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Lakewatch

Kehewin Lake

The Alberta Lake Management Society
Volunteer Lake Monitoring Report

And you really live by the river? What a jolly life!"

"By it and with it and on it and in it," said the Rat. "It's brother and sister to me. What it hasn't got is not worth having, and what it doesn't know is not worth knowing." *Kenneth Grahame The Wind in the Willows*

"The world's supply of fresh water is running out. Already one person in five has no access to safe drinking water." *BBC World Water Crisis Homepage*

A note from the Lakewatch Coordinator Preston McEachern

Lakewatch has several important objectives, one of which is to document and interpret water quality in Alberta Lakes. Equally important are the objectives of educating lake users about their aquatic environment; enhancing public involvement in lake management; and facilitating a link between aquatic scientists and lake users. The Lakewatch Reports are designed to summarize basic lake data in understandable terms for a lay audience, and are not meant to be a complete synopsis of information about specific lakes. Substantial additional information is generally available on the lakes that have participated in Lakewatch and readers requiring more information are encouraged to seek these sources.

The 2002 Lakewatch Report has undergone a substantial change in format from previous years. I am no longer the author as much as an editor including text and figures from others who have done an excellent job describing lakes throughout Alberta. I have attempted to give due credit to these outstanding people and apologize for blatant plagiarism where it occurs. As editor, feel free to castigate me for errors. I have included easily accessible information that is likely to have been updated in recent years and readers are encouraged to help update these reports by sending new information to me.

I would like to thank all people who share my love for aquatic environments and particularly those who have helped in the Lakewatch program. These people prove that ecological apathy can be overcome and give us hope that water will not be the limiting factor in the health of our planet.

Acknowledgements

The Lakewatch program is made possible through the dedication of its volunteers and Alberta Environment employees. Mike Bilyk, John Willis, Doreen LeClair and Dave Trew from Alberta Environment were instrumental in funding, training people and organizing with Lakewatch data. Comments on this report by Dave Trew were appreciated. Alberta Lake Management Society members and the board of directors helped in many facets of water collection and management. Sophie Lewin and Lucille Kowalchuk were our summer field coordinators and were an excellent addition to the program. Without the dedication of these people and the interest of cottage owners, Lakewatch would not have occurred.

Kehewin

Alternate spellings for Kehewin Lake are found in various literature. Official documents and spellings even differ on the two highway signs for the lake. *"Kehew"* is a Cree word meaning eagle, indicating that "Kehewin" is likely the most appropriate spelling (Dion, 2002 Pers. Comm.). Kehewin is actually named after an Indian chief, who in 1876, signed treaty no.6 for Kehewin Indian Reserve no.123 (Mitchell and Prepas, 1990). The Kehewin Indian Reserve is 8212.2 ha with 863 residents of 1,581 members in October 2002 (INAC, 2002). Kehewin Indian Reserve is in the county of Bonnyville, while most of Kehewin Lake resides in the County of St. Paul. Kehewin Lake is within the Beaver River drainage basin, which is the westernmost part of the Churchill River System. Specifically, it lies in the Moose Lake sub watershed. The outflow of the lake drains into Bangs Lake to the north via Kehewin Creek, it then joins with Yelling Creek and flows to Thin Lake, which finally, drains into Moose Lake via Thin Lake River. Agriculture in Kehewin's drainage basin is limited to pasture and hay fields. The drainage basin overlies geological formations that are rich in heavy oils; therefore oil extraction is common in the region.

