*THE ALBERTA LAKE MANAGEMENT SOCIETY*
*VOLUNTEER LAKE MONITORING PROGRAM*

# 2013 Wolf Lake 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.
Historical data has been re-queried and summarized for the 2012 report.

## Acknowledgements

The Lakewatch program is made possible through the dedication of volunteers. We would like to thank Monty Moore for his time and effort in collecting field data during 2013. Thank you to Nicole Meyers, who was the LakeWatch technician responsible for sampling Wolf Lake and to Bradley Peter, who coordinated the LakeWatch program. Arin MacFarlane Dyer and Bradley Peter prepared the 2013 report.

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.

# WOLF LAKE:

Wolf Lake is a beautiful lake located just south of the Primrose Lake Air Weapons Range, approximately 70 km north of the town of Bonnyville and 310 km northeast of the city of Edmonton. It is within the boundaries of the municipal district of Bonnyville. Wolf Lake Provincial Recreation Area, with campground, boat launch and beach, is located on the south shore. The lake's name is a translation from the Cree *Mahikan Sakhahegan*. In 1911, wolves near the lake were reported to have chased a fur-buyer's sleigh for quite a distance[1].

Figure 1 – The southern shore of Wolf Lake, 2013. Photo by Bradley Peter.

Wolf Lake is a large lake (31.5 $km^2$) with a maximum depth of 38.5 m and an average depth of 9m. It consists of three distinct basins: the northwest basin slopes rapidly to a maximum depth of 15.5 m and most of it is deeper than 10 m; the central basin has a maximum depth of 20.5 m, but a large part of it is less than 6 m deep; the eastern basin is long and narrow and contains the deepest part of the lake. Wolf Lake is a stratified lake with algae and nutrient concentrations that classify it as mesotrophic.

It is has a recreational fishery for perch and northern pike but the walleye fishery has been closed. Wolf Lake also supports a limited commercial fishery for whitefish, perch, pike and walleye[2].

The drainage basin of Wolf Lake is 22 times the size of the lake (Figure 1)[3]. Most of the watershed is located northeast of the lake. The outlet, the Wolf River, flows east to the Sand River, which eventually joins the Beaver River. Wolf Lake is located in the central mixed-wood natural subregion. The dominant trees in dry areas are trembling aspen,

[1] Chipeniuk, R.C. 1975. Lakes of the Lac la Biche District. R.C. Chipeniuk, Lac La Biche.

[2] 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

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

balsam poplar, jack pine, and white spruce. In wet areas, black spruce, willows, and sedges are dominant.

Wolf Lake is surrounded by crown land and its watershed remains mostly forested. Some agricultural lands (grazing leases) are found in the south of the watershed, surrounding Margarite Lake. The main human land uses in the lake's watershed are oil and gas exploration and development. Specifically, there is an in-situ oilsands production facility in the north-eastern portion of the watershed that was the site of a large bitumen spill in the summer of 2013 (CNRL Wolf Lake).

