THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2013 Ghost Reservoir 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

The LakeWatch program is made possible through the dedication of its volunteers. We would like to thank Karen and Dana Lausten who volunteered with the monitoring of Ghost Lake in 2013. We would also like to thank Jared Ellenor, Nicole Meyers, and Elynne Murray who were summer technicians with ALMS in 2013. Program Coordinator Bradley Peter was instrumental in planning and organizing the field program. Technologists Chris Ware and Sarah Hustins 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.

GHOST RESERVOIR:

Fig. 1 –Debris in Ghost Reservoir due to flooding in 2013. Photo by Jared Ellenor.

Ghost Reservoir is a glacier-fed, man-made lake created in 1929 by damming the Bow River just below the confluence of the Ghost River. It is 20 km west of the town of Cochrane and 45 km west of Calgary. The Summer Village of Ghost Lake and Ghost Reservoir Provincial Recreation Area are on the northern shore of the lake. Its watershed lies within both the MD of Bighorn and Rocky View County but most of the lake itself is on Stoney First Nation Reserve land.

The lake is long and narrow, with a water surface of 11.6 km^2.[1] Average depth of Ghost Lake is 14.5 m and maximum depth may be as deep as 34 m, however, water levels fluctuate greatly from month to month.

The lake and dam are primarily used for power generation, however the location brings consistent, strong winds, which make the lake suitable for windsurfing, sailing, and iceboating. It is also used for other recreational activities such as power boating, swimming, and fishing.

Sport fish include lake trout, mountain whitefish, lake whitefish and brown trout. Other fish species include longnose sucker, white sucker, burbot, brook stickleback, and longnose dace. Macrophytes are very sparse, as the gravel shore and fluctuations in water levels maintain a barren shoreline. The Ghost Reservoir does not provide good nesting habitat for waterfowl because of the fluctuating water level and the absence of shoreline vegetation, however Canada Geese are seen at its western end during spring migration[2].

Ghost Lake has a large watershed (6,460 km^2), 600 times the size of the lake, which is largely undeveloped. The watershed contains several protected areas, including Banff National Park, Peter Lougheed Provincial Park, the Ghost Wilderness, and parts of the Don Getty Provincial Wildland. The remainder of the area is considered multiple-use, supporting municipal development, summer grazing leases for cattle, forestry, oil and gas exploration and production, and recreation such as horseback riding, hunting, hiking, rock and ice climbing, mountain biking, and motorized off-highway vehicles.

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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] Bow River Basin Council. 2010. Bow River Basin State of the Watershed Summary Report. Available at: http://wsow.brbc.ab.ca

In June 2013, an extreme rainfall event caused flooding along the Bow and Ghost Rivers. Developed and undeveloped areas upstream of the lake were damaged including the communities of Canmore, Morley, Lac Dec Arcs, Exshaw, Benchlands & Waiparous. Influxes of debris and sediment were noticed in Ghost Lake after the flooding (Figure 1).

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.

The reservoir is drawn down through the winter and early spring to allow partial capture of snowmelt – stored water is released to maintain flows in the Bow River. Typical winter drawdown is about 5.3 m and exposes most of the bay behind the breakwater at the Summer Village of Ghost Lake (Figure 2). During the summer the water level is regulated to a higher elevation for recreational use.