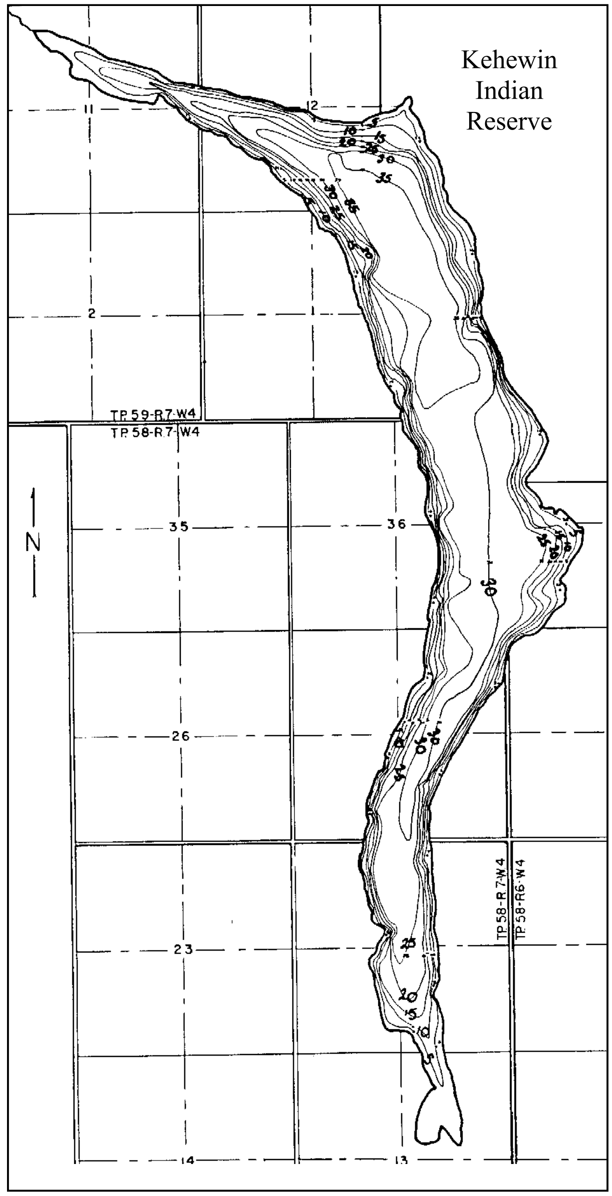


Fig. 1: Bathymetry of Kehewin Lake. Each depth contour represents 5 feet.

Kehiwin Lake is long and narrow and lies in a large melt-water channel predominated by glacial till and alluvial deposits. (Mitchell, and Prepas 1990). It is surrounded by rough broken land with steep slopes. The rocky shoreline is dominated by aspen. Extensive marshes on the north and south ends of the lake provide excellent habitat for waterfowl.

Marsh vegetation includes Reed Grass, Bulrush, Sedge and Cattail. Common submergent and floating aquatic plants include Water Smartweed, Coontail, Richardson's Pondweed, Northern Water Milfoil, Sago Pondweed, Large Sheath Pondweed, Duckweed and Arrowhead (Wilcox ASRD, 2002). Little is known about the phytoplankton composition, a detailed survey has not been completed, but a dense algal (blue-green) bloom occurred in the fall of 2002. As a popular sport fishing lake, Kehewin is noted for its large northern pike (AENV, 1983). Also present, are yellow perch, walleye, cisco, burbot, and white suckers (Wilcox, ASRD, 2002). Commercial and domestic fishing has been active in the last decade (Bodden, ADRD 2002). Commercial fishing has been recorded as far back as 1945 (AENV, 1983). Kehewin Lake has two recreational facilities: one located on the southeast shore just off highway 41, and the other located on the southwest shore.

Results

Water Levels

Water levels in Kehewin Lake have been monitored since 1967. In 2002, the mean elevation was similar to the 1967-2002 average (539.5 m). Kehewin Lake has maintained very stable water levels; minimum water level was 839 m in 1993 and reached a maximum of 540.5 m in 1997, a difference of only 1.5 m over thirty five years. Kehewin Lake receives a steady inflow of water because its drainage basin is very large (755 km^2) as compared to its surface area (6.2 km^2). Thus, unlike other lakes in Alberta, decreasing water levels is not a problem in Kehewin Lake.