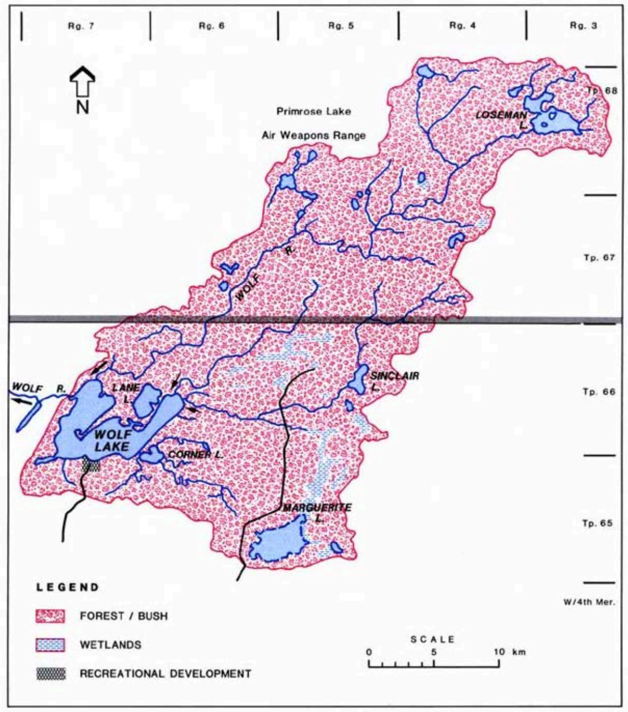
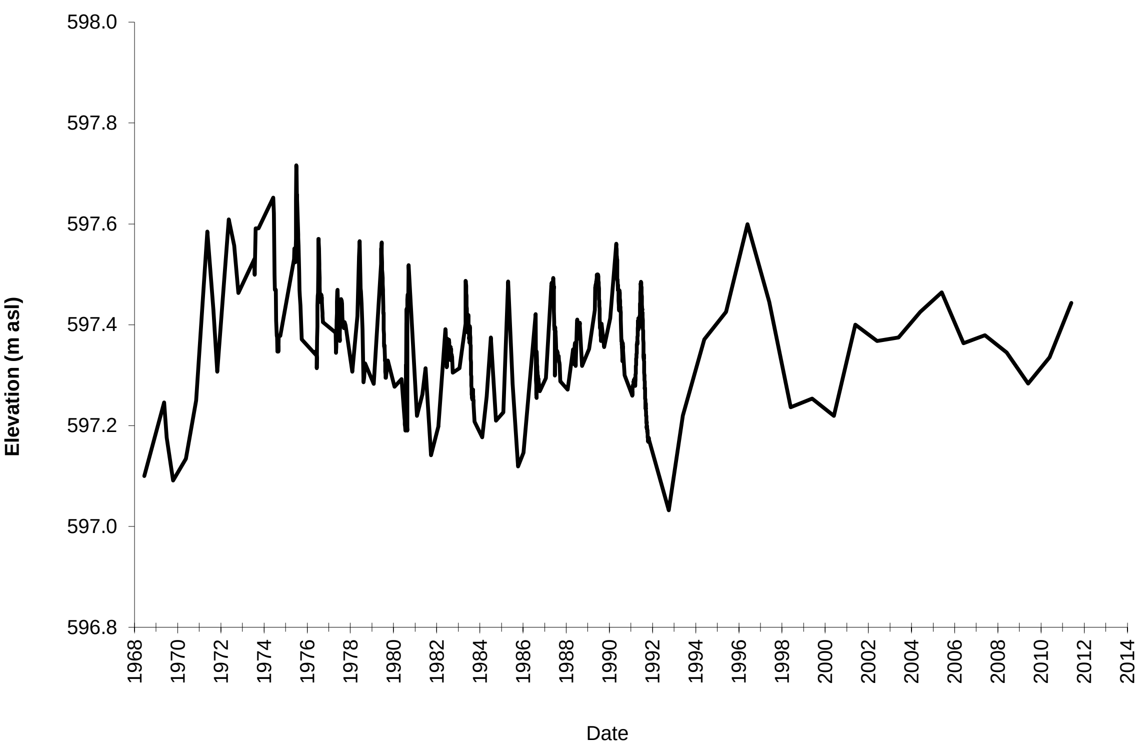



Figure 2 - Wolf Lake Watershed. Atlas of Alberta Lakes.

### WATER QUANTITY:

Water levels have been measured at Wolf Lake since 1968 by Alberta Environment (1968-1992) and Environment Canada (1993-2011). Water levels have changed little over the course of monitoring, with fluctuations not exceeding one-meter. Maximum water levels were observed in 1975 at 597.716 m asl and minimum levels were observed in 1992 at 597.032 m asl – resulting in a maximum fluctuation of 0.684 m.



## WATER CLARITY & SECCHI DEPTH:

Average Secchi disk depth at Wolf Lake in 2013 measured 2.58 m. An average Secchi disk depth of 2.58 m seems low given the concentrations of chlorophyll-*a* in the lake. As fluctuations of chlorophyll-*a* in the lake did not appear to affect Secchi disk depth, it is possible that colouration or suspended solids are the primary factors affecting water clarity at Wolf Lake. Secchi disk depth changed little throughout the summer, measuring a maximum of 2.80 m on July 25$^{th}$ and a minimum of 2.40 m on June 14$^{th}$.

