Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Goose Lake

2005 Report

Completed with support from:

Alberta Lake Management Society

Lakeland Industry & Community Association

Alberta Environment

Alberta Lake Management Society's Lakewatch Program

Lakewatch has several important objectives, one of which is to collect and interpret water quality 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.

Acknowledgments

The Lakewatch program is made possible through the Lakewatch Chairs, Théo Charette and Ron Zurawell, and the individual volunteers who dedicate their personal time. For Goose Lake, Marlene and Darrell Orton were the local volunteers who made sampling possible. The 2005 summer field technician Vien Lam was a valuable and hard-working addition to the program. Numerous Alberta Environment staff also contributed to successful completion of the 2005 program. Shelley Manchur was the Technical Program Coordinator, responsible for planning and organizing the field program. Technologists Mike Bilyk, Brian Jackson and John Willis were involved in the logistics and training aspects. Doreen LeClair was responsible for data management. Théo Charette (ALMS President) was responsible for program administration and planning. ALMS gratefully acknowledges Alberta Environment, the Lakeland Industry and Community Association (LICA) and Lakeland County for their financial support of the Lakewatch program.

Goose Lake

Goose Lake is located 20 km west of Fort Assiniboine in the Athabasca River Basin. It is both fed and drained by Goose Creek, which enters the lake in the northwest corner and exits in the southwest. Public access is on the south shore at Lone Pine. Some private ownership exists on the south shore as cottages with sporadic clearings for agricultural purposes elsewhere around the lake. Most of the remaining lakeshore is crown land.

Soil near the lake is sandy, gradually moving to heavier clay further out in the drainage basin. Goose Lake is located in the High Boreal Mixedwood ecoregion (Table 1) and

Table 1. Summary of details describing the high boreal mixedwood ecoregion in which Goose Lake is situated (adapted from Strong and Leggat, 1992).

High Boreal Mixedwood Characteristics*		
Vegetation	Aspen-Balsam Poplar-White Spruce mix succeeding to White Spruce and Balsam Fir	
Summer	Average Temp.	12.0 ^{0}C
	Average Min. Temp.	6.9 ^{0}C
	Average Max. Temp.	16.9 ^{0}C
	Month of Max. Precip.	July
	Total Summer Precip. (mm)	266
Winter	Average Temp.	unavail.
	Average Min. Temp.	unavail.
	Average Max. Temp.	unavail.
	Total Winter Precip. (mm)	unavail.
Total Annual Precipitation (mm)		unavail.

*precipitation numbers are median values

topography around the lake is best described as gently rolling. It is suspected that the lake has a good connection with groundwater but this has not yet been monitored (Mitchell, 1993). The lake itself lies on a slight northwest to southeast axis with a steeper northern shore. Water is generally shallow throughout and the lake is fairly exposed to prevailing winds with only small bays and coves along its shoreline (Figure 1). The drainage basin is very large relative to lake size (Table 2) and the runoff the lake receives is probably considerable as

Table 2. Physical characteristics of Goose Lake (Mitchell, 1993).

Lake surface area	2.87 m^2
Drainage basin	116.45 km^2
Mean depth	4.5 m
Maximum depth	approx. 6 m

