Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Garnier Lake

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2005 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 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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Garnier Lake

Figure 1. Air photo of Garnier Lake and its surroundings. Source: Neil Guay.

Garnier Lake is sometimes referred to as Big Garnier, Garnier North, or Lower Garnier. It lies in the southern portion of Muriel Lake's drainage basin. Garnier Lake is one of the biggest inflows into Muriel Lake (Figure 1).

Garnier Lake is a small (5.2 km2) and narrow lake that is fairly deep for its size. Historically, the maximum depth of Garnier Lake has been recorded at 9.5 m, a later sampling in the winter recorded 6.5 m (Alberta Government, 2002). The presence of Beaver dams on the outlet is thought to keep water levels more stable than Bluet Lake (AENV 1983, vol.5). Water levels have been decreasing due to the lack of precipitation in recent years. Cattails (*Typha latifolia*) and willow (*Salix* spp.) fringe the southern bay, and bulrushes (*Scirpus* spp.) dominate the west and northern shores (AENV 1983, vol.5).

Garnier Lake's drainage basin is rolling hummocky morainal plain with irregular knob and kettle topography (Mitchell and Prepas, 1990). The western shoreline has a very distinct ridge with rough irregular slopes. The east side is moderately rolling along in a north-south valley. Vegetation in the area is predominantly aspen (*Populus* spp.) forest. Within the forested areas are grazing pastures and oil and gas leases. Recreation and cottage developments do not exist. The lake is used as drinking water for cattle, and for trapping, hunting waterfowl, and fishing. Northern pike (*Esox lucius*), yellow perch (*Perca flavescens*) and burbot (*Lota lota*) were the only sport fish found in previous surveys (Alberta Government, 2002). There is no record of domestic or commercial fisheries for Garnier Lake (Bodden, 2002).

Water Levels

Water levels in Garnier Lake have been monitored since 1968 by Environment Canada under the joint federal-provincial hydrometric agreement. Water levels were quite stable during the 1970's and early 1980's reaching a maximum of 606.1 m above sea level in 1979 (Figure 2). Since then the water levels have steadily declined, except for an increase in 1997, one of the wettest years on record. The lowest water level occurred in 2004, where lake levels dropped to 602.84 m above sea level. This decrease in lake water levels is a result of the drought conditions experienced in the area for the past 8 years.

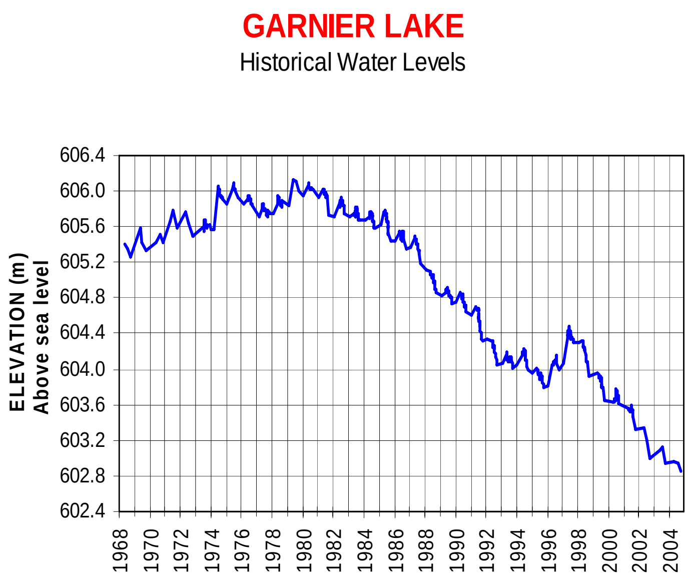

Figure 2. Historic water levels of Garnier Lake

Results

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.

Garnier Lake's water column showed a weak thermal stratification in late June and again in early July at 5 meters (**Figure 3**). Dissolved oxygen concentrations dropped steadily below the thermocline, during June/July, but remained well oxygenated during periods of mixing (August and September; **Figure 3**). This decrease in oxygen concentrations below the thermocline occurs because oxygen from the atmosphere is prevented from reaching the lake bottom where microbial decomposition occurs. Despite this, the water column of Garnier Lake was within surface water quality guidelines for most of the water column throughout the summer.

