The Alberta Lake Management Society
Volunteer Lake monitoring report

Marie Lake

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2007 Report

Completed with support from:

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

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Marie Lake

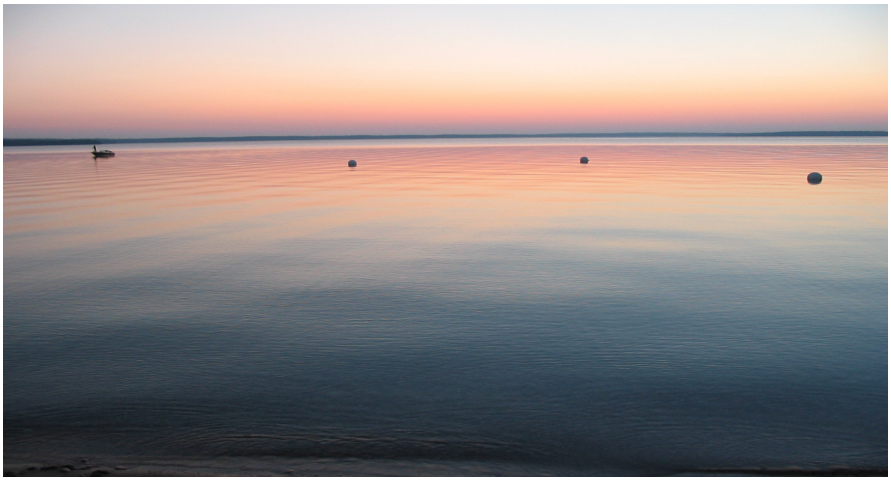

Figure 1. Marie Lake, Alberta July 2004. Photo: Theo Charette AB Env

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 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 (*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).

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.

