THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2013 Clear Lake Report

COMPLETED WITH SUPPORT FROM:

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 those 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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If you would like your lake monitored with the LakeWatch Program – contact ALMS at 780-415-9785 or info@alms.ca

CLEAR LAKE:

Known as "Barne's Lake" until 1993, Clear Lake is located in the North Saskatchewan River drainage basin in east-central Alberta, near the Battle River valley. The lake sits at an elevation of 663 m above sea level and has a length of approximately 1.2 km and a width of 0.9 km. The maximum depth of this lake is ~18 m.

Figure 1 – Technician Elynne Murray and volunteer Mary Smith monitoring Clear Lake in 2013.

Clear Lake is located in the M.D. of Wainwright which has a population of ~4400. The M.D.'s main industries are agriculture, oil and natural gas production, and the Canadian Forces Base Wainwright. Clear Lake and its larger neighbour Arm Lake are a popular recreation area in the region. Clear Lake has roughly 135 cottages, of which 10 are permanent homes, a public beach, and a picnic area. Popular activities on the lake include swimming, boating, sailing, water skiing, and fishing.

WATER QUANTITY:

There are many factors influencing water quantity. Some of these factors include the size of the lakes drainage basin, precipitation, evaporation, water consumption, ground water influences, and the efficiency of the outlet channel structure at removing water from the lake. Requests for water quantity monitoring should go through Environment and Sustainable Resource Developments Monitoring and Science division.

Currently no long term water quantity data exists for Clear Lake.

WATER CLARITY AND SECCHI DEPTH:

Water clarity is influenced by suspended materials, both living and dead, as well as dissolved colored compounds in the water column. During the melting of snow and ice in spring, lake water can become turbid (cloudy) from silt transported into the lake. Lake water usually clears in late spring but then becomes more turbid with increased algal growth as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi disk depth.

As its name would suggest, Clear Lake typically has deep Secchi Disk depths. In 2013, Secchi Disk depth ranged from a minimum of 2.2 m on August 15th to 4.3 m on July 23rd (Table 1). It is typical for Secchi Disk depth to decrease throughout the summer as algae/cyanobacteria populations grow – however, chlorophyll-*a* levels are low in Clear Lake, thus total suspended solids may also affect water clarity at Clear Lake. Average Secchi Disk depth in 2013 measured 3.08 m – slightly lower than historical averages, though consistent with chlorophyll-*a* concentrations (Table 1).

WATER TEMPERATURE AND DISSOLVED OXYGEN:

Water temperature and dissolved oxygen profiles in the water column can provide information on water quality and fish habitat. The depth of the thermocline is important in determining the depth to which dissolved oxygen from the surface can be mixed. Please refer to the end of this report for descriptions of technical terms.

Clear Lake remained thermally stratified throughout the field season (Figure 2a). Surface water temperatures ranged from a minimum of 18.46 °C on June 27th to a maximum of 21.64 °C on August 15th. Thermal stratification began as early as 5.0 m on July 23rd, and consistently ended around 12.0 m. Temperatures at the sediment were consistently cold, measuring consistently around 5.5 °C. Warm surface waters and cold bottom waters are typical of deep lakes in Alberta. It is likely that this strong stratification breaks down in the fall, allowing for lake mixing, as data from 2006 shows a lack of stratification in late September.

