The Alberta Lake Management Society Volunteer Lake monitoring report

Beaver Lake

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2008 Report

Completed with support from:

LICA Lakeland Industry & Community Association

Alberta Environment

Beaver River Watershed Alliance

Alberta Lake Management Society

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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

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, Théo Charette and Ron Zurawell. We would like to thank Dave Lozinski for his efforts in collecting data in 2008. We would also like to thank Lisa Brodziak and Sophie Damlencour who were summer interns with ALMS in 2008. 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. Heather Jones and Ron Zurawell (Limnologist, AENV) prepared the original report, which was updated by Sarah Lord for 2008. Alberta Environment and the Beaver River Watershed Alliance (BRWA) were major sponsors of the Lakewatch program.

Beaver Lake

Beaver Lake (**Figure 1**) is a large lake located near the Town of Lac La Biche (east on secondary highway 663 from highway 36). Beaver Lake lies within the Lakeland region, which is rich in history including various missions, hunting, trapping, and both European and Native settlements. In 1919 a settler named Max Huppie purchased a large tract of land on the northwest corner of Beaver Lake, an area that, today, supports a provincial campground, a forest firefighter base camp and one large residential sub-division.

Beaver Lake is popular for fishing. Nine species of fish have been reported in Beaver Lake including: northern pike (*Esox lucius*), walleye (*Sander vitreus*), yellow perch (*Perca flavescens*), lake whitefish (*Coregonus clupeaformis*), burbot (*Lota lota*), white sucker (*Catostomus commersoni*), brook stickleback (*Culaea inconstans*), Iowa darter (*Etheostoma exile*), and spottail shiner (*Notopis hudsonius*).

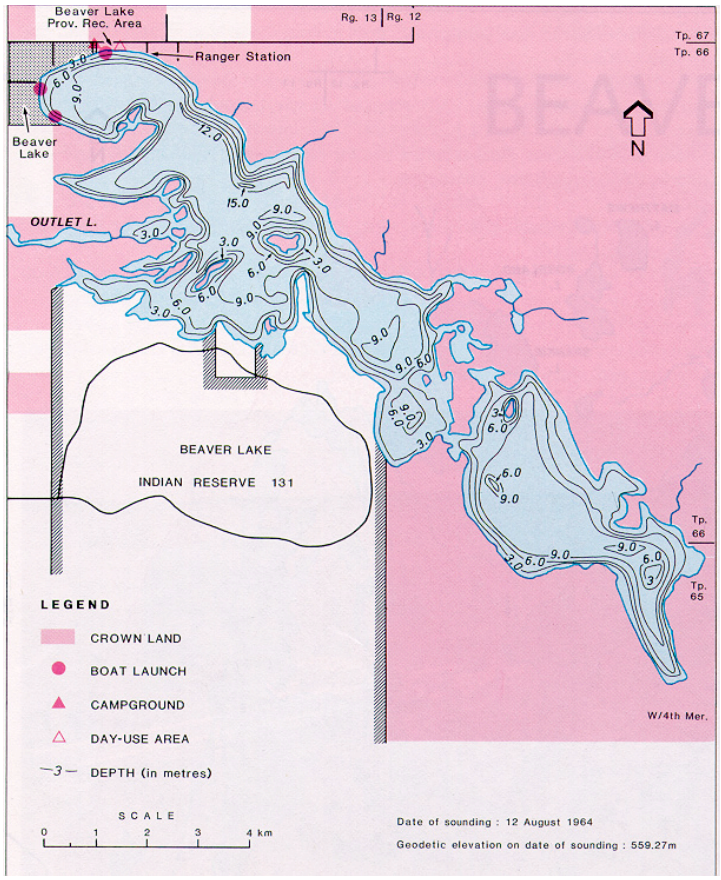

Figure 1. Depth contours (3m intervals) and shoreline features of Beaver Lake (Mitchell and Prepas 1990).

Beaver Lake is a large body of water with a surface area of 33 km^2. It consists of two large basins linked by a shallow, narrow channel, with a northwest to southeast orientation. Depth is generally 6 to 9 m in both basins, with a narrow trough reaching 15 m in depth on the northeast side of the north basin. Access to the south basin is limited to boats with very shallow draft or times of higher water. Beaver Lake contains several islands, the number of which varies with the water level. Both basins slope quite steeply to their greatest depth; the bottom of each basin is quite flat, except in the vicinity of the islands.