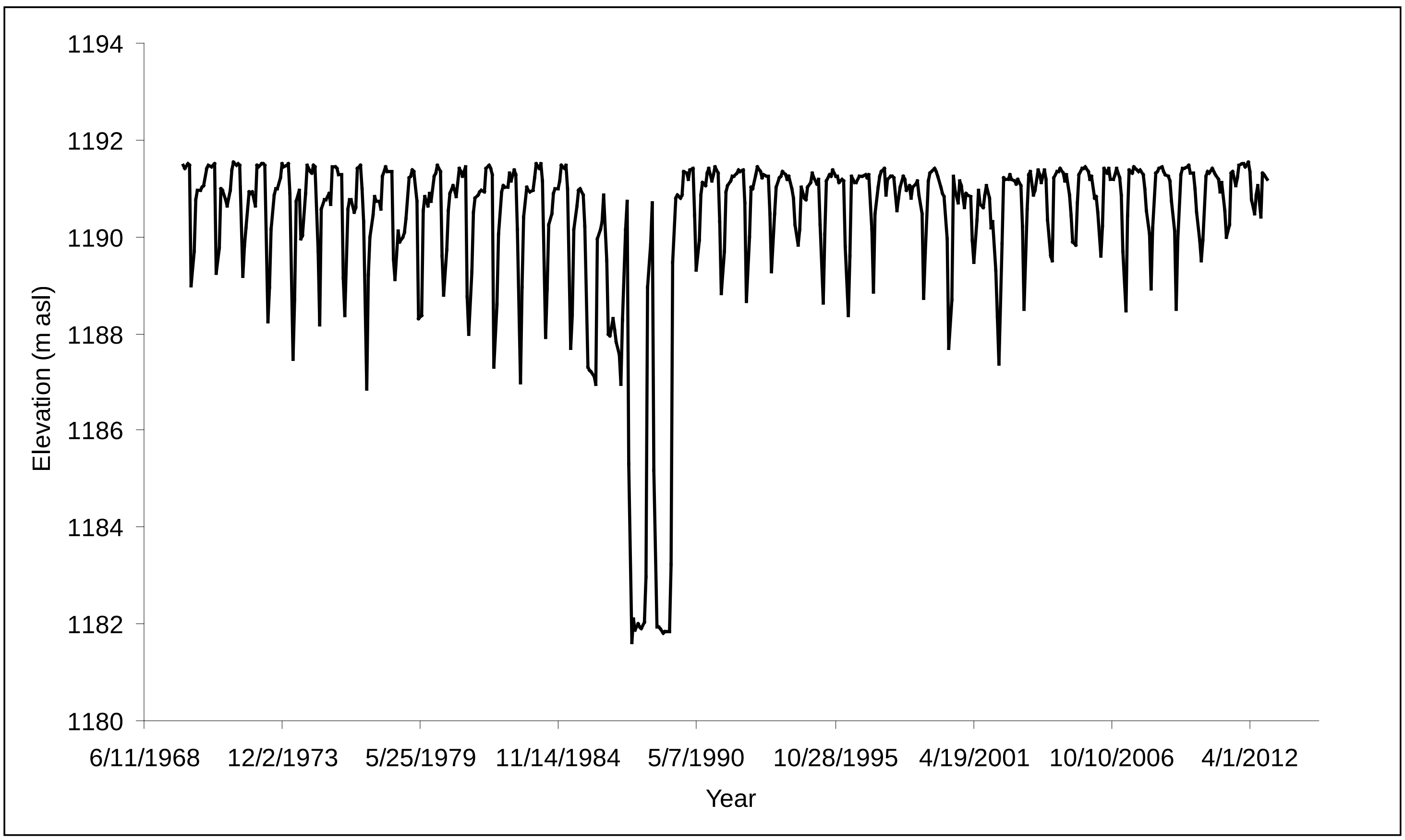

Figure 2 – Water levels measured from 1970-2012 in meters above sea level (m asl). Data retrieved online from http://www.wsc.ec.gc.ca/applications/H2O/index-eng.cfm.

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.

Figure 3 – Debris on the surface of Ghost Reservoir, July 2013. Photo by Jared Ellenor.

Secchi disk depth changed little throughout the summer, measuring a minimum of 2.20 m on June 14th to a maximum of 2.85 m on August 22. These numbers are low when compared to the Secchi disk depths collected by ALMS in 2001, which measured as high as 9.50 m in August. It is possible that flooding, which brought floating debris into Ghost Lake in 2013, lowered water clarity; however, turbidity measurements taken during profile readings were low throughout the summer, as were total suspended solid concentrations retrieved from the composite samples (Table 1). In addition, chlorophyll-*a* concentration, a measurement of phytoplankton pigments, was low throughout the summer, suggesting phytoplankton blooms were likely not impeding water clarity.

