The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Gull Lake

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2006 Report

Completed with support from:

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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 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, 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 usually available for 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 Lakewatch Chairs, Théo Charette and Ron Zurawell, and the volunteers. Caria McCann was the main volunteer for Gull Lake. She supplied the watercraft and made sampling possible through the dedication of her time. Our summer field technicians and volunteer coordinators, Megan Mclean and Amanda Krowski, were valuable additions and contributors to this year's program. Numerous Alberta Environment staff also contributed to successful completion of the 2006 program. Project Technical Coordinator, Shelley Manchur was instrumental in planning and organizing the field program. Technologists, Mike Bilyk, Brian Jackson and John Willis were involved in the logistics planning and training aspects of the program. Doreen LeClair was responsible for data management. Théo Charette (ALMS Director) was responsible for program administration and planning. Zofia Taranu, Jesse Vermaire and Erika Brown prepared this report. Alberta Environment and Lakeland Industry and Community Association (LICA) financially supported the Lakewatch program.

Gull Lake

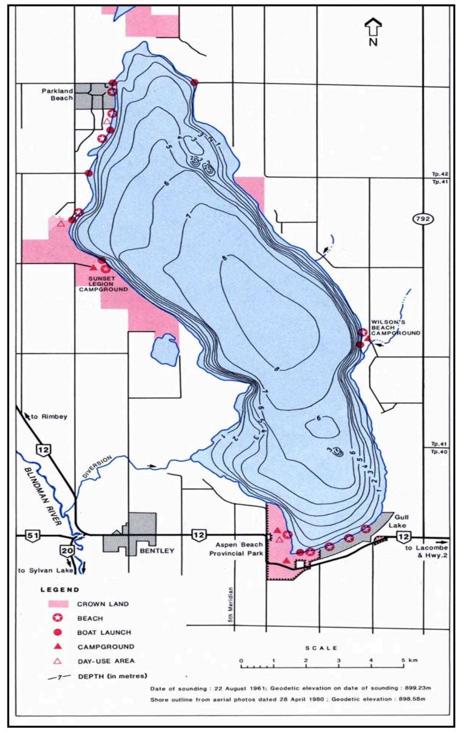


Figure 1: Bathymetry of Gull Lake, Mitchell and Prepas, 1990

Gull Lake has a large surface area and is considered to be a shallow lake (mean depth = 5.4 m). As this lake is situated between two major cities (Edmonton and Calgary), it is heavily populated and visited by many during summer months. The lake is renown for its clear water and sandy beaches. It also supports moderate sport fishing of predominantly northern pike, walleye and whitefish. The lake is situated approximately 17 km east of the town of Lacombe and 136 km from the city of Edmonton. To get to Gull Lake from either Edmonton or Calgary take Highway 2 towards Lacombe, then head west on Highway 12 towards the Gull Lake Summer Village (for ~ 14 km).

The surrounding region of Gull Lake was first settled in 1895. At the turn of the 20th century a lumber industry was established and had a steamboat used for the sawmill operation (located at the northwest shore of Gull lake, namely Birch Bay) and also for transportation of passengers. By 1908, the lake served as a hydroelectric reservoir, however, in 1910 the dam was destroyed. Following the destruction of the dam, Gull Lake water levels continually decreased and were cause for concern. Although the community of Gull Lake had a dam built at the outlet in 1921, the lake water level nonetheless continued to decrease. The dam is now located approximately 1.6 km from shore (Bailey 1970), and the water level dropped, on average, ~ 6 cm/yr from 1924 to 1968. By 1977 a pipeline and canal was built diverting water from the Blindman River to increase water levels.

There is a 2.15-km^2 provincial park (Aspen Beach Provincial Park) on the southwest shore of the lake, which was established in 1932 making it one of the first parks of the Alberta park system (Finlay and Finlay 1987). The park includes 4 campgrounds, a boat launch, beaches, day-use areas, toilets and showers. Numerous recreational activities (sailing, power boating, windsurfing, etc) are commonplace on the south and southeastern shores of Gull Lake. There are approximately 487 cottages along the lake's shoreline (~ 330 in the County of Lacombe and ~ 157 in the County of Ponoka).

