The Alberta Lake Management Society
Volunteer Lake Monitoring Program

2013 Lac Ste. Anne 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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LAC STE ANNE:

Figure 1 – Swimming at Alberta Beach.

Lac Ste. Anne is a large lake of cultural significance. It is a special lake for many people because of its long history and spiritual symbolism as well as its recreational attributes. The lake is 80 km west of the city of Edmonton and lies within the county of Lac Ste. Anne. The Alexis Indian Reserve of the Alexis Nakoda Nation is located on the northern shore of the lake, and Alberta Beach is located on the southeastern shore. The Summer Villages of Ross Haven and Yellowstone, along with the subdivision of Corsair Cove, and the unincorporated hamlet of Gunn, lie along the northern shore. The Summer Villages of Castle Island, Sunset Point, and Val Quentin lie to either side of Alberta Beach. The Summer Village of West Cove lies on the southern shore of the west basin.

The lake has a total area of 54.5 km^2, a maximum depth of 9 m, and an average depth of 4.8 m. It is separated into two basins by a narrows spanned by a bridge. Two islands are found in the centre of the western basin, Farming Island and Horse Island, while the small Castle Island and tiny Rock Island lie at the eastern tip of the lake.[1] Lac Ste. Anne is an eutrophic lake.

The recorded history of Lac Ste. Anne goes back to 1843 when Father Jean Baptiste Thibault established a mission on the south shore where Mission Creek enters the lake. Before Father Thibault renamed the lake for Ste. Anne, it was called by the Cree name *Manitou Sakhahigan*, which means "Lake of the Spirit".[2] Long before Europeans arrived, the Cree and other native people visited the lake because the water was thought to have healing properties. Now, every year, tens of thousands of people journey in July to experience the healing properties and the spiritual awareness of the lake. The site of the pilgrimage was designated a National Historic Site in 2004 as “an important place of spiritual, cultural and social rejuvenation, central aspects of summer gatherings of Aboriginal people.”[3]

Lac Ste. Anne has high sport fishing pressure and populations of walleye have collapsed. Currently a Special Fish Harvest License must be obtained to catch walleye. [4] Perch, lake

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[1] University of Alberta. 2005. Atlas of Alberta Lakes. University of Alberta Press. Available at: http://sunsite.ualberta.ca/Projects/Alberta-Lakes/

[2] Holmgren, E.J. and P.M. Holmgren. 1976. Over 2000 place names of Alberta. 3rd ed. West. Producer Prairie Books, Saskatoon.

[3] Parks Canada. 2005. News Release: Minister Anderson announces new historic designations in Canada. Available at: http://www.pc.gc.ca/APPS/CP-NR/release_e.asp?id=805&andor1=nr

[4] Government of Alberta. 2013. Alberta Guide to Sportfishing Regulations. Available at: http://albertaregulations.ca/fishingregs/pp2.html

whitefish, and burbot, are also found in the lake. A restricted commercial fishery for whitefish, perch, pike and walleye operates each winter.[5] Other popular recreational activities include sightseeing, swimming, power boating, sailing, water skiing and wind surfing in summer, and snowmobiling and cross-country skiing in winter.

The watershed has an area of 619 km^2, 11 times greater than the lake, and includes both Isle and Birch Lakes.[1] It is formed along the Sturgeon River through which it drains into the North Saskatchewan River. Land-use in the watershed is dominated by agriculture and cottage development. Remaining forested areas are representative of the dry mixedwood natural subregion of the boreal forest natural region of Alberta.

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.

Water levels at Lac St. Anne have been measured by both Environment and Sustainable Resource Development and Environment Canada. Water levels were available from Environment Canada until 2011 - while there are large year to year fluctuations, average water levels in 2011 (722.5 m asl) are very similar to those measured in 1933 (722.6 m asl) (Figure 2). Due to the gradual slope of the lake, small losses in volume can result in large losses in lake area.

[5] Alberta Environment and Sustainable Resource Development. 2013. Guide to Commercial Fishery Seasons 2013-2014. Available at: http://srd.alberta.ca/FishWildlife/FisheriesManagement/documents/CommercialFishingSeasonsGuide-Sep10-2013.pdf