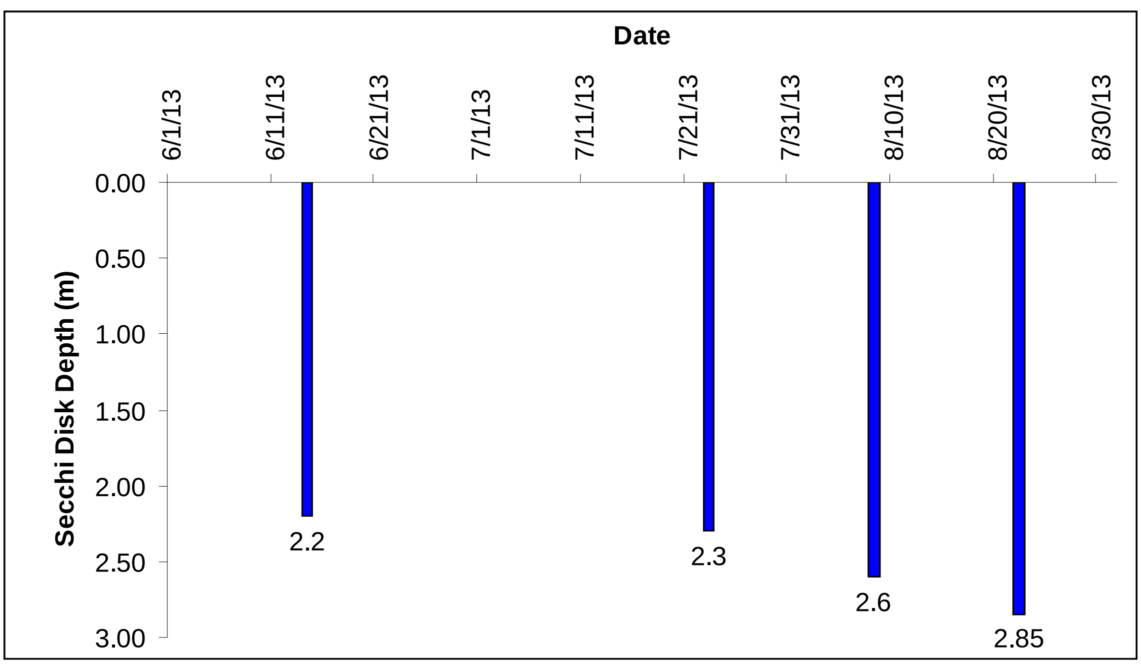

Figure 3 – Secchi disk depth measurements obtained from the profile site on Ghost Reservoir in 2013.

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.

Because of the low water residence time (22 days) at Ghost Lake, as well as the low water temperatures, it is difficult for thermal stratification to develop. In 2013, no thermal stratification was observed at Ghost Lake. However, it is possible that temporary thermal stratification develops in shallower, more sheltered areas of the lake on calm, hot days. Throughout the summer surface water temperatures ranged from a minimum of 12.00 °C on June 14th to a maximum of 16.45 °C on July 23rd. On each sampling trip the water column remained fairly isothermal, with only a couple degree differences between the surface and sediment temperatures.

