The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Thunder Lake

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2009 Report

Completed with support from:

Alberta Environment

Alberta Lake Management Society

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

Alberta Lake Management Society's Lakewatch Program

Lakewatch has several important objectives, one of which is to collect and interpret water quality data on Alberta Lakes. Equally important is educating lake users about their aquatic environment, encouraging public involvement in lake management, and facilitating cooperation and partnerships between government, industry, the scientific community and lake users. Lakewatch Reports are designed to summarize basic lake data in understandable terms for a lay audience and are not meant to be a complete synopsis of information about specific lakes. Additional information is available for many lakes that have been included in Lakewatch and readers requiring more information are encouraged to seek these sources.

ALMS would like to thank all who express interest in Alberta's aquatic environments and particularly those who have participated in the Lakewatch program. These people prove that ecological apathy can be overcome and give us hope that our water resources will not be the limiting factor in the health of our environment.

Acknowledgements

The Lakewatch program is made possible through the dedication of its volunteers and Lakewatch Chairs, Al Sosiak and Ron Zurawell. We would like to thank Ryan Harrison for his efforts in collecting data in 2009. We would also like to thank Noemie Jenni and Cristen Symes who were summer interns with ALMS in 2009. Project Technical Coordinator, Jill Anderson was instrumental in planning and organizing the field program. Technologists, Shelley Manchur, Mike Bilyk, Brian Jackson and John Willis were involved in the logistics planning and training aspects of the program. Doreen LeClair and Chris Rickard were responsible for data management. Théo Charette (ALMS President) and Jill Anderson (Program Manager) were responsible for program administration and planning. Théo Charette, Ron Zurawell (Limnologist, AENV), Lori Neufeld, and Sarah Lord prepared the original report. Alberta Environment and the Beaver River Watershed Alliance (BRWA) were major sponsors of the Lakewatch program.

Thunder Lake

Thunder Lake (**Figure 1**) is an attractive recreational lake located in the County of Barrhead. It is situated approximately 22 km west of the town of Barrhead and 130 km northwest of the city of Edmonton. Thunder Lake Provincial Park is on the northeast side of the lake, and can be reached by Highway 18 from Barrhead. The lake's name is a translation of an Indian word that described the loud thundering sound made by the lake's ice cracking in winter (Holmgren and Holmgren 1976).

Figure 1. Photo of Thunder Lake, AB. August 28, 2007.

Thunder Lake is a medium-sized water body, approximately 6 km long with a maximum width of 2.4 km. The western half of the lake slopes gently to a maximum depth of approximately 4.5 m, while the eastern half slopes more steeply to a maximum depth of 6.1 m. There are several islands in the lake; three of them are part of the provincial park (**Figure 2**).

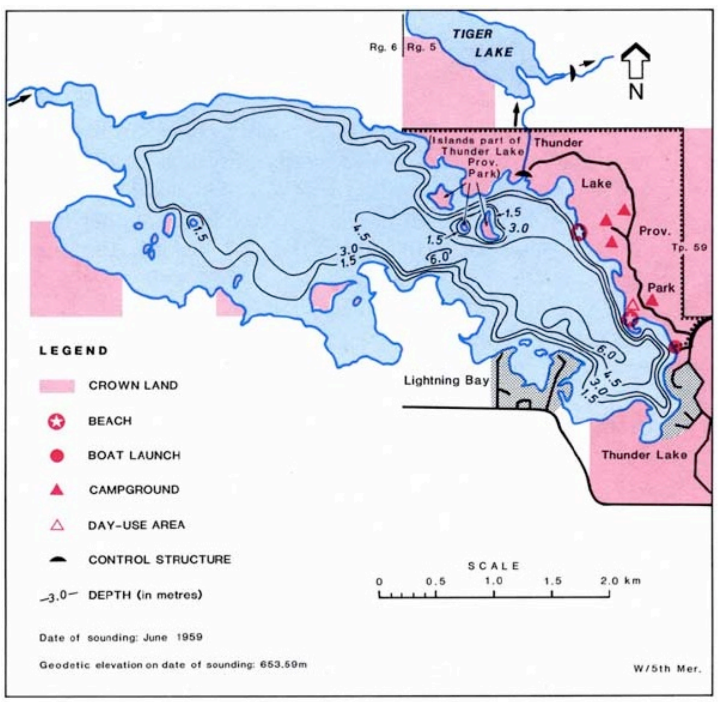

Figure 2. Bathymetry of Thunder Lake, AB. Contour intervals are 3 m.

