO_4 = sulfate, Cl = chloride, HCO_3 = bicarbonate, CO_3 = arbonate.

Chlorophyll *a* (i.e. water greeness) concentrations in Marie Lake were relatively low in 2004, average 4.8 ug/L (**Table 1**). This is an average increase of .8 ug/L from 2003. An algal bloom occurred in Marie Lake in early July with chlorophyll concentrations following the increased concentrations of total phosphorus, and total nitrogen (**Figure 5**). After the bloom, algal biomass quickly returned to the low concentrations seen for most of the summer.

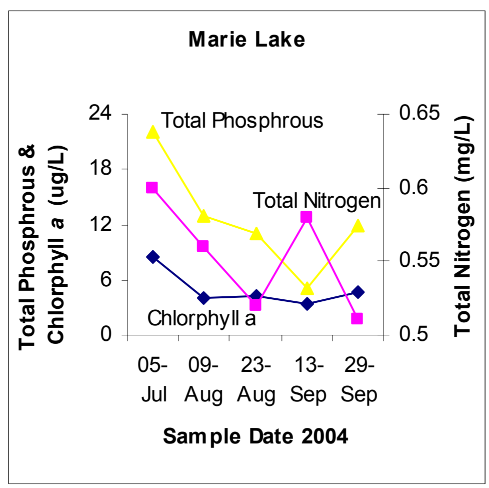

Figure 5. Total phosphorus, total nitrogen and chlorophyll *a* (i.e., water greenness) concentrations, summer 2004.

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. The water quality of Marie Lake as noted by the water chemistry has remained relatively pristine.

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. 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. Metal concentrations were low and none surpassed provincial and federal Water Quality Guidelines for the Protection of Aquatic Life (see Appendix 1).

A brief introduction to Limnology

Indicators of water quality

The goal of **Lakewatch** is to collect water samples necessary to determine the water quality of lakes. Though not all encompassing, the variables measured in **Lakewatch** are sensitive to human activities in watersheds that may cause impacts to 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 affected (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 fish habitat and production of noxious odors. Large increases in nutrients over time may also indicate sewage inputs, which in turn, may result in other human health concerns such as harmful bacteria or protozoans (e.g. *Cryptosporidium*).

Temperature and mixing

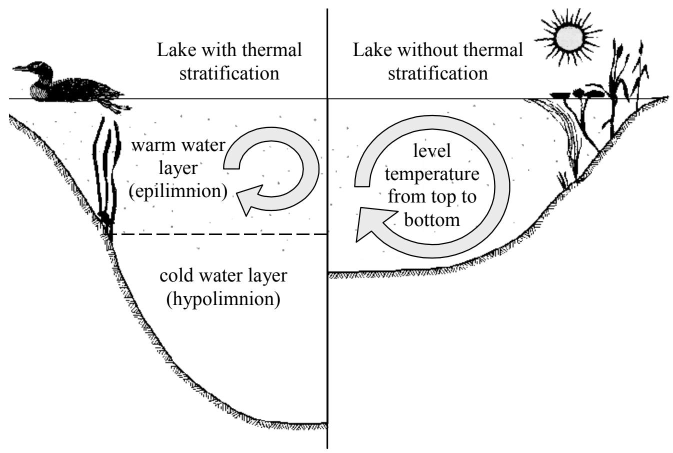

Figure 6: Difference in the circulation of the water column depending on thermal stratification.

Water temperature in a lake dictates the behavior of many chemical parameters responsible for water quality (Figure 6). 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 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 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 and should not average less than 6.5 mg/L over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 mg/L 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. Larger aquatic plants, known as macrophytes, rather than algae, dominate some highly productive lakes. In these lakes, chlorophyll-*a* and nutrient values taken from water samples do not include productivity from large aquatic plants. As a result, lakes like Chestermere, which are dominated by macrophytes, can exist at 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 Depth

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. Secchi disk depth is the oldest, simplest, and quickest quantitative measure of water clarity. A Secchi disk is a black and white disk that is lowered down through the water column until it can no longer be seen. Secchi disk depth is the midpoint between the depth at which it disappears when lowered and reappears when it is pulled up again. The Secchi disk depth in lakes with high algal biomass will generally be shallow. However, Secchi disk depth is not only affected by algae. 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 shallow Secchi disk depths despite low algal growth and nutrient concentrations.