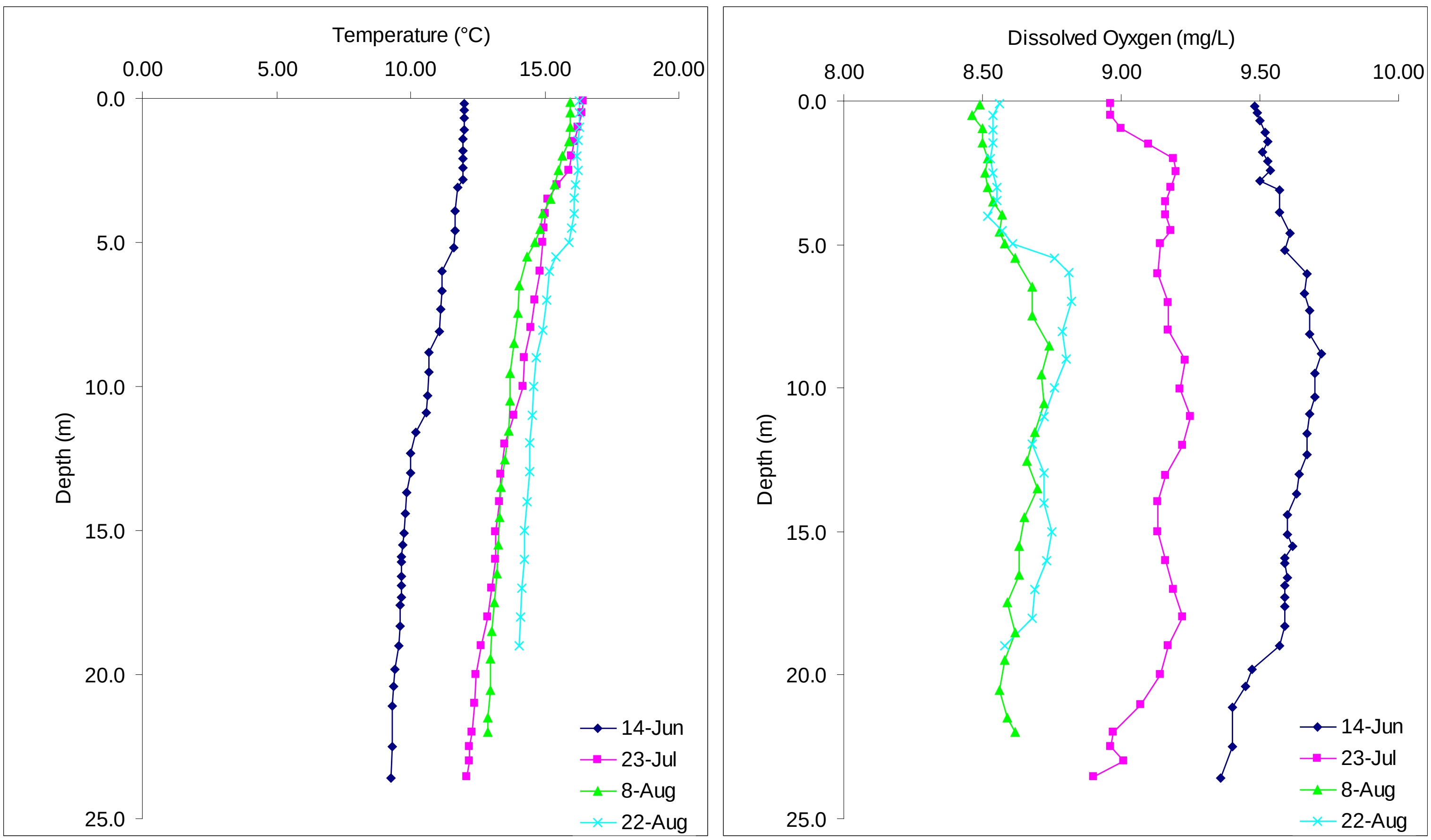

Figure 4 – a) Temperature and b) dissolved oxygen profiles measured at Ghost Reservoir during the summer of 2013.

As with temperature, dissolved oxygen changed very little with depth in Ghost Reservoir in 2013. On each sampling trip concentrations remained well above the Canadian Council for Ministers of the Environment (CCME) guidelines of 6.5 mg/L for the Protection of Aquatic Life (PAL). Throughout the summer, dissolved oxygen concentration ranged between a minimum of 8.49 mg/L on August 8th to a maximum of 9.48 mg/L on June 14th.

