Lakewatch

THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2010 Skeleton Lake Report

COMPLETED WITH SUPPORT FROM:

Beaver River Watershed Alliance

Government of Alberta

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.

Acknowledgements

The Lakewatch program is made possible through the dedication of its volunteers and Lakewatch Chairs, Al Sosiak and Ron Zurawell. We would like to thank Orest Kitts for his dedication to data collection at North Skeleton Lake and Roy Nilson for his efforts in data collection on South Skeleton Lake. We would also like to thank Bradley Peter and Emily Port who were summer interns with ALMS in 2010. Project Technical Coordinator Jill Anderson was instrumental in planning and organizing the field program. Technologists Shelley Manchur, Mike Bilyk, Brian Jackson, and John Willis were involved in the training aspects of the program. Doreen LeClair and Chris Rickard were responsible for data management. Jill Anderson (Program Manager) was responsible for program administration and planning. Théo Charette, Ron Zurawell, Lori Neufeld, and Sarah Lord prepared the original report, which was updated for 2010 by Bradley Peter and Arin Dyer. Alberta Environment, the Beaver River Watershed Alliance (BRWA), and the Municipal District of Wainwright were major sponsors of the Lakewatch program.

SKELETON LAKE:

Skeleton Lake is located in the western portion of the Beaver River watershed. The lake's name is a translation of the Cree *Cheply Sakahigan,* which means "place of the skeletons". It is thought that a Cree chief is buried along the shores of the lake.

The lake is located within the County of Athabasca, 160 km northeast of the city of Edmonton and 6.5 km northeast of the village of Boyle. Skeleton Lake has an extensively developed shoreline with the summer villages of Mewatha and Bondiss on the southern shore of the lake and additional cottage developments on the north shore. Since 1968, Skeleton Lake has been the main source of drinking water for the Town of Boyle.

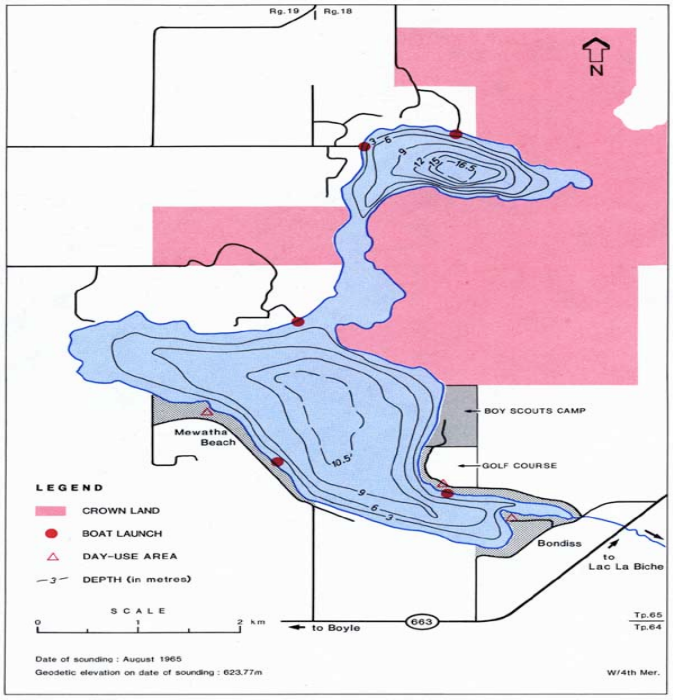

Figure 1 – Bathymetric map of Skeleton Lake obtained from Alberta Environment.

The watershed is located in the Dry Mixedwood subregion of the Boreal Mixedwood natural region. Several small intermittent streams flow into the lake and drain a watershed that is four times the size of the lake. The outlet is a small creek located at the southeast end of the lake, and drains eastward into Amisk Lake. Beaver dams, however, often block the outlet. Tree cover in the watershed is primarily trembling aspen and secondarily white spruce, balsam poplar, and white birch. Peatlands are also significant, and most agricultural activities in the watershed take place in the southern and northwestern sections.

Figure 2 – A view of the north bay of Skeleton Lake. Photo: Pauline Pozsonyi.