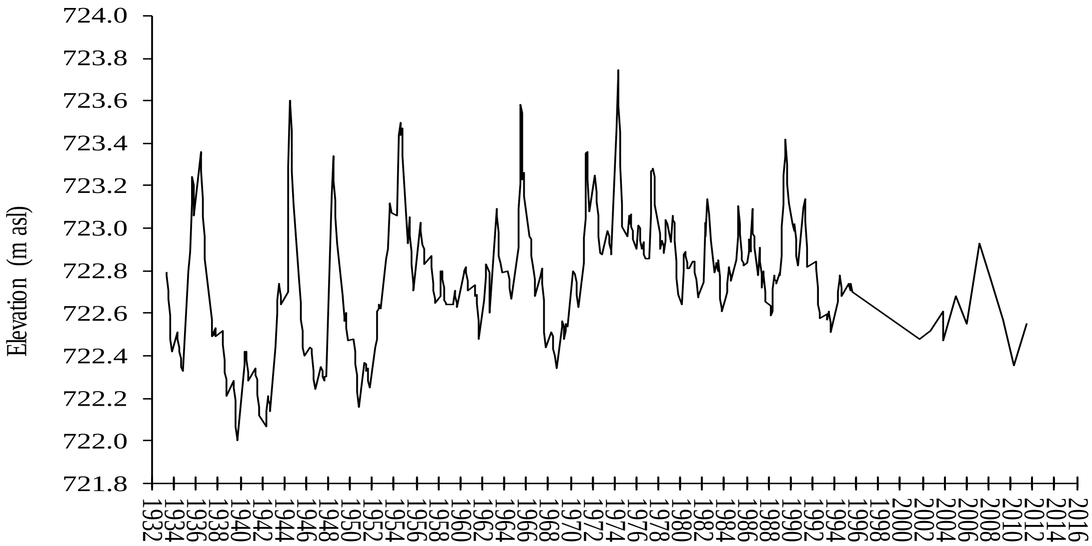

Figure 2 – Water levels in Lac Ste. Anne from 1932-2011. Data retrieved from Environment and Sustainable Resource Development.

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.

Average Secchi disk depth measured 3.09 m in 2013 (Table 1). This value falls into the mesotrophic, or moderately productive, classification. Throughout the summer, Secchi disk depth ranged between a minimum of 2.40 m on September 25th to a maximum of 4.35 m on June 24th. The 2013 average is slightly higher than historical averages measured in 1984, 2002, and 2012 (Table 1). In Alberta, cyanobacteria/blue-green algae and suspended sediments are the two primary factors reducing lake water clarity.

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.

Surface water temperatures remained relatively low throughout the summer at Lac St. Anne (Figure 3a). A minimum surface water temperature of 15.48 °C was measured on September 25th, and a maximum surface water temperature of 20.09 °C was observed on August 9th. No thermal stratification was observed at Lac St. Anne in 2013, suggesting the wind was able to mix the water column throughout the summer. This may indicate the wind is able to suspend bottom sediments, reducing water clarity. Moreover, lack of thermal stratification has important implications for dissolved oxygen concentrations.