## WATER TEMPERATURE AND DISSOLVED OXYGEN:

In early June, the water column was weakly thermally stratified, suggesting the lake had mixed in the early spring. As is typical of deep lakes in Alberta thermal stratification persisted throughout the summer. At the surface, water temperature did not exceed 20°C, though temperature dropped quickly below the thermocline, measuring below 5 °C at the sediment-water interface. The presence of strong thermal stratification has important implications for dissolved oxygen concentrations.

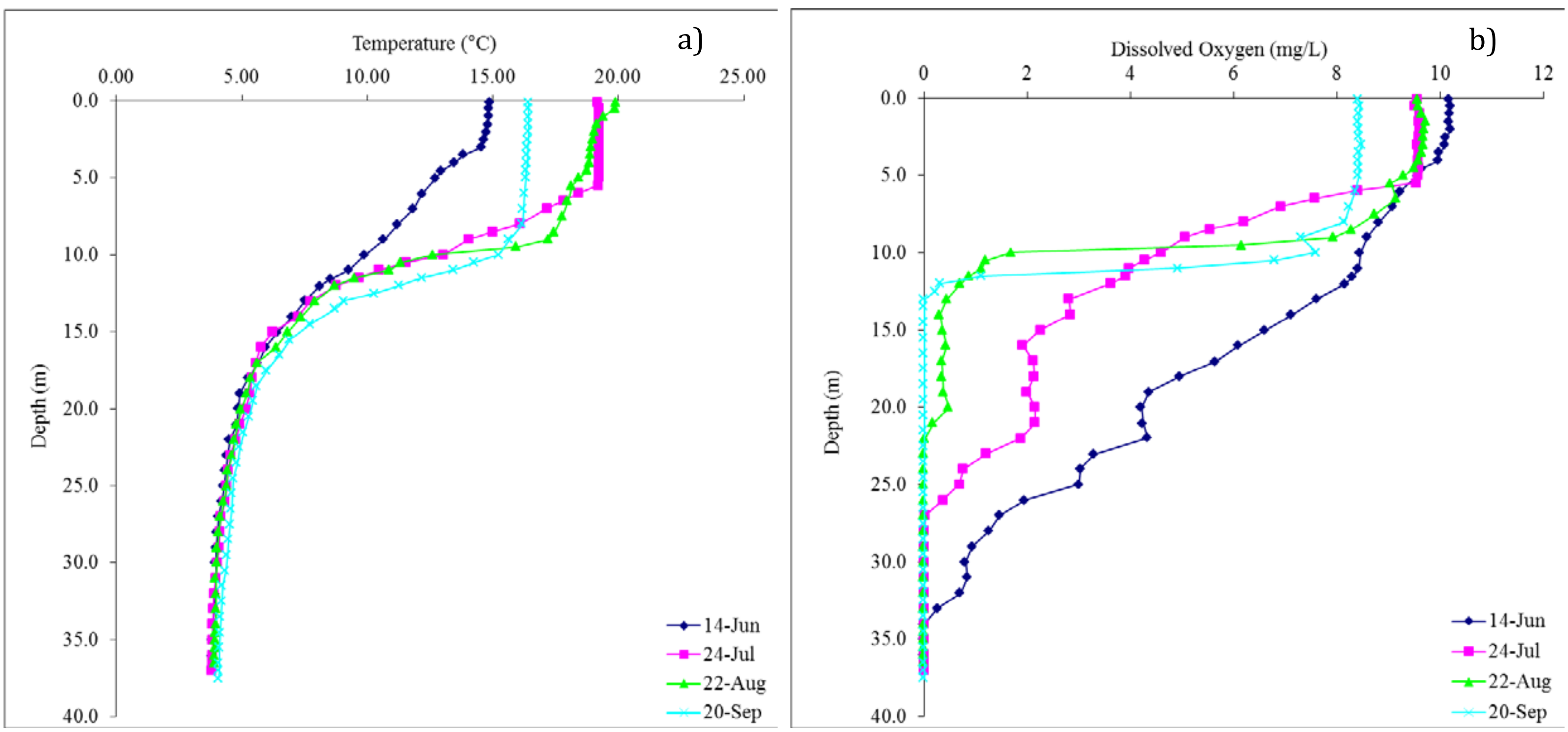



Figure 4 -a) Surface water temperature (°C) and b) dissolved oxygen concentrations (mg/L) measured four times over the course of the summer at Wolf Lake.