The area of Beaver Lake's watershed is 9 times larger than that of the lake itself. The terrain surrounding Beaver Lake is gently rolling and heavily forested. Trembling aspen (*Populus tremuloides*) is dominant in areas with well-drained soils while trembling aspen and balsam poplar (*Populus balsamifera*) co-dominate in less well-drained areas. Jack pine (*Pinus banksiana*) grows on well-drained ridges near wetlands and black spruce (*Picea mariana*) and tamarac (*Larix laricina*) grow on poorly drained organic soils. Soil in the drainage basin is most commonly Orthic Gray Luvisol of a clay or loamy type.

Water Level

Water levels in Beaver Lake have been monitored by Environment Canada since 1972 under the joint Federal-Provincial Hydrometric agreement. Water levels were quite stable during the 1970s and reached a maximum of 559.4 m in August 1975 (**Figure 2**). Since then, water levels have declined steadily, except for an increase in 1997, one of the wettest years on record. The lowest water level occurred in October 2002 when it dropped to 556.7 m. Compared to 30 years ago, the surface area of Beaver Lake has been reduced by approximately 4 km^2.

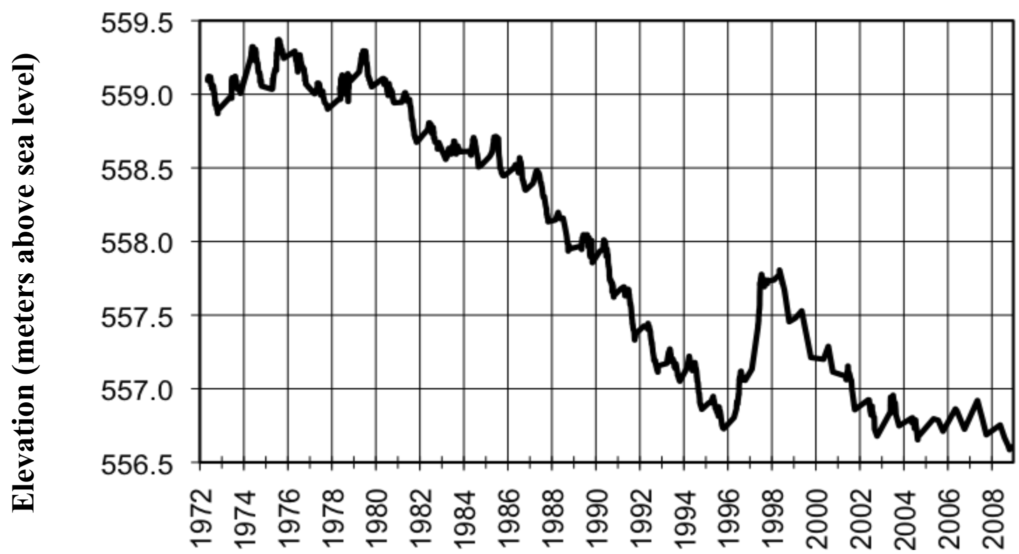

Figure 2. Historical water levels (meters above sea level (asl)) in Beaver Lake, Alberta 1972 – 2009.

Results

Water temperature and dissolved oxygen

Thermal stratification in Beaver Lake was not observed during the summer 2008 (e.g. the lake was isothermic) (**Figure 3**). Water temperature on 4 June was 15.9°C at 0.1 m below the surface, while water at the lakebed was less than two degrees cooler. Surface waters warmed to 18.3°C by 27 June, and further to 21.2°C on 23 July and remained at 21.2°C on 19 August. Water temperatures declined to 15.8°C by 14 September. The lack of a thermocline on all sampling dates suggests that wind action was sufficient to completely mix the water column throughout the summer.

Dissolved oxygen (DO) concentrations in upper layers of surface waters of Beaver 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 declined slowly at a depth of 6 m in early June, indicating a weak chemocline was present, and water at the lakebed was anoxic. This weak chemocline had disappeared by 27 June, and bottom waters were well-oxygenated, indicating complete mixing of the water column had occurred. This isochemic pattern remained on 23 July. Another chemocline formed at 7 m depth in mid-August, but the water column mixed completely again prior to prior to 14 September. The formation of weak chemoclines and their subsequent disapearance suggests that Beaver Lake is a polymictic lake, in which the water column mixes completely multiple times over the summer. This corresponds to the lack of a thermocline on these sampling dates.