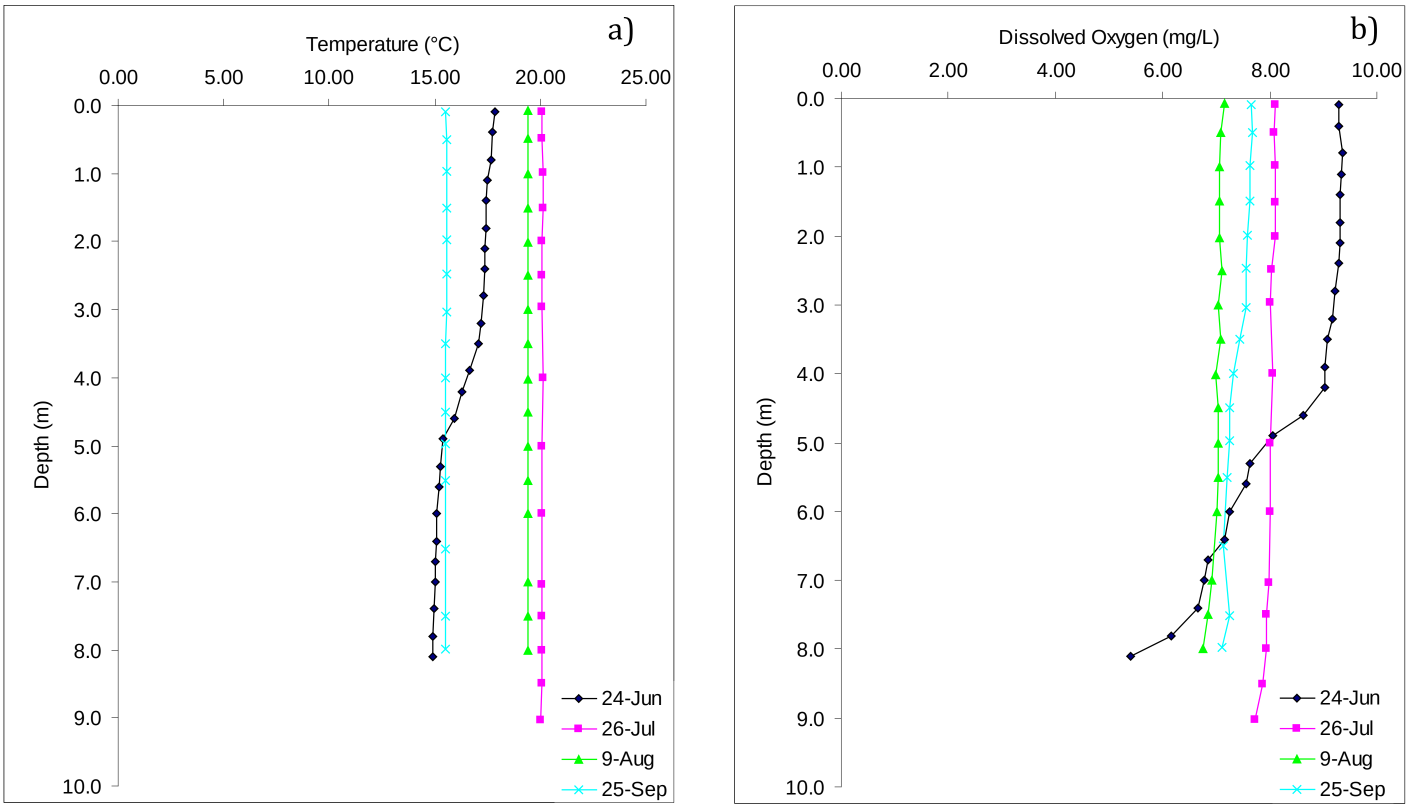

Figure 3 – a) Temperature (°C) profiles and b) dissolved oxygen profiles measured five times throughout the summer of 2013.

The water column at Lac St. Anne remained well oxygenated for the entire summer (Figure 3b). Because of a lack of thermal stratification, surface oxygen could be mixed with bottom waters which may otherwise become anoxic throughout the summer. Dissolved oxygen remained well above the Canadian Council for Ministers of the Environment Guidelines of 6.5 mg/L for the Protection of Aquatic Life. Surface concentrations ranged from a minimum of 7.15 mg/L on August 9th to a maximum of 9.30 mg/L on June 24th.

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 78.5 µg/L in 2013, which falls into the eutrophic, or nutrient rich, classification (Table 1). This value is slightly reduced compared to the hypereutrophic concentration of 110.7 µg/L measured in 2012. TP concentration fluctuated greatly throughout the summer, measuring a minimum of 48 µg/L on June 24th and a maximum of 96 µg/L on September 25th.

As with TP, average chlorophyll-*a* concentration was reduced compared to 2012, (though still fell into the hypereutrophic, or extremely productive, classification) measuring an average of 34.03 µg/L in 2013 (Table 1). Throughout the summer, chlorophyll-*a* concentration ranged from a minimum of 5.42 µg/L on June 24th to a maximum of 63.1 µg/L on July 26th. Due to high concentrations of blue-green algae, Alberta Health Services issued a Blue-Green Algae Advisory for Lac St. Anne in mid-August – this advisory was later lifted on October 3rd.

Finally, Total Kjeldahl Nitrogen (TKN) measured an average of 1490 µg/L in 2013 (Table 1). A value of 1490 µg/L falls into the hypereutrophic classification – however, TKN likely plays less of a role in promoting blue-green algae populations compared to TP.

