THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2012 Lac St. Cyr Report

COMPLETED WITH SUPPORT FROM:

Beaver River Watershed Alliance

Alberta Government

LICA Lakeland Industry & Community Association

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.

If you are interested in becoming a volunteer with the LakeWatch program or having your lake monitored, please e-mail us at info@alms.ca or call us at 780-415-9785.

Acknowledgements

The LakeWatch program is made possible through the dedication of its volunteers. We would like to thank Alain Richard, Terry LaBoucanne, and Dick Holten for their assistance with sampling Lac St. Cyr in 2012. We would also like to thank Randi Newton and Erin Rodger who were summer technicians with ALMS in 2012. Program Coordinator Bradley Peter was instrumental in planning and organizing the field program. Technologists Trina Ball and Brian Jackson were involved in the training aspects of the program. Lisa Reinbolt was responsible for data management. This report was prepared by Bradley Peter and Arin Dyer. Alberta Environment and the Beaver River Watershed Alliance (BRWA) were major sponsors of the program.

LAC ST. CYR:

Lac St. Cyr is a small (2.46 km^2) lake located 12 km Southeast of the town of St. Paul.[1] The lake has an irregular shape, and is divided roughly into three basins (Figure 1). The north basin is deep, measuring ~21 m in depth, while the East and West basins are shallower, measuring 6 and 8 m, respectively. In 2013, ALMS treated the East and West basins as a single basin, which will be referred to as the South basin; data was collected separately from the North and South basins.

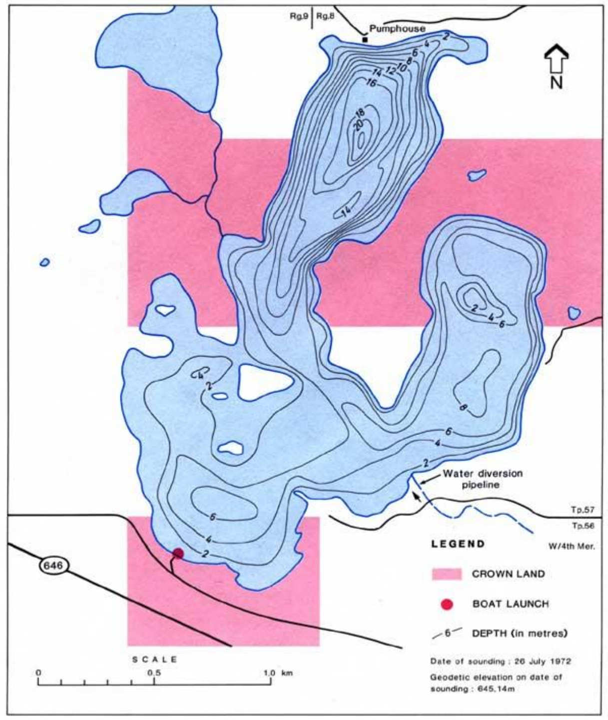

Figure 1 – Bathymetric map of Lac St. Cyr. Retrieved from the Atlas of Alberta Lakes[1].

Lac St. Cyr has been used as a water supply by the town of St. Paul since 1951. With no primary inflows and a drainage basin area 11 times the size of the lake, declines in water levels were observed after withdrawals began.[1] In 1978, concerns over these declines prompted Alberta Environment to begin diverting water from the North Saskatchewan River into Lac St. Cyr. Because river water has a different chemistry than lake water, a study was initiated to evaluate the effects of a diversion on Lac St. Cyr's water chemistry.[2] This study lasted from 1976-1986, and showed significant increases in the concentration of major ions in the lake. The primary concern, however, was related to eutrophication, as the diversion increased phosphorus loadings by 25% and nitrogen loadings by 28%. However, no significant increase in chlorophyll-*a* concentration, an indirect measure of algal/cyanobacterial biomass, was observed.

In 2013, ALMS with the direction of Environment and Sustainable Resource Development (ESRD) sampled the lake five times. This report simply highlights the basic results of those sampling efforts and does not aim to compare the results to historical values. A more in-depth report evaluating trends in the lake's chemistry will be available from ESRD.

