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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 is educating lake users about their aquatic environment, encouraging public involvement in lake management, and facilitating cooperation and partnerships between aquatic scientists 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. Substantial additional information is generally available on the lakes that have participated in Lakewatch and readers requiring more information are encouraged to seek these.

Since 2002, Lakewatch Reports have 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 castrate 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.

Another exciting event occurred in 2003. Laboratory analyses have been switched from the University of Alberta Limnology Lab to the Alberta Research Council lab in Vegreville. The ARCV has a very broad spectrum of analyses possible and their detection levels are very good. Thus, we have added metals to our suite of analyses in 2003.

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. Shelley Manchur, Mike Bilyk, Brian Jackson, John Willis and Doreen LeClair from Alberta Environment were instrumental in funding, training and organizing data. Jean-Francois Bouffard was our summer field coordinator and was an excellent addition to the program. Bob and Linda Hornseth and Laurier Sylvestre made sampling at Moose Lake possible, without their help Moose would not have been included. Francine Forrest, Jean-Francois Bouffard, and Théo Charette helped in report writing. Without the dedication of these people and the interest of cottage owners and local industry, Lakewatch would not have occurred. Financial support from Alberta Environment, the Lakeland Industry & Community Association (LICA) and the Summer Temporary Employment Program (STEP) were essential in 2003.

Moose Lake

Fig. 1: Moose Lake, Aug 2002. Photo S. Lewin.

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 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).*

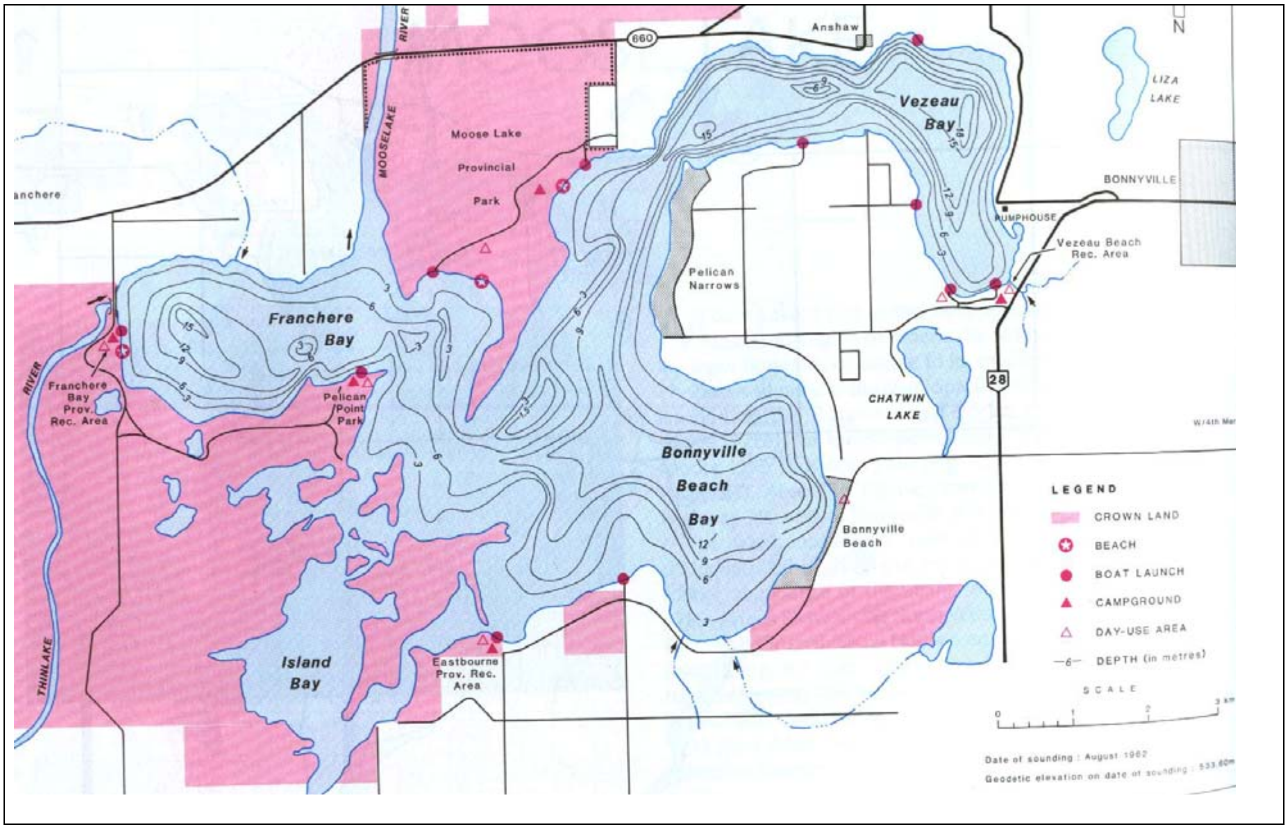

Fig. 2: Bathymetry of Moose Lake. Mitchell and Prepas (1990).