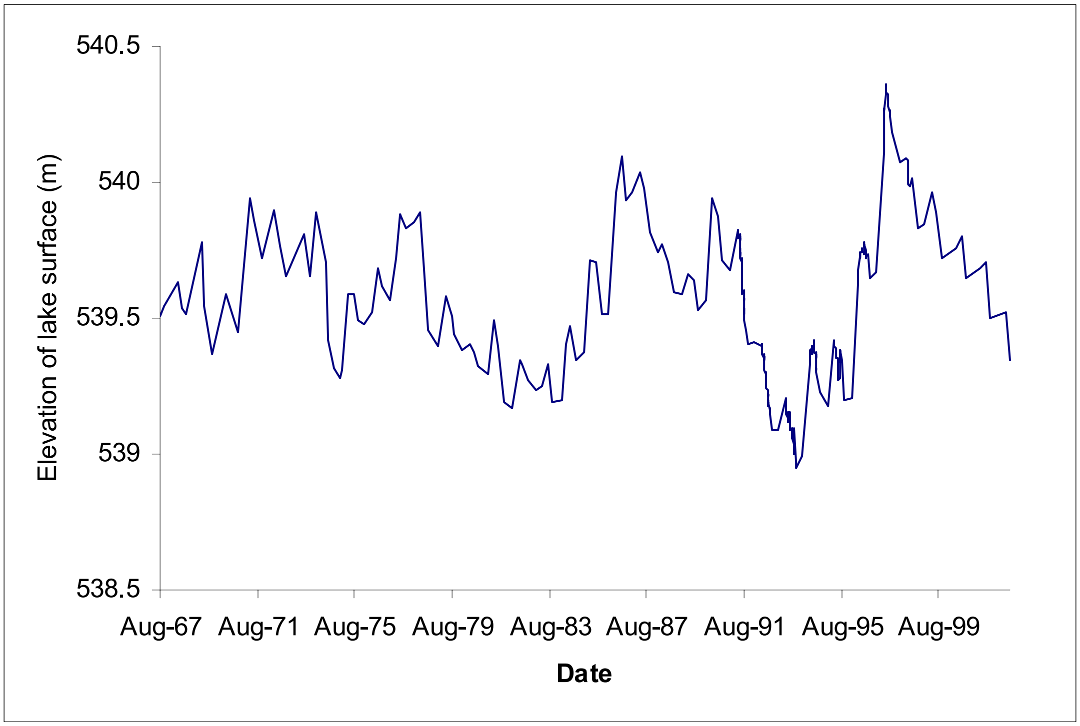
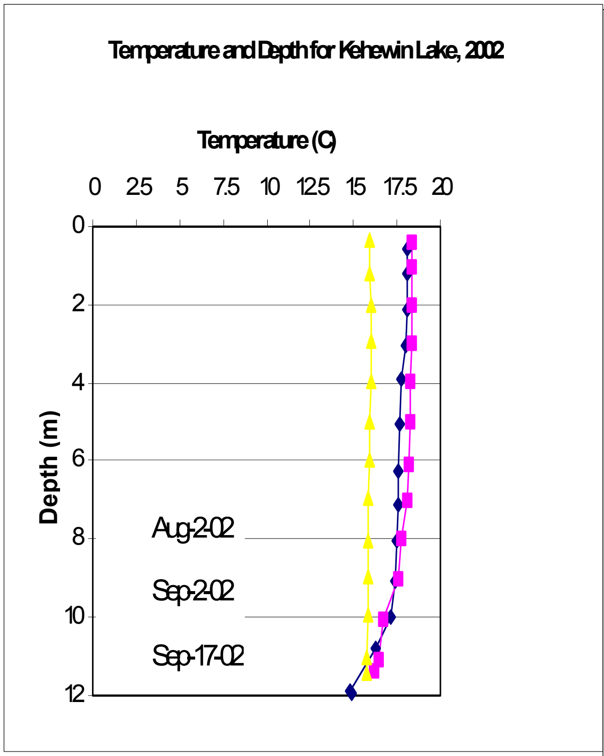


Fig. 2: Lake levels (meters above sea level) for Kehewin Lake, 1967 to 2002.

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.