WATER QUANTITY:

[1] Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes, University of Alberta Press. Retrieved from http://sunsite.ualberta.ca/projects/alberta-lakes/

[2] Mitchell, P. 1987. Alberta Environment. Lac St. Cyr: The Impact of River Diversion on Water Quality. Retrieved from http://www.environment.gov.ab.ca/info/library/8053.pdf

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.

In 1959, Lac St. Cyr measured a maximum water quantity of 647.06 m asl, though declined approximately three meters to 644.21 m asl by 1978 (Figure 2). To counter this decline, diversions from the North Saskatchewan River began in 1978, and water was added for three months each fall.[2] Water levels have remained fairly stable since diversions began, and in 2012, average water quantity measured 645.322 m asl.

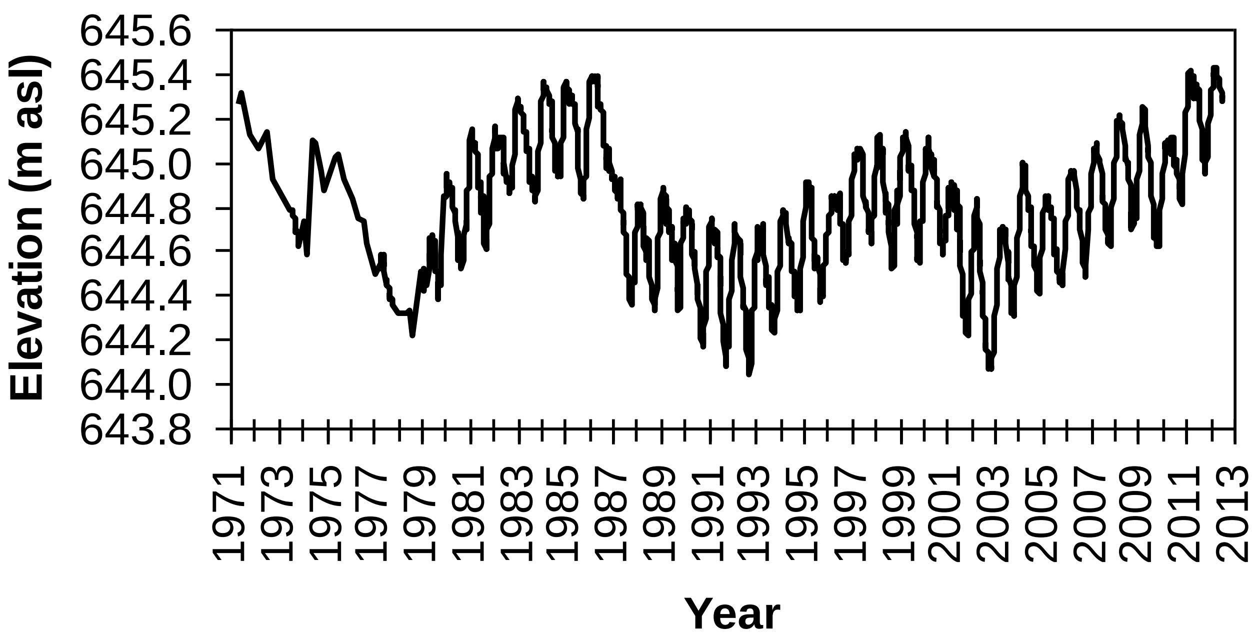

Figure 2 – Water levels in meters above sea level (m asl) measured from 1971-2012. Data retrieved from Alberta Environment.

WATER CLARITY & 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.

North: On each sampling trip, measurements were taken with a light meter to determine the euphotic depth, or the depth to which only 1% of surface light remains. Throughout the summer, this depth ranged from a maximum of 12.0 m on June 23rd to a minimum of

8.5 m on September 13th. Overall, the euphotic depth did not change dramatically throughout the summer, suggesting that algae/cyanobacteria blooms did not play a large role in reducing the water clarity of Lac St. Cyr's North basin. Secchi disk depth measurements corresponded closely to the measurements obtained with the light meter (Table 1). Similarly, concentrations of total suspended solids were low (0.92 mg/L), suggesting suspended sediments were not a factor influencing water clarity, and concentrations of dissolved organic carbon was low, suggesting colouration of the water was also not a factor influencing water clarity.