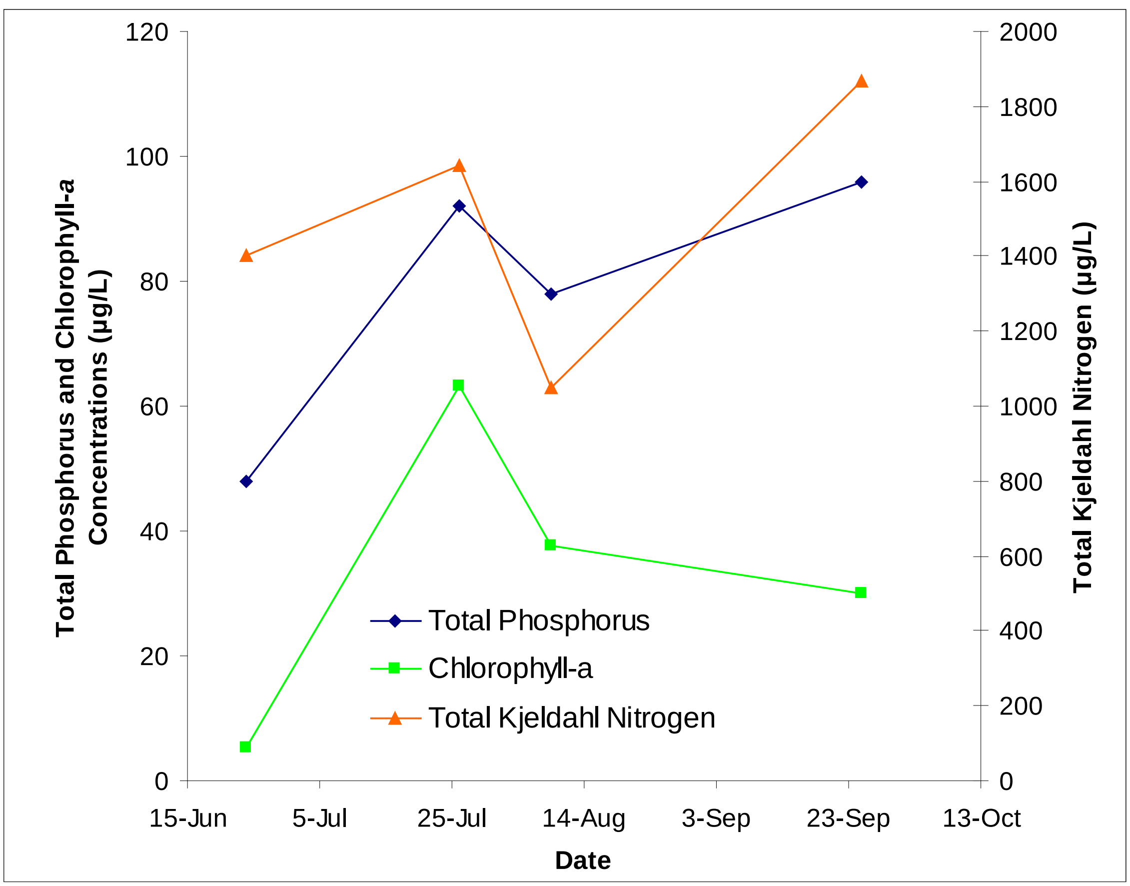

Figure 3 – Total phosphorus (µg/L), chlorophyll-*a* (µg/L), and total Kjeldahl nitrogen (mg/L) concentrations measured five times over the course of the summer of 2013.

Average pH measured 8.44 in 2013 – this value is well above neutral (Table 1). Lac St. Anne has high alkalinity (170 mg/L CaCO3) and bicarbonate (197.8 mg/L HCO_3) concentration which help to buffer against changes to pH (Table 1). Conductivity in Lac St. Anne is low (367 uS/cm) with sodium (29.17 mg/L) and calcium (27.07 mg/L) as dominant ions. Microcystin was present in Lac Ste. Anne, though in concentrations well below the recreational guidelines of 20 µg/L. In 2013, average microcystin concentration measured 0.27 µg/L and reached a maximum concentration of 0.58 µg/L on September 25th.

Metals were sampled for twice during the summer of 2013 and all values 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 Lac St. Anne.

Table 1 – Average Secchi disk depth and water chemistry values for Lac Ste. Anne. Previous years averages are provided for comparison.

Parameter	**1984**	**2002**	**2012**	**2013**
TP (μg/L)	48	44	110.7	78.5
TDP (μg/L)	18	8	20.3	26
Chlorophyll-*a* (μg/L)	18	19	62.2	34.03
Secchi depth (m)	2.2	2	1.75	3.09
TKN (μg/L)	919	1153	1901	1490
NO_2 and NO_3 (μg/L)	1.5	2.2	16.2	3.1
NH_3 (μg/L)	24	12	48.3	151.8
DOC (mg/L)			/	17.1
Ca (mg/L)	30	30	21.95	27.1
Mg (mg/L)	9	11	12.03	11.8
Na (mg/L)	16	21	29.8	29.2
K (mg/L)	7	9.8	10.5	14.8
SO_4^{2-} (mg/L)	10	7.4	5.4	5.2
Cl^- (mg/L)	2	5.5	7.81	7.53
CO_3 (mg/L)	3	8.4	10.98	4.89
HCO_3 (mg/L)	176	169	177.8	197.8
pH	8.5	8.7	8.73	8.44
Conductivity (μS/cm)	/	/	338	367
Hardness (mg/L)	/	/	104.3	116.3
TDS (mg/L)	/	/	186.3	198.3
Microcystin (μg/L)	/	/	1.22	
Total Alkalinity (mg/L $CaCO_3$)	152	152	164	170.5