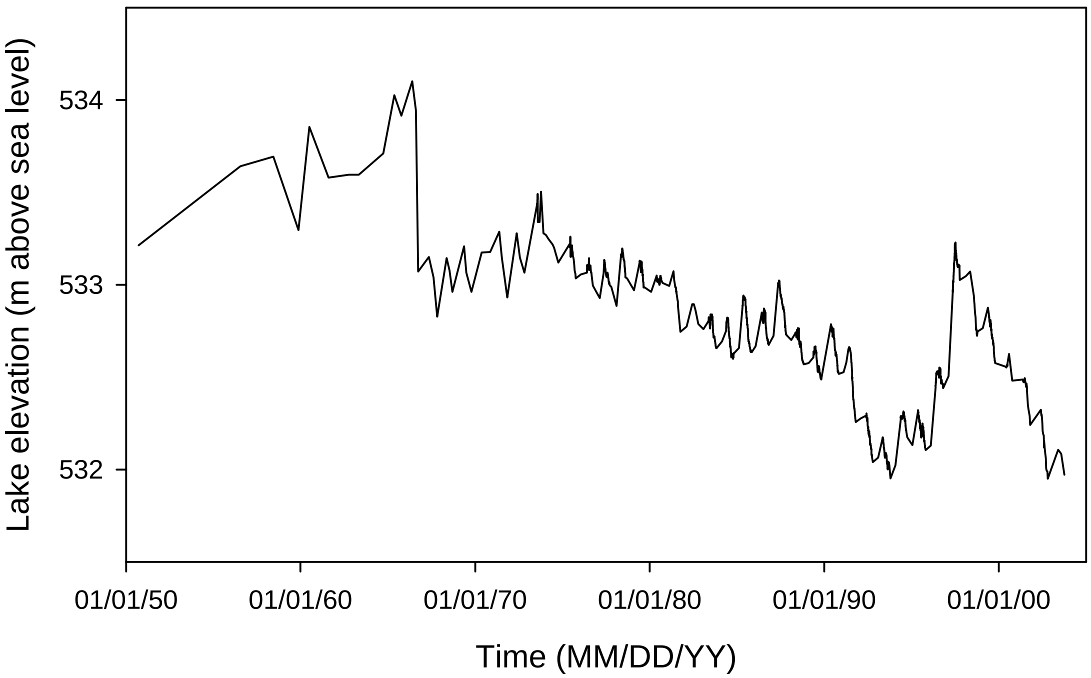

Fig. 3: Moose Lake water levels, 1950 to 2003.

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. Unfortunately, due to recent droughts, water levels reached new lows recently. In 2003, the average water level was 532.05 m, 0.62 m below the long term average. In addition, the lowest water level on record was matched in October 2002. The water withdrawl limit for the Town of Bonnyville is 3 million m^3/year, approximately 0.8 m of depth if the town extracted water to the limit and there was no runoff from the watershed (Mitchell and Prepas 1990).