The first settlement in the area was at Fort Assiniboine, 23 km north of Thunder Lake. The North West Company established a trading post there in 1825, but had abandoned it by 1859. The area between Thunder Lake and Barrhead was settled between 1900 and 1910. In 1912, Barrhead was founded a short distance northeast of its present site. The town relocated in 1927 when the railroad arrived, bringing a new wave of settlers to the area (Wynnyk *et al*. 1969). Rugged topography and poor farmland discouraged much development near the lake. The first cottage development at the lake was started in 1958; at present, Lightning Bay village and Thunder Lake community are situated on the southeast shore.

Local residents used the lake recreationally for many years and in 1951 they petitioned the provincial government for a park. That same year, the Barrhead Kinsmen cleared a beach at the lake, and in 1958 the province established Thunder Lake Provincial Park. There are three camping loops with a total of 127 sites, a group camping area, a sewage disposal facility, tap water, playgrounds, a change house, a concession, picnic shelters, two swimming areas and beaches, two boat mooring areas, a boat launch and several walking trails. There are no boating restrictions over most of the lake, but in posted areas such as designated swimming areas, all boats are prohibited. In other posted areas, power boats are restricted to a maximum speed of 12 km/hour.

Algae turn the water in Thunder Lake green during summer and aquatic vegetation grows around much of the shoreline. During winter, levels of dissolved oxygen frequently become critical for the fish population, and winterkills have occurred several times since the late 1960s. The lake has been stocked with northern pike and yellow perch, and these species provide a popular sport fishery.

Results

Water Level

Thunder Lake had no well-defined outlet prior to 1963, and land near the lake flooded when water levels were high. To control lake levels, Ducks Unlimited (Canada) and the provincial government began construction of a weir and canal on the north shore in 1963. Water flows north from Thunder Lake to nearby Tiger Lake via this canal, then to the Paddle River via Little Paddle Creek. During the spring runoff period, water is diverted into Thunder Lake until the lake's elevation reaches a maximum of 654.1 m asl; the control structure has a range of about 1.65 m above and below the operating full supply level. The elevation attained in spring depends on the amount of runoff available. During summer, the water level is gradually drawn down to about 653.8 m asl.

Water levels in Thunder Lake were first recorded in 1960 and 1961, and have been monitored regularly since 1964 (**Figure 3**). During a drought in 1967, the town of Barrhead used Thunder Lake, via the Paddle River, as an emergency water supply. That year the water level dropped 0.47 m, and by September of 1968, the lake level had declined to the historic minimum of 653.1 m asl. The elevation rose considerably during 1971, which was a year of high precipitation levels, and continued to rise until May 1972, when the historic maximum elevation of 654.2 m asl was reached. From 1980 to 1987 water level fluctuated over a range of 0.36 m, which would result in only a small change in lake area. However, water level at Thunder Lake has declined significantly over the past decade, and approached the historic minimum, reaching 653.2 m asl in October 2009. This reduction in water level has impaired the operation of the boat launch in the provincial park.