South: As with the North basin, measurements of the euphotic depth were recorded with the light meter. In the South basin, the euphotic depth was greater than the depth of the basin (6.0 m) on each sampling trip. Secchi depth measurements taken later in the summer suggest a euphotic depth range between 7.00 m and 10.30 m (Table 1). As with the North basin, concentrations of total suspended solids (0.92 mg/L) and dissolved organic carbon (6.28 mg/L) were low, suggesting suspended sediments and water colouration did not have significant effects on water clarity (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.

North: Surface water temperatures changed greatly throughout the summer in the North basin of Lac St. Cyr (Figure 3a). On August 10th, surface water temperature was at a maximum, measuring 22.62 °C, where as on September 13th, surface water temperatures had declined to a minimum of 15.05 °C. Because of the depth of the North basin, thermal stratification was observed on each sampling trip. Thermal stratification was strong, beginning as early as 4.5 m on July 23rd. By September 13th thermal stratification began to weaken, beginning at 8.00 m. Historical data suggests that the lake turns-over only once each year (monomictic) in the fall, as opposed to many lakes which mix both in the spring and fall (dimictic).[2] Thermal stratification acts as a barrier to mixing, resulting in decreased transfer of nutrients and oxygen between shallow and deep portions of the water column. On each sampling trip, water temperatures proceeded to ~5.00 °C at the lakebed, at this temperature water is nearing its maximum density.

South: Surface water temperatures in the South basin ranged from a maximum of 22.38 °C on August 10th to a minimum of 14.21 °C on September 13th (Figure 3b). Compared to the North basin, temperature in the South basin behaved very differently wind energy is better able to mix the shallow water column. Weak thermal stratification was observed on June 23rd, August 10th, and August 24th. On both July 23rd and September 13th, temperatures remained relatively uniform as the water column was well mixed. Near the lakebed, a minimum of temperature of 13.75 °C was observed on September 13th.

