The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Laurier Lake

2009 Report

Completed with support from:

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

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Laurier Lake

Laurier Lake is one of four lakes (**Figure 1**) that were left behind 10,000 years ago when glaciers carved a setting of hummocky terrain of kettles, eskers and lake basins. Archeological evidence indicates the area was inhabited at least 7000 years ago, and the first Europeans came through the area in 1754 by way of the nearby North Saskatchewan River.

Figure 1. Photo of Laurier Lake, Alberta (L. Kowalchuk, ALMS).

The Whitney Lakes Provincial Park adjacent to Laurier Lake (**Figure 2**) was established in 1982. It boasts a diverse setting of jack pine (*Pinus banksiana*) meadows, aspen (*Populus* spp.) groves, willow (*Salix* spp.) thickets, marshes, fens, and mixed wood forests. As many as 148 bird species have been observed in the park with an excellent viewing point on the west side of Laurier Lake (Mitchell and Prepas 1990).

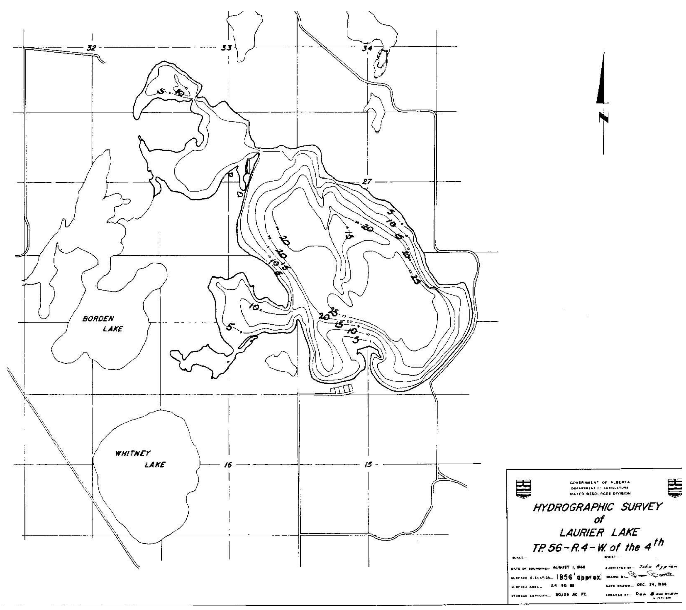

Figure 2. Bathymetric map of Laurier Lake, Alberta. Contour intervals are 5 feet.

The land surrounding Laurier Lake includes a mixture of recreational cottage development, cleared agricultural land and natural deciduous forest. Protected Crown land makes up the north shore of the lake the remainder of the shoreline is privately owned.

The lake is enjoyed for recreational activities such as hiking, wildlife viewing and water-based recreation. Popular activities include wind surfing, water-skiing, sailing, swimming and fishing. Yellow perch, walleye, and northern pike are the sport fish of Laurier Lake; fish stocking occurred in 1953 when sport and forage fish were transferred from Moose Lake into Laurier Lake. The lake has not been managed for commercial or domestic fishing.

Laurier Lake has a surface area of 6.42 km^2 with a maximum 2004 depth of 6.6 m (**Figure 2**). The lake has historically been both mesotrophic and eutrophic. Its location and surrounding topography make Laurier open to prevailing winds. These winds mix the water column and Laurier usually does not thermally stratify throughout most of the summer. Mixing also allows nutrients and organic material to remain suspended in the water column, making the lake naturally fertile. Algal blooms are known to occur during summer months, but detailed studies of phytoplankton have not been completed for the lake. Common emergent plants that fringe the lake are bulrushes (*Scirpus* spp.), cattails (*Typha latifolia*) and sedges (*Carex* spp.).

Results

Water Level

Laurier Lake shares a 92-km^2 drainage area with Ross, Borden and Whitney Lakes. One intermittent and three permanent streams feed the lake. The outflow, on the northwest end, drains into Borden Lake and subsequently to the North Saskatchewan River. Water levels in Laurier Lake have been monitored since 1968. Water level reached a maximum of 567.2 m asl in 1974 but has since dropped almost 3 m to a minimum recorded level of 564.0 m asl in 2004 (**Figure 3**). Water levels have been slowly dropping for the last 2 decades, with a slight increase from 2005-2008. The average elevation is 565.7 m above sea level. Alberta experienced a relatively wet year in 1997 that restored water levels in many lakes. In Laurier Lake, the wet year of 1997 temporarily halted water level declines, but the reprieve was short-lived and the decline resumed after 1997.