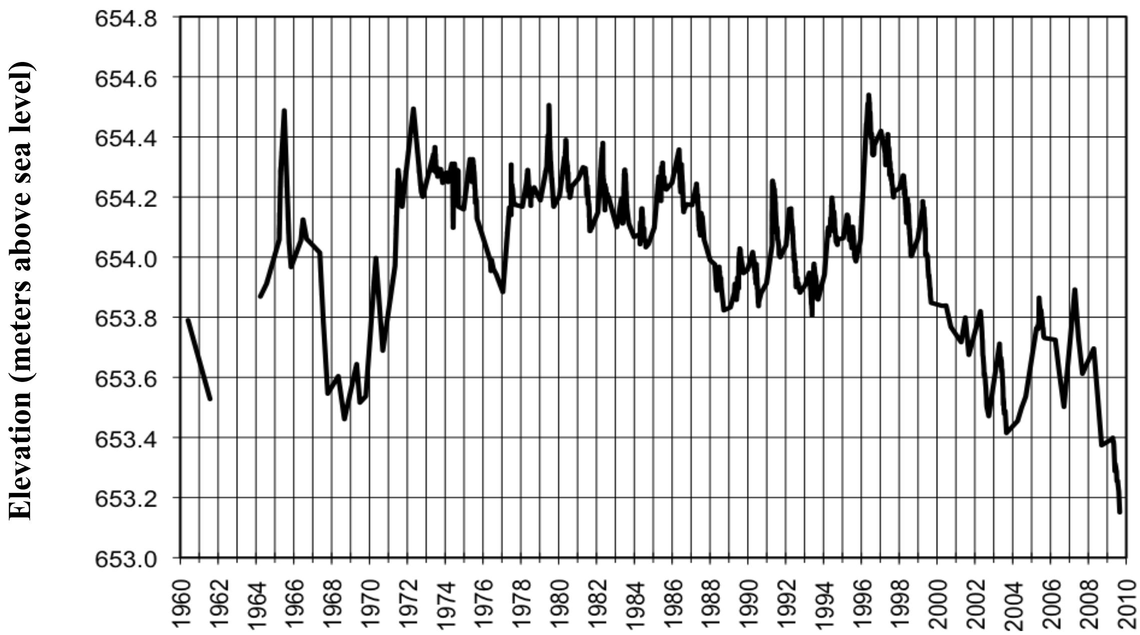

Figure 3. Historical water levels (m asl) in Thunder Lake, Alberta 1960 – 2009.

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.

Thermal stratification in Thunder Lake was not observed during the summer of 2009 (**Figure 4**). On 27 June, water temperature was uniform through the water column (e.g. isothermic) at 17.3°C. On 17 July a weak thermocline had formed at 2 m depth, with water temperature warming to 20.9°C at the surface and decreasing to 17.7°C at the lakebed. This weak thermocline disappeared by 29 August, when surface water temperature was 18.9°C, and declined to 17.1°C at the lakebed. The absence of a strong thermocline on all sampling dates shows that the lake waters were well-mixed during the sampling period.

Dissolved oxygen (DO) concentrations in upper layers of surface waters of Thunder Lake were ≥ 7 mg/L on all sampling dates through the summer, well within the acceptable range for surface water quality (DO ≥ 5.0 mg/L) (**Figure 4**). DO concentrations were equal at all depths on 27 June, but a rapid decline in DO was observed at 0.5 m depth on 17 July and 29 August. On these two sampling dates, DO concentrations declined from >12 mg/L at the surface to near zero (e.g. anoxic) below a depth of 4 m. Deep-water anoxia is common in summer, and the decomposition of organic matter produced during the open water season continues on into the winter months, which in turn, leads to low winter oxygen concentrations (as decomposition consumes oxygen).