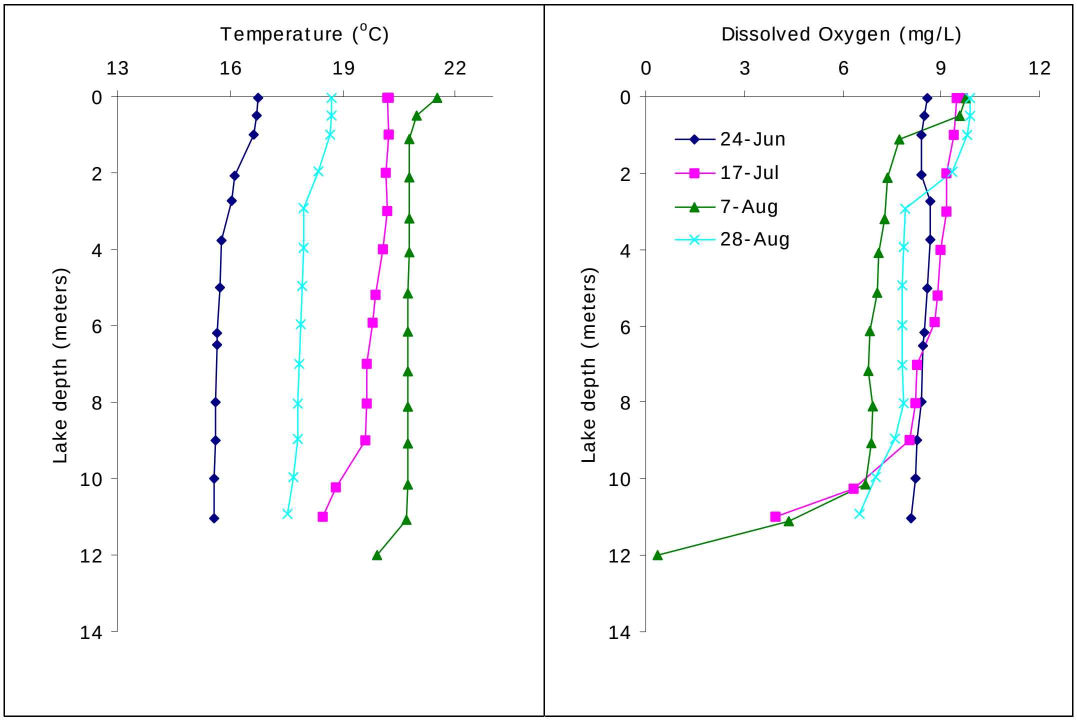

Fig. 4: Temperature and dissolved oxygen profiles in Moose Lake, summer 2003.

Results

Water Temperature and Dissolved Oxygen

Water temperature and dissolved oxygen profiles in the water column can provide information on water quality and fish habitat. Please refer to the end of this report for descriptions of technical terms.

Despite water temperatures exceeding 20 °C, no thermal stratification was apparent during the summer of 2003 in Moose Lake (Fig. 4). Consequently, the entire water column was well-airated and dissolved oxygen concentrations were above 5 mg/L, the acute provincial guideline for the protection of aquatic life, except at the very bottom near the sediments. This is common since the lake bottom is where most of the oxygen-consuming decomposition of organic matter occurs. In general, the water column of Moose Lake was well-airated.

Water clarity and Secchi Depth

Water clarity is influenced by suspended materials, both living and dead, as well as some coloured dissolved compounds in the water column. During the melting of snow and ice in spring, lake water can become cloudy from silt transported into the lake. Lake water usually clears in late spring but then becomes more turbid with increased algal biomass as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi disk depth.

In 2003, Moose Lake's water was fairly clear with a mean Secchi disk depth of 2.25 m. Water clarity followed patterns in algal biomass, or water greenness (Fig. 4). Water clarity was best in early summer (Secchi disk depth 3.75 m) and decreased progressively up to late summer (Secchi disk depth 1.25 m) as water became greener.

Water chemistry

Moose Lake had high nutrient concentrations and algal biomass compared to lakes throughout Canada, and therefore is considered eutrophic (see details on trophic status classification at end of this report). In the Alberta context, Moose Lake is perhaps a bit above average in these characteristics. In 2003, total phosphorus, total nitrogen, and consequently, algal biomass, all increased throughout the summer. Algal biomass increased almost 5-fold from June to July, at which point it was more indicative of hyper-eutrophic conditions. Blue-green algal blooms were likely a problem in the late summer 2003 of Moose Lake. Moose Lake follows the typical pattern in Alberta lakes of an increase in nutrient and algae over the summer due to nutrient loading from sediment. Metal concentrations were low and none surpassed provincial and federal Water Quality Guidelines for the Protection of Aquatic Life, which are the most stringent guidelines. In general, the water quality of Moose Lake is fair.

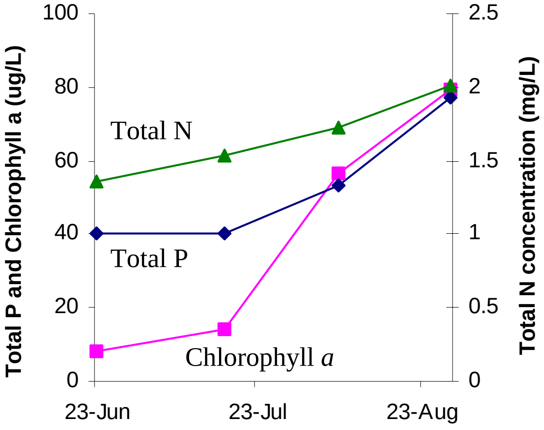

Fig. 5: Total phosphorus, chlorophyll *a* (a measure of algal biomass or water greenness) and Kjeldahl nitrogen for Moose Lake, summer 2003.

Table 1: Mean summer water quality in Moose Lake.

