The Alberta Lake Management Society Volunteer Lake Monitoring Program

Sylvan 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) The Sacred Balance

Alberta Lake Management Society's Lakewatch Program

Lakewatch has several important objectives, one of which is to collect and interpret water quality 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 Kent Williamson and Lisa for their 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. Francine Forrest and Théo Charette prepared the original report, which was updated by Sarah Lord for 2009. Alberta Environment and the Beaver River Watershed Alliance (BRWA) were major sponsors of the Lakewatch program.

Sylvan Lake

Sylvan Lake is a large (42.8 km^2), moderately deep lake (maximum depth = 18.3 m) located west of the city of Red Deer. The lake was first named "Snake Lake" from the Indian name *Kinabik*, which referred to the numerous garter snakes in the area. The name was officially changed to Sylvan Lake in 1903. "Sylvan" is from the Latin name *Sylvanus*, which means "of a forest". Most of the surrounding land was originally forested with trembling aspen. However, approximately 90% of the watershed has been converted to agriculture.

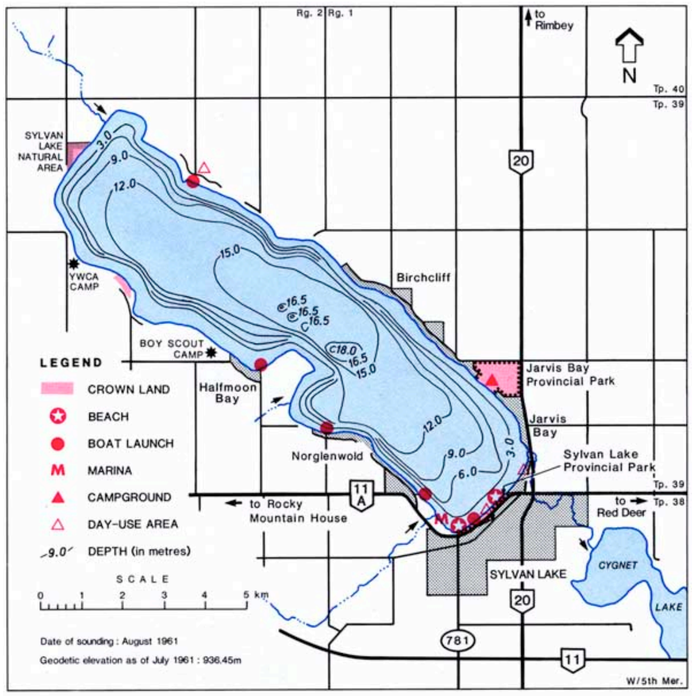

Figure 1. Bathymetry of Sylvn Lake. Most contours represent 3 m intervals.

Sylvan Lake was first settled in 1899 and within 5 years time (by 1904) it had become a summer resort area. Its popularity was due to the lake's picturesque shoreline. Since this time, the shore of Sylvan Lake has undergone intensive development with four summer villages, the town of Sylvan Lake, and six subdivisions. Two provincial parks also occupy the lakeshore, Jarvis Bay Provincial Park and Sylvan Lake Provincial Park.

Large sandstone banks, reaching up to 20 m above lake level, are located along the northeast shore. The lake's shoreline is generally composed of sand or a mixture of rock and gravel. Rooted aquatic plants occur in patches in sheltered areas around the lake and grow densely in the northwest end of the lake. The most common emergent species are bulrush (*Scirpus* sp.) and common cattail (*Typha latifolia*). Submergent macrophytes, which can grow up to a lake depth of 3.5 m, include pondweeds (*Potamogeton* spp.), water buttercup (*Ranunculus circinata*), Canada waterweed (*Elodea canadensis*) and the macroalgae stonewort (*Chara* sp.).

There are at least seven species of fish in Sylvan Lake: northern pike, yellow perch, walleye, burbot, spottail shiners, brook stickleback, and fathead minnows.

Results

Water Level

There has been a general trend of water level decline in Sylvan Lake from 1990 – 2006, followed by a recovery to historical levels from 2005 – 2009 (**Figure 2**). During this period the maximum lake elevation occurred in 1992, measuring 937.1 m above sea level. The lowest lake level since 1990 was experienced in 2004 recorded at 936.4 m asl.