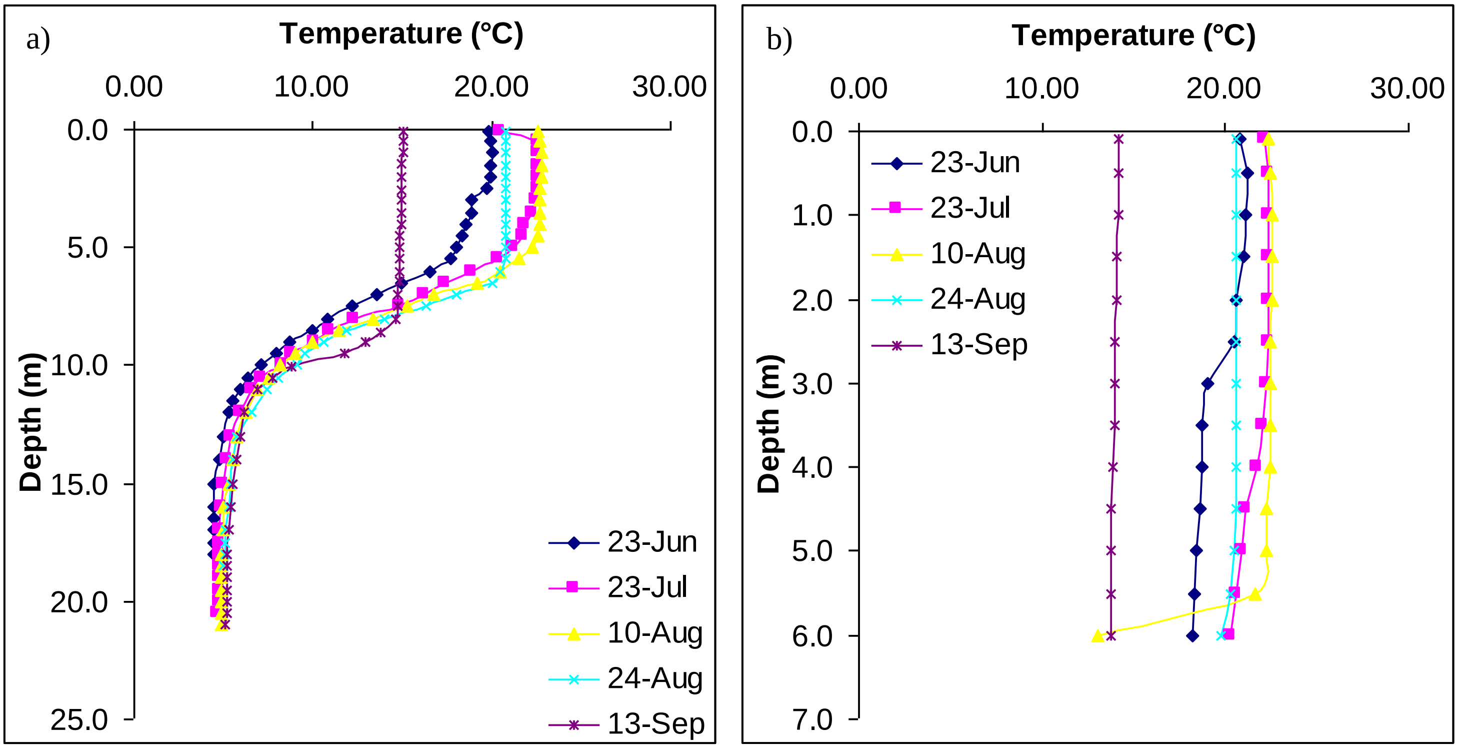

Figure 3 – Temperature profiles (°C) measured five times throughout the summer for the a) North, and b) South basins of Lac St. Cyr.

North: On each sampling trip, dissolved oxygen concentrations measured well above the Canadian Council for Ministers of the Environment (CCME) guidelines of 6.5 mg/L for the Protection of Aquatic Life (PAL: Figure 4a). Below the thermocline, however, dissolved oxygen concentrations decreased dramatically, quickly proceeding towards anoxia. This pattern of decline in dissolved oxygen concentration below the thermocline is typical of small, deep lakes. Anoxic conditions persisted well into September. The oxygen-consuming process of decomposition which occurs on the lakebed likely contributes to the absence of oxygen below the thermocline.

South: The South basin of Lac St. Cyr remained well oxygenated for much of the summer (Figure 4b). Frequent mixing of the water column in the South basin helps to replenish dissolved oxygen concentrations in deeper waters. However, decreases in oxygen were observed near the sediment, reaching as low as 1.77 mg/L on August 10^{th} when weak thermal stratification was present. On both June 23^{rd} and September 13^{th}, the water column remained extremely well oxygenated, measuring more than 8.00 mg/L at the lakebed.