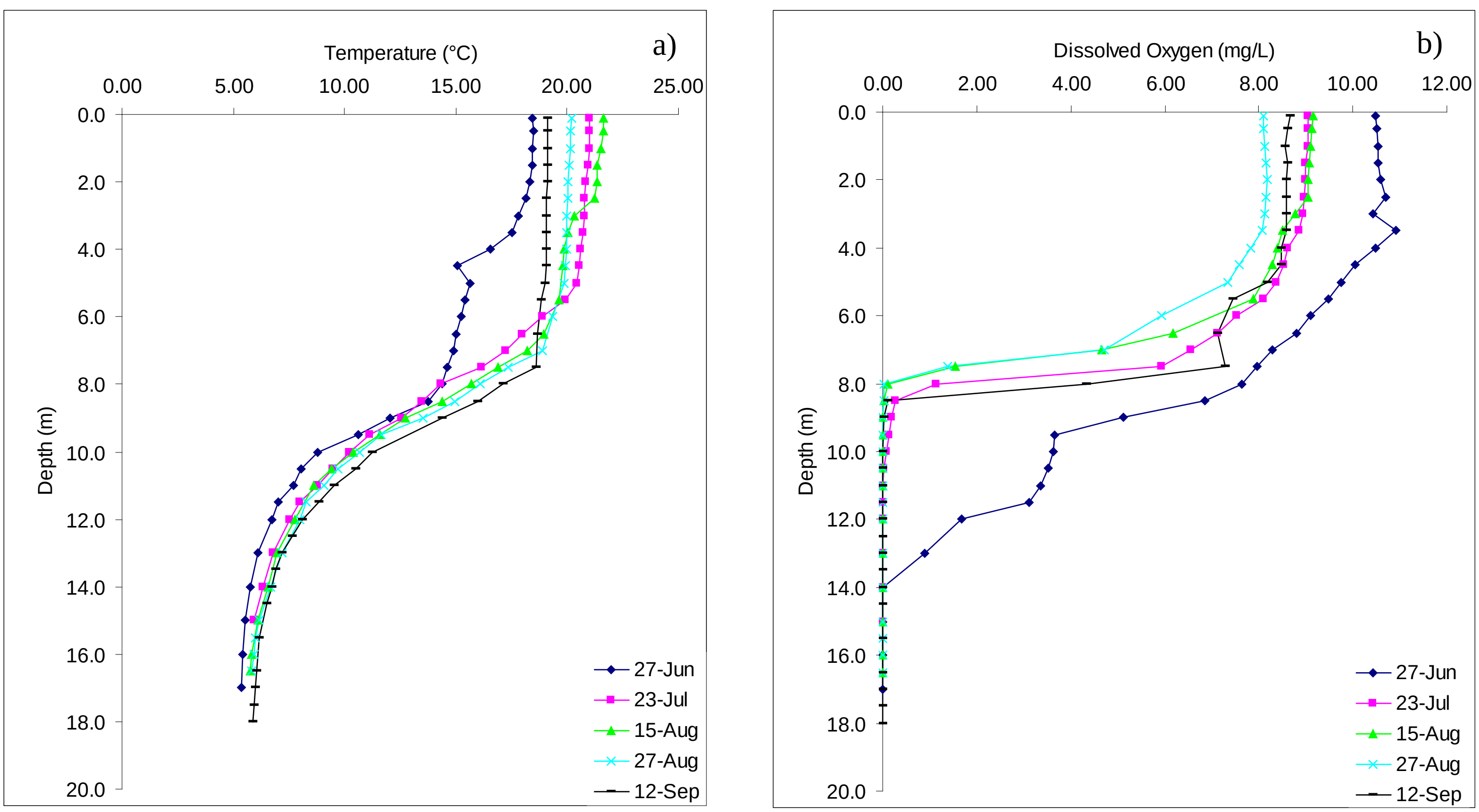

Figure 2 – a) Temperature (°C) and b) dissolved oxygen (mg/L) concentration measured five times over the course of the summer at Clear Lake.

Dissolved oxygen concentrations at the surface measured well above the Canadian Council for Ministers of the Environment Guidelines (CCME) for the Protection of Aquatic Life of 6.5 mg/L (Figure 2b). However, thermal stratification, which prevents the mixing of oxygen-rich surface waters with deeper waters, caused sharp declines in dissolved oxygen: dissolved oxygen concentrations reached anoxia as early as 8.0 m. Anoxia near lake sediments has the potential to increase the amount of phosphorus released from the sediments into overlying waters. This pattern of dissolved oxygen concentration is typical of deep, thermally stratified lakes.