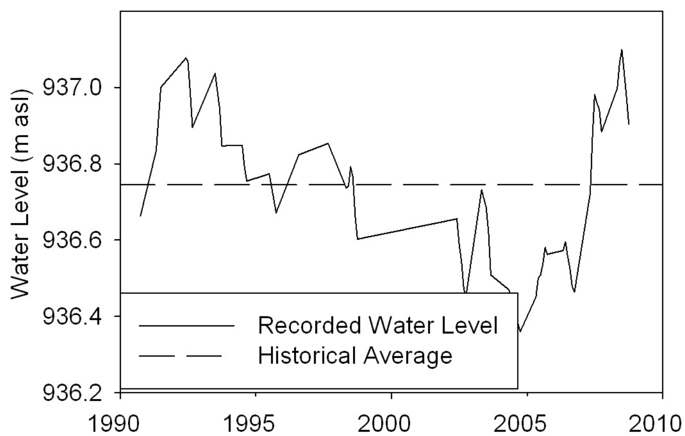

Figure 2. Historical water levels (m asl) in Sylvan Lake, Alberta 1990 – 2009.

The catchment to lake surface area ratio of Sylvan Lake is small (only 2.5 times the lake area) and as such there is likely little incoming water from the drainage basin potentially contributing to changes in water level. This is further supported by the intermittent nature of the inflowing streams and the presence of numerous submerged springs. Evaporation from the large surface area of Sylvan Lake seems to be the primary outlet for water, since very little water flows out of the lake. Between 1955 and 1976, the outlet stream flowed only during part of three years. Thus Sylvan Lake's water balance is controlled by direct evaporation and precipitation at the lake's surface.

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.

Minimal thermal stratification in Sylvan Lake was observed during the summer 2009 (**Figure 3**). On 12 June, surface water temperature was 13.4°C and dropped to 8.0°C at the lakebed, with no significant thermocline observed. On 3 July, surface water temperature had increased to 15.9°C and a thermocline had formed at 12 m depth. Surface water temperature reached a seasonal maximum of 20.6°C on 28 July, but the depth profile of the lake on this sampling date ended at 12 m depth, so if a thermocline was present it was not recorded. By 20 August surface waters had cooled to 18.1°C and the thermocline had weakened, dropping to 14 m depth.

Dissolved oxygen (DO) concentrations in upper layers of surface waters of Sylvan Lake were ≥ 8 mg/L on all sampling dates through the summer, well within the acceptable range for surface water quality (DO ≥ 5.0 mg/L) (**Figure 3**). DO concentrations were nearly constant with depth until within 2 m of the lakebed on all sampling dates. A rapid decline in DO was observed below 12 m depth on 3 July; this gradient could not be measured on 28 July due to insufficient sampling depth. On 20 August, waters below 15 m depth had DO concentrations near zero (e.g. anoxic). 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.

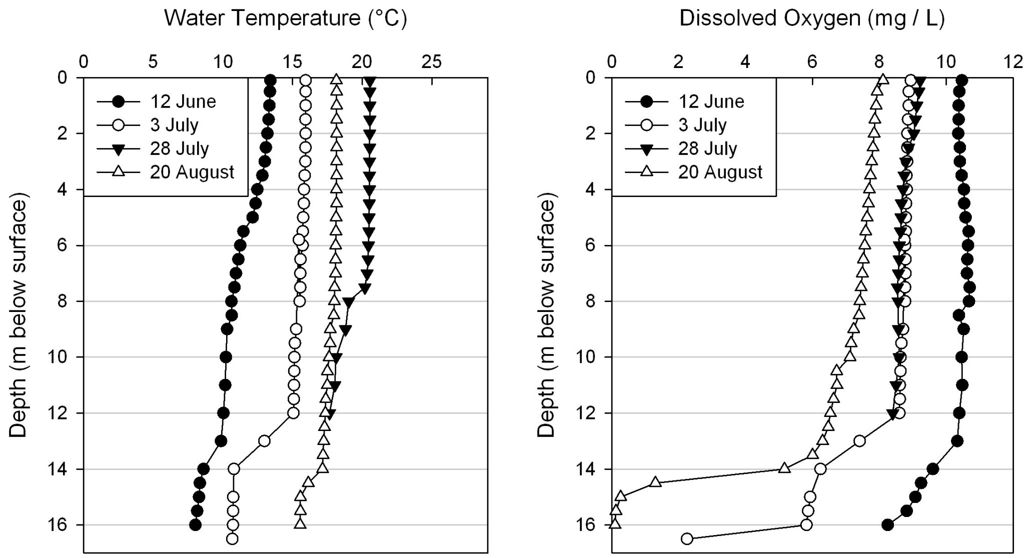

Figure 3. Water temperature (°C) and dissolved oxygen (mg/L) profiles for Sylvan Lake during the summer of 2009.