Skeleton Lake is divided into two basins. The north basin (Figure 2) is separated from the south basin by a shallow, weedy narrows. During the late 1940's, when lake levels were low, the two basins were separated by exposed land at the narrows. In 2008, the lake levels were again low enough that the narrows were dry and have remained dry to date. The north basin is small and deep, with steeply sloped sides that reach a

maximum depth of about 17 m. The larger south basin slopes gradually to a maximum depth of 11 m. Skeleton Lake is very fertile and blooms of blue-green algae turn the water green in both basins during the summer months. The average concentrations of algae in the south basin are higher than in the north basin. Because the basins are not currently connected and the morphology and water quality characteristics of the two basins differ, the water quality of the north and south basins are reported separately for the 2010 Lakewatch Report.

WATER LEVELS:

Water levels in Skeleton Lake have been monitored by Environment Canada since 1965 under the joint Federal-Provincial Hydrometric agreement (Figure 3). Consistent with other lakes in the area, water levels have decreased steadily by about 1.6 meters since the 1970s, with the exception of 1997, an extremely wet period, during which the water level increased to a historical maximum of 632.9 meters above sea level (m asl). Over the past 14 years, water levels in Skeleton Lake have declined to a historical minimum of 621.8 m asl in 2009 Declining water levels are a major stakeholder concern for this lake.

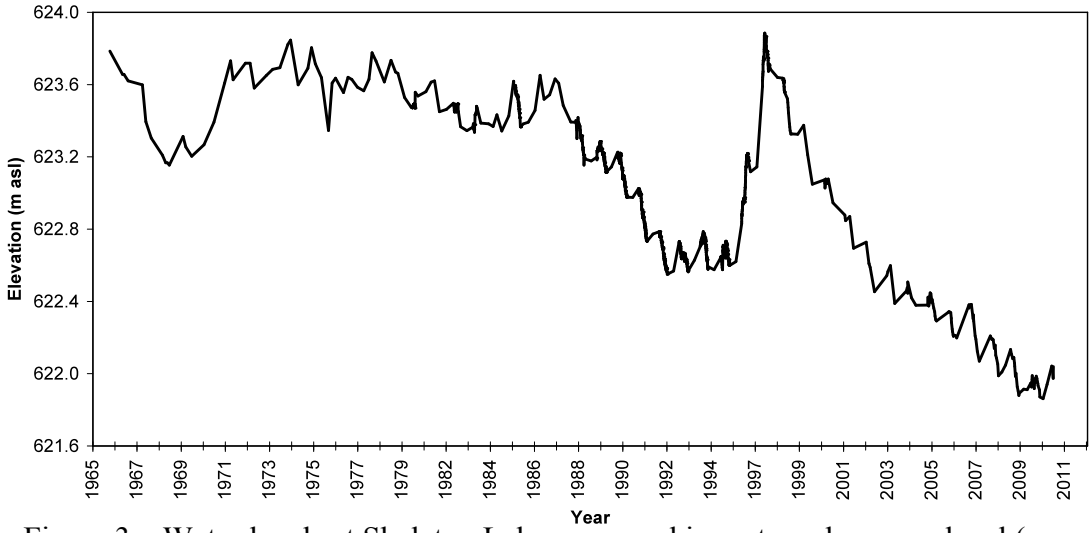

Figure 3 – Water levels at Skeleton Lake measured in meters above sea level (m asl). Data obtained from Alberta Environment.

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 2010 secchi disc depth in North Skeleton Lake measured 1.75 m, much shallower than secchi disc depths in previous years (Table 1). A maximum secchi disc

depth of 2.0 m was measured on June 6th and July 4th, while a minimum of 1.25 m was measured on August 31st. It is typical for secchi disc depth to decrease throughout the summer as algal biomass increases. However, algal biomass was less in 2010 than in previous years, thus the reduced water clarity may be due to the suspension of sediments either from the watershed or the lakebed.

Average 2010 Secchi disc depth in South Skeleton Lake measured 1.4 m, slightly lower than the long-term average (Table 1). The algal biomass in this basin, however, was higher than average in 2010 which could explain the reduced water clarity. Secchi disc depth in the south basin reached a maximum of 2.00 m on June 7th and a minimum of 1.25 m on each of the other sampling trips. While the 2010 average is slightly lower than the long term average, it is not outside of the historical variation seen in the south basin.