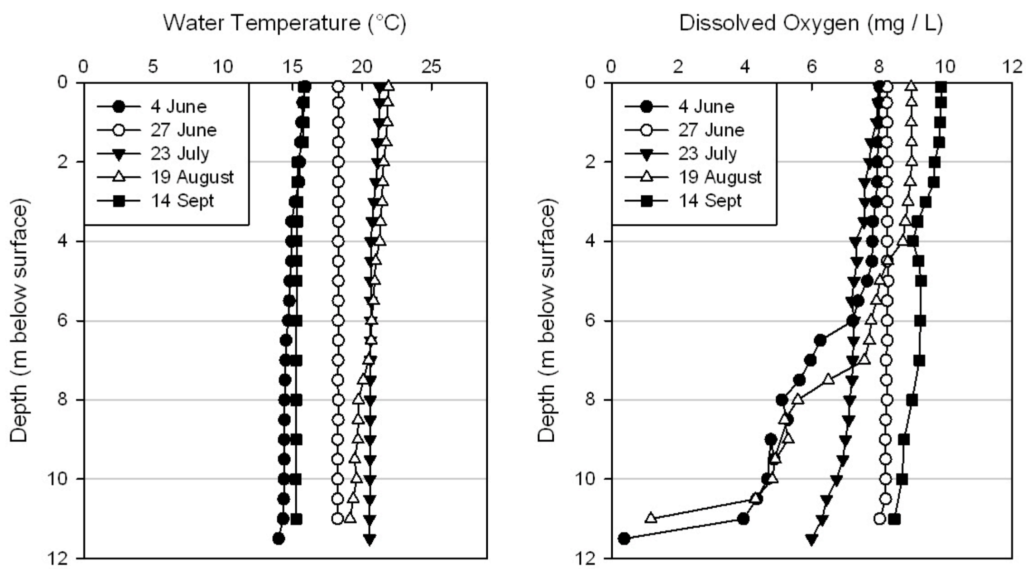

Figure 3. Water temperature (°C) and dissolved oxygen (mg/L) profiles for Beaver Lake during the summer of 2008.

Water clarity and Secchi Disk Depth

Water clarity is influenced by suspended material, both living and dead, as well as some coloured dissolved compounds in the water column. The most widely used measure of lake water clarity is the Secchi disk depth. Following the period of ice and snowmelt, a lake can have low clarity due to spring runoff and the inflow of suspended sediments into the lake. Lake water usually clears in the spring but then becomes more turbid due to algal growth taking place throughout the summer open water season.

Water clarity data for Beaver Lake was measured five times during the summer of 2008. Beaver Lake was relatively clear compared to other lakes in Alberta, with average Secchi disk depth = 5.6 m (**Table 1**). In early June, Beaver Lake was very clear, with a Secchi disk depth of 10.25 m or ~90% of the total lake depth, which allowed for algal growth in the entire water column of the lake. By 27 June, Secchi disk depth had decreased to 6.75 m, but the euphotic zone still encompassed the entire water column. In mid-July and mid-August, Secchi disk depth dropped further to 4.25 m and the bottom 3 m of the lake did not have enough light penetration to support algal photosynthesis. Water clarity dropped further in mid-September, with a Secchi disk depth of 2.5 m.

Water chemistry

Based on lake water characteristics, Beaver Lake is considered eutrophic (see *A Brief Introduction to Limnology* at the end of this report). Average total phosphorus (TP = 36.6 μg/L) and total Kjeldahl nitrogen (TN = 1292 μg/L) concentrations were within the eutrophic range in 2008 (**Table 1**). Chlorophyll *a* (chl *a* = 6.09 μg/L) was within the mesotrophic range.

Total phosphorous increased over the first half of the summer, from 28 μg/L on 4 June to a maximum of 49 μg/L on 23 July (**Figure 4**). Total phosphorous then decreased to 36 μg/L on 19 August, recovering slightly to 40 μg/L on 14 September. Total nitrogen remained relatively steady, fluctuating from a maximum of 1.4 mg/L on 19 August, to a minimum of 1.23 mg/L on 14 September. Chlorophyll a (a measure of algal biomass) increased steadily from 2.05 ug/L on 4 June to 3.57 ug/L on 27 June, and then continued to increase to a maximum of 12 ug/L by 14 September. As the depletion of phosphorous in late July to early August by algal growth was not accompanied by a significant decrease in nitrogen, algal growth in Beaver Lake is probably phosphorous-limited and not nitrogen-limited.

Beaver Lake follows the typical pattern in Alberta lakes of an increase in nutrient and algae over the summer due to the release of nutrient from underlying sediments. Nutrients (i.e., total N and P) and water greenness appear to have increased over the past two decades, while water clarity decreased. Further sampling of Beaver Lake is required to determine if this apparent increase is due to year-to-year variation or a long-term trend in water quality (**Table 1**), but total N and P in summer 2008 had subsided back to 1986 levels. Chlorophyll a concentrations in 2008 were actually below 1986 levels. This suggests that the hypereutrophic years of 2003 and 2004 were within the normal range of variation for Beaver Lake.