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 Sylvan Lake was measured four times during the summer of 2009. Sylvan Lake was very clear compared to other lakes in Alberta, with average Secchi depth of 4.7 m (**Table 1**). On 12 June, light penetrated 4.3 m or ~27% of the total lake depth, which allowed for algal growth in the top 8.6 m of the water column. On 3 July, Secchi depth reached a seasonal maximum of 5.75 m, and then declined to 4.0 m by 28 July. Water clarity increased in late August, with a Secchi depth of 4.75 m. This pattern of water clarity dynamics is typical of highly productive Alberta lakes, when algal growth during July and August causes reduced water clarity. Water clarity typically recovers in September as lower temperatures limit growth, and dying algae fall out of the water column and settle on the lakebed where they are decomposed by anaerobic bacteria.

Water Chemistry

Based on lake water characteristics, Sylvan Lake is considered mesotrophic (see *A Brief Introduction to Limnology* at the end of this report). In 2009, Sylvan Lake had moderate concentrations of total phosphorus (average TP = 20.0 μg/L), total nitrogen (average TN = 636.7 μg/L), and algal biomass (average chlorophyll *a* = 2.58 μg/L) (**Table 1**). Total phosphorous declined over the summer, from 24 μg/L on 12 June to a low of 17 μg/L on 28 July (**Figure 4**), as algal growth consumed nutrients in the water column. Total nitrogen remained relatively steady, increasing slightly from a 0.625 mg/L on 12 June to 0.655 mg/L on 20 August. Chlorophyll *a* (a measure of algal biomass) remained relatively steady over the summer, fluctuating between a maximum of 3.44 μg/L on 20 August and a minimum of 1.79 μg/L on 3 July.

During the summer 2009, Sylvan Lake was well buffered from acidification with an average pH = 8.79, which is well above that of pure water (i.e., pH 7). Dominant ions include bicarbonate, sodium, and magnesium (**Table 1**). The relatively high concentrations of sodium support the strong atmospheric influence on the lake. High magnesium and bicarbonate reflect substantial groundwater inflow. Ion concentrations in Sylvan Lake appear to have remained relatively constant from 1986 to present, and water quality remains high. The concentrations of various metals in Sylvan Lake were not measured in the summer of 2009.