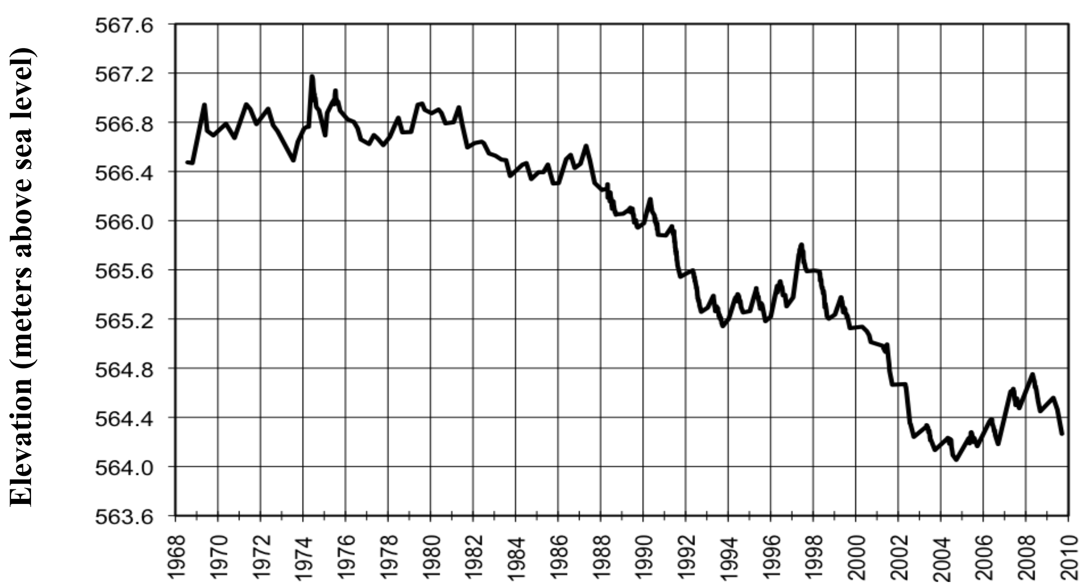

Figure 3. Historical water levels (m asl) in Laurier Lake, Alberta 1968 – 2009.

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.

Laurier Lake is a polymictic lake that typically mixes many times throughout the summer. Because of frequent mixing, water temperature and dissolved oxygen concentrations are relatively similar throughout the entire water column of the lake (e.g. isothermic) (**Figure 4**). In 2009, surface water temperature was at a seasonal minimum of 15.7ºC on 5 June. Surface water temperature increased to 19.7ºC on 2 July, and reached a seasonal maximum of 20.7ºC on 23 July, declining by only one degree Celsius at the lakebed. Surface water temperature cooled only slightly to 20.5ºC on 13 August.

In contrast to the isothermic temperature profile of the water column, dissolved oxygen (DO) concentrations were not the same at all depths. On 5 June both surface and bottom waters were well-oxygenated, but by 2 July the DO concentration of waters near the lakebed had begun to decline. A rapid decline in DO concentration occurred at 3.5 m depth on 23 July, and 4.5 m depth on 13 August (**Figure 4)**. Deep-water anoxia is common during summer, when bacterial decomposition of organic matter in lake sediments consumes oxygen. DO in surface waters of Laurier Lake was >7 mg/L on all sampling dates, well within the acceptable range for surface water quality according to Alberta Environment guidelines (DO ≥ 5.0 mg/L).