During the summer 2008, Beaver Lake was well buffered from acidification with an average pH = 8.4, which is well above that of pure water (i.e., pH 7). Dominant ions include bicarbonate, carbonate, sodium, and magnesium (**Table 1**). Concentrations of ammonia, nitrate + nitrite, chloride, and sodium have all increased significantly (by factors of ten, six, four, and two respectively) since initial water quality monitoring in 1986. This is an inevitable result of decreasing water levels, potentially caused by a dry climate (increased evaporative loss from the watershed, and lack of precipitation to replenish water levels) and also reflects an increasing proportion of groundwater (which is usually more saline than rainwater or surface runoff) in the lake.

The average concentrations of various heavy metals (as total recoverable concentrations) in Beaver Lake were measured twice in the summer of 2008. All concentrations were within CCME guidelines for the Protection of Freshwater Aquatic Life (**Appendix 1**).

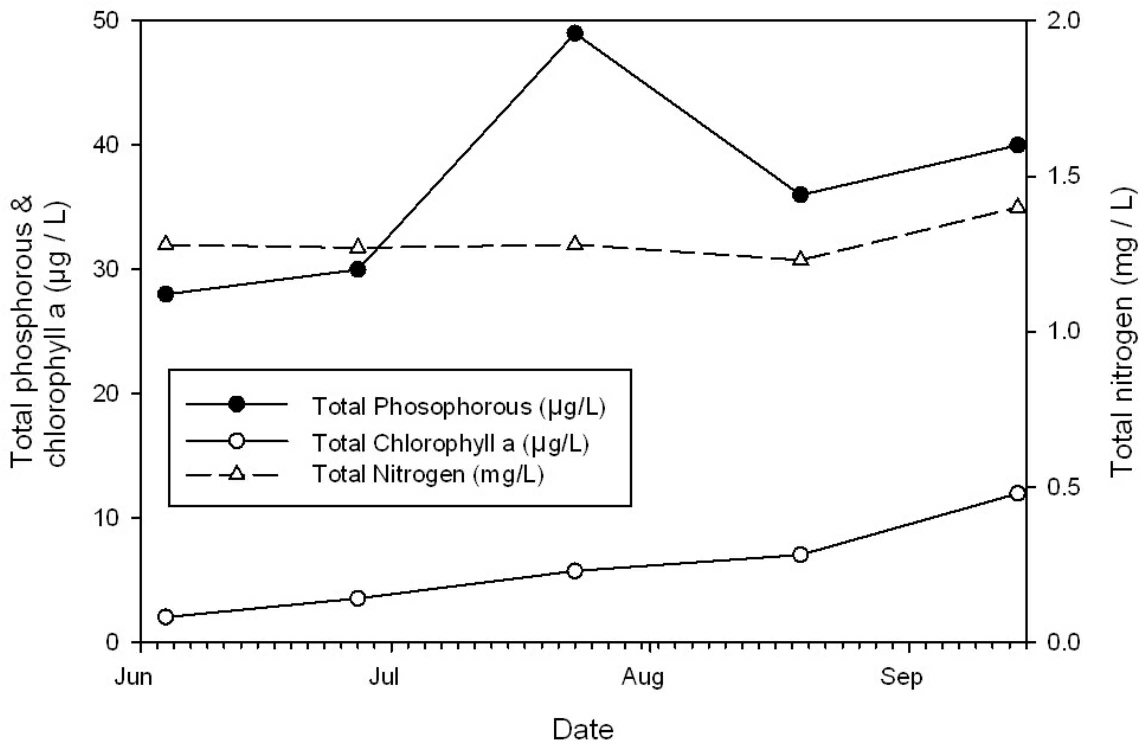

Figure 4. Total phosphorous, chlorophyll a (a measure of algal biomass), and total nitrogen concentrations for Beaver Lake during the summer of 2008.

Table 1. Water chemistry values for Beaver Lake, summer 2008.