The drainage basin of Gull Lake is approximately 2 times the lake's surface area. There are presently no inlet or outlet streams (the outlet has been completely dry for decades), which may in part explain the continually decreasing lake level (see above). Gull Lake is located in the Aspen Parkland and Boreal Mixed wood Ecoregions. The dominant trees are trembling aspen, balsam poplar, white spruce and willow. Much of the lake's catchment is devoted to agricultural activities and cattle production.

Gull Lake has a large surface area of 80.6 km^2 and is composed of one basin, which is relatively shallow with a maximum depth of 8 m and mean depth of 5.4 m. As such, the lake is polymictic during the open-water season, mixing periodically throughout spring and summer months. No true thermocline exists in Gull Lake, however, weak thermal stratification may occasionally occur on warm, calm summer days.

Temporary stratification events are important if they last several days because they allow the reduction of dissolved oxygen concentrations in deeper water and the release of phosphorus into the water column when the temporary stratification breaks down.

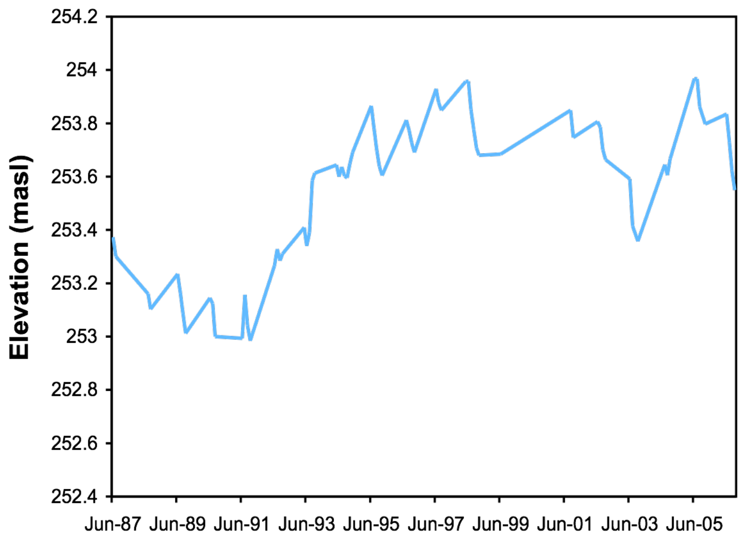
Gull Lake is eutrophic based on nutrient, chlorophyll and transparency criteria. However, due to the lake's slightly saline conditions, it is possible that algal biomass is depressed somewhat relative to the nutrient (phosphorus) concentrations as reported in other Alberta lakes (Bierhuizen and Prepas 1985). The main sources of phosphorus to the lake are from agriculture activities in the catchment and internally derived nutrients stored in bottom water sediments (as explained above).

Results

Water Levels

Near Sunnyside Marina:

Between the years 2000 and 2002 Gull Lake experienced a decline in water level of roughly 0.5 m. Since this time period, water levels have remained fairly constant with the exception of a large 0.3 m increase recorded in May of 2003. The maximum lake level measured between 1999 and 2006 was of 899.022 m above sea level and was recorded during the August 2000 sampling. The minimum occurred in September of 2004, with an elevation of 898.497 m above sea level.



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.

Low dissolved oxygen (DO) concentrations during winter are possible, however Gull Lake remained well oxygenated through the summer except in July when DO was reduced to 2 mg/L at the 7 m depth (**Figure 2**). DO depletion occurred despite the lack of an apparent thermocline. A thermocline may have existed prior to sampling, however, the rapid decline in DO following this temporary stratification suggests that the lake is more sensitive to oxygen depletion than previously perceived. DO concentrations in the top 4 m of water column were always above 7.98 mg/L. A severe winter with long ice-cover could thus significantly lower winter oxygen concentrations as seen by the rapid decline in July.