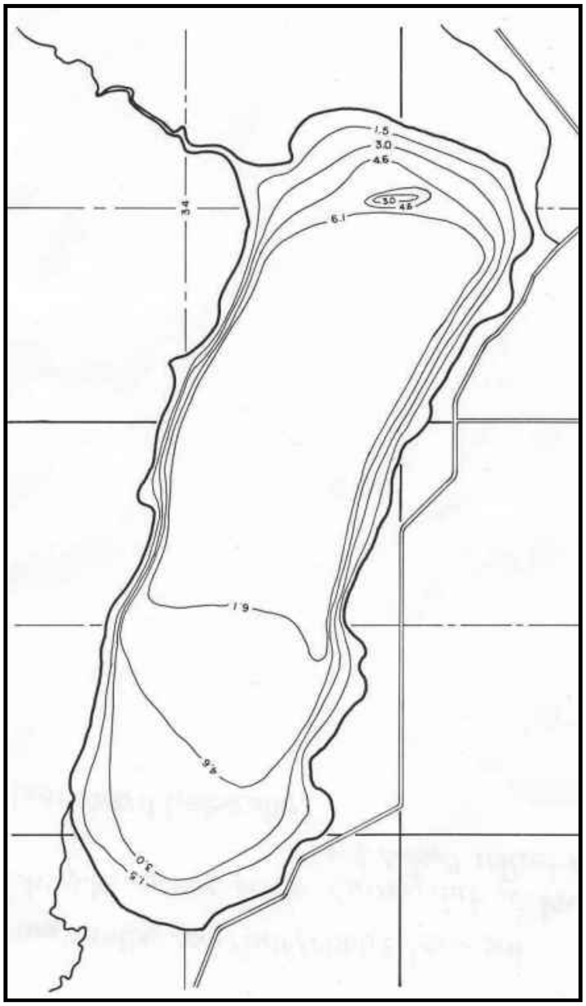

Figure 1. Bathymetric map of Goose Lake (Mitchell, 1993).

a result. Pike and perch occur naturally and there have been attempts in the 1960s and '70s to introduce walleye and more perch (none very successful).

Goose Lake has been investigated a few times in the past. In 1960, the lake was surveyed to assess recreation potential after a request from a local landowner for the introduction of more sport fish species (Paterson, 1960). It was visited again in the late 1960s for a routine physical survey and sounding, at which time it was noted that the shallowness of the lake probably left it susceptible to winterkill (Erikson and Smith, 1969). As a response to public concerns at the time, a weir was installed at the outlet in 1976. Throughout the 1980s, letters between Alberta government departments indicated growing divisions between lake users over recreation conflicts, specifically water skiing and angling, and perception problems over lake levels, fish stocks and appropriate corrective measures to both (Alberta Environment Historical Library). In 1992 the lake was sampled by the Volunteer Citizens' Lake Monitoring Program, a precursor to the ALMS Lakewatch Program (Mitchell, 1993).

Methods

Lakes monitored under the Alberta Lake Management Society's Lakewatch program are all monitored using standard Alberta Environment procedures: composite samples are collected from numerous sites around the lake and water is profiled at the deep water spot in each lake once per month through the warmer months. This usually results in 4 sampling trips per open-water season. On each trip, the deep-water profiles include measurements for temperature and dissolved oxygen recorded from lake surface to lake bottom, as well as maximum depth. A Secchi depth is also measured, from which the range of the euphotic zone is estimated. Once the euphotic zone depth is known, the composite samples are collected for lab analyses. After the water has been analyzed, results are examined for trends and summarized.

Water Levels

The water levels on Goose Lake have been monitored from 1968 to present (Figure 2). Over this period, the lake's surface has ranged from a high of 725.12 m above sea level (asl) in the summer of 2001, to a low of 723.863 m asl in late spring 1968. The average

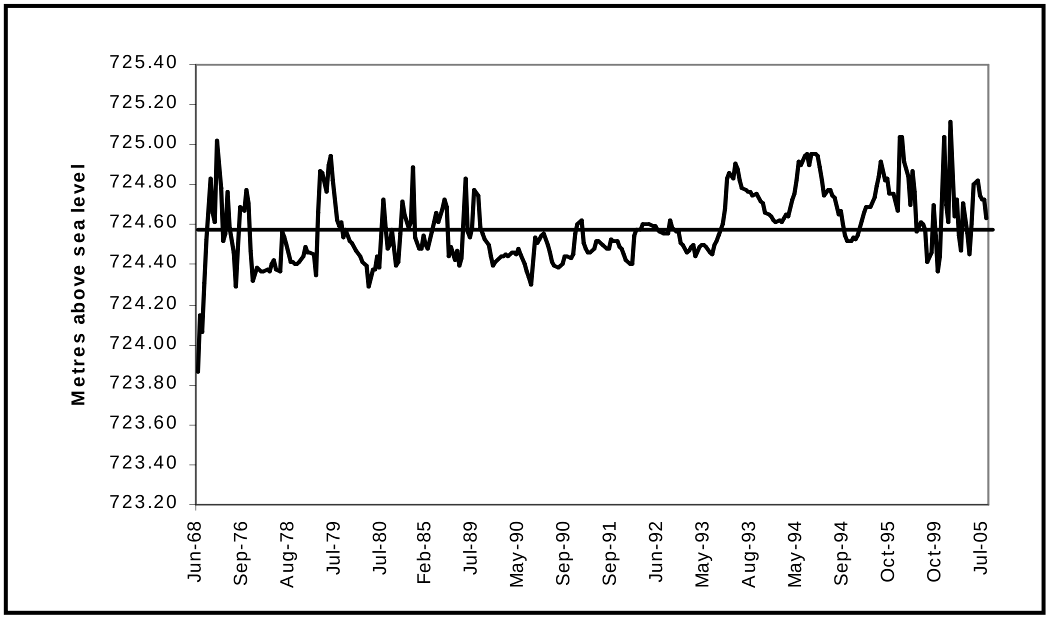

Figure 2. Historical water levels of Goose Lake. The heavier horizontal line indicates the average over the time period. Alberta Environment data.