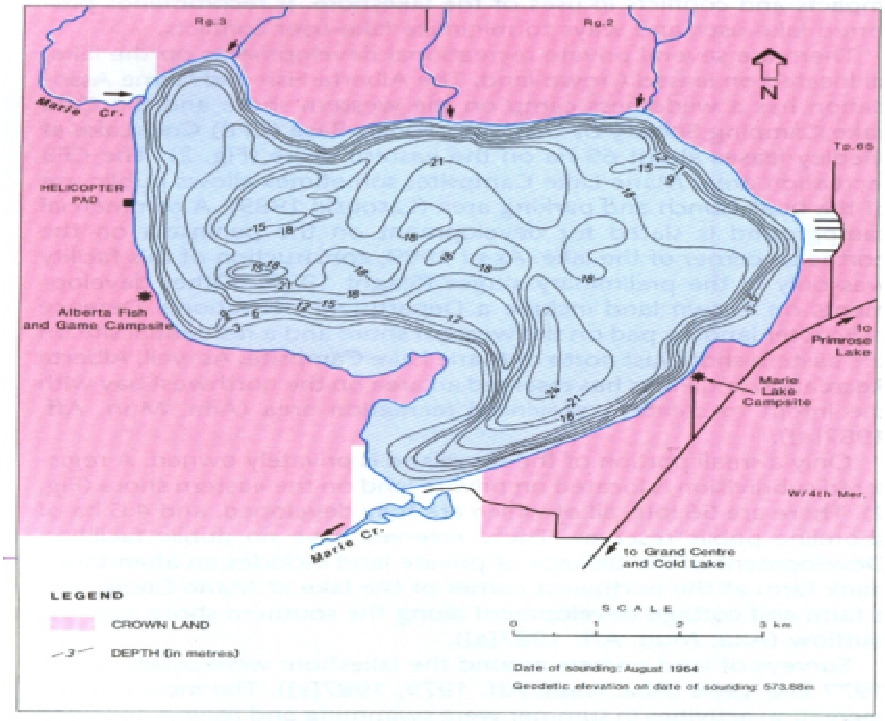

Figure 2. Bathymetry of Marie Lake, Alberta. From Mitchell and Prepas 1990

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

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

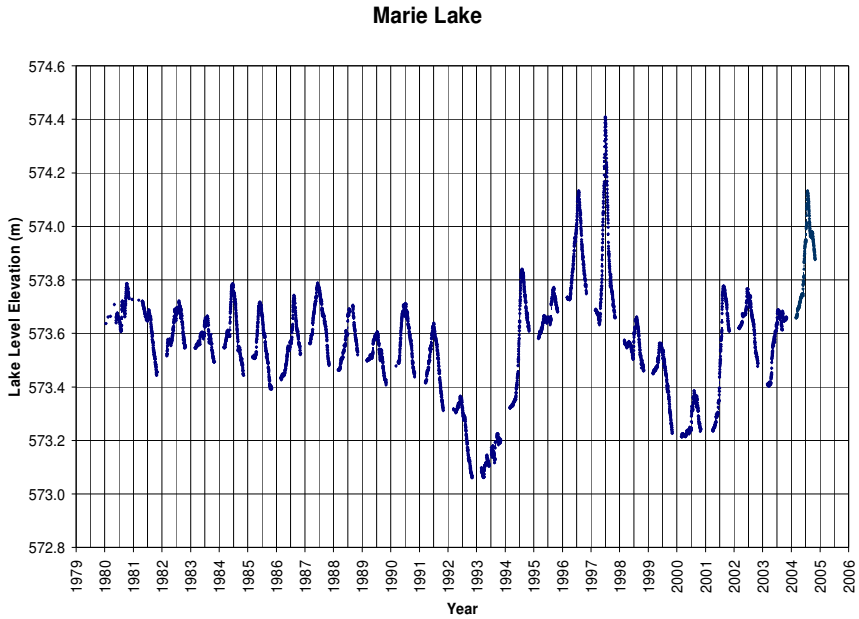

Figure 3. Historical water levels of Marie Lake, Alberta.

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 occurred in Alberta over recent years. Average annual precipitation from 2002-2006 was 26% lower than the long-term mean at Cold Lake. 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 water allocation from Marie Lake may reach 0.425 x 10^6 m^3 /year (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 and the potential for reduced surface water levels in the region.

Results

Water Temperature and Dissolved Oxygen

Marie Lake was thermally stratified between June and September 2007 (**Figure 4**). Surface water temperature peaked at 20.7º C on 11 July and declined to 13º C on 9 September 2007. The upper layer (epilimnion) extended to ~6m in June. The thermocline extended to ~11m in mid-August and to 17m in September. Fall mixing had begun in early September, as evidenced by semi-isothermic (same water temperature at all depths) conditions. Marie Lake had not fully mixed prior to the 19 September sample date, but a strong thermal stratification was evident only in July and August 2007.

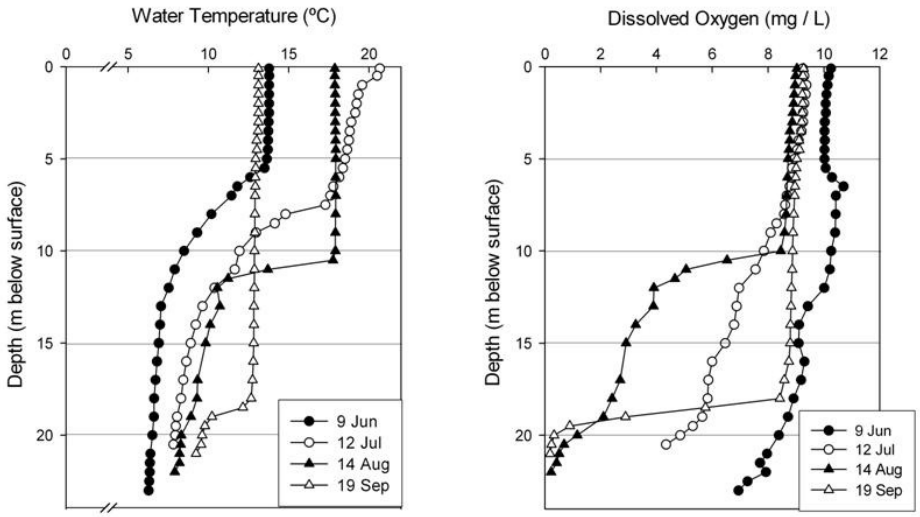

Figure 4. Water temperature (°C) and dissolved oxygen (mg /L) profiles for Marie Lake during the summer of 2007.