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 14.75 μg/L in 2014 (Table 1). This value falls on the low end of the mesotrophic, or moderately productive classification. As the test for TP includes all particulate matter, it is likely that debris entering the lake due to flooding has raised the TP concentration in 2013. This may explain why TP concentrations are high compared to historical averages. In addition, TP was highest in June after spring runoff (24 μg/L; Figure 5) – however, a June sample was not obtained in 2001, possibly skewing the 2001 results.

Low concentrations of chlorophyll-*a* were observed in 2013. On average, chlorophyll-*a* concentration measured 1.17 μg/L. This value falls into the oligotrophic, or low productivity, trophic classification. Unlike eutrophic prairie lakes which tend to have increasing chlorophyll-*a* concentrations throughout the summer, chlorophyll-*a* concentrations changed very little in Ghost Reservoir, measuring an observed maximum of 1.89 μg/L on June 14th and an observed minimum of 0.706 μg/L on August 22nd.

Finally, total Kjeldahl nitrogen (TKN) concentration measured an average of 370.75 μg/L in 2013. Like TP, TKN concentrations fall on the low end of the mesotrophic trophic classification. Compared to historical results, the 2013 average is much less than that observed in 2001. It is unclear what caused the spike in TKN in 2001.

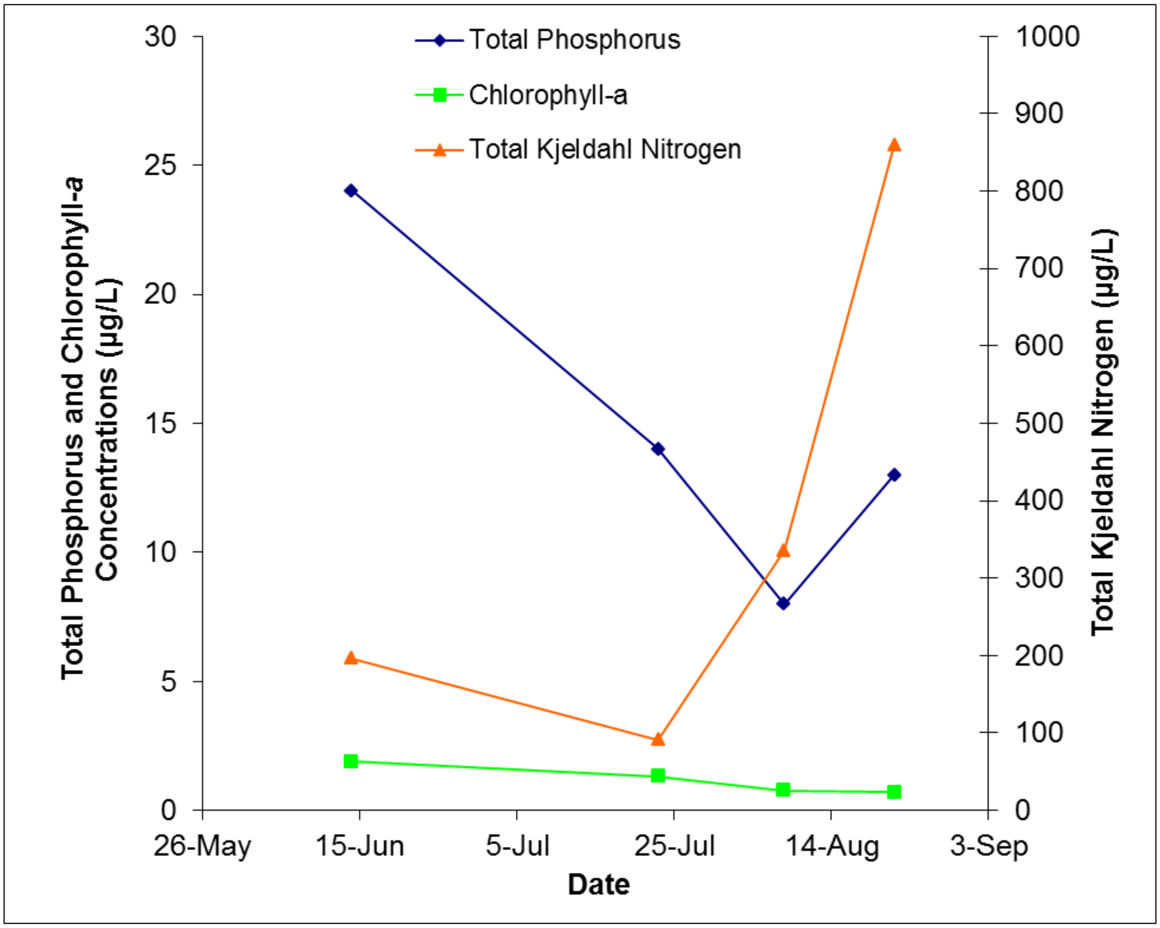

Figure 5 – Total phosphorus (µg/L), chlorophyll-*a* (µg/L), and total Kjeldahl nitrogen (µg/L) concentrations measured in Ghost Reservoir in 2013.

Average pH in Ghost Reservoir measured 7.845 in 2013 – this value is just above neutral though appears consistent with the variation observed in Ghost Reservoir since 1985 (Table 1). Ghost Reservoir has moderate alkalinity (122.25 mg/L $CaCO_3$) and bicarbonate concentration (148.75 mg/L HCO_3) which contribute to its ability to buffer against changes to pH. Concentrations of ions and the resulting conductivity of Ghost Reservoir have changed little since 2001 – dominant ions in Ghost Reservoir include calcium (39.95 mg/L) and (27.5 mg/L). On average, conductivity in Ghost Reservoir in 2013 was 294.5 uS/cm.