water level during this time was 724.6 m asl. At the lake's deepest point, this translates into a depth range of about 6 to 7 m with an average depth close to 6 m. Although there are noticeable variations from year to year, the lake has maintained a relatively stable level since monitoring began probably due to the 1976 weir installation. Sill height of the weir in 1992 was estimated at 724.51 m asl (Mitchell, 1994).

Temperature and Dissolved Oxygen Profiles

For being so shallow, Goose Lake remains surprisingly anoxic at its deepest point throughout the summer sampling months (Figure 3). The values presented for late August suggest strong winds are having a mixing effect and/or actively growing algae are adding oxygen to the water column. However, the additions are not reaching the lowest point in the lake. Goose Lake has only weak thermal stratification at best and tends towards being nearly the same temperature from top to bottom.

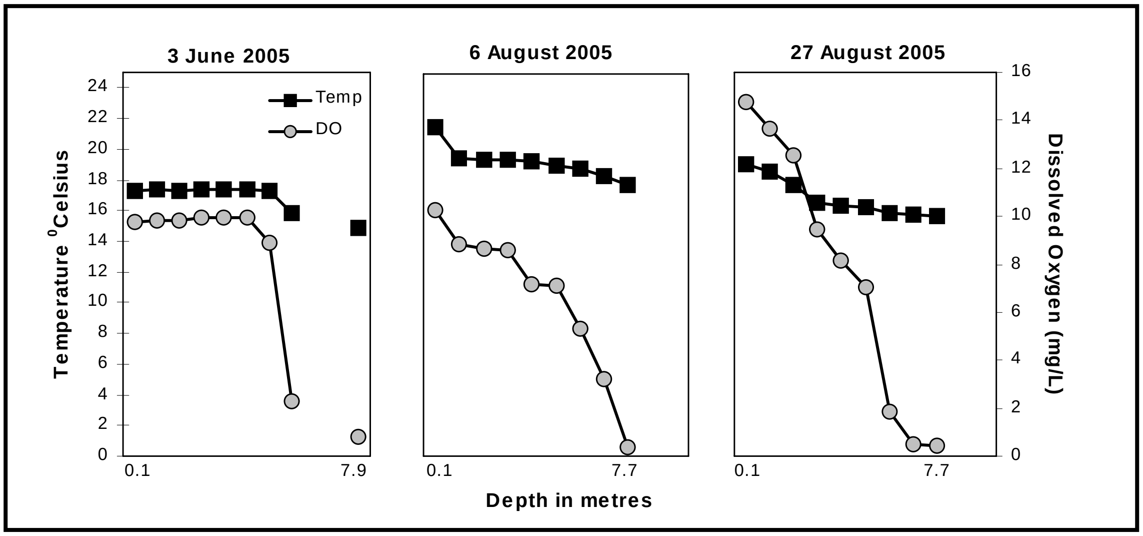

Figure 3. Temperature and dissolved oxygen profiles of Goose Lake for summer 2005. Alberta Environment data.

Water Clarity

Goose Lake is extremely productive and hypereutrophic (Figure 4), with chlorophyll *a* levels extremely high in 2005. As suggested previously, the peaking algal bloom reflected by chlorophyll *a* numbers probably helped enhance the dissolved oxygen values for August. Water clarity decreases sharply as the bloom develops and begins to recover once algal cell death starts to occur through September (Figure 5). Chlorophyll *a* levels shadow nutrient concentrations closely (Figure 6), suggesting that even though nutrient levels are high they are still limiting even more potential algal growth. Goose