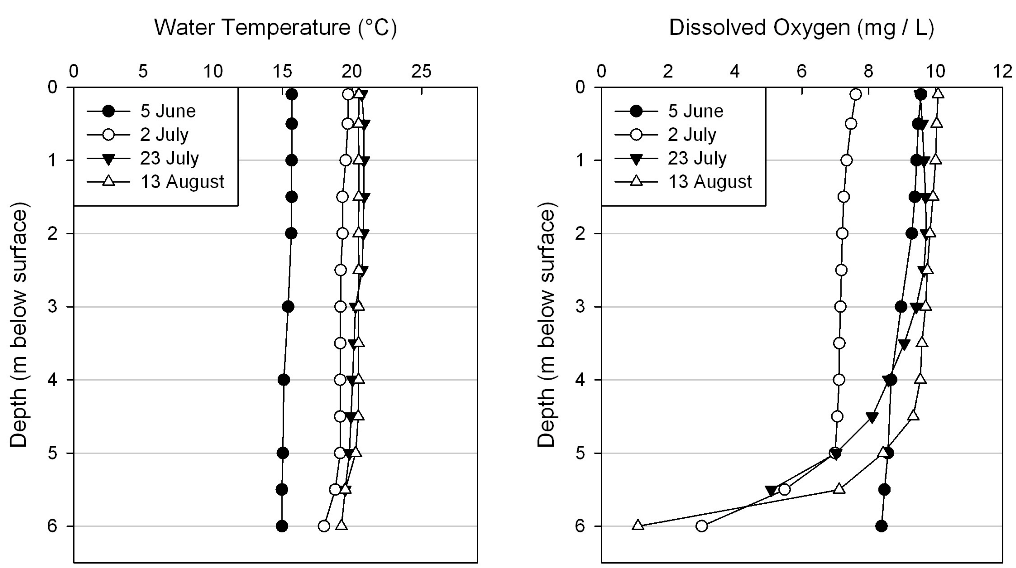

Figure 4. Water temperature (°C) and dissolved oxygen (mg/L) profiles for Laurier Lake during the summer of 2009.

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.

Laurier Lake is a shallow, polymictic lake and has moderate water clarity, with an average Secchi depth of 2.0 m in 2009. During that summer, light penetrated to an average 33% of the total lake depth, allowing algae to grow in the upper 4.0 m of the water column (**Table 1**). Water clarity fluctuated throughout the summer, with a seasonal minimum Secchi depth of 1.25 m on 5 June that increased to a seasonal maximum of 3.75 m by 2 July. Secchi depth then declined to 1.75 m on 23 July and 1.25 m on 13 August. This pattern of water clarity followed the changes in algal growth over the summer, with maximum water clarity being reached when algal biomass reached a seasonal minimum on 2 July.

Water Chemistry

Based on lake water characteristics, Laurier Lake is currently considered eutrophic (see *A Brief Introductory to Limnology* at the end of this report). In 2009, Laurier Lake had high concentrations of total phosphorous (average TP = 50.5 µg/L), total nitrogen (average TN = 2.762 mg/L), and algal biomass (average chlorophyll *a* = 9.13 µg/L) in 2009. Total phosphorous concentration was 55 µg/ on 5 June and declined to a seasonal minimum of 37 µg/ on 2 July, then increased steadily through late July and August to a seasonal maximum of 61 µg/L on 13 August (**Figure 5**). Total nitrogen concentrations followed a similar pattern, with a seasonal minimum of 2.438 mg/L occurring on 2 July and a maximum of 2.945 mg/L on 13 August. Chlorophyll *a* (a measure of algal biomass) concentrations tracked these changes in nutrient concentrations, peaking in late August at 13.5 µg/L. Compared to other Alberta Lakes, algal biomass in Laurier Lake was moderate and relatively stable over the course of the summer.

Laurier Lake is well buffered against acidification. In 2009, lake pH = 9.0 was well above that of pure water (i.e., pH 7). Laurier Lake is a hardwater, slightly saline lake. Ion concentrations were relatively high 2009 (**Table 1**); dominant ions included bicarbonate, sulfate, and sodium. The increase in ion concentrations from 1978 to present suggests a reduction in surface runoff and throughflow, which has allowed groundwater (with higher concentrations of magnesium, sulphate, carbonate, and other ions) to contribute a larger proportion of water to Laurier Lake.

The average concentrations of various metals (as total recoverable concentrations) were measured twice in Laurier Lake in 2009, and did not surpass provincial and federal Water Quality Guidelines for the Protection of Aquatic Life (**Appendix 1**).