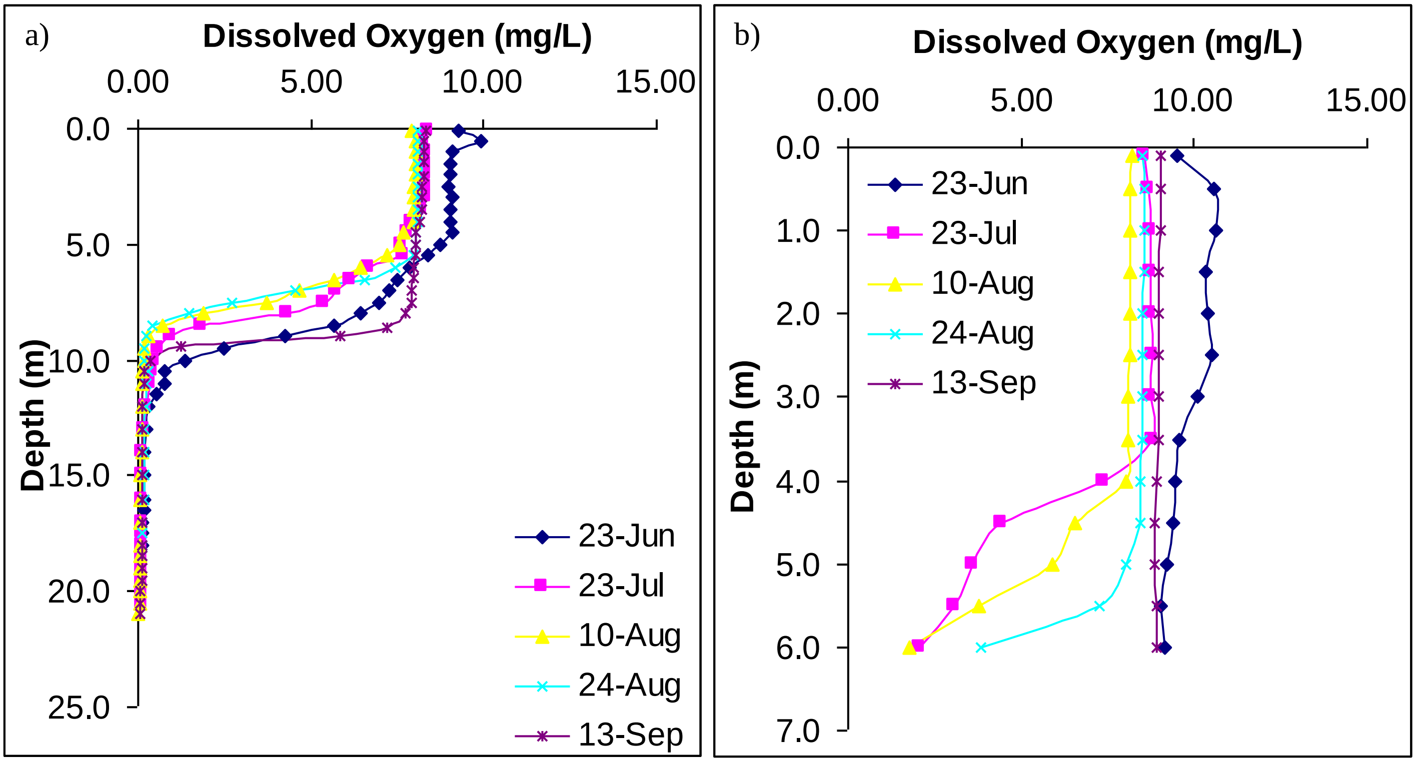

Figure 4 – Dissolved oxygen profiles (mg/L) measured five times throughout the summer for the a) North and b) South basins of Lac St. Cyr.

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.

North: Total phosphorus (TP) concentration measured an average of 23.4 μg/L in 2012 (Table 1). This value falls into the mesotrophic, or moderately productive, classification. Throughout the summer, TP ranged between a minimum of 13 μg/L on July 23rd to a maximum of 47 μg/L on August 24th (Figure 5).

Chlorophyll-*a* concentration measured an average of 2.83 μg/L in 2012 (Table 1). Unlike TP, this value falls into the oligotrophic, or low productivity, classification. Throughout the summer, chlorophyll-*a* concentration changed very little, ranging between a minimum of 1.86 μg/L on June 23rd, to a maximum of 3.70 μg/L on September 13th (Figure 5)

Finally, Total Kjeldahl Nitrogen (TKN) measured an average of 728 μg/L in 2012 (Table 1). This value falls into the eutrophic, or nutrient rich, classification (Figure 5).

Fortunately, TP is likely the nutrient limiting the amount of algae/cyanobacteria growth in the lake.