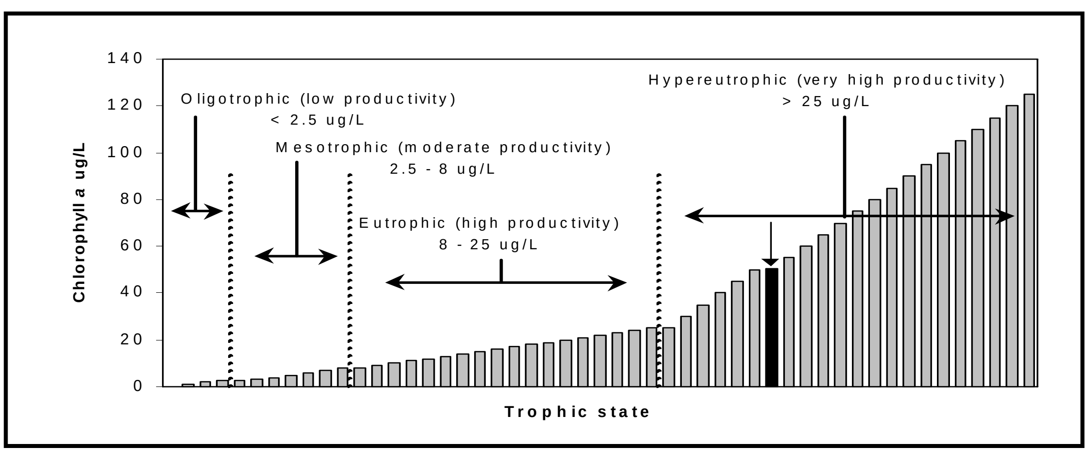

Figure 4. The black bar below the down arrow represents average chlorophyll a concentration for Goose Lake from summer 2005. Adapted from Mitchell, 1994.

Lake's large drainage basin, runoff, precipitation, and nutrients stored in sediments are all nitrogen and phosphorus sources for possible blooms.

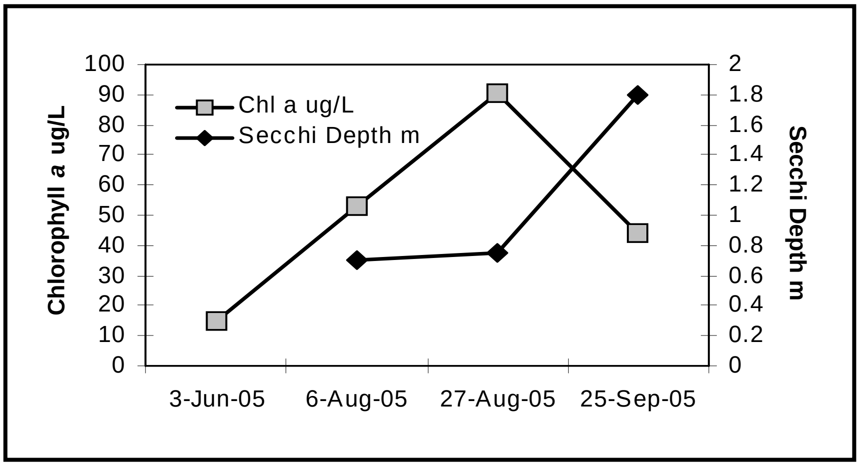

Figure 5. Secchi depth begins to increase in late summer/early autumn as algal death occurs reflected by the drop in chlorophyll *a.*

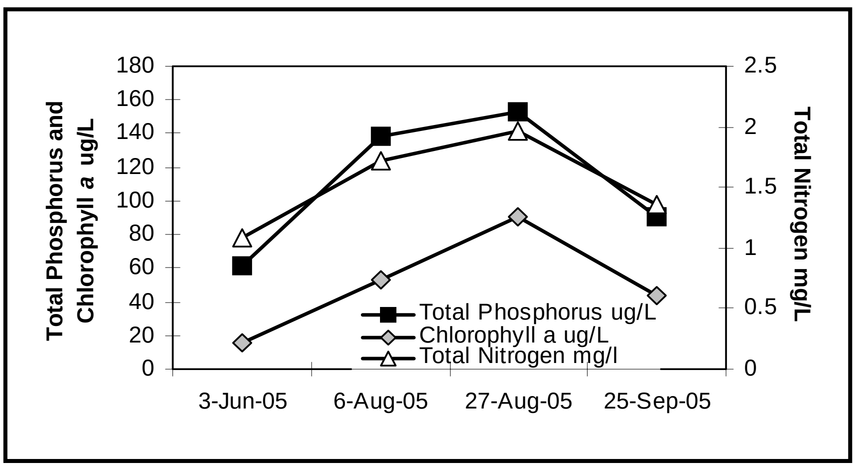

Figure 6. The highly similar lines for chlorophyll *a* concentrations and nutrients suggest that both phosphorus and nitrogen are limiting reagents for algal growth in Goose Lake.