WATER CHEMISTRY:

ALMS measures a suite of water chemistry parameters. Phosphorus, nitrogen, and chlorophyll-a are important because they are indicators of eutrophication, or excess nutrients, which can lead to harmful algal/cyanobacteria blooms. One direct measure of harmful cyanobacteria blooms are Microcystins, a common group of toxins produced by cyanobacteria. See Table 1 for a complete list of parameters.

Average Total Phosphorus (TP) measured 23.6 μg/L in 2013 (Table 1). An average value of 23.6 μg/L falls into the mesotrophic, or moderately productive classification – this value falls well within the natural variation observed from 2006-2007 and Clear Lake has fallen into this classification each year of monitoring Throughout the summer, TP concentration ranged from a minimum of 21 μg/L on August 15th to a maximum of 30 μg/L on September 12th (Figure 3). Patterns in TP concentration have not been obvious in the four years that ALMS has monitored Clear Lake.

Average chlorophyll-*a* concentration measured 3.43 μg/L in 2013 – this value falls into the oligotrophic, or nutrient poor, classification (Table 1). As the cut-off for this classification is 3.5 μg/L, Clear Lake has fluctuated between an oligotrophic and mesotrophic classification in the four years of monitoring. Throughout the summer, chlorophyll-*a* concentration ranged from a minimum of 2.82 μg/L on August 27th, to a maximum of 4.22 μg/L on June 27th (Figure 3).

Finally, total Kjeldahl nitrogen (TKN) measured an average of 888 μg/L in the summer of 2013 (Table 1). This value falls into the eutrophic, or nutrient rich, classification and is consistent with the variation previously measured at Clear Lake. Throughout the summer TKN ranged from a minimum of 864 μg/L on July 23rd to a maximum of 970 μg/L on August 27th (Figure 3).