Parameter	1986	2003	2004	2008
TP (μg/L)	33	47	56	36.6
TDP (μg/L)	12	17	13	14.4
Chlorophyll-*a* (μg/L)	11	18	24	6.09
Secchi disk depth (m)	2.9	2.4	1.8	5.6
TKN (μg/L)	1137	1358	1510	1292
$NO_{2,3}$ (μg/L)	5.6	17	13	32
NH_4 (μg/L)	3.0	2.8	3.1	31.8
Dissolved organic C (mg/L)	-	-	-	17.3
Ca (mg/L)	35	31	32	32.5
Mg (mg/L)	23	31	30	32.3
Na (mg/L)	13	13	21	22.5
K (mg/L)	10	10	14	13.4
SO_4^{2-} (mg/L)	29	42	62	65.7
Cl^- (mg/L)	0.5	1.6	2.3	2.77
TDS (mg/L)	-	-	-	294.3
pH	8.5	8.7	8.5	8.4
Conductivity (μS/cm)	409	492	499	1171
Hardness (mg/L)	-	-	-	213.7
HCO_3 (mg/L)	222	222	239	242.7
CO_3 (mg/L)	6.3	15	10	6
Total Alkalinity (mg/L $CaCO_3$)	191	206	499	208.7

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).

Appendix 1

The concentrations of metals were measured in Beaver Lake on 27 June and 14 September 2008. Values shown for 2008 are an average of those dates. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference.

Metals (total)	2004	2008	Guidelines
ALUMINUM µg/L	10.7	10.9	100[a]
ANTIMONY µg/L	0.068	0.051	6[e]
ARSENIC µg/L	1.47	1.75	5
BARIUM µg/L	57.1	58.2	1000[e]
BERYLLIUM µg/L	<0.003	<0.003	100[d,f]
BISMUTH µg/L	<0.001	0.003	
BORON µg/L	79.6	81.5	5000[e,f]
CADMIUM µg/L	<0.002	0.0029	0.085[b]
CHROMIUM µg/L	0.14	0.165	
COBALT µg/L	0.019	0.0186	1000[f]
COPPER µg/L	0.42	0.23	4[c]
IRON µg/L	8	7.4	300
LEAD µg/L	0.0278	0.0221	7[c]
LITHIUM µg/L	32.3	31.4	2500[g]
MANGANESE µg/L	138	26.9	200[g]
MOLYBDENUM µg/L	0.169	0.249	73[d]
NICKEL µg/L	<0.005	<0.005	150[c]
SELENIUM µg/L	<0.1	0.121	1
STRONTIUM µg/L	231	235.5	
SILVER µg/L	<0.0005	0.0022	
THALLIUM µg/L	0.0007	0.0014	0.8
THORIUM µg/L	0.00071	0.0127	
TIN µg/L	0.036	0.0854	
TITANIUM µg/L	1.07	1.40	
URANIUM µg/L	0.162	0.223	100[e]
VANADIUM µg/L	0.285	0.377	100[f,g]
ZINC µg/L	4.85	0.693	30

Values represent means of total recoverable metal concentrations.

[a] Based on pH ≥ 6.5; calcium ion concentration $[Ca^{+2}]$ ≥ 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).

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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

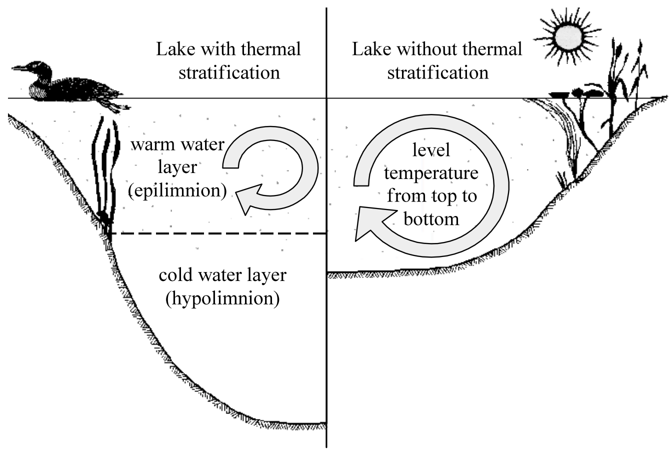

Figure 6: Difference in the circulation of the water column depending on thermal stratification.

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.

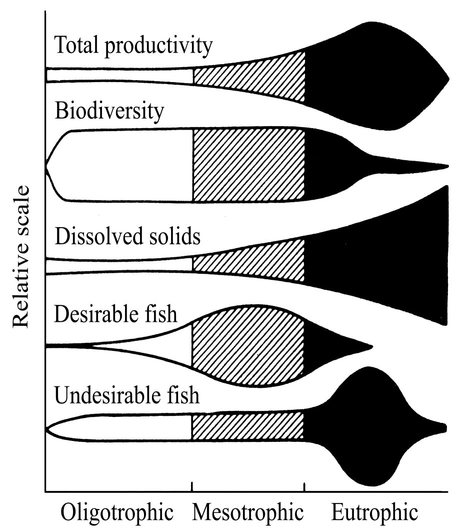

Figure 7: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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.