Surface waters in Marie Lake were well oxygenated during all sample dates (**Figure 4**). In June and July, dissolved oxygen (DO) concentrations were nearly the same at all water

depths. In mid-August, DO decreased at 18m and neared zero (e.g. anoxic) at the lake bed. In September, DO decreased at 10m and neared zero (e.g. anoxic) at 20 m depth. The DO pattern is typical for a stratified lake. The oxygen levels in the surface layer were within the acceptable range for surface water quality, according to Alberta Environment guidelines (DO ≥ 5.0 mg/L).

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.

Marie Lake a moderately deep lake compared to many lakes in Alberta. Compared to shallower lakes, Marie Lake appears relatively clear, with an average Secchi depth = 3.4 meters. In 2007, light penetrated to an average 15% of the total lake depth (**Table 1**), thus algal growth was limited to the top layers of the lake.

Water clarity was measured twice in 2007. Maximum water clarity was observed on 19 September (depth = 3.5m) and minimum clarity on 9 June (depth = 3.3m). There was a slight increase in algal biomass in September (**Figure 5**), which suggests that algae removed suspended particles from the water column, allowing light to penetrate to greater depths.

Water chemistry

Based on lake water characteristics, Marie Lake is considered mesotrophic (see *A Brief Introduction to Limnology* at the end of this report). The pattern is based on two sample dates in 2007 (**Figure 5**). Given that lakes in Alberta tend to be productive, Marie Lake is below average in nutrient concentrations and algae biomass. Mean total phosphorus (TP = 15 µg/L) and total Kjeldahl nitrogen (TN = 495 µg/L) concentrations and algae biomass (chl *a* = 2.6 µg/L) were within the mesotrophic range in 2007. An algal bloom was noted in 2004 when TP and TN concentrations increased. When TP increased in 2007, algal biomass increased slightly. Marie Lake does not appear to be impacted by the eutrophication that is common to other lakes in

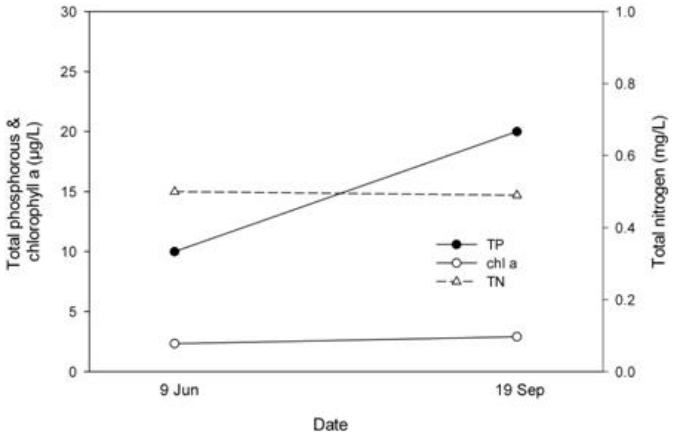

Figure 5. Total phosphorus, total nitrogen, and chlorophyll *a* (a measure of algae biomass) concentrations for Marie Lake during the summer of 2007.

Alberta associated with non-point source discharges of nutrients.

In the Alberta, Marie Lake is one of few lakes with good water quality. Nutrient concentrations remained relatively constant through the ice-free period, although data for 2007 are sparse. The relatively stable nutrient concentrations observed in Marie Lake in previous years are the result of a relative insensitivity to loading events from the watershed or internal processes due to high lake volume. Marie Lake does not appear to be impacted by nutrient loading associated with human use and land use activities in the watershed.