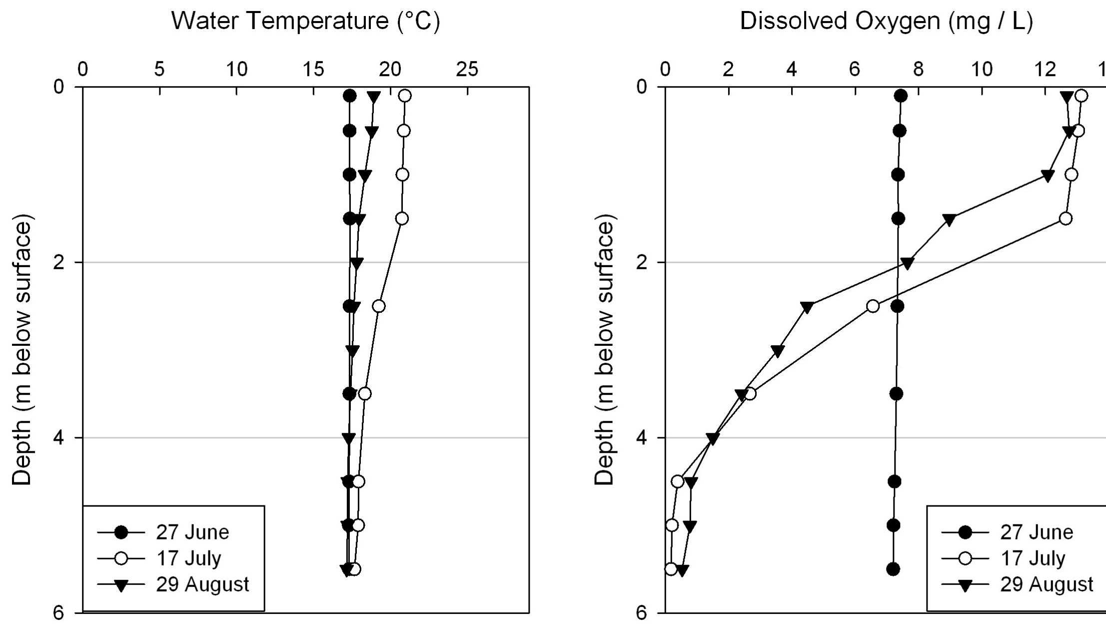

Figure 4. Water temperature (°C) and dissolved oxygen (mg/L) profiles for Thunder Lake during the summer of 2009.

Water Clarity and Secchi Depth

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

Water clarity on Thunder Lake was measured three times during the summer of 2009. Thunder Lake was somewhat turbid compared to other lakes in Alberta, with an average Secchi depth of 0.65 m (**Table 1**). On 27 June, light penetrated 0.5 m or ~8% of the total lake depth, which allowed for algal growth in the top 1.2 m of the lake. By 17 July, Secchi depth had increased to 0.75 m, but then declined to 0.7 m on 29 August.

Water Chemistry

Based on lake water characteristics, Thunder Lake is considered hypereutrophic (see *A Brief Introduction to Limnology* at the end of this report). In 2009, Thunder Lake had very high concentrations of total phosphorus (average TP = 111.7 μg/L), total nitrogen (average TN = 3705 μg/L), and algal biomass (average chlorophyll *a* = 39.9 μg/L) (**Table 1**). Total phosphorous declined over the first part of the summer, from 119 μg/L on 27 June to a low of 73 μg/L on 17 July (**Figure 5**), as algal growth consumed nutrients in the water column. By 29 August, total phosphorous recovered to its seasonal maximum of 143 μg/L. Total nitrogen followed a similar pattern, fluctuating from a minimum of 2.869

mg/L on 17 July to a maximum of 4.165 mg/L on 29 August. Chlorophyll *a* (a measure of algal biomass) increased from 28.1 µg/L on 27 June to its seasonal maximum of 48.6 µg/L on 17 July, and then declined slightly to 42.9 µg/L on 29 August.

During the summer 2009, Thunder Lake was well buffered from acidification with an average pH = 9.1, which is well above that of pure water (i.e., pH 7). Dominant ions include bicarbonate, sodium, and carbonate (**Table 1**). Because there are no long-term records of ion concentrations from Thunder Lake it is not possible to assess possible changes in ion concentrations over time. The average concentrations of various metals in Thunder Lake were not measured in the summer of 2009.