At the surface, dissolved oxygen concentrations remained well above the Canadian Council for Ministers of the Environment (CCME) guidelines for the Protection of Aquatic Life (PAL) of 6.5 mg/L. Due to thermal stratification, however, dissolved oxygen concentrations declined dramatically below the thermocline, reaching anoxia as early as 10.0 m (Figure 4b). Decreased oxygen concentrations below the thermocline are a result of a separation from atmospheric oxygen and the oxygen-consuming process of decomposition that occurs at the lake-sediment interface.

**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) at Wolf Lake in 2013 measured 33 µg/L (Table 1). This value is well above the historical variation observed at Wolf Lake and falls into the eutrophic (nutrient rich) classification. The high concentrations of TP observed (maximum: 50 µg/L on July 24$^{th}$) did not seem to elicit a response from the phytoplankton community (Figure 5). It is unclear what resulted in the high phosphorus levels observed in 2013.

Average chlorophyll-*a* concentration in Wolf Lake was low throughout the summer, measuring an average of 3.06 µg/L; this value falls into the oligotrophic (low productivity) classification and lies well within the historical variation observed at Wolf Lake. Throughout the summer there were no noticeable blooms of cyanobacteria or algae. Chlorophyll-*a* concentration measured a maximum of 4.95 µg/L on July 24$^{th}$ and a minimum of 0.786 µg/L on September 20$^{th}$.

Average total Kjeldahl nitrogen (TKN) measured an average of 859.5 µg/L in 2013. This value falls into the eutrophic (nutrient rich) classification and appears to fall well within the historical variation observed at Wolf Lake. Throughout the summer TKN fluctuated little, measuring a minimum of 787 µg/L on July 24$^{th}$ and a maximum of 903 µg/L.