Maire Lake is well protected from acidification; its pH of 8.4 is well above that of pure water (i.e., pH 7). Ion concentrations have remained virtually unchanged in Marie Lake since data were collected in 1980 (**Table 1**), although carbonate and bicarbonate were not measured prior to 2007. Mineral ions such as calcium and sulfate are supplied by weathering in the watershed and from groundwater inflows. The stable ion concentrations suggest the hydrology of Marie Lake has remained in equilibrium during the sampling years. Stable sulfate concentrations indicate that atmospheric deposition of acidic petroleum-related pollutants does not currently influence the chemistry of runoff into Marie Lake. Excessive evaporation, changes in surface runoff that favor groundwater contributions, and issues related to wastewater well-injections would result in changes in base cation concentrations of lake water. Such changes were not observed in Marie Lake indicating that these types of developments have not influenced the lake.

The concentrations of various heavy metals (as total recoverable concentrations) in Marie Lake were measured once in September 2007. Metal concentrations were below CCME guidelines for the Protection of Freshwater Aquatic Life (**Appendix 1**).

Table1. Mean water chemistry values from Marie Lake in 2007, measured from two sample periods (9 June and 19 September), compared to historical values.

Parameter	1980	1981	2002	2003	2004	2007
TP ($\mu g\ L^{-1}$)	-	15	13	12	19	15
TDP ($\mu g\ L^{-1}$)	-	8	5	4	3	5.5
Chla ($\mu g\ L^{-1}$)	6.5	4.6	2.1	4	4.8	2.6
Secchi (m)	2.5	3.0	4.6	5.75	3.7	3.4
TN ($\mu g\ L^{-1}$)	-	-	517	495	550	495
NO_{2+3} ($\mu g\ L^{-1}$)	<1	-	1.8	4.8	5.2	<5
NH_4^+ ($\mu g\ L^{-1}$)	-	<22	9.3	6.5	9.0	9
Dissolved organic C ($mg\ L^{-1}$)	-	-	-	-	-	10.8
Ca ($mg\ L^{-1}$)	30	-	35	34	33	34.2
Mg ($mg\ L^{-1}$)	12	-	12	14	12	12.2
Na ($mg\ L^{-1}$)	6	-	6	6	6.6	6.9
K ($mg\ L^{-1}$)	2	-	2	2	2	2
SO_4^{2-} ($mg\ L^{-1}$)	< 3	-	0.69	<3	<3	<3
Cl^- ($mg\ L^{-1}$)	< 1	-	0.56	0.47	0.6	0.8
CO_3 ($mg\ L^{-1}$)	-	-	-	-	-	5
HCO_3 ($mg\ L^{-1}$)	-	-	-	-	-	171
Conductivity ($\mu S\ cm^{-1}$)	-	-	-	-	-	267
pH	-	-	-	-	8.44	8.4
TDS ($mg\ L^{-1}$)	-	-	-	-	-	146.5
Total Alkalinity ($mg\ L^{-1}\ CaCO_3$)	135	-	147	152	171	148

Note: TP = total phosphorous, TDP = total dissolved phosphorous, TN = total Kjeldahl nitrogen, Chla = chlorophyll *a*, NO_{2+3} = nitrate+nitrite, NH_4 = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulphate, Cl = chloride, CO_3 = carbonate, HCO_3 = bicarbonate, Cond = Specific conductivity, TDS = Total dissolved solids.

References

AENV 1983 Vol.6

AENV 1983 Main Report

Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes. University of Alberta Press.

Appendix 1

Concentrations of metals in Marie Lake, measured on 19 September 2007. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life are presented for reference.