Water Chemistry

Goose Lake has been sampled intermittently since 1987. Mean summer phosphorus concentrations over this period have varied greatly and showed a marked decline throughout the 1990s (Figure 7). Chlorophyll *a* concentrations also show yearly fluctuations although all values still place the lake in either the eutrophic or hypereutrophic range. Mean Secchi depth shows an overall downward trend in water clarity.

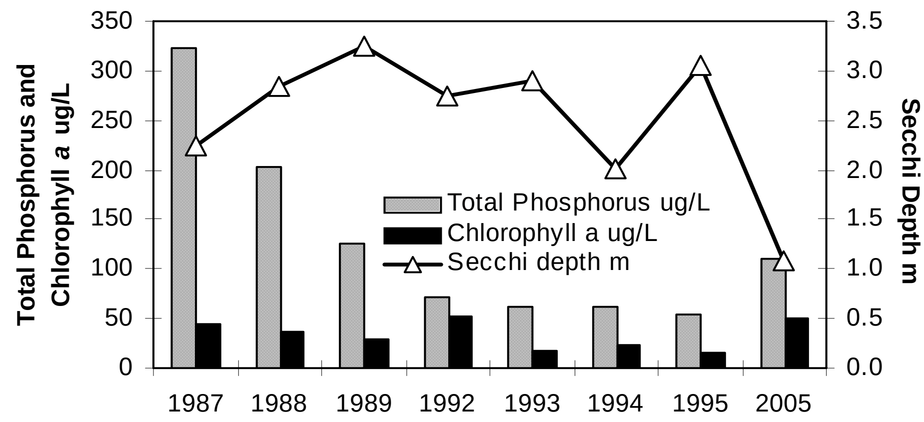

Figure 7. Summer averages for TP, chl a and Secchi depth. Dramatic changes in phosphorus levels might be a result of transport during wetter years, as the drainage basin for Goose Lake is very large relative to lake area.

Levels for total dissolved solids and cations indicate that Goose Lake has low salinity water (Table 3). In terms of chemistry, it is nutrient levels that set the lake above the average. Although the lake may have a good flushing rate, in high runoff events the size of the drainage basin provides ever more phosphorus and nitrogen. The low oxygen levels near the lake bottom allow the release of stored nutrients from sediments. This process is called internal loading, and succeeds in adding even more available nutrients to the water column.

Table 3. Goose Lake cation concentrations place the lake in the low salinity range. Adapted from Atlas of Alberta Lakes.

Salinity Range	**Average Cation Concentrations mg/L**			
(based on Total Dissolved Solids mg/L)	Sodium	Potassium	Calcium	Magnesium
Low salinity (<500)	20	5	29	15
Slightly saline (500-1000)	113	29	31	59
Moderately saline (1000-5000)	379	34	21	46
Goose Lake (136.0)	**8.0**	**2.8**	**31.4**	**7.8**

Results for other water quality measurements averaged from 2005 are summarized in Appendix I, as well as historical values where available.

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Appendix 1. Summary of historical and summer 2005 averages for various water quality parameters. 1987 represents a single sampling effort.