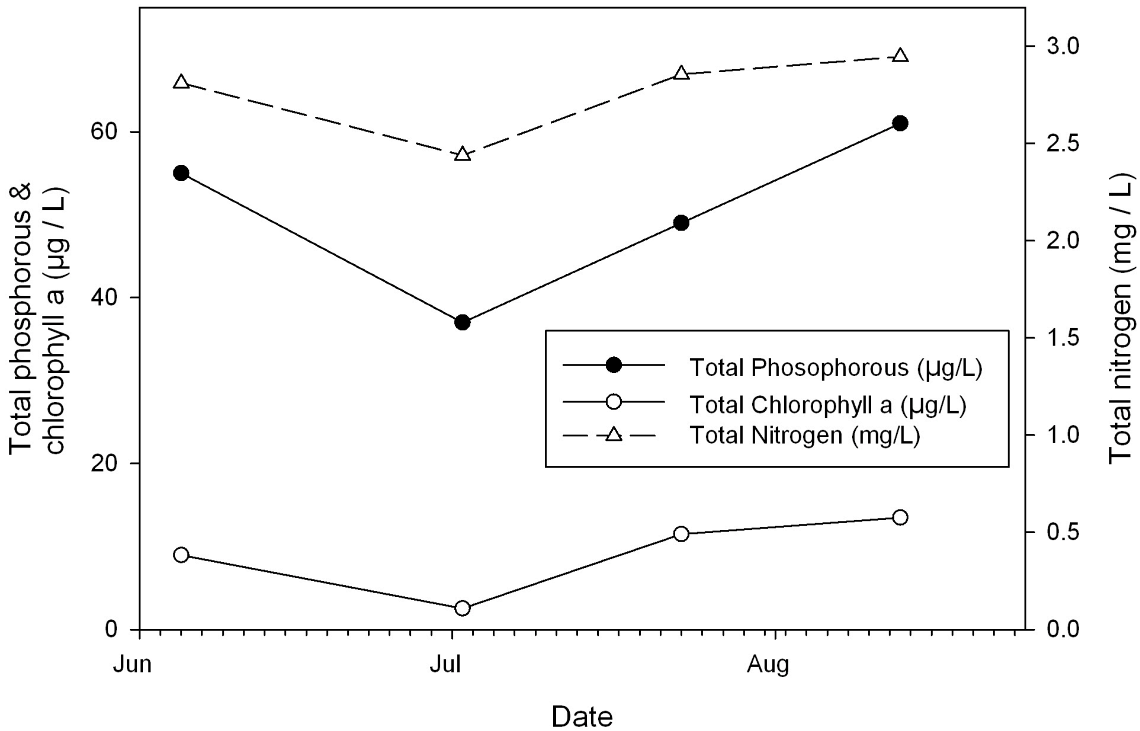

Figure 5. Total phosphorous, chlorophyll *a* (a measure of algal biomass), and total nitrogen concentrations for Laurier Lake during the summer of 2009.

Table 1. Mean water chemistry and Secchi depth values for Laurier Lake, Alberta, for summer 2009 and previous years.

Parameter	1978	1980	1987	1997	1998	2000	2002	2003	2004	2007	2008	2009
TP (μg/L)	-	-	-	32	48	37	36	27	40	41.6	51.2	50.5
TDP (μg/L)	-	-	-	-	-	-	15	15	18	22	18.8	20.5
Chl a (μg/L)	-	-	-	5.3	8.9	5.5	5.8	2.6	5.0	4.3	11.9	9.13
Secchi (m)	-	1.3	1.2	4.6	1.3	1.8	2.5	4.4	3.2	2.4	1.3	2.0
TKN (mg/L)	-	-	-	-	-	-	2.5	2.6	2.7	2.2	2.7	2.76
NO_{2+3} (μg/L)	<50	50	<1	-	-	-	3.8	2.11	7.7	<7	<0.005	0.007
NH_4 (μg/L)	-	-	-	-	-	-	23	41	76	46.2	39.2	39.3
Dissolved organic C (mg/L)	-	-	-	-	-	-	-	-	-	37.9	37.9	39.0
Ca (mg/L)	23	27	19	20	21	13	12	10	10.5	14.6	14.5	12.1
Mg (mg/L)	48	54	52	73	81	83	99	106	107	-	92.9	88.1
Na (mg/L)	49	45	59	86	92	98	77	128	129	122.7	120.6	132.3
K (mg/L)	14	14	17	24	25	25	26	31	34	32.8	31.9	38.0
SO_4 (mg/L)	36	40	41	62	66	73	94	99	105	111.7	121.3	135.7
Cl (mg/L)	5	6	9	12	13	15	12	18	20	19.5	20.2	21.2
CO_3 (mg/L)	-	-	-	39	62	66	102	112	84	86	84.7	70.0
HCO_3 (mg/L)	-	-	-	493	468	469	515	522	603	535.7	544.3	582.3
pH	-	-	-	8.8	8.9	8.0	9.2	9.2	9.1	9.1	9.0	9.0
Conductivity (μS/cm)	-	-	-	-	-	-	-	-	-	1163	1197	1246
TDS (mg/L)	-	-	-	562	598	602	-	764	-	-	754	784
Total Alkalinity (mg/L $CaCO_3$)	310	329	360	470	488	493	592	615	634	583	588	594

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

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Appendix 1

Mean concentrations of metals in Laurier Lake for summer 2007-2009. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference.