Metals (total)	2007	Guidelines
ALUMINUM µg/L	9.1	100[a]
ANTIMONY µg/L	0.012	6[e]
ARSENIC µg/L	0.51	5
BARIUM µg/L	33.3	1000[e]
BERYLLIUM µg/L	<0.003	100[d,f]
BISMUTH µg/L	<0.001	
BORON µg/L	17.7	5000[e,f]
CADMIUM µg/L	<0.002	0.085[b]
CHROMIUM µg/L	0.08	
COBALT µg/L	<0.001	1000[f]
COPPER µg/L	0.13	4[c]
IRON µg/L	39.9	300
LEAD µg/L	0.021	7[c]
LITHIUM µg/L	4.37	2500[g]
MANGANESE µg/L	21.9	200[g]
MOLYBDENUM µg/L	0.154	73[d]
NICKEL µg/L	<0.005	150[c]
SELENIUM µg/L	0.06	1
STRONTIUM µg/L	90.8	
SILVER µg/L	<0.0005	
THALLIUM µg/L	<0.0003	0.8
THORIUM µg/L	0.007	
TIN µg/L	0.03	
TITANIUM µg/L	1.38	
URANIUM µg/L	0.08	100[e]
VANADIUM µg/L	0.14	100[f,g]
ZINC µg/L	0.64	30

Values represent means of total recoverable metal concentrations.
* one sample collected 27 June 2007.
[a] Based on pH $\geq$ 6.5; calcium ion concentration [Ca^{+2}] $\geq$ 4 mg/L; and dissolved organic carbon concentration [DOC] $\geq$ 2 mg/L.
[b] Based on water Hardness of 300 mg/L (as $CaCO_3$).
[c] Based on water Hardness > 180 mg/L (as $CaCO_3$).
[d] CCME interim value.
[e] Based of Canadian Drinking Water Quality guideline values.
[f] Based of CCME Guidelines for Agricultural Use (Livestock Watering).
[g] Based of CCME Guidelines for Agricultural Use (Irrigation).

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

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. A transition layer known as the metalimnion, which contains the effective wall separating top and bottom waters called a thermocline, separates the layers. 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.

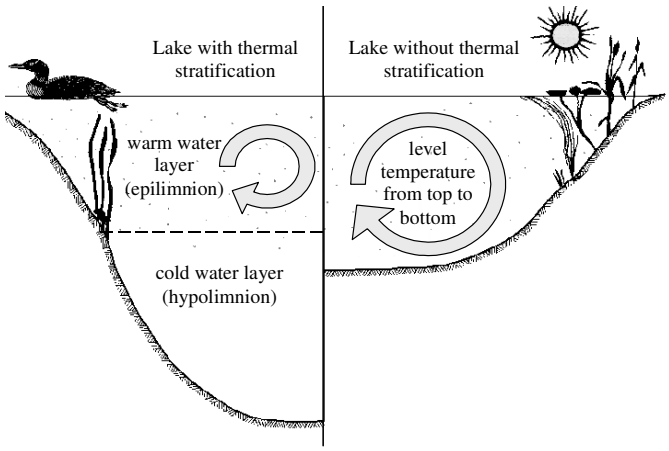

Figure 6: Difference in the circulation of the water column depending on thermal stratification.

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, algae do not only affect Secchi disk depth.

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.

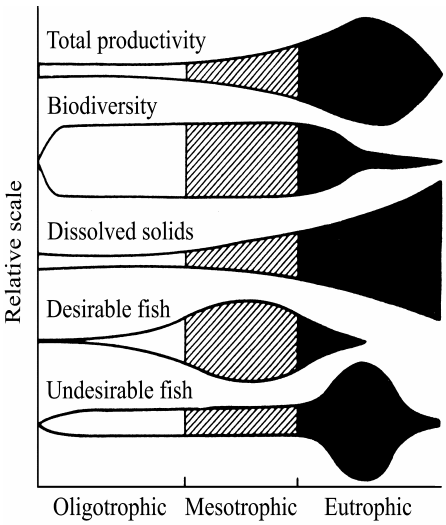

Figure 7: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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.