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Lakewatch

Battle 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 sources.

Since 2002, Lakewatch Reports have undergone a substantial change in format. 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. 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 people and organizing Lakewatch data. Jean-Francois Bouffard was our summer field coordinator and was a valuable addition to the program. Francine Forrest, Jean-Francois Bouffard, and Théo Charette helped in report writing. Finally, the volunteers for Battle Lake were Michael and Chris Black, and Dave Dose, who supplied boats and time. Without the dedication of these people and the interest of cottage owners, Lakewatch would not have occurred. Financial support from Alberta Environment, the Lakeland Industry & Community Association (LICA) and the Summer Temporary Employment Program (STEP) was essential in 2003.

Battle Lake

Battle Lake is long lake nestled within a glacial meltwater channel located 102 km southwest of Edmonton in the County of Wetaskiwin. During the Pleistocene, Lake Edmonton drained through this channel leaving a very steep-sided valley. Battle Lake fed by Battle Creek and several tributaries that are the headwaters for the Battle River (Edmonton Natural History Club, 1995). Frequent territorial battles between the Blackfoot and Cree tribes lead to the name – Battle Lake. Later, settlers began arriving in 1900. Logging activity began in 1904. Logs were floated downstream to towns as far away as Ponoka. The industry warranted a small sawmill operation that was established in the 1920's. By about 1944 logging had ended and today the area is encouraged as a natural area for secondary recreational use (hiking, canoeing, relaxation, and sight seeing) (Mitchell and Prepas, 1990). Battle Lake's steep sided valley is connected by a steep ravine carved by a creek that formed a delta along the west side of the lake where a fern glade of Ostrich ferns is grown. The back setting of the ravine exposes 65 million year old bedrock of sandstone and shale that underlies Battle Lake. The lake's shoreline is forested with aspen, balsam poplar, black and white spruce, birch, willow and alder (Edmonton Natural History Club, 1995). The terrain limits extensive agricultural use and few cottages are developed along the shoreline, except near the outlet (the lowest elevation). There is also a 4-H facility located on the southwestern shore and a public campground with boat launch on the southeastern shore. Fishing for sport fish such as; lake whitefish, pike, perch, suckers and walleye is a popular activity. Walleye stocking programs have been implemented in the past. Historically, from 1949 to 1969, the lake operated a commercial fishery (Mitchell and Prepas, 1990.). Today, only domestic fishing is maintained (Bodden, 2002).

Battle Lake is 13.1 m in the deepest area (Fig. 1) of the basin. The substrate is sand and few gravel shoals. Although the water appears fairly clear, the lake is eutrophic. Algal blooms occur in late summer due to mixing and phosphorus release from the sediment in September. Phytoplankton are dominated by Cryptophyta until mid summer. Then Cyanophyta are dominant until September, but also important are Pyrrophyta. Bacillariophyta (Diatoms) dominate in May (*Asterionalla formosa*) and in October and November (*Stephanodiscus niagarae*). Macrophyte beds are fringed narrowly along the shore and most dense in shallower, less steep areas as around the northern inlet and southern outlet. The dominant aquatic macrophytes are bulrush (*Scirpus validus)* and Cattail *(Typha Latifolia)* (Mitchell and Prepas, 1990).