Very weak thermal stratification formed at 3 m and at 10 m in August. Consequently, a decrease in oxygen concentration also occurred at these depths. Also in early September, a very small change in temperature resulted in a decrease in oxygen levels. However, in late September where no stratification occurred oxygen levels were very low throughout the column at 2.8 mg/L. In each sampling, water was anoxic near the sediment. An algal bloom was reported during the last week in September and windy conditions were capable of mixing the lower oxygen concentrations throughout the column. More sampling would have determined if these conditions could result in fish kills.



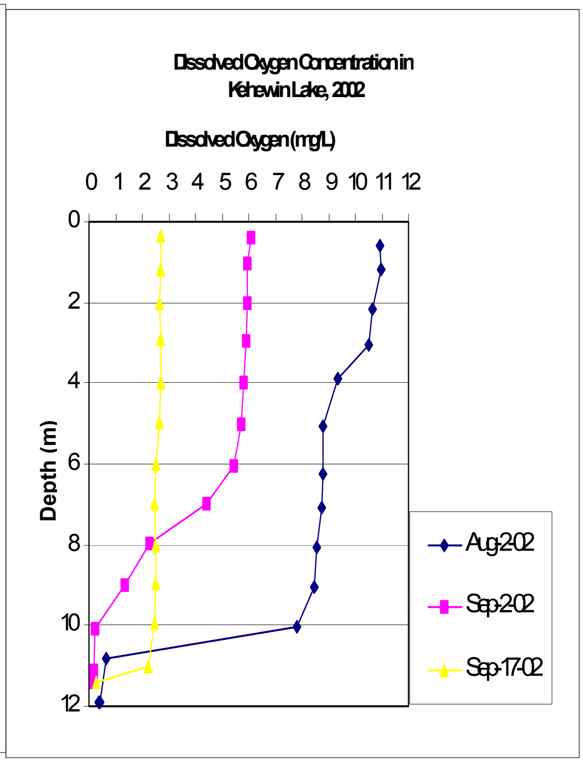


Fig. 3 & 4: Temperature and dissolved oxygen profiles for Kehewin Lake, summer 2002.

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.

Kehewin Lake's water was fairly turbid during the summer of 2002: Secchi disk depth averaged about two meters. During most of the summer, water clarity was low and hovered around 1 to 2 m. However, clarity was very good in mid-September, when Secchi disk depth reached a maximum of 4.25 m. Average water clarity in the summer of 2002 seems typical for Kehewin Lake and is consistent with historical records (Table 1).

Water chemistry

Kehewin Lake had very high nutrient concentrations and algal biomass compared to lakes throughout Canada; it is considered hyper-eutrophic (see details on trophic status classification at end of this report). In the Alberta context, Kehiwin Lake is more fertile than a typical lake in its natural state. In 2002, nitrogen and phosphorus concentrations were fairly steady during most of the summer but then doubled in September (Fig. 5). Conversely, algal biomass (measured as chlorophyll *a*), was at its peak in late August/early September and then decreased to its lowest levels towards the end of September. This pattern of increase in algal biomass from spring to late summer is typical for Alberta lakes. However, it is unusual that algal biomass did not increase to a degree similar as the nutrients in late summer. The linkage between nutrients and algae was not very strong in 2002.