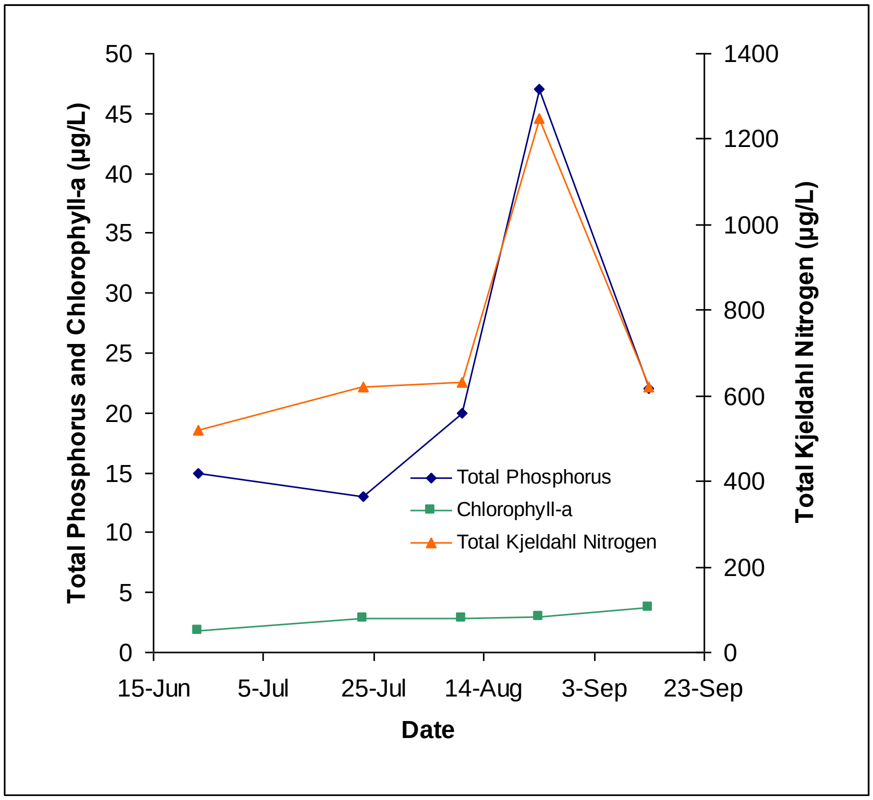

Figure 5 – Concentrations of total phosphorus, chlorophyll-a, and total Kjeldahl nitrogen (µg/L) measured five times in 2012 in the South basin of Lac St. Cyr.

pH in the North basin measured an average of 8.068 (Table 1). Moderately high alkalinity (124.8 mg/L $CaCO_3$) and bicarbonate (152 mg/L HCO_3) concentration likely help to buffer the lake against changes to pH. Conductivity in the North basin was relatively low, measuring an average of 325.4 uS/cm – dominant ions contributing to this conductivity include bicarbonate, calcium (29.74 mg/L), and magnesium (16.46 mg/L). Microcystin, a toxin produced by cyanobacteria, measured an average of 0.068 µg/L – this value falls well below the recommend recreational 20 µg/L guidelines. Similarly, all metals sampled for fell within their recommended guidelines (Table 2).

South: Because there is not great separation between the two basins of Lac St. Cyr, water chemistry parameters were very similar. TP measured an average of 19.4 µg/L, falling into the mesotrophic classification, as with the North basin (Table 1). TP concentration ranged from a minimum of 9 µg/L on June 23rd to a maximum of 31 µg/L on September 13th (Figure 6).

Chlorophyll-*a* concentration measured an average of 2.92 µg/L in 2012 (Table 1). Similar to the North basin, this value falls into the oligotrophic classification. Throughout the summer, chlorophyll-*a* concentration ranged between a minimum of 1.99 µg/Lon June 23rd to a maximum of 3.50 µg/L on August 24th (Figure 6).

Finally, TKN in the South basin measured an average of 624 µg/L in 2012 (Table 1). As with the North basin, this value falls into the eutrophic classification.