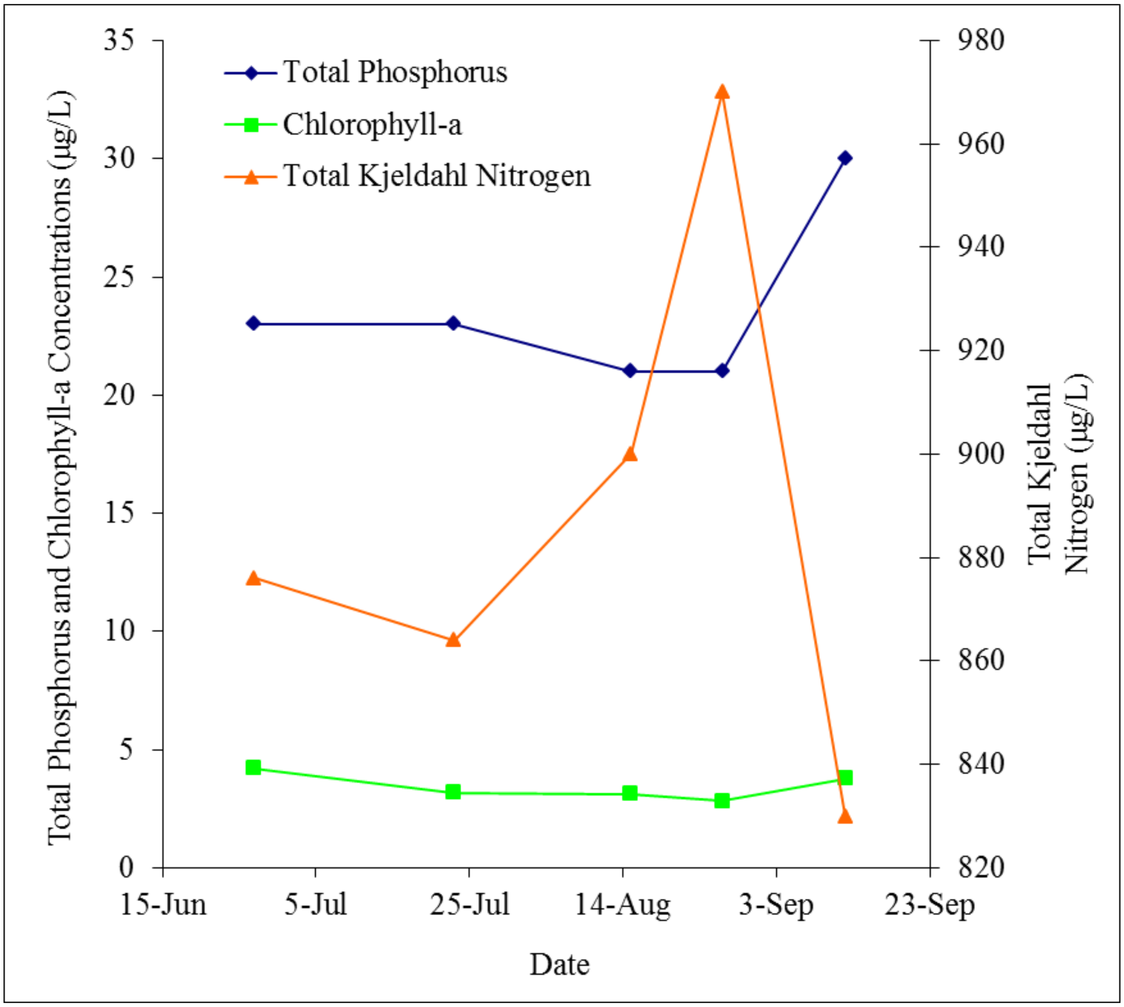

Figure 3 – Total phosphorus, chlorophyll-*a*, and total Kjeldahl nitrogen concentrations (µg/L) measured five times over the course of the summer at Clear Lake.

Average pH measured 8.76 in 2013 – this value is well above neutral. Clear Lake has high alkalinity (276.6 mg/L CaCO3) and bicarbonate (283.4 mg/L HCO_3) concentration which help to buffer against changes to pH (Table 1). Conductivity in Clear Lake is moderate (493.4 uS/cm) with magnesium (47.9 mg/L), calcium (21.4 mg/L) and sodium (20.8 mg/L) as dominant ions.

Microcystin concentrations were low throughout the summer at clear lake, never exceeding 1.0 µg/L. On average, microcystin concentration measured 0.045 µg/L, well below the recreational guidelines of 20 µg/L. Though a cyanobacteria bloom may not be producing large amounts of microcystins, caution should still be observed when recreating around blooms as there are many other toxins which may be produced by these bacteria.

Metals concentrations were monitored twice throughout the summer, and all concentrations fell within their respective guidelines (Table 2).

INVASIVE SPECIES:

Quagga and Zebra mussels are invasive species which, if introduced to our lakes, will have significant negative ecological, economical, and recreational impacts. ALMS collects water samples which are analyzed for mussel veligers (juveniles) and monitors substrates for adult mussels. In order to prevent the spread of invasive mussels, always clean, drain, and dry your boat between lakes. To report mussel sightings or mussel-fouled boats, call the confidential Alberta hotline at 1-855-336-BOAT.

In 2013, no zebra or quagga mussels were detected in Clear Lake.

Table 1 – Average Secchi disk depth and water chemistry values for Clear Lake. Previous years averages are provided for comparison.