Metals	2007	2008	2009	Guidelines
ALUMINUM µg/L	29.4	9.69	12.2	100[a]
ANTIMONY µg/L	0.137	0.117	0.117	6[e]
ARSENIC µg/L	2.6	3.0	2.83	5
BARIUM µg/L	20.2	16.95	18.2	1000[e]
BERYLLIUM µg/L	<0.003	<0.003	<0.003	100[d,f]
BISMUTH µg/L	<0.005	0.0051	0.0039	-
BORON µg/L	175.5	182	171.5	5000[e,f]
CADMIUM µg/L	0.008	0.0038	0.0039	0.085[b]
CHROMIUM µg/L	0.611	0.56	0.465	-
COBALT µg/L	0.099	0.058	0.0568	1000[f]
COPPER µg/L	0.613	0.555	0.565	4[c]
IRON µg/L	37.1	15.8	3.42	300
LEAD µg/L	0.057	0.023	0.0396	7[c]
LITHIUM µg/L	102.9	100.2	109.5	2500[g]
MANGANESE µg/L	5.15	7.97	5.44	200[g]
MOLYBDENUM µg/L	0.661	0.587	0.782	73[d]
NICKEL µg/L	0.275	0.127	0.0815	150[c]
SELENIUM µg/L	0.547	0.372	0.243	1
SILVER µg/L	<0.003	0.0086	0.0031	0.1
STRONTIUM µg/L	84.5	62.9	58.1	-
THALLIUM µg/L	<0.001	0.0024	0.0012	0.8
THORIUM µg/L	<0.01	0.017	0.0029	-
TIN µg/L	<0.06	<0.03	0.0344	-
TITANIUM µg/L	1.24	1.36	1.51	-
URANIUM µg/L	0.811	0.808	0.858	100[e]
VANADIUM µg/L	0.742	0.512	0.519	100[f,g]
ZINC µg/L	1.53	0.916	0.949	30
FLUORIDE mg/L	-	-	-	1.5

With the exception of fluoride (which reflects the mean concentration of dissolved fluoride only), values represent means of total recoverable metal concentrations.

[a] Based on pH ≥ 6.5; calcium ion concentration $[Ca^{+2}] \geq 4$ mg/L; and dissolved organic carbon concentration [DOC] ≥ 2 mg/L.

[b] Based on water Hardness of 300 mg/L (as $CaCO_3$).

[c] Based on water Hardness > 180 mg/L (as $CaCO_3$).

[d] CCME interim value.

[e] Based of Canadian Drinking Water Quality guideline values.

[f] Based of CCME Guidelines for Agricultural Use (Livestock Watering).

[g] Based of CCME Guidelines for Agricultural Use (Irrigation).

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

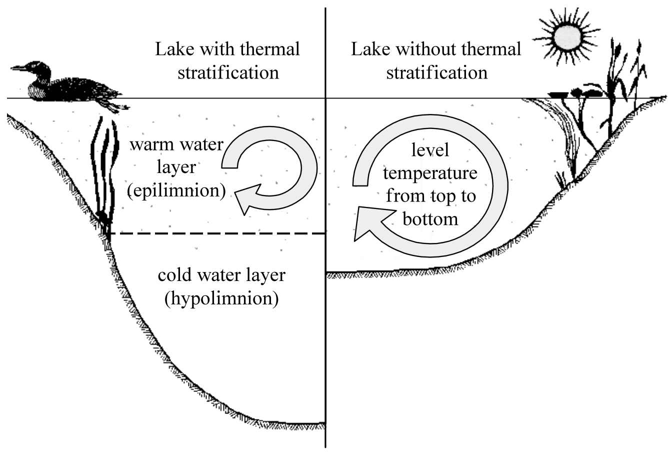

Figure 6: Difference in the circulation of the water column depending on thermal stratification.

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. A transition layer known as the metalimnion, which contains the effective wall separating top and bottom waters called a thermocline, separates the layers. 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, algae do not only affect Secchi disk depth. 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.

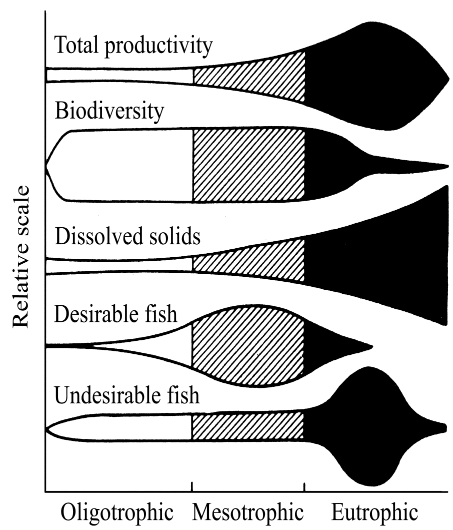

Figure 7: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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.