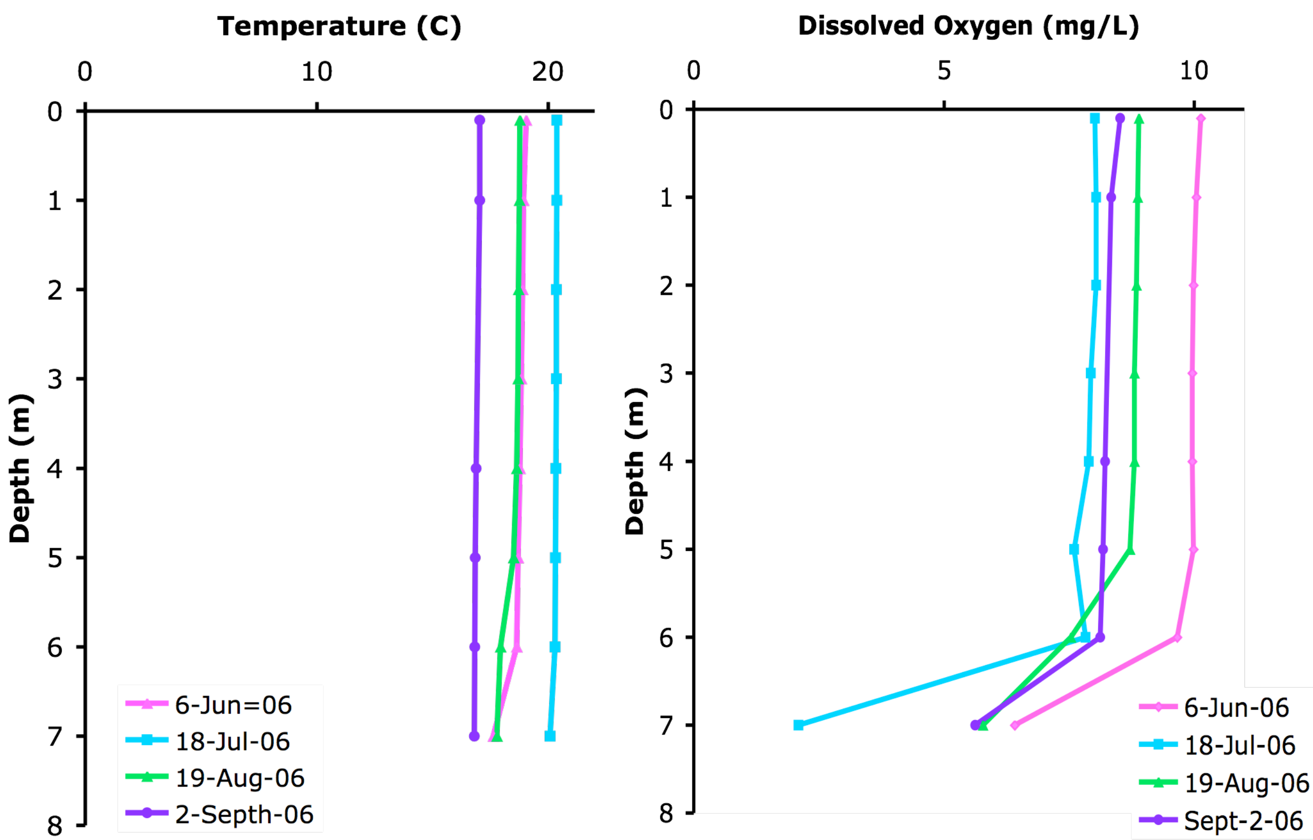


Figure 2. Temperature and dissolved oxygen concentrations with depth of Gull Lake, summer 2006.

Water clarity and Secchi Depth

During the melting of snow and ice in spring, lake water can become cloudy from silt transported into the lake. Lake water usually clears in late spring but then becomes more turbid with increased algal biomass as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi disk depth.

Gull Lake's water was turbid during the summer of 2006 (average Secchi disk depth of 1.65 m; **Table 1**). Maximum water clarity was observed during mid-summer sampling dates, where the Secchi disk depth reached 1.75 m. Overall, the Secchi disk depth remained stable throughout the open water season.

Water chemistry

In summer 2006, Gull Lake was classified as eutrophic based on the nutrient, algae and transparency criteria. The lake water is therefore generally green with limited visibility; many lakes in Alberta have similar conditions. Occasional blooms of noxious algae, low winter oxygen concentrations and winter fish-kills are therefore all plausible.