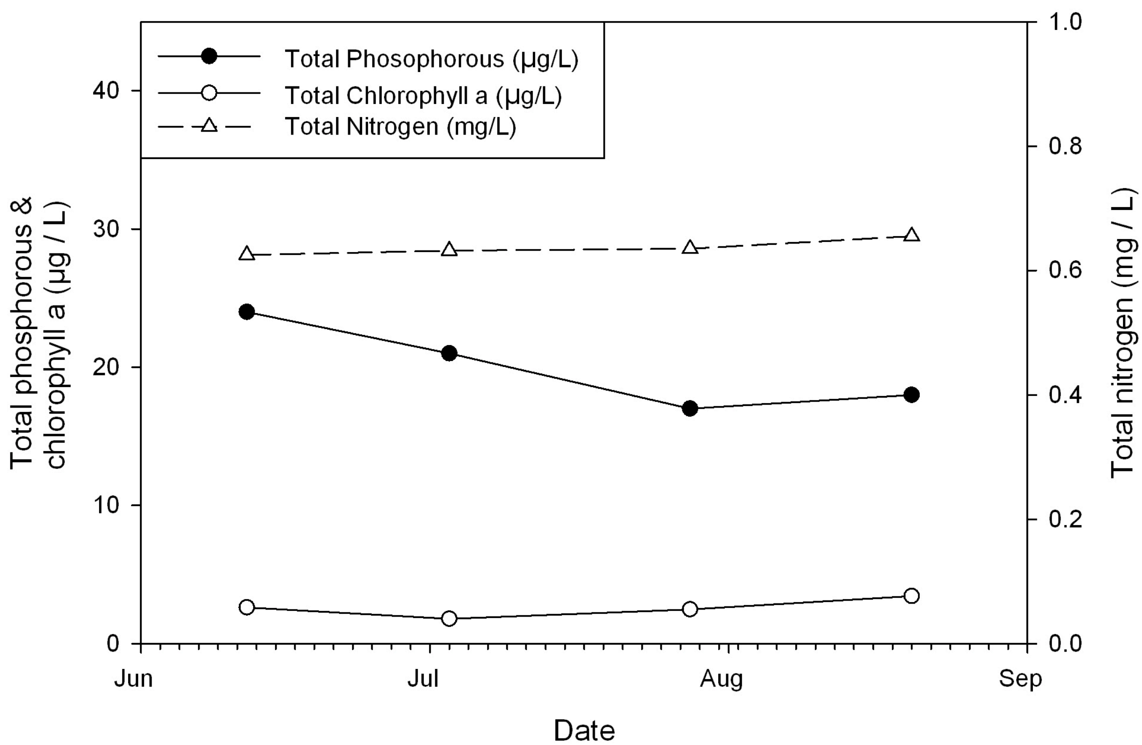

Figure 4. Total phosphorous, chlorophyll *a* (a measure of algal biomass), and total nitrogen concentrations for Sylvan Lake during the summer of 2009.

Table 1. Mean water chemistry and Secchi depth values for Sylvan Lake, summer 2009 compared with historical values 1984 - 2006.

Parameter	1984	1986	2000	2001	2003	2006	2009
TP (μg/L)	20	21	19	23	14	24.5	20.0
TDP (μg/L)	-	-	7.4	8	5	7.6	10.8
Chlorophyll-*a* (μg/L)	3.8	3.7	4.5	9	3.8	6.5	2.58
Secchi disk depth (m)	5.0	4.7	5	-	4.8	4.1	4.7
TKN (μg/L)	-	-	618	836	610	713	630
$NO_{2,3}$ (μg/L)	-	-	1.2	2	5	<5	6.75
NH_4 (μg/L)	-	-	6.9	9	8	12	9.5
Dissolved organic C (mg/L)	-	-	-	-	-	-	6.93
Ca (mg/L)	-	18	17	17	17	17	16.2
Mg (mg/L)	-	37	37	36	37	36	34.1
Na (mg/L)	-	64	63	60	71	73	70.2
K (mg/L)	-	7	8	7	8	8	7.77
SO_4^{2-} (mg/L)	-	16	13	14	14	14	16.3
Cl^- (mg/L)	-	,<1	2.8	3	2	2.7	3.26
TDS (mg/L)	-	-	-	-	350	353	350.3
pH	-	8.9	8.7	9	8.8	8.86	8.79
Conductivity (μS/cm)	-	597	585	572	611	606	608
Hardness (mg/L)	-	-	-	-	193	190.7	181
HCO_3 (mg/L)	-	354	348	343	359	361.7	366
CO_3 (mg/L)	-	21	18	22	26	26.3	22.0
Total Alkalinity (mg/L $CaCO_3$)	-	325	316	318	337	340	337.3

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

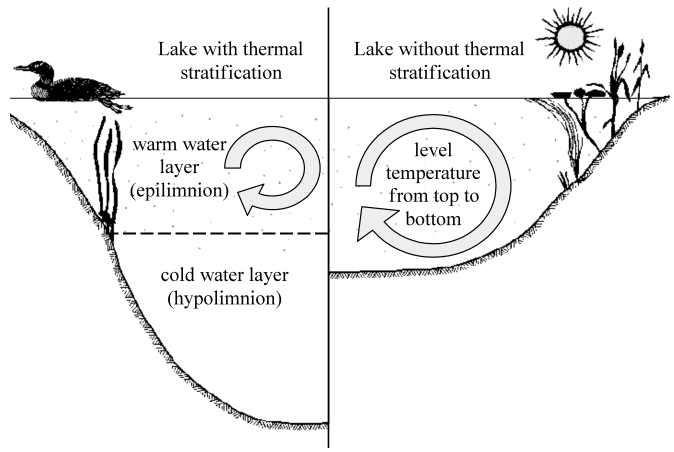

Figure 6: Difference in the circulation of the water column depending on thermal stratification.

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.

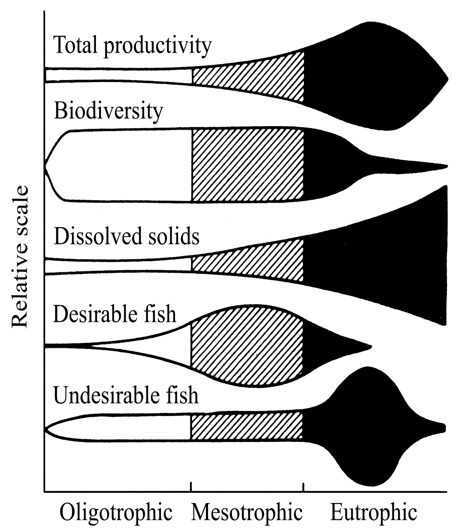

Figure 7: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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.