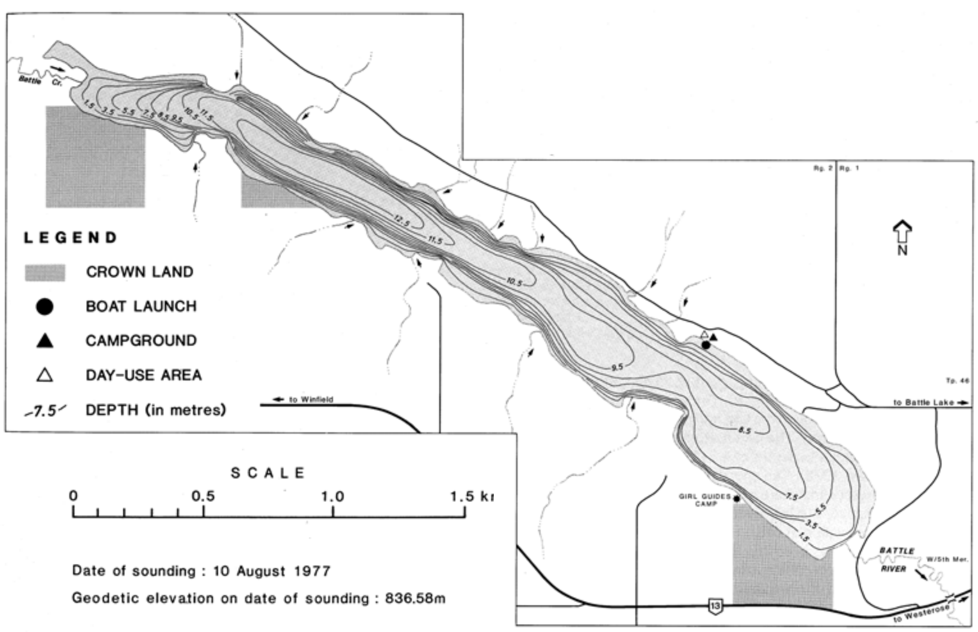


Fig. 1: Bathymetry of Battle Lake. Modified from Mitchell and Prepas 1990.

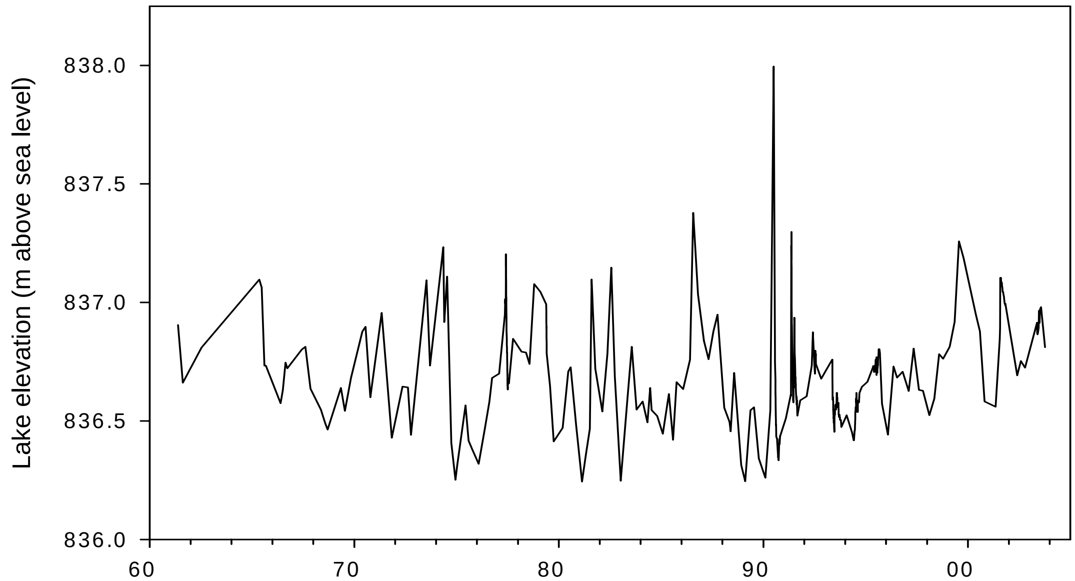
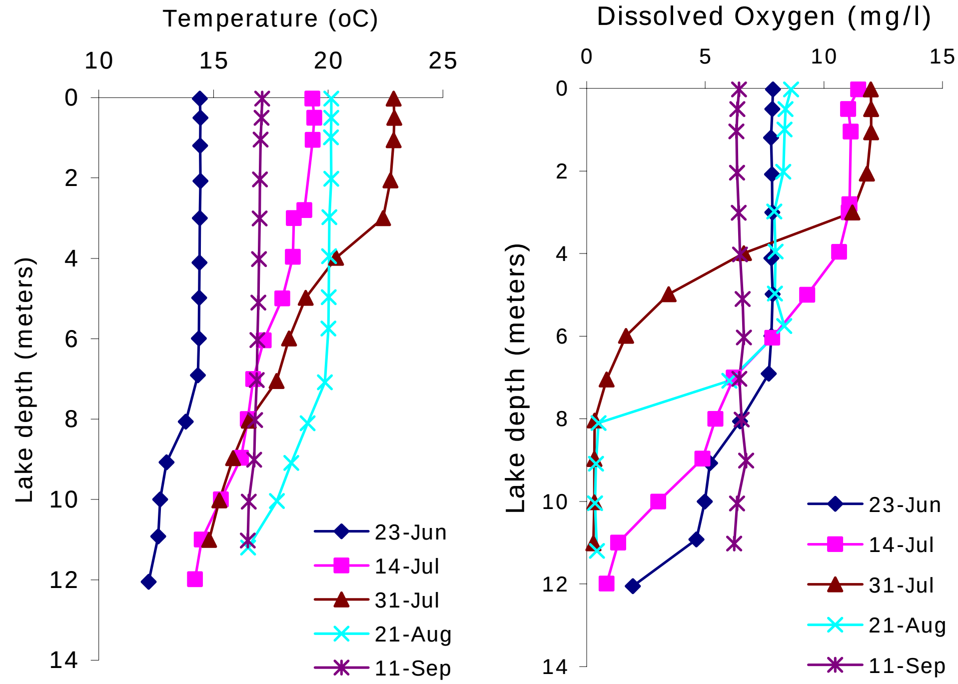