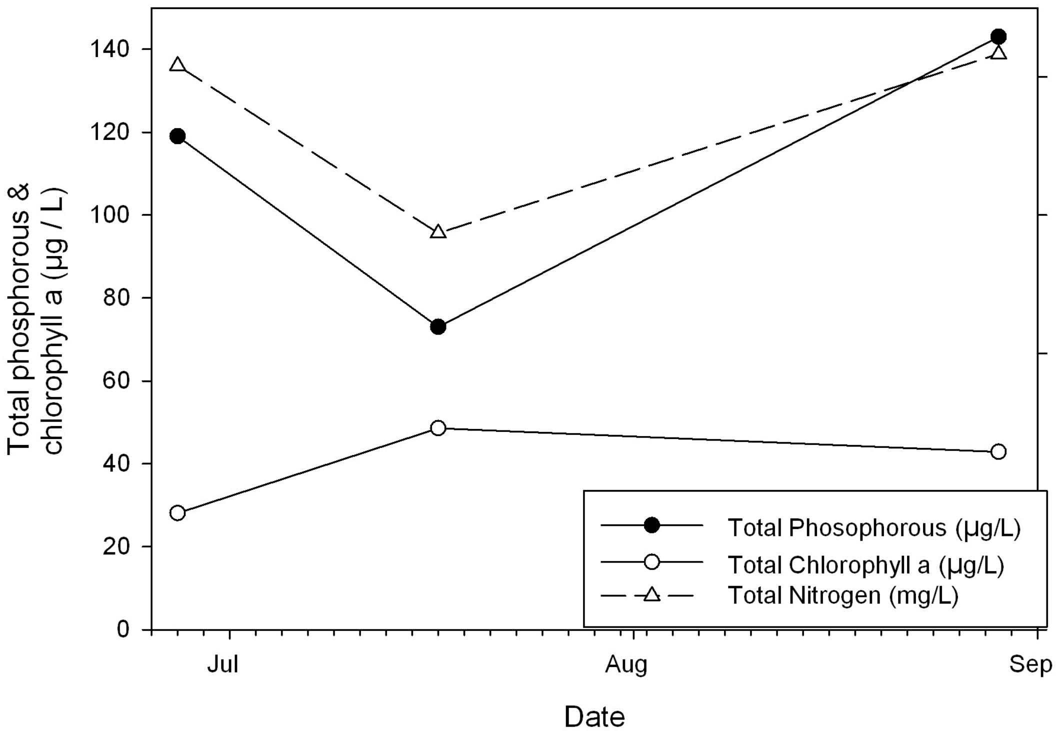

Figure 5. Total phosphorous, chlorophyll *a* (a measure of algal biomass), and total nitrogen concentrations for Thunder Lake during the summer of 2009.

Table 1. Mean water chemistry and Secchi depth values for Thunder Lake, summer 2009.

Parameter	2009
TP (μg/L)	111.7
TDP (μg/L)	44.7
Chlorophyll-*a* (μg/L)	39.9
Secchi depth (m)	0.65
TKN (μg/L)	3686.7
$NO_{2,3}$ (μg/L)	0.025
NH_4 (μg/L)	107.3
Dissolved organic C (mg/L)	38.9
Ca (mg/L)	17.8
Mg (mg/L)	25.0
Na (mg/L)	68.0
K (mg/L)	20.2
SO_4^{2-} (mg/L)	13.5
Cl^- (mg/L)	5.5
TDS (mg/L)	329
pH	9.1
Conductivity (μS/cm)	525
Hardness (mg/L)	147.5
HCO_3 (mg/L)	296
CO_3 (mg/L)	34
Total Alkalinity (mg/L $CaCO_3$)	299

Note: TP = total phosphorous, TDP = total dissolved phosphorous, Chla = chlorophyll *a*, TKN = total Kjeldahl nitrogen, 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.

*Atlas of Alberta Lakes (Mitchell and Prepas, 1990).

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A Brief Introduction to Limnology

Indicators of water quality

The goal of **Lakewatch** is to collect water samples necessary to determine the water quality of lakes. Though not all encompassing, the variables measured in **Lakewatch** are sensitive to human activities in watersheds that may cause impacts to water quality. For example, nutrients such as phosphorus and nitrogen are important determinants of lake productivity. The concentrations of these nutrients in a lake are affected (typically elevated) by land use changes such as increased crop production or livestock grazing. Elevated nutrient concentrations can cause increases in undesirable algae blooms resulting in low dissolved oxygen concentrations, degraded fish habitat and production of noxious odors. Large increases in nutrients over time may also indicate sewage inputs, which in turn, may result in other human health concerns such as harmful bacteria or protozoans (e.g. *Cryptosporidium*).

Temperature and mixing

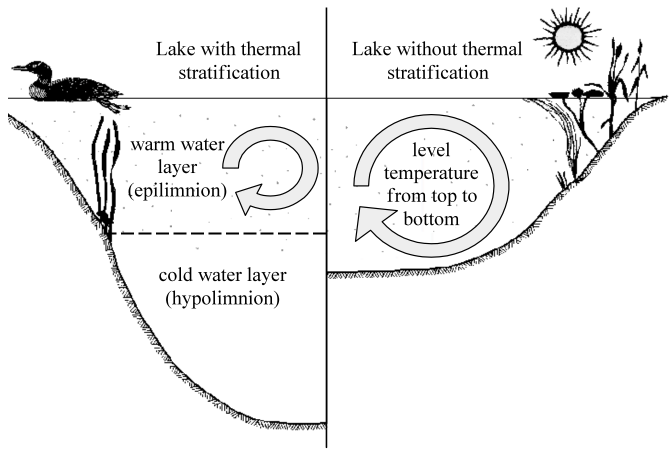

Figure 6: Difference in the circulation of the water column depending on thermal stratification.