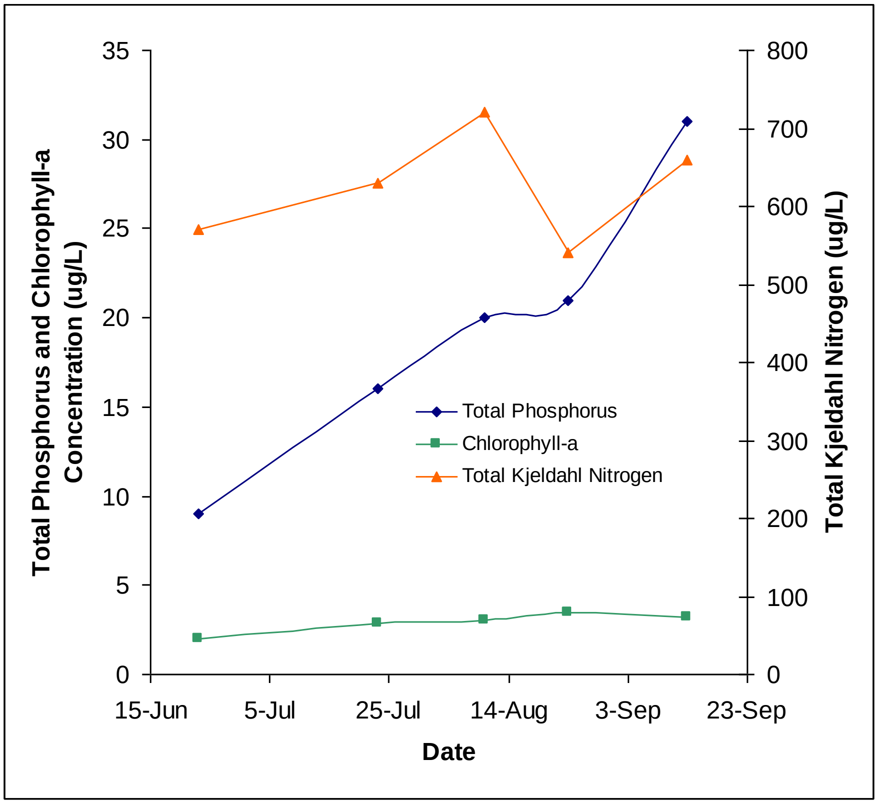

Figure 6 – Concentrations of total phosphorus, chlorophyll-a, and total Kjeldahl nitrogen (µg/L) measured five times in 2012 in the South basin of Lac St. Cyr.

Average pH in the South basin measured 8.004 (Table 1). As with the North basin, moderately high alkalinity (121.8 mg/L $CaCO_3$) and bicarbonate (148.4 mg/L HCO_3) concentration likely help to buffer the lake against changes to pH. Conductivity in the South basin was relatively low, measuring 320 uS/cm – dominant ions contributing to this conductivity include bicarbonate, calcium (29.2 mg/L), and magnesium (16.44 µg/L). Microcystin, a toxin produced by cyanobacteria, measured an average of 0.044 µg/L – this value falls well below the recommended recreational guidelines of 20 µg/L. Similarly, all metals sampled for fell within their recommended guidelines (Table 2).

Table 1 – Average Secchi disk depth and water chemistry values for the North and South basins of Lac St. Cyr. Previous years averages are provided for comparison.

Parameter	2012	
	North	South
TP (μg/L)	23.40	19.4
TDP (μg/L)	14.80	11.4
Chlorophyll-*a* (μg/L)	2.83	2.918
Secchi depth (m)	3.82	3.97
TKN (μg/L)	728	624
NO_2 and NO_3 (μg/L)	3.9	5.3
NH_3 (μg/L)	15.2	15.2
DOC (mg/L)	6.08	6.28
Ca (mg/L)	29.74	29.2
Mg (mg/L)	16.46	16.44
Na (mg/L)	8.34	7.92
K (mg/L)	3.6	3.58
SO_4^{2-} (mg/L)	40	39.4
Cl^- (mg/L)	5.9	5.92
CO_3 (mg/L)	0.5	148.4
HCO_3 (mg/L)	152	0.5
pH	8.068	8.004
Conductivity (μS/cm)	325.4	320
Hardness (mg/L)	142.2	140.6
TDS (mg/L)	178.8	175.4
TSS	0.92	0.92
Microcystin (μg/L)	0.068	0.044
Total Alkalinity (mg/L $CaCO_3$)	124.8	121.8

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. Cyr on August 10th and September 13th 2012. Values shown for 2012 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.