Fig. 2: Water levels in Battle Lake from 1961 to present.

Water Levels

Water levels in Battle Lake have been monitored since 1961 (Fig. 2). Water levels were lowest in February 1981 at 836.2 m, and increased by 1.75 m to a maximum 838 m in July 1990. Even though the maximum value resulted in floods along the Battle River, the average level for that year was still lower than the long-term average of 836.7 m. Since 1990, water levels remain less than ± 0.2 m of the average, except in 1999 and 2001 where when levels rose 0.4 m and 0.35 m above the average. This year, 2003, water levels remained close to average at 836.9 m (AENV, 2003). Even though Battle Lake's water levels can be quite variable on a year-by-year basis, there are no apparent long-term trends.



Figs. 3 & 4: Temperature and dissolved oxygen profiles for Battle 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.

Battle Lake is moderately deep and is sheltered from wind by its steep banks. The water column is usually thermally stratified to some degree during summer. Thermal stratification was strongest during July to August reaching a 6.5m depth in late August (Fig. 3). Weak stratification was apparent on all other sampling occasions, which started in late June and ended in mid September. Dissolved oxygen concentrations were greater than 7 mg/L through the summer above the 6 m depth mark, except during fall turnover (September; Fig. 4). In late July dissolved oxygen levels were above 10 mg/l until 3 m in depth, below which levels dropped precipitously. This coincided with a thermocline at 3 m likely due to the hot midsummer weather in 2003. As a result of stratification, dissolved oxygen concentrations were near anoxic between 9 m and 10 m in late July/August. Near lake bottom, dissolved oxygen concentrations were typically low for most months.

Water clarity

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.

Battle Lake's water was fairly clear in the beginning of summer (late June) when the Secchi depth was 3.5 m. The water gradually became more turbid over the summer, reaching a low of 1.25 m in late July and then increasing back to 1.75 m the rest of the summer and fall.

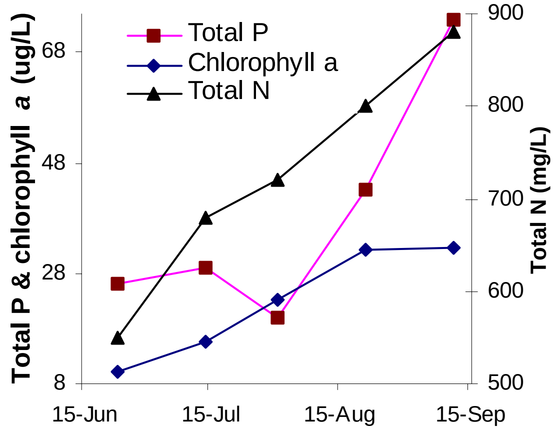


Fig. 5: Total P, total N, and algal biomass (measured as chlorophyll a) in Battle Lake, summer 2003.

Water chemistry

Because Battle Lake had moderate nutrient concentrations and algal biomass in 2003 compared to lakes throughout Canada, it is considered mesotrophic, or moderately productive (see details on trophic status classification at end of this report). In the Alberta context, Battle Lake is considered average in these characteristics. In 2003, total phosphorus concentrations were fairly stable and hovered around 25 µg/L during the beginning of the summer but then increased substantially (i.e., about 2 times) during August and September. Phosphorus concentrations in Battle Lake are highest in September. This suggests an increase in phosphorus from mixing of nutrient-rich bottom water into the surface water when the lake mixes in September.