In 2013, ALMS had samples collected to be analyzed for metal concentrations; all metals analyzed for fell within their respective guidelines (Table 2).

MICROCYSTIN:

Microcystins are toxins produced by cyanobacteria (blue-green algae) which, when ingested, can cause severe liver damage. Microcystins are produced by many species of cyanobacteria which are common to Alberta's Lakes, and are thought to be the one of the most common cyanobacteria toxins. In Alberta, recreational guidelines for microcystin are set at 20 µg/L.

Throughout the summer, microcystin concentrations remained below the minimum detection limit of 0.05 mg/L (Table 1).

Table 1 – Microcystin concentrations (µg/L) measured at Ghost Reservoir during the summer of 2013. Values represent samples taken as whole-lake composites.

Date	Microcystin (µg/L)
June 14	<0.05
July 23	<0.05
August 8	<0.05
August 22	<0.05

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 Ghost Reservoir.

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

Parameter	1985	1994	2001	2013
TP (µg/L)	7	5	4	14.75
TDP (µg/L)	4	0	4	1.63
Chlorophyll-*a* (µg/L)	2	0.5	0.6	1.17
Secchi depth (m)	6.4	7.3	8.75	2.49
TKN (µg/L)	462	/	1314	370.75
NO_2 and NO_3 (µg/L)	30	/	46	76.5
NH_3 (µg/L)	30	/	5	11.25
DOC (mg/L)	/	/	/	0.9
Ca (mg/L)	37	33	33.4	39.95
Mg (mg/L)	10	11	11.2	10.34
Na (mg/L)	2	2	1.5	1.95
K (mg/L)	0.4	0.3	0.4	0.45
SO_4^{2-} (mg/L)	31	26	29.8	27.5
Cl^- (mg/L)	1	1.2	1.5	1.9
CO_3 (mg/L)	0.5	1.2	1.5	0.5
HCO_3 (mg/L)	137	124	118.06	148.75
pH	7.3-7.9	8.46-8.52	8.38	8.315
Conductivity (µS/cm)	277	252	254.3	294.5
Hardness (mg/L)	134.6	134.6	145.6	142.5
TDS (mg/L)	/	143.7	149.6	154
TSS	/	0.5	2	6.93
Microcystin (µg/L)	/	/	/	<0.05
Total Alkalinity (mg/L $CaCO_3$)	135	106	100.7	122.25