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 Lac St. Anne on August 9th and September 25th, 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	9.19	100[a]
Antimony µg/L	0.03975	6[e]
Arsenic µg/L	1.345	5
Barium µg/L	69.4	1000[e]
Beryllium µg/L	0.0015	100[d,f]
Bismuth µg/L	0.0005	/
Boron µg/L	61.2	5000[ef]
Cadmium µg/L	0.0362	0.085[b]
Chromium µg/L	0.14985	/
Cobalt µg/L	0.01345	1000[f]
Copper µg/L	0.237	4[c]
Iron µg/L	13.45	300
Lead µg/L	0.01925	7[c]
Lithium µg/L	16.9	2500[g]
Manganese µg/L	66.05	200[g]
Molybdenum µg/L	0.3355	73[d]
Nickel µg/L	0.05225	150[c]
Selenium µg/L	0.076	1
Silver µg/L	0.02075	0.1
Strontium µg/L	183	/
Thallium µg/L	0.00125	0.8
Thorium µg/L	0.00015	/
Tin µg/L	0.0226	/
Titanium µg/L	1.645	/
Uranium µg/L	0.1525	100[e]
Vanadium µg/L	0.196	100[f,g]
Zinc µg/L	0.415	30

Values represent means of total recoverable metal concentrations.
[a] Based on pH ≥ 6.5; calcium ion concentrations $[Ca^{+2}] \geq 4$ 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 > 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:

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

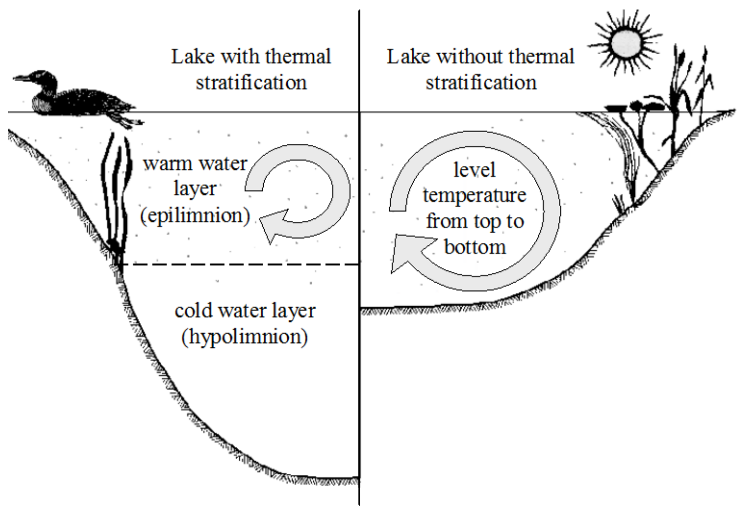

Figure A: Difference in the circulation of the water column depending on thermal stratification.

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.

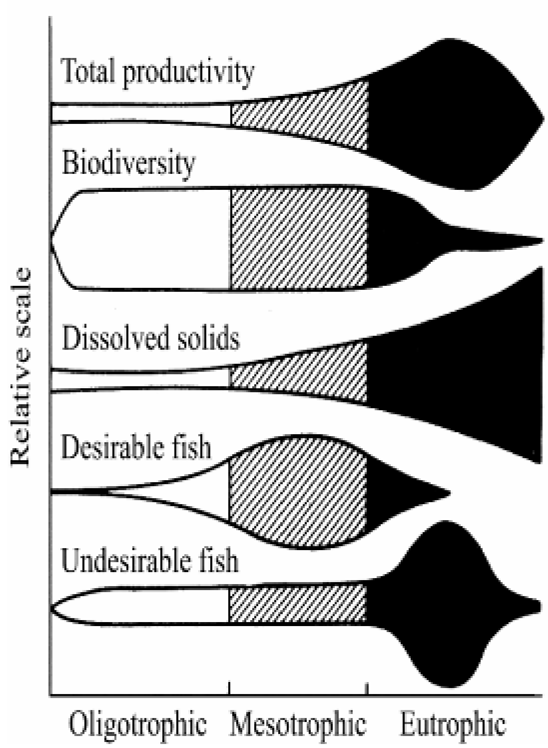

Figure B: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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

Trophic state	Total Phosphorus ($\mu g \bullet L^{-1}$)	Total Nitrogen ($\mu g \bullet L^{-1}$)	Chlorophyll a ($\mu g \bullet L^{-1}$)	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