Parameter	2006	2007	2008	2013
TP (µg/L)	24	22	27	23.6
TDP (µg/L)	9.4	10	13.8	9.7
Chlorophyll-*a* (µg/L)	5.4	1.8	2.6	3.43
Secchi depth (m)	3.2	5.5	5.7	3.08
TKN (µg/L)	940	870	880	888
NO_2 and NO_3 (µg/L)	2.5	8	2.5	3.8
NH_3 (µg/L)	29	37.3	36.8	13.8
DOC (mg/L)	9.8	10.9	9.6	13.07
Ca (mg/L)	18	19.6	20.5	21.4
Mg (mg/L)	43	43.5	43.7	47.9
Na (mg/L)	21	21.1	21	20.8
K (mg/L)	6.2	6.5	6.1	5.97
SO_4^{2-} (mg/L)	10.7	/	7.7	8
Cl^- (mg/L)	1.7	1.9	2	2.27
CO_3 (mg/L)	18	26.5	18	21.2
HCO_3 (mg/L)	292	300	294	283.4
pH	8.7	8.7	8.7	8.76
Conductivity (µS/cm)	479	470	479	493.4
Hardness (mg/L)	240	273	284	251
TDS (mg/L)	261	259	264	267.7
Microcystin (µg/L)	/	5.06	0.15	0.045
Total Alkalinity (mg/L $CaCO_3$)	268	274	271	267.6

Note: TP = total phosphorus, TDP = total dissolved phosphorus, Chl-*a* = chlorophyll-*a*, TKN = total Kjeldahl nitrogen. NO_{2+3} = nitrate+nitrite, NH_3 = ammonia, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulphate, Cl = chloride, CO_3 = carbonate, HCO_3 = bicarbonate. A forward slash (/) indicates an absence of data.

Table 2 - Concentrations of metals measured in Clear Lake on August 15th and September 29th 2013. Values shown for 2013 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 Recoverable)	**2013**	**Guidelines**
Aluminum µg/L	14.17	100[a]
Antimony µg/L	0.06475	6[e]
Arsenic µg/L	3.965	5
Barium µg/L	47.3	1000[e]
Beryllium µg/L	0.0015	100[d,f]
Bismuth µg/L	0.0063	/
Boron µg/L	97.5	5000[ef]
Cadmium µg/L	0.00455	0.085[b]
Chromium µg/L	0.2005	/
Cobalt µg/L	0.02655	1000[f]
Copper µg/L	2.685	4[c]
Iron µg/L	15.55	300
Lead µg/L	0.06125	7[c]
Lithium µg/L	55.75	2500[g]
Manganese µg/L	5.62	200[g]
Molybdenum µg/L	1.555	73[d]
Nickel µg/L	0.228	150[c]
Selenium µg/L	0.086	1
Silver µg/L	0.0174	0.1
Strontium µg/L	99.95	/
Thallium µg/L	0.000275	0.8
Thorium µg/L	0.008075	/
Tin µg/L	0.03045	/
Titanium µg/L	0.6485	/
Uranium µg/L	1.475	100[e]
Vanadium µg/L	0.508	100[f,g]
Zinc µg/L	0.428	30

Values represent means of total recoverable metal concentrations.
[a] Based on pH ≥ 6.5; calcium ion concentrations [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 > 180mg/L (as $CaCO_3$)
[d] CCME interim value.
[e] Based on Canadian Drinking Water Quality guideline values.
[f] Based on CCME Guidelines for Agricultural use (Livestock Watering).
[g] Based on CCME Guidelines for Agricultural Use (Irrigation).
A forward slash (/) indicates an absence of data or guidelines.

A BRIEF INTRODUCTION TO LIMNOLOGY

INDICATORS OF WATER QUALITY:

Water samples are collected in LakeWatch to determine the chemical characteristics that characterize general water quality. 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:

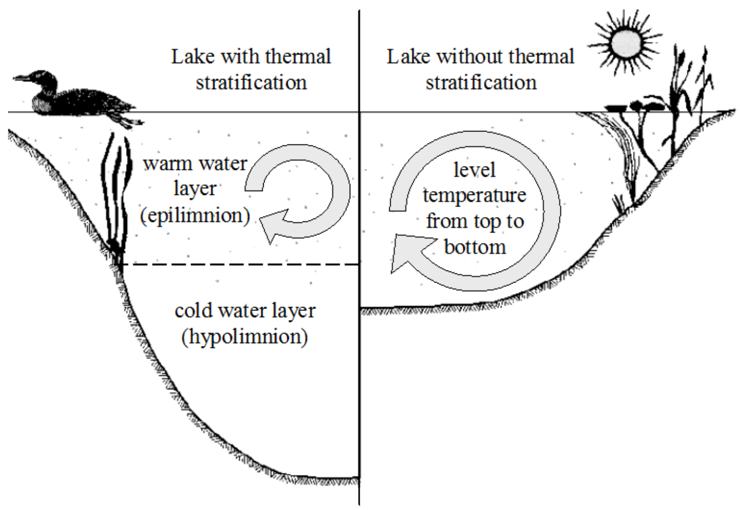

Figure A: Difference in the circulation of the water column depending on thermal stratification.

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 often 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 near 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 $mg \bullet L^{-1}$ and should not average less than 6.5 $mg \bullet L^{-1}$ over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 $mg \bullet L^{-1}$ 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 rather than suspended algae. In these lakes, chlorophyll *a* and nutrient values taken from water samples do not include productivity from large aquatic plants. The result, in lakes like Chestermere which are dominated by larger plants known as macrophytes, can be 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 TRANSPARENCY:

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. A measure of the transparency or clarity of the water is performed with a Secchi disk with an alternating black and white pattern. To measure the clarity of the water, the Secchi disk is lowered down into the water column and the depth where the disk disappears is recorded. The Secchi depth in lakes with a lot of algal growth will be small while the Secchi depth in lakes with little algal growth can be very deep. However, low Secchi depths are not caused by algal growth alone. 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 low Secchi depths despite low algal growth and nutrient concentrations.

The euphotic zone or the maximum depth that light can penetrate into the water column for actively growing plants is calculated as twice the Secchi depth. Murky waters, with shallow Secchi depths, can prevent aquatic plants from growing on the lake bottom. Conversely, aquatic plants can ensure lakes have clear water by reducing shoreline erosion and stabilizing lake bottom sediments. In Alberta, many lakes are shallow and bottom sediments contain 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 insects, depend on aquatic plants for food and shelter.

TROPHIC STATE:

Trophic state is classification of lakes into four categories of 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 (Table 2)**.

A majority of lakes in Alberta contain naturally high levels of chlorophyll *a* (8 to 25 µg/L) due to our deep fertile soils. These lakes are usually considered fertile and are termed eutrophic. 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.

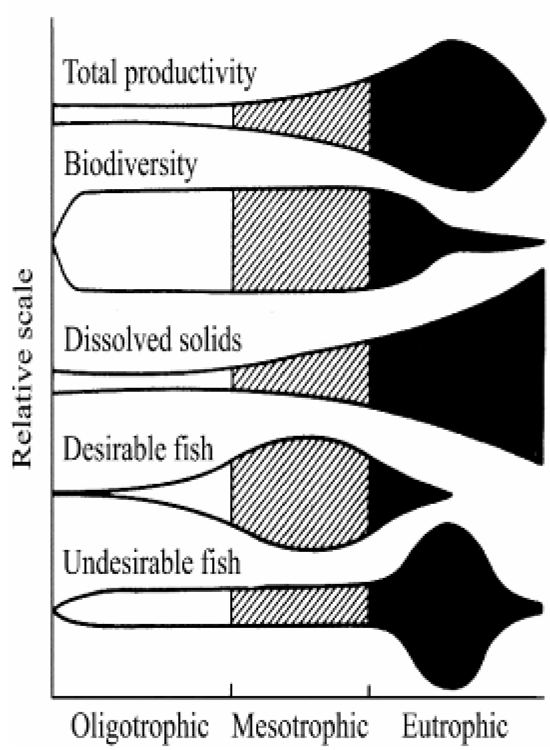

Figure B: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

Table A - Trophic status classification based on lake water characteristics.

Trophic state	Total Phosphorus (µg•L^{-1})	Total Nitrogen (µg•L^{-1})	Chlorophyll a (µg•L^{-1})	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