Parameter	1986	1993	1997	2002	2003
Total P (µg/L)	40	41	48	48	52
TDP (µg/L)	-	-	-	13	15
Chl *a* (µg/L)	18	23	25	17	39
Secchi depth (m)	2.5	2.0	2.8	1.6	2.2
TKN (mg/L)	-	-	-	1.4	1.7
NO_{2+3} (µg/L)	-	3.0	-	1.5	16
NH_4 (µg/L)	-	-	-	6.1	33
Ca (mg/L)	27	24	28	27	25
Mg (mg/L)	36	44	42	50	54
Na (mg/L)	66	84	84	97	111
K (mg/L)	12	14	15	18	17
SO_4 (mg/L)	92	115	118	144	149
Cl (mg/L)	13	16	19	22	23
CO_3 (mg/L)	16	30	16	26	29
HCO_3 (mg/L)	289	330	314	336	343
Cond (µS/cm)	678	787	776	922	954
TDS (mg/L)	400	474	480	590	573
Hardness (mg/L)	216	242	246	-	284
pH	8.6	9.0	8.6	8.8	8.9
Total Alkalinity (mg/L $CaCO_3$)	257	295	284	319	330

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

Moose Lake is well-protected from acidification; its pH of 8.9 is well above that of pure water (i.e., pH 7). Bicarbonate, sulphate, sodium, and magnesium are the dominant ions in Moose Lake. The concentration of most ions increased over the last two decades, indicating that Moose Lake is not in hydrologic equilibrium. Since runoff has been quite low in the Cold Lake area over the same time, evaporative concentration is likely responsible for the change in ion concentration. The water level graph (Fig. 3) confirms reduced water contributions. Also, because groundwater is a significant contributor to the water budget of Moose Lake, the relative increase of groundwater during drought may also explain the change in ion concentration. Groundwater is generally magnesium and sodium sulfate or chloride dominated. Atmospheric deposition of acidifying pollutants is another possibility for the increasing sulfate concentrations. Increased sodium concentrations from sewage effluent or road salt application are typically associated with increasing chloride concentrations as well. However, since other ions not generated by petroleum burning or road salt also doubled during this time, these activities are not likely solely responsible for the differences. Despite these increases in ion concentrations, nutrients and algae have not changed much over the last two decades, meaning that Moose Lake does not seem to be impacted by eutrophication. 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: S. Lewin, ALMS

A brief introduction to Limnology

Indicators of water quality

Water samples are collected in Lakewatch to determine the water quality of lakes. 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

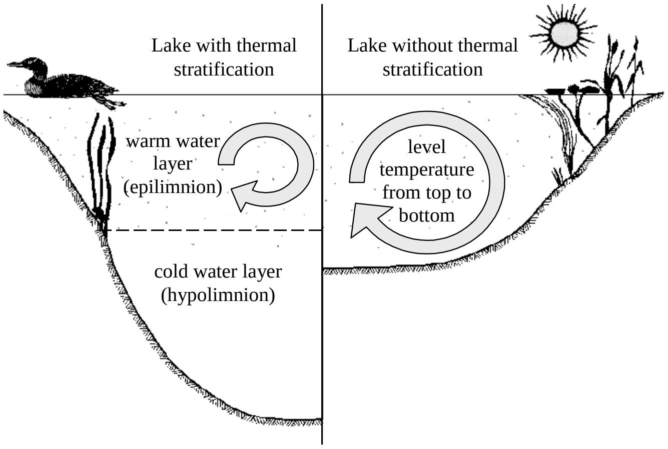

Fig. 6: Difference in the circulation of the water column depending on thermal stratification.

Water temperature in a lake dictates the behavior of many chemical parameters responsible for water quality. 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. Some highly productive lakes are dominated by larger aquatic plants, known as macrophytes, rather than suspended algae. 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 be 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) concentrations, the trophic states are: **oligotrophic**, **mesotrophic**, **eutrophic** and **hypereutrophic**. 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. 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 Fig 7.

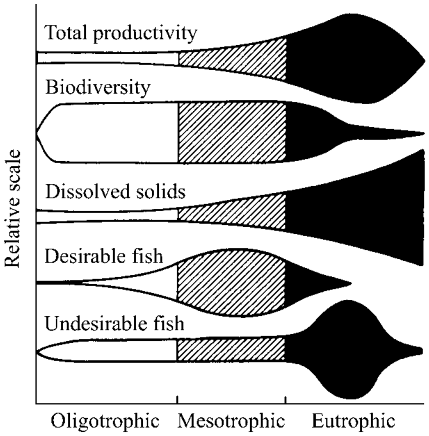

Fig. 7: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980

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.