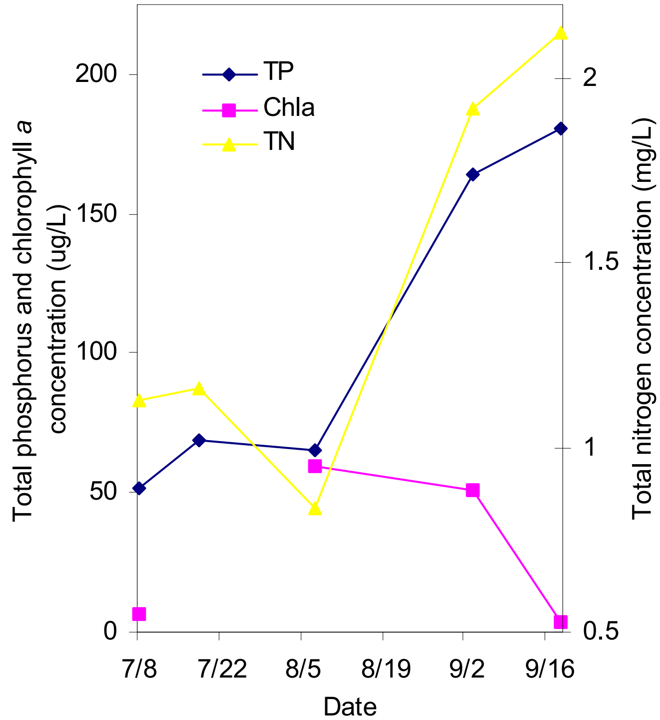


Fig. 5: Total phosphorus, chlorophyll *a* and Kjeldahl nitrogen for Kehewin Lake, summer 2002.

Kehewin Lake is well-buffered from acidification: its pH of 8.5 is well above that of pure water (i.e., pH 7). Its dominant ion is bicarbonate, corresponding to the alkaline nature of the groundwater in the area. Ammonium concentrations were quite high in 2002, especially at the end of summer / beginning of fall when they reached about 500 µg/L. Ammonium is produced by bacterial decomposition of organic matter, which mostly occurs at the lake bottom. Fall mixing of the water column likely transported the high ammonium from the bottom to the surface of Kehewin Lake.

Access to historic data from Kehewin Lake was very limited when preparing this report. Therefore, we cannot comment on changes in water chemistry over time. However, water quality in Kehewin Lake was consistent with other hypereutrophic lakes in Alberta.

Table1: Mean chemical characteristics of Kehewin Lake during summer 2002.

Parameter	2002
Total phosphorus (µg/L)	106
TDP (µg/L)	65
Chlorophyll *a* (µg/L)	30
Secchi disk depth (m)	2.1
Total nitrogen (µg/L)	1433
NO_{2+3} (µg/L)	20
NH_4 (µg/L)	149
Ca (mg/L)	25
Mg (mg/L)	29
Na (mg/L)	32
K (mg/L)	14
SO_4 (mg/L)	20
Cl (mg/L)	16
CO_3	6.2
HCO_3	189
Total Alkalinity (mg/L $CaCO_3$)	165
pH	8.5

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

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

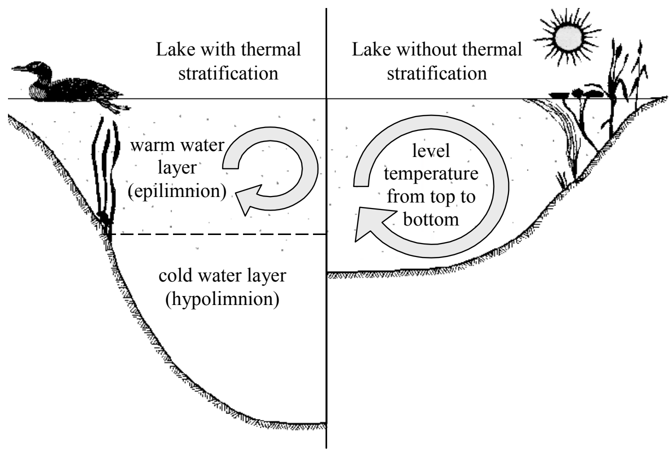


Fig. 6: Difference in the circulation of the water column depending on thermal stratification.

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.

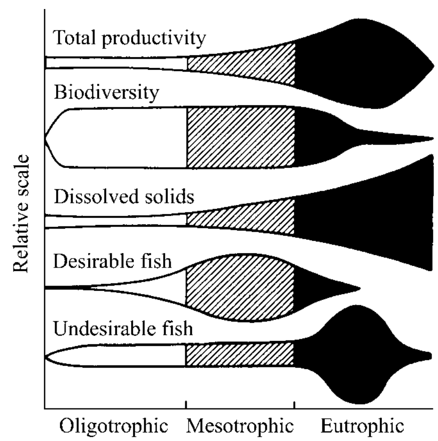


Fig. 7: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980

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.