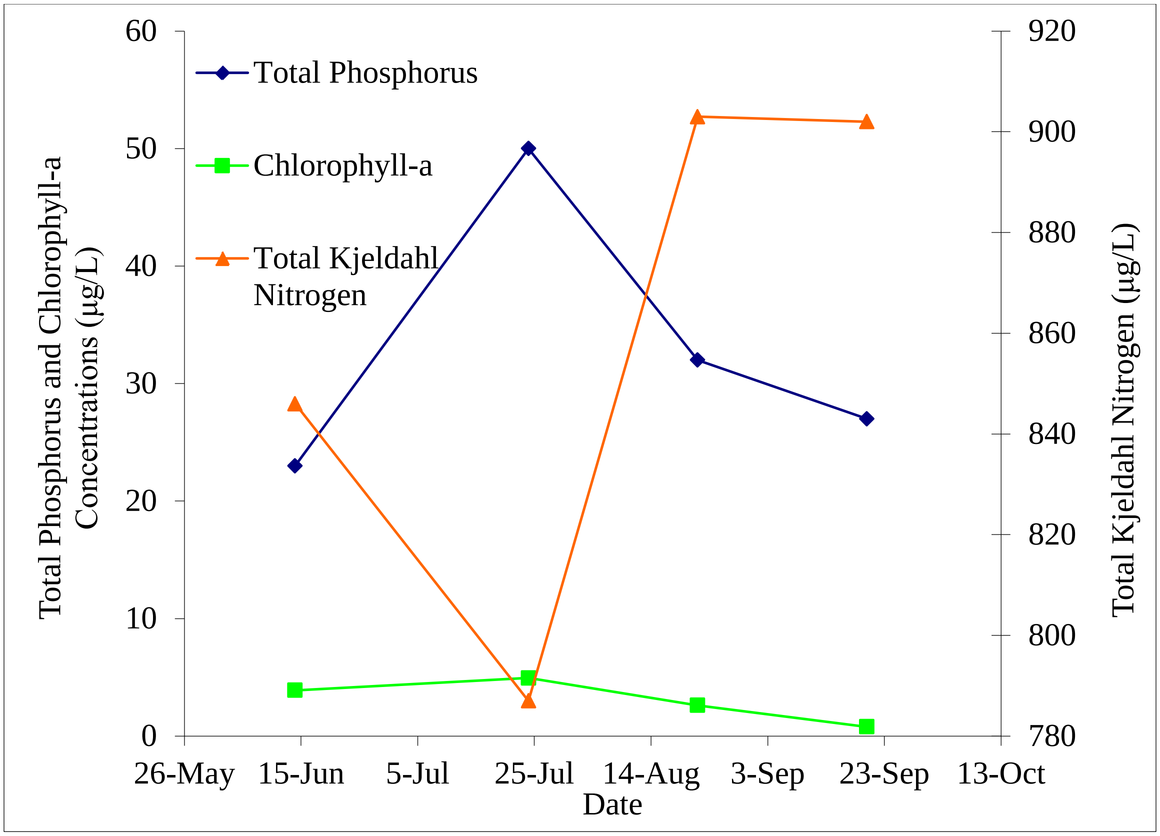



Figure 5 - Total phosphorous (µg/L), chlorophyll-*a* concentration (µg/L), and total Kjeldahl nitrogen (µg/L) measured four times over the course of the summer at Wolf Lake.

Average pH measured 8.21 in 2013 – this value is well above neutral and is the highest average pH measured in Crane Lake. Wolf Lake has moderate alkalinity (158.25 mg/L CaCO3) and bicarbonate (182.25 mg/L $HCO_3$) concentration which contributes to the lake's ability to buffer changes to its pH. Conductivity in Wolf Lake is also low, measuring 294 uS/cm in 2013. Thus, concentrations of ions are low, with calcium (30.2 mg/L) acting as one of the dominant ions in Wolf Lake. Microcystin concentrations were low in Wolf Lake in 2013, measuring an average of 0.03 µg/L – this value falls well below the recreational guidelines of 20 µg/L.

Metals were sampled twice throughout the summer and all values fell within their respective guidelines.

**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 Wolf Lake.

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

| Parameter | 1981 | 2005 | 2006 | 2007 | 2013 |
|---|---|---|---|---|---|
| TP (µg/L) | 25 | 22 | 19 | 17.5 | 33 |
| TDP (µg/L) | 10 | 6.6 | 8.3 | 7.3 | 14 |
| Chlorophyll-*a* (µg/L) | 7.9 | 4.6 | 3.3 | 2.7 | 3.06 |
| Secchi depth (m) | 2.8 | 3.5 | 3.3 | 3.6 | 2.58 |
| TKN (µg/L) | 911 | 830 | 825 | 758 | 859.5 |
| $NO_2$ and $NO_3$ (µg/L) | 4 | 6 | 2.5 | 3.5 | 2.5 |
| $NH_3$ (µg/L) | 17.5 | 25 | 14 | 17 | 13.8 |
| DOC (mg/L) | 13 | 14 | 15.1 | 15.1 | 14.2 |
| Ca (mg/L) | 30 | 30 | 30 | 29.3 | 30.2 |
| Mg (mg/L) | 16 | 15 | 16 | 16.8 | 16.9 |
| Na (mg/L) | 11 | 12 | 12 | 13.1 | 12.5 |
| K (mg/L) | 2 | 2.1 | 2 | 2.2 | 2.03 |
| $SO_4^{2-}$ (mg/L) | 2 | 3 | 5 | 1.5 | 1.5 |
| $Cl^-$ (mg/L) | 1 | 0.9 | 1.15 | 1.2 | 1.6 |
| $CO_3$ (mg/L) | 0.3 | 7 | 7.7 | 7.5 | 5.375 |
| $HCO_3$ (mg/L) | 189 | 180 | 182 | 192 | 182.25 |
| pH | 7.4-8.5 | 8.5 | 8.6 | 8.4 | 8.21 |
| Conductivity (µS/cm) | 295 | 291 | 297 | 297 | 294 |
| Hardness (mg/L) | | 129 | 139.3 | 142.7 | 145.3 |
| TDS (mg/L) | 156 | 156 | 161 | 164 | 159.67 |
| Microcystin (µg/L) | / | / | / | / | 0.03 |
| Total Alkalinity (mg/L $CaCO_3$) | 156 | 159 | 162 | 165 | 158.25 |