Chlorophyll *a*, a measure of algal biomass, also increased over the summer (Fig. 5). This pattern of increased P and chlorophyll *a* concentrations in Battle Lake towards the end of summer is typical of most lakes in Alberta. Battle Lake was moderately concentrated in nitrogen with total N ranging from 550 to just under 900 µg/L and averaging 770 µg/L. In general, the aesthetics of Battle Lake water have not changed much over the last 15 years (Table 1). Metal concentrations were low and none surpassed provincial and federal Water Quality Guidelines for the Protection of Aquatic Life. Historical and recent water quality and clarity of Battle Lake have been fair.

Table1: Mean summer chemistry of Battle Lake over the last two decades.

Parameter	1983	1984	2002	2003
Total P (µg/L)	29	33	43	26
TDP (µg/L)	13	10	10	16
Chla (µg/L)	13.1	9.4	15.5	23
Secchi disk depth (m)	3.7	3.8	2.8	2.2
Total N (µg/L)	659	612	642	770
NO_{2+3} (µg/L)	4	2	2.7	7.9
NH_4 (µg/L)	31	13	8.6	26
Ca (mg/L)	-	37	36	34
Mg (mg/L)	-	10	11	12
Na (mg/L)	-	20	22	23
K (mg/L)	-	3	3.8	3.9
SO_4 (mg/L)	-	9	8.7	10
Cl (mg/L)	-	<2	3.1	3.1
CO_3 (mg/L)	-	<4	6.2	7.3
HCO_3 (mg/L)	-	215	190	187
Conductivity (µS/cm)	-	352	-	333
Total Alkalinity (mg/L $CaCO_3$)	-	182	166	166
pH	-	-	8.5	8.6

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

Battle Lake is well buffered: its pH of 8.6 is well above that of pure water (i.e., pH 7). Ions levels were fairly low in 2003 and were dominated by bicarbonate and calcium. Ion concentrations were very similar to historic values (Table 1). Mineral ions such as calcium and sulfate are supplied by weathering in the watershed and from groundwater inflows. The fairly stable ion concentrations suggest Battle Lake has remained in equilibrium with its hydrology over the period of data records. Atmospheric deposition of acidifying pollutants from petroleum activities can often be seen in increasing sulfate concentrations. Excessive evaporation or changes in surface runoff that favor groundwater contributions or even problems with well injections of wastewater all can result in changes in base cation concentrations. Such changes were not observed in Battle Lake indicating that it was not impacted by these types of development.

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

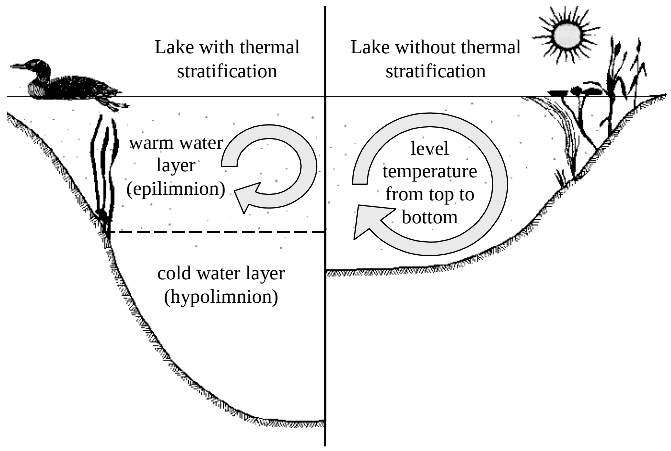


Fig. 6: Difference in the circulation of the water column depending on thermal stratification.

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.

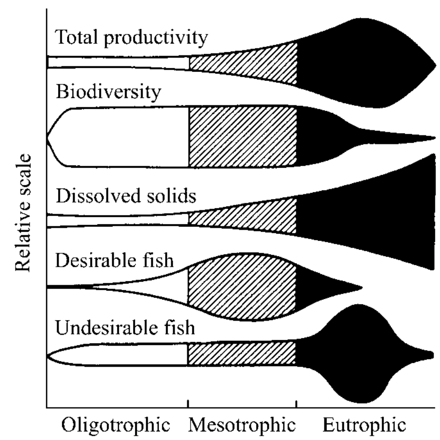


Fig. 7: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980

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.