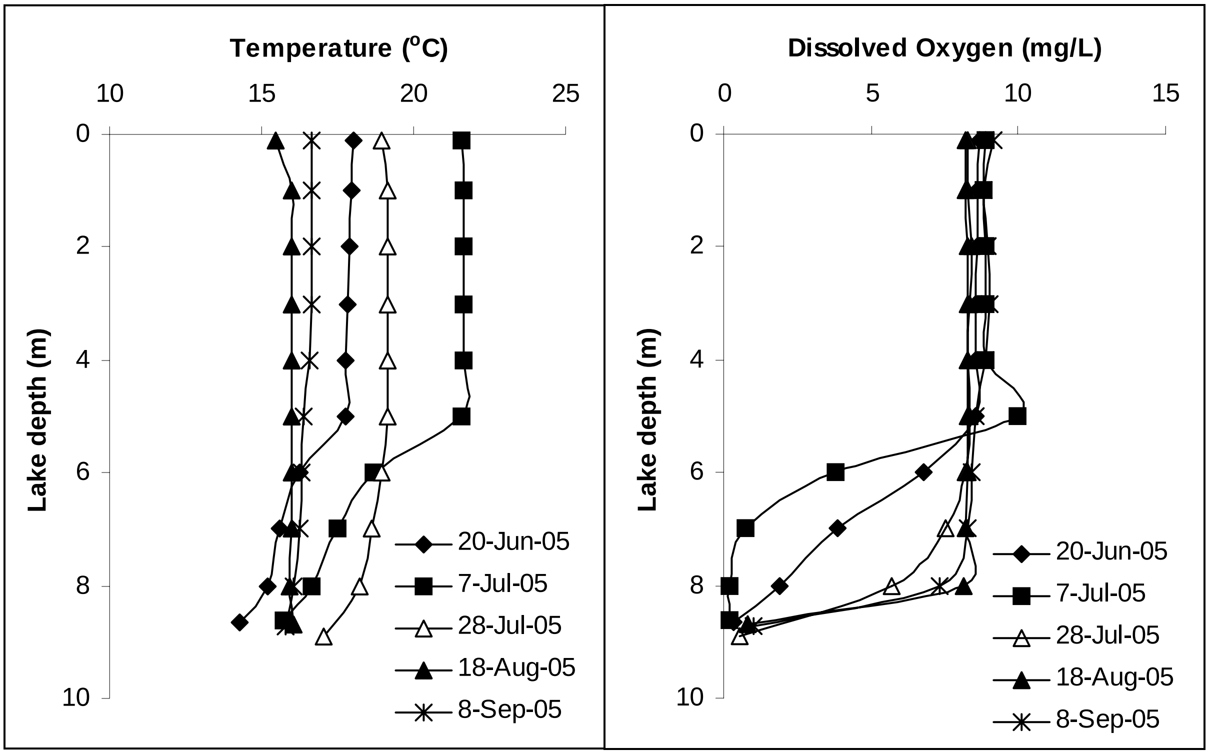

Figure 3: Temperature and dissolved oxygen profiles in Garnier Lake, summer 2005.

Water clarity and Secchi Depth

Water clarity is influenced by suspended materials, both living and dead, as well as dissolved coloured 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 biomass as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi disk depth.

Garnier Lake's water was clear during the summer of 2005 (average Secchi disk depth of 3.7 m; **Table 1**). This is an increase of about 1 m from the 2004 average. Maximum water clarity was observed in mid-June when the Secchi disk depth reached 4.6 m. Secchi disk depth decreased to 2.7 m by mid-August and then increased to 3.5 m in early September.

Water chemistry

Based on the trophic status of lake water characteristics, Garnier Lake is considered to be mesotrophic (see *A Brief Introductory to Limnology* at the end of this report). Given that lakes in Alberta are productive, in the Alberta context, Garnier Lake is below average in nutrient concentrations and algae. In 2005, total phosphorus concentrations were fairly stable showing an increase in mid-August. Chlorophyll a, a measure of algal biomass, hovered about 4 µg/L (Figure 4). Total nitrogen concentrations fluctuated over the summer and are representative of mesotrophic conditions. The quality and clarity of Garnier Lake during the 2005 Lakewatch sampling season was good.