	2012	
Metals (Total Recoverable)	**North**	**South**
Aluminum µg/L	15.185	13.595
Antimony µg/L	0.04625	0.04785
Arsenic µg/L	0.719	0.728
Barium µg/L	56.55	54.75
Beryllium µg/L	0.0078	0.0054
Bismuth µg/L	0.0005	0.0005
Boron µg/L	30.2	32.35
Cadmium µg/L	0.0036	0.00325
Chromium µg/L	0.10615	28.8
Cobalt µg/L	0.0109	0.10585
Copper µg/L	0.4165	0.00905
Iron µg/L	9.55	0.4035
Lead µg/L	0.0319	0.03195
Lithium µg/L	5.935	6.405
Manganese µg/L	18.6	21.05
Molybdenum µg/L	0.388	0.3855
Nickel µg/L	0.0025	0.0025
Selenium µg/L	0.115	0.136
Silver µg/L	0.000525	0.0035
Strontium µg/L	269	267.5
Thallium µg/L	0.015	0.0017
Thorium µg/L	0.00015	0.00015
Tin µg/L	0.356	0.03095
Titanium µg/L	0.00135	0.3075
Uranium µg/L	0.1855	0.1785
Vanadium µg/L	0.195	0.1845
Zinc µg/L	0.4375	0.537

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:

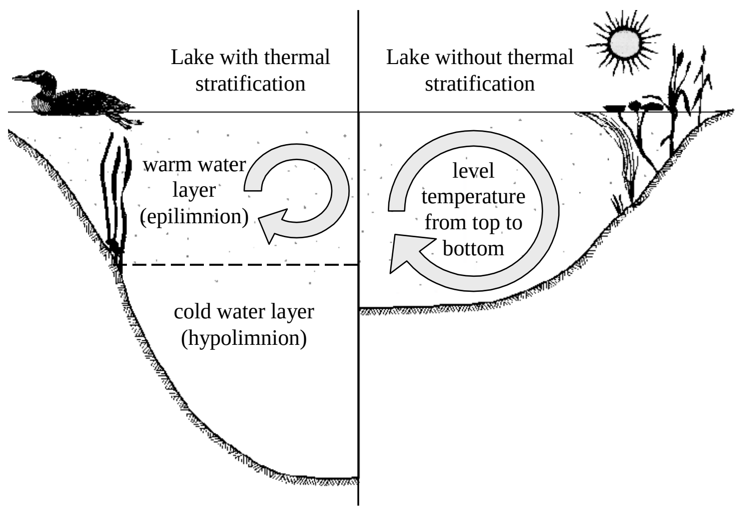

Figure A: Difference in the circulation of the water column depending on thermal stratification.

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.

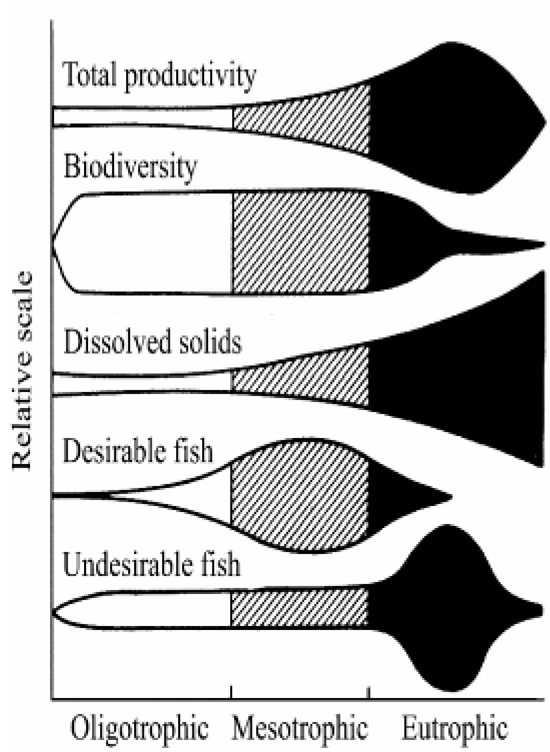

Figure B: Suggested changes in various lake characteristics with eutrophication. From “Ecological Effects of Wastewater”, 1980.

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

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