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 Wolf Lake on August 22nd and September 20th 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 | 17.89 | 100[a] |
| Antimony µg/L | 0.01775 | 6[e] |
| Arsenic µg/L | 0.9275 | 5 |
| Barium µg/L | 32.2 | 1000[e] |
| Beryllium µg/L | 0.006 | 100[d,f] |
| Bismuth µg/L | 0.00135 | / |
| Boron µg/L | 41.1 | 5000[ef] |
| Cadmium µg/L | 0.0026 | 0.085[b] |
| Chromium µg/L | 0.221 | / |
| Cobalt µg/L | 0.0266 | 1000[f] |
| Copper µg/L | 0.185 | 4[c] |
| Iron µg/L | 33.6 | 300 |
| Lead µg/L | 0.0484 | 7[c] |
| Lithium µg/L | 12.9 | 2500[g] |
| Manganese µg/L | 24.25 | 200[g] |
| Molybdenum µg/L | 0.276 | 73[d] |
| Nickel µg/L | 0.0976 | 150[c] |
| Selenium µg/L | 0.05 | 1 |
| Silver µg/L | 0.0183 | 0.1 |
| Strontium µg/L | 111.5 | / |
| Thallium µg/L | 0.001025 | 0.8 |
| Thorium µg/L | 0.001725 | / |
| Tin µg/L | 0.015 | / |
| Titanium µg/L | 1.5825 | / |
| Uranium µg/L | 0.0909 | 100[e] |
| Vanadium µg/L | 0.0931 | 100[f,g] |
| Zinc µg/L | 0.456 | 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 such as those associated with bacteria or the protozoan *Cryptosporidium*.

## TEMPERATURE AND MIXING:

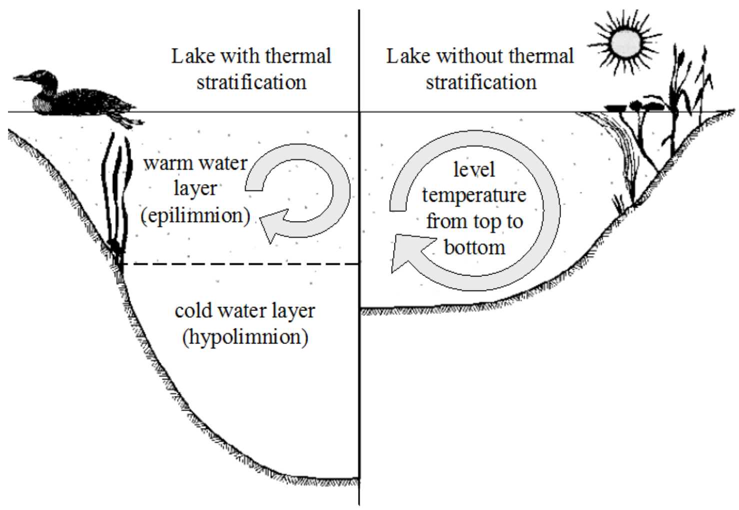



Figure A: Difference in the circulation of the water column depending on thermal stratification.

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 the 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 for 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.

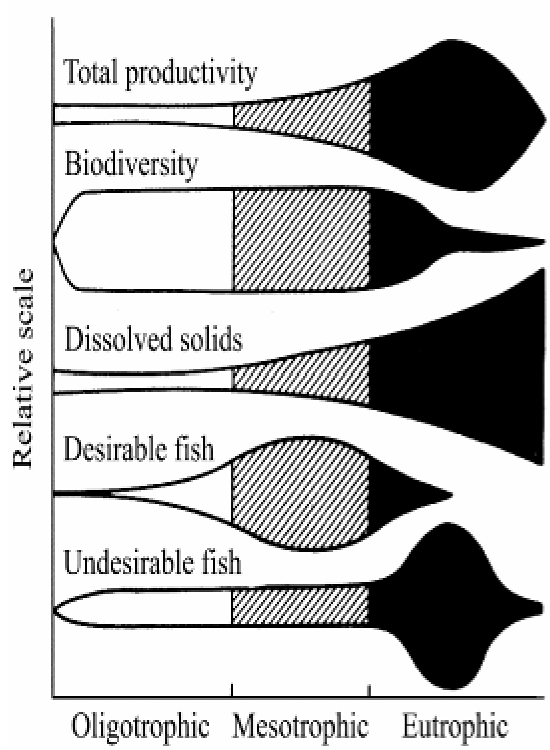



Figure B: Suggested changes in various lake characteristics with eutrophication. From “Ecological Effects of Wastewater”, 1980.

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 |