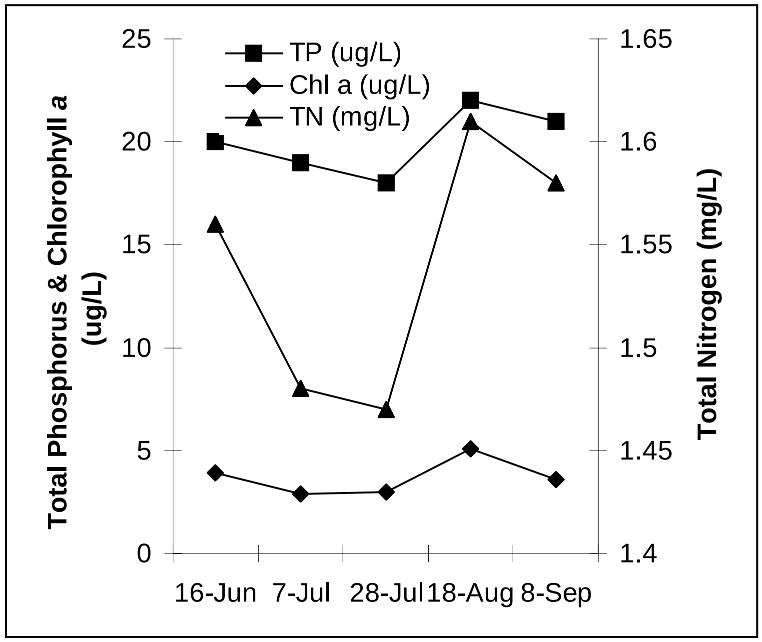

Figure 4. Total phosphorus, total nitrogen and chlorophyll-*a* (i.e., water greenness concentrations), summer 2005.

Garnier Lake is well-protected from acidification; its pH of 9 is well above that of pure water (i.e., pH 7; Table 1). Garnier is a hardwater lake: ion concentrations (Table 1) are fairly high. Dominant ions include bicarbonate, carbonate, sulphate, sodium, and magnesium. Atmospheric deposition of acidifying pollutants from petroleum activities can often be seen in increasing sulphate and nitrate/nitrite concentrations. Sulphate and nitrate/nitrite concentrations have remained steady over the past 4 years. Mineral ions are also supplied by weathering in the watershed and from groundwater inflows. High magnesium, bicarbonate, and sulphate indicate the potential for substantial groundwater inflows. Reduced water level can also cause a concentration of ions.

The most obvious change in water quality since the Lakewatch program has been conducted on Garnier Lake is a doubling in greenness, or algal biomass, in 2003. Usually, phosphorus is the most important nutrient limiting algal growth. However, because phosphorus concentrations remained unchanged, it is possible that algae in Garnier Lake benefited from a doubling in bioavailable nitrogen (i.e., ammonium and nitrate/nitrite). Overall, water quality in Garnier Lake was consistent with other mesotrophic lakes in Alberta.

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 1.

Table 1: Mean values from summer 2005 samples compared to values reported previously.

Parameter	2002	2003	2004	2005
Total P (µg/L)	27	27	25	20
Chlorophyll-*a* (µg/L)	4.7	7.8	4.2	3.7
Secchi disk depth (m)	2.8	2.2	2.8	3.7
Total N (mg/L)	1.6	1.6	1.6	1.2
NO_{2+3} (µg/L)	2.6	7.9	2.5	5.0
NH_4 (µg/L)	10	23	19	14
Ca (mg/L)	16	18	17	19
Mg (mg/L)	76	80	72	70
Na (mg/L)	41	51	45	44
K (mg/L)	18	19	17	17
SO_4 (mg/L)	82	96	89	90
Cl (mg/L)	3.7	7.1	7.6	7.0
CO_3 (mg/L)	47	42	40	39
HCO_3 (mg/L)	343	361	370	365
Total dissolved solids (mg/L)	-	491	470	465
pH	9.0	9.0	9.0	9.0
Total Alkalinity (mg/L $CaCO_3$)	357	366	370	364

Note: TP = total phosphorus, Chla = chlorophyll *a*, 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).

References

Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes. University of Alberta Press.

Appendix 1

Mean concentrations of metals in Garnier Lake during the summers of 2003, 2004, and 2005 compared to CCME Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated).