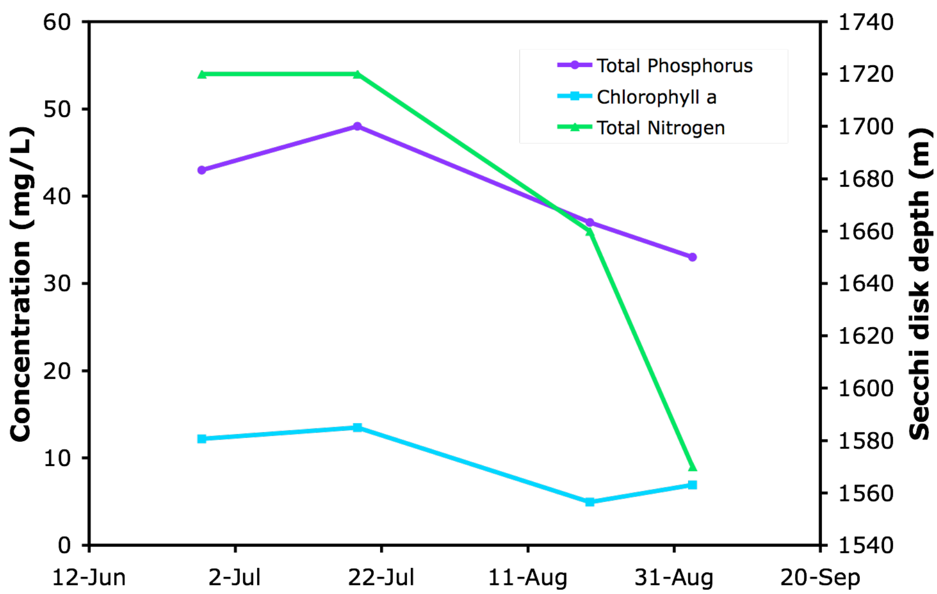


Figure 3. Total Phosphorus & Chlorophyll a (amount of algae) concentrations, and Total Nitrogen for Gull Lake, summer 2006.

Total phosphorus (TP) increased from June to July however it decreased for the remainder of the summer season (**Figure 3**). Water greenness (Chlorophyll a) was variable throughout the summer 2006 sampling season, where June to July values were indicative of eutrophic conditions, followed by a reduction in trophic status to mesotrophic for the remainder of the summer. Total nitrogen (TN) concentrations in Gull Lake were high (>1600 μg/L) however both nitrate and ammonium concentrations were relatively low, indicating that TN concentrations were likely not a problem. Furthermore, the lake was considered to be phosphorus and not nitrogen limited as the TN: TP ratio of ~ 40:1 was well above the cut-off of value (i.e. ratios of 16:1 or lower indicate nitrogen limitation). Inputs from animal husbandry (feed lots) and sewage typically have N: P ratios less than 5. Thus the high TN: TP ration of Gull Lake and the low variability in nutrient concentrations in recent times suggest that human impact is not pronounced as of yet.

Mean calcium concentrations were low (8.33 mg/L), but concentrations of the following ions were relatively high: magnesium (67.85 mg/L), sodium (233.5 mg/L), and potassium (21.7 mg/L) (**Appendix 1**). Chloride concentrations were low for a eutrophic lake (5.85 mg/L) and on an ion equivalent basis were 2.5% of sodium concentrations. A low chloride to sodium ratio indicates that human and animal sewage were not likely a source. The high concentration of sodium and potassium cations is indicative of high evaporative loss from both the watershed and catchment, which is an unavoidable consequence of a dry climate and extensive agricultural practices.

The average concentrations of various heavy metals (as total recoverable concentrations) were below CCME guidelines for the Protection of Freshwater Aquatic Life. Results of the metal analyses, compared to guideline values, are listed in **Appendix 2**.

Appendix 1

Table1: Mean chemical characteristics of Gull Lake.