Water temperature in a lake dictates the behavior of many chemical parameters responsible for water quality (Figure 6). Heat is transferred to a lake at its surface and slowly moves downward depending on water circulation in the lake. Lakes with a large surface area or a small volume tend to have greater mixing due to wind. In deeper lakes, circulation is not strong enough to move warm water to depths typically greater than 4 or 5 m and as a result cooler denser water remains at the bottom of the lake. As the difference in temperature between warm surface and cold deeper water increases, two distinct layers are formed. Limnologists call these layers of water the **epilimnion** at the surface and the **hypolimnion** at the bottom. The layers are separated by a transition layer known as the **metalimnion** which contains the effective wall separating top and bottom waters called a **thermocline**. A thermocline typically occurs when water temperature changes by more than one degree within one-meter depth. The hypolimnion and epilimnion do not mix, nor do elements such as oxygen supplied at the surface move downward into the hypolimnion. In the fall, surface waters begin to cool and eventually reach the same temperature as hypolimnetic water. At this point the water mixes from top to bottom in what is called a **turnover** event. Surface water cools further as ice forms and again a thermocline develops this time with 4° C water at the bottom and 0° C water on the top.

In spring another turnover event occurs when surface waters warm to 4° C. Lakes with this mixing pattern of two stratification periods and two turnover events are called **dimictic** lakes. In shallower lakes, the water column may mix from top to bottom most of the ice-free season with occasional stratification during periods of calm warm conditions. Lakes that mix frequently are termed **polymictic** lakes. In our cold climate, many shallow lakes are **cold monomictic** meaning a thermocline develops every winter, there is one turnover event in spring but the remainder of the ice-free season the lake is polymictic.

Dissolved Oxygen

Oxygen enters a lake at the lake surface and throughout the water column when produced by photosynthesizing plants, including algae, in the lake. Oxygen is consumed within the lake by respiration of living organisms and decomposition of organic material in the lake sediments. In lakes that stratify (see temperature above), oxygen that dissolves into the lake at the surface cannot mix downward into the hypolimnion. At the same time oxygen is depleted in the hypolimnion by decomposition. The result is that the hypolimnion of a lake can become **anoxic**, meaning it contains little or no dissolved oxygen. When a lake is frozen, the entire water column can become anoxic because the surface is sealed off from the atmosphere. Winter anoxic conditions can result in a fish-kill which is particularly common during harsh winters with extended ice-cover. Alberta Surface Water Quality Guidelines suggest dissolved oxygen concentrations (in the epilimnion) must not decline below 5 mg/L and should not average less than 6.5 mg/L over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 mg/L in areas where early life stages of aquatic biota, particularly fish, are present.

General Water Chemistry

Water in lakes always contains substances that have been transported by rain and snow or have entered the lake in groundwater and inflow streams. These substances may be dissolved in the water or suspended as particles. Some of these substances are familiar minerals, such as sodium and chloride, which when combined form table salt, but when dissolved in water separate into the two electrically charged components called **ions**. Most dissolved substances in water are in ionic forms and are held in solution due to the polar nature of the water molecule. **Hydrophobic** (water-fearing) compounds such as oils contain little or no ionic character, are non-polar and for this reason do not readily dissolve in water. Although hydrophobic compounds do not readily dissolve, they can still be transported to lakes by flowing water. Within individual lakes, ion concentrations vary from year to year depending on the amount and mineral content of the water entering the lake. This mineral content can be influenced by the amount of precipitation and other climate variables as well as human activities such as fertilizer and road salt application.

Phosphorus and Nitrogen

Phosphorus and nitrogen are important nutrients limiting the growth of algae in Alberta lakes. While nitrogen usually limits agricultural plants, phosphorus is usually in shortest supply in lakes. Even a slight increase of phosphorus in a lake can, given the right conditions, promote algal blooms causing the water to turn green in the summer and impair recreational uses. When pollution originating from livestock manure and human sewage enters lakes not only are the concentrations of phosphorus and nitrogen increased but nitrogen can become a limiting nutrient which is thought to cause blooms of toxic algae belonging to the cyanobacteria. Not all cyanobacteria are toxic, however, the blooms can form decomposing mats that smell and impair dissolved oxygen concentrations in the lake.