Metals (total)	**2003**	**2004**	**2005**	**Guidelines**
ALUMINUM ug/L	20	27	4.1	100[a]
ANTIMONY ug/L	0.04	0.08	0.08	6[e]
ARSENIC ug/L	1.3	1.3	1.3	5
BARIUM ug/L	18	18	18	1000[e]
BERYLLIUM ug/L	0.08	0.002	0.004	100[d,f]
BISMUTH ug/L	0.006	0.001	0.003	
BORON ug/L	92	92	100	5000[e,f]
CADMIUM ug/L	0.04	0.003	0.003	0.085[b]
CHROMIUM ug/L	0.47	0.22	0.37	
COBALT ug/L	0.03	0.04	0.04	1000[f]
COPPER ug/L	0.41	0.54	0.45	4[c]
IRON ug/L	10	3	18	300
LEAD ug/L	0.06	0.09	0.05	7[c]
LITHIUM ug/L	43	58	59	2500[g]
MANGANESE ug/L	12	12	14	200[g]
MOLYBDENUM ug/L	0.31	0.26	0.25	73[d]
NICKEL ug/L	0.03	0.002	0.14	150[c]
SELENIUM ug/L	0.25	0.27	0.13	1
SILVER ug/L	0.025	0.001	0.002	0.1
STRONTIUM ug/L	58	57	68	
THALLIUM ug/L	0.06	0.0004	0.002	0.8
THORIUM ug/L	0.008	0.005	0.007	
TIN ug/L	0.1	0.032	0.043	
TITANIUM ug/L	0.5	0.59	0.53	
URANIUM ug/L	1.0	1.1	1.2	100[e]
VANADIUM ug/L	0.33	0.34	0.32	100[f,g]
ZINC ug/L	5.7	3.0	4.6	30
FLUORIDE mg/L	-	0.27	0.26	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

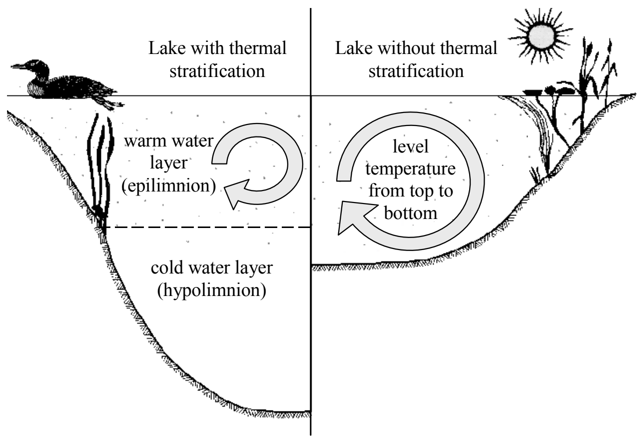

Figure 5: Difference in the circulation of the water column depending on thermal stratification.

Water temperature in a lake dictates the behavior of many chemical parameters responsible for water quality (Figure 5). 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 third layer, known as the metalimnion, provides an effective barrier between the epi- and hypolimnion. The metalimnion reflects a rapid transition in water temperature known as the **thermocline**. A thermocline typically occurs when water temperature changes by several degrees within one-meter of depth. The thermocline acts as an effective physico-chemical barrier to mixing between the hypolimnion and epilimnion, restricts downward movement of elements, such as oxygen, from the surface 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 state 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 terrestrial plants and plants and algae of tropical lakes, phosphorus is usually in shortest supply in temperate 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, reflect lower-nutrient trophic states than would otherwise result if macrophyte-based chlorophyll were 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 low. Secchi disk depth, however, is not only affected by algae, high concentrations of suspended sediments, particularly fine clays or glacial till common in plains or mountain reservoirs of Alberta, also impact water clarity. 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.

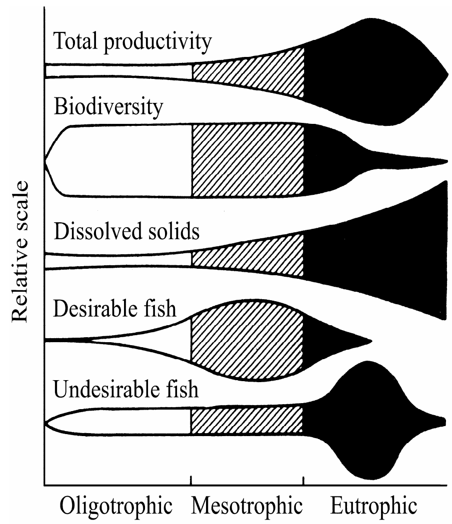

Figure 6: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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. 6.

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 and Kerekes (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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