Parameter	1987	1988	1989	1992	1993	1994	1995	2005
Total Phosphorus ug/L	322.3	203.3	125.5	71.8	62.8	62.5	54.8	110.8
Total Dissolved Phosphorus ug/L	260.4	147.1	85.8	20.8	32.3	25.8	22.3	50.8
Total Dissolved Solids mg/L	153.0	161.0	151.0	149.9	151.9	141.4	148.3	136.0
Chlorophyll a ug/L	43.6	37.3	28.6	51.5	17.9	22.6	14.8	50.6
Secchi depth m	2.3	2.8	3.2	2.7	2.9	2.0	3.1	1.1
Total Nitrogen mg/L	1.5	1.7	1.7	1.5	1.0	1.4	0.9	1.5
Nitrate + Nitrite mg/L	0.009	0.031	0.015	0.012	0.004	0.031	0.019	0.027
Ammonium mg/L	0.063	0.126	0.181	0.017	0.055	0.163	0.045	0.052
Calcium mg/L	37.0	38.7	34.6	33.6	33.1	32.2	35.4	31.4
Magnesium mg/L	10.0	10.9	10.0	10.7	10.9	10.2	10.1	7.8
Sodium mg/L	9.0	9.0	9.0	11.3	11.7	9.8	9.4	8.0
Potassium mg/L	2.4	2.4	2.2	2.4	2.3	2.2	2.1	2.8
Sulphate mg/L	L5	4.7	2.2	4.0	L3	L3	3.0	5.0
Chloride mg/L	L1	0.5	1.1	0.7	0.7	0.7	0.7	0.8
Alkalinity mg/L as $CaCO_3$	148.0	156.9	146.2	150.2	151.7	140.1	147.1	134.0
Carbonate mg/L	37.0	38.7	34.6	33.6	33.1	32.2	35.4	31.4
Bicarbonate mg/L	107.0	176.5	164.2	178.6	182.3	168.4	179.0	158.5
pH	9.2	8.5	8.3	8.5	8.4	8.3	8.1	8.3
Conductivity uS/cm	263.0	293.7	272.2	267.6	280.7	262.9	270.3	254.0
Iron mg/L	0.06	0.11	0.11	0.07	0.05	0.10	0.07	0.13
Fluoride mg/L	0.12	0.11	0.12	0.12	0.12	0.12	0.12	0.13
Mercury	L0.0001							

A brief introduction to Limnology

Indicators of water quality

Water samples are collected in Lakewatch to determine the water quality of lakes. Though not all encompassing, the variables collected in Lakewatch are sensitive to human activities in watersheds that can cause degraded water quality. For example, nutrients such as phosphorus and nitrogen are important determinants of lake productivity. The concentrations of these nutrients in a lake are impacted (typically elevated) by land use changes such as increased crop production or livestock grazing. Elevated nutrient concentrations can cause increases in undesirable algae blooms resulting in low dissolved oxygen concentrations, degraded habitat for fish and noxious smells. A large increase in nutrients over time may also indicate sewage inputs which in turn may result in other human health concerns associated with bacteria or the protozoan *Cryptosporidium*.

Temperature and mixing

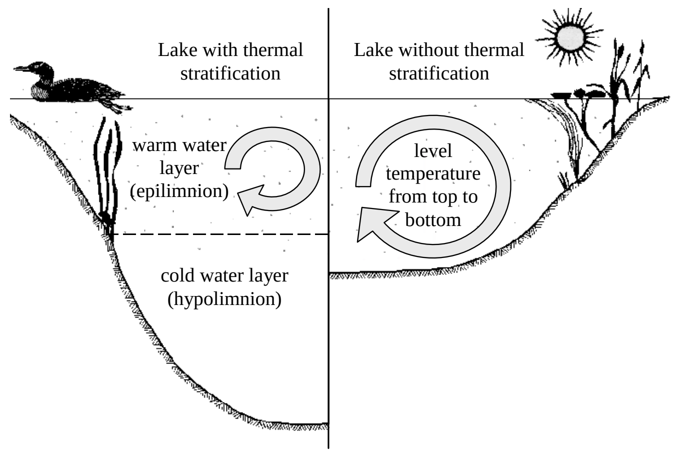

Fig. 1: Difference in the circulation of the water column depending on thermal stratification.

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

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

Dissolved Oxygen

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

General Water Chemistry

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

Phosphorus and Nitrogen

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

Chlorophyll a

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

Secchi Disk Depth

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

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

Trophic state

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

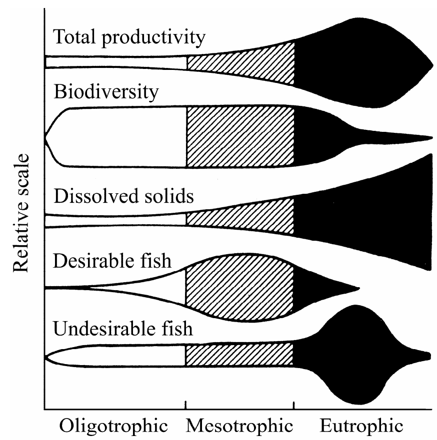

Fig. 2: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980

Trophic status based on lake water characteristics.

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

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

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