Chlorophyll-a

Chlorophyll-*a* is a photosynthetic pigment that green plants, including algae, possess enabling them to convert the sun's energy to living material. Chlorophyll-*a* can be easily extracted from algae in the laboratory. Consequently, chlorophyll-*a* is a good estimate of the amount of algae in the water. Larger aquatic plants, known as macrophytes, rather than algae, dominate some highly productive lakes. In these lakes, chlorophyll-*a* and nutrient values taken from water samples do not include productivity from large aquatic plants. As a result, lakes like Chestermere, which are dominated by macrophytes, can exist at a lower trophic state than if macrophyte biomass was included. Unfortunately, the productivity and nutrient cycling contributions of macrophytes are difficult to sample accurately and are therefore not typically included in trophic state indices.

Secchi Disk Depth

Lakes that are clear are more attractive for recreation, whereas those that are turbid or murky are considered by lake users to have poor water quality. Secchi disk depth is the oldest, simplest, and quickest quantitative measure of water clarity. A Secchi disk is a black and white disk that is lowered down through the water column until it can no longer be seen. Secchi disk depth is the midpoint between the depth at which it disappears when lowered and reappears when it is pulled up again. The Secchi disk depth in lakes with high algal biomass will generally be shallow. However, Secchi disk depth is not only affected by algae. High concentrations of suspended sediments, particularly fine clays or glacial till, are common in plains or mountain reservoirs of Alberta. Mountain reservoirs may have exceedingly shallow Secchi disk depths despite low algal growth and nutrient concentrations.

The euphotic zone, calculated as twice the Secchi disk depth, is the portion of the water column that has sufficient light for aquatic plants to grow. Murky waters, with shallow Secchi depths, can prevent aquatic plants from growing on the lake bottom. Aquatic plants are important because they ensure clear lake water by reducing shoreline erosion and stabilizing lake bottom sediments. Many lakes in Alberta are shallow and have bottom sediments with high concentrations of nutrients. Without aquatic plants, water quality may decline in these lakes due to murky, sediment-laden water and excessive algal blooms. Maintaining aquatic plants in certain areas of a lake is often essential for ensuring good water clarity and a healthy lake as many organisms, like aquatic invertebrates and fish, depend on aquatic plants for food and shelter.

Trophic State

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

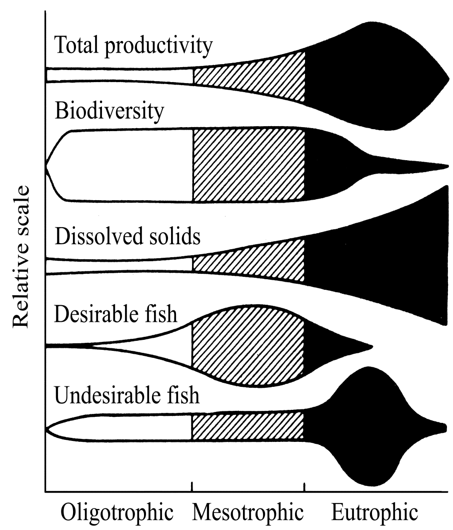

Figure 7: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

Table 2: Trophic status based on lake water characteristics

Trophic state	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll a (µg/L)	Secchi Depth (m)
Oligotrophic	< 10	< 350	< 3.5	> 4
Mesotrophic	10 - 30	350 - 650	3.5 - 9	4 - 2
Eutrophic	30 - 100	650 - 1200	9 - 25	2 - 1
Hypereutrophic	> 100	> 1200	> 25	< 1

Note: These values are from a detailed study of global lakes reported in Nurnberg 1996. Alberta Environment uses slightly different values for TP and CHL based on those of the OECD reported by Vollenweider (1982). The AENV and OECD cutoffs for TP are 10, 35 and 100; for CHL are 3, 8 and 25. AENV does not have TN or Secchi depth criteria. The corresponding OECD exists for Secchi depth and the cutoffs are 6, 3 and 1.5 m.