The euphotic zone, calculated as twice the Secchi disk depth, is the portion of the water column that has sufficient light for aquatic plants to grow. Murky waters, with shallow Secchi depths, can prevent aquatic plants from growing on the lake bottom. Aquatic plants are important because they ensure clear lake water by reducing shoreline erosion and stabilizing lake bottom sediments. Many lakes in Alberta are shallow and have bottom sediments with 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 fish, depend on aquatic plants for food and shelter.

Trophic state

Trophic state is a classification system for lakes that depends on fertility and is a useful index for rating and comparing lakes. From low to high nutrient and algal biomass (as chlorophyll-*a*) concentrations, the trophic states are: **oligotrophic**, **mesotrophic**, **eutrophic** and **hypereutrophic**. The nutrient and algal biomass concentrations that define these categories are shown in table 2 and a graph of Alberta lakes compared by trophic state can be found on the ALMS website. A majority of lakes in Alberta are meso- to eutrophic because they naturally contain high nutrient concentrations due to our deep fertile soils. Thus, lakes in Alberta are susceptible to human impacts because they are already nutrient-rich; any further nutrient increases can bring about undesirable conditions illustrated in Figure. 7.

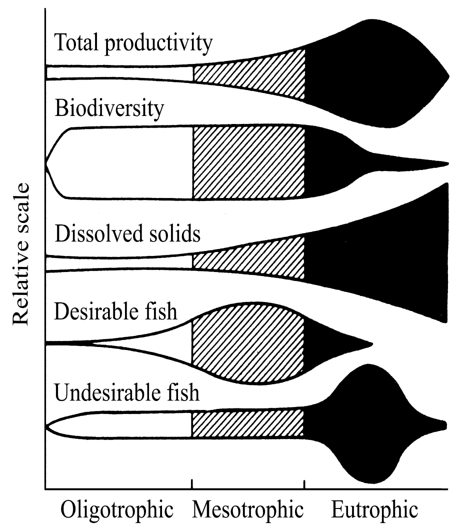

Figure 7: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

Table 2: Trophic status based on lake water characteristics

Trophic state	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll a (µg/L)	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.

Appendix 1

Means of μ/L of metals tested at Marie Lake, 2004.

METAL	Canadian Environmental Guidelines for the Protection of Freshwater Aquatic Life ug/L	Averages of Metals Tested 2004. ug/L
Silver	0.1	0.00025
Aluminum	100	5.04
Arsenic	5	0.605
Cadmium	0.04	0.0033
Copper	7	0.326
Molybdenum	73	0.15
Lead	2	0.021
Thallium	0.8	0.00067
Zinc	30	1.27
Selenium	1	0.09
Nickel	65	0.0025

*Canadian Council of Ministers for Environment. Maximum acceptable concentrations for Canadian protection of aquatic life.

Appendix 2

METAL	Concentration ug/L
Aluminum	5.04
Antimony	0.02245
Arsenic	0.605
Boron	26.5
Barium	34.7
Beryllium	0.0015
Bismuth	0.0005
Cadmium	0.0033
Cobalt	0.0058
Chromium	0.0058
Copper	0.326
Lead	0.021
Lithium	8.025
Manganese	26.5
Molybdenum	0.15
Nickel	0.0025
Selenium	0.09
Silver	0.00025
Strontium	95.1
Thallium	0.00067
Thorium	0.0033
Tin	0.015
Titanium	0.42
Uranium	0.05
Vanadium	0.09
Zinc	1.27

Note. Concentrations are averages of total recoverable metal concentrations from two sampling events that occurred during the summer of 2004.