Parameter	2006
Total P (µg/L)	40.25
TDP (µg/L)	17.5
Chlorophyll *a* (µg/L)	9.39
Secchi disk depth (m)	1.65
Total N (µg/L)	1668
NO_{2+3} (µg/L)	<5
NH_4 (µg/L)	28.5
Ca (mg/L)	8.33
Mg (mg/L)	67.85
Na (mg/L)	233.5
K (mg/L)	21.7
SO_4 (mg/L)	90
Cl (mg/L)	5.85
CO_3 (mg/L)	103.5
HCO_3 (mg/L)	657.5
Total Alkalinity (mg/L $CaCO_3$)	712
pH	9.165
Total dissolved solids (mg/L)	844.5

Note: TDP = total dissolved phosphorus, NO_{2+3} = nitrate+nitrite, NH_4 = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulfate, Cl = chloride, HCO_3 = bicarbonate, CO_3 = carbonate.

Appendix 2

Metals (total)	2005	2006	Guidelines
ALUMINUM ug/L	4.04	18.99	100[a]
ANTIMONY ug/L	0.021	0.0153	6[e]
ARSENIC ug/L	0.944	0.9525	5
BARIUM ug/L	32	31.5	1000[e]
BERYLLIUM ug/L	<0.003	<0.003	100[d,f]
BISMUTH ug/L	<0.001	0.0061	
BORON ug/L	54.7	55.5	5000[e,f]
CADMIUM ug/L	0.0024	0.0029	0.085[b]
CHROMIUM ug/L	0.123	0.07	
COBALT ug/L	0.0188	0.01125	1000[f]
COPPER ug/L	0.176	0.241	4[c]
IRON ug/L	35.4	34	300
FLUORIDE mg/L	0.17	-	1.5
LEAD ug/L	0.0366	006445	7[c]
LITHIUM ug/L	11.3	13.6	2500[g]
MANGANESE ug/L	33.5	19.25	200[g]
MOLYBDENUM ug/L	0.328	0.331	73[d]
NICKEL ug/L	<0.005	0.172	150[c]
SELENIUM ug/L	0.104	<0.1	1
STRONTIUM ug/L	121	115.5	
SILVER ug/L	0.0022	0.0022	
THALLIUM ug/L	<0.0003	0.00165	0.8
THORIUM ug/L	0.0039	0.00695	
TIN ug/L	0.0332	<0.03	
TITANIUM ug/L	0.481	0.6485	
URANIUM ug/L	0.103	0.105	100[e]
VANADIUM ug/L	0.0845	0.1078	100[f,g]
ZINC ug/L	8.35	2.315	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).

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

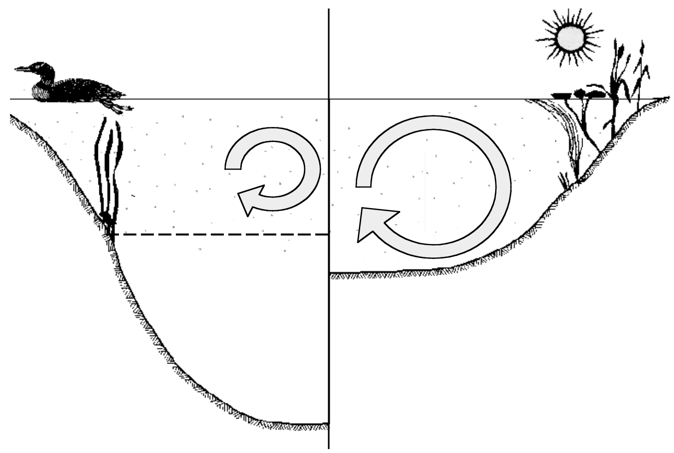


Fig. 1: Difference in the circulation of the water column depending on thermal stratification.

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.

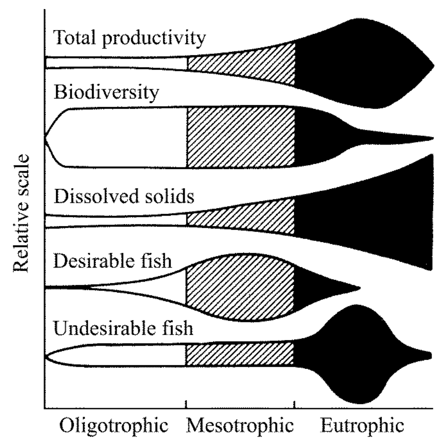


Fig. 2: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980

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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