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 Ghost Reservoir on August 8th, 2013. 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	72.6	100[a]
Antimony μg/L	0.0438	6[e]
Arsenic μg/L	0.162	5
Barium μg/L	36.2	1000[e]
Beryllium μg/L	0.0151	100[d,f]
Bismuth μg/L	0.0005	/
Boron μg/L	7.06	5000[ef]
Cadmium μg/L	0.0124	0.085[b]
Chromium μg/L	0.211	/
Cobalt μg/L	0.0188	1000[f]
Copper μg/L	0.512	4[c]
Iron μg/L	64.3	300
Lead μg/L	0.0459	7[c]
Lithium μg/L	2.02	2500[g]
Manganese μg/L	2.99	200[g]
Molybdenum μg/L	0.636	73[d]
Nickel μg/L	0.14	150[c]
Selenium μg/L	0.425	1
Silver μg/L	0.0173	0.1
Strontium μg/L	159	/
Thallium μg/L	0.0084	0.8
Thorium μg/L	0.0005	/
Tin μg/L	0.0724	/
Titanium μg/L	1.28	/
Uranium μg/L	0.461	100[e]
Vanadium μg/L	0.279	100[f,g]
Zinc μg/L	0.899	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:

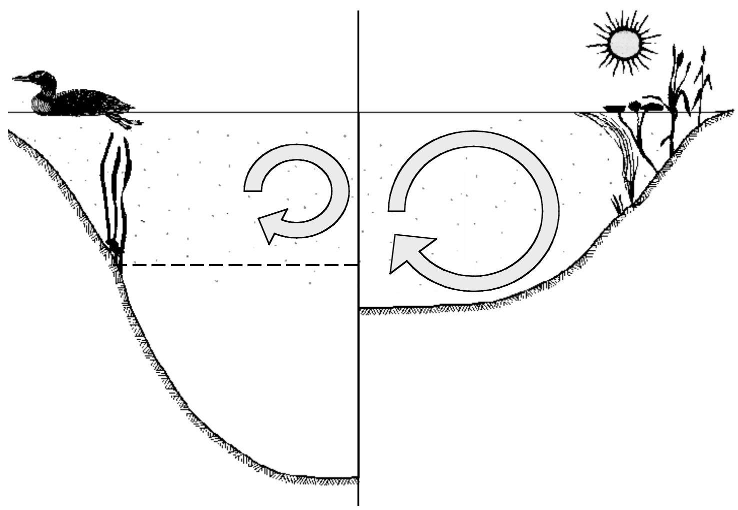

Figure A: Difference in the circulation of the water column depending on thermal stratification.

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.

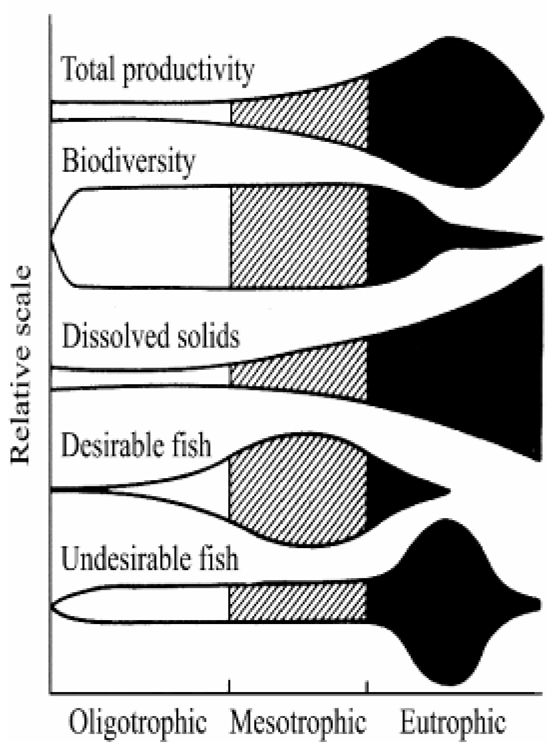

Figure B: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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