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 Skeleton Lake remained stratified throughout the summer of 2010 (Figure 4a). Because the North basin is sheltered and deep with a small surface area, it is difficult for wind energy to mix the entire water column. On June 6th, surface water temperature was 14.23 °C, with stratification present between 5.0-8.0 m. On July 4th, surface water temperature had increased to 18.44 °C and the range of stratification increased to 4.5-8.0 m. On July 27th, surface water temperatures increased to 20.41 °C and the zone of stratification increased in size to 4.5-8.0 m. On August 17th, though surface temperature had increase to 20.41 °C, the zone of stratification remained between 4.5-9.0 m. Finally, on August 31st, surface temperatures decreased to 16.10 °C and the zone of stratification began to break down, present between 7.5-9.5 m. During all sampling trips, temperature at the lakebed measured between 6.66 °C and 8.01 °C.

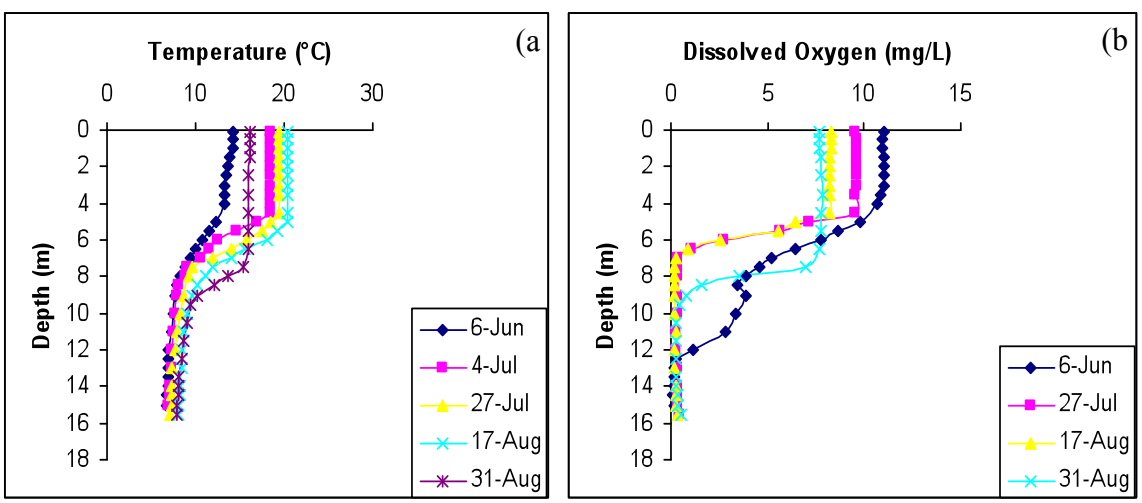

Figure 4 – a) Water temperature (°C) and b) dissolved oxygen (mg/L) profiles for North Skeleton Lake measured during the summer of 2010.

Dissolved oxygen was measured five times in the North basin over the course of the 2010 summer, but due to a probe malfunction only four dissolved oxygen profiles are presented (Figure 4b). Large zones of anoxia were observed in 2010. On June 6th, surface dissolved oxygen measured 11.03 mg/L and decreased steadily to anoxia around 12.5 m. On July 27th, surface dissolved oxygen had decreased to 9.49 mg/L and anoxia began much higher in the water column, around 6.5 m. On August 17th, surface dissolved oxygen continued to decrease, measuring 8.26 mg/L, and anoxia was again present around 6.5 m. On August 31st, surface dissolved oxygen measured 7.67 mg/L, and, with the increased mixing of the water column, anoxic waters began around 8.5 m. Loss of oxygen in bottom waters is a combination of two factors: the oxygen-consuming decomposition that occurs at the lakebed, and the lack of mixing of oxygen-rich top water with oxygen-depleted bottom waters due to stratification. Much of the water column at North Skeleton Lake fell below the Canadian Council for Ministers of the Environment (CCME) guideline for the Protection of Aquatic Life of 6.5 mg/L. Fish habitat within Skeleton Lake North may have compressed due to narrowed zones of favored levels of dissolved oxygen and temperatures.

During 2010, no thermal stratification was observed at South Skeleton Lake as water temperature remained relatively uniform throughout the water column for each sampling trip (Figure 5a). On June 7th, surface water temperature measured 14.48 °C and decreased to 12.74 °C at the lakebed. On July 9th, surface water temperature increased to 18.82 °C and decreased to 16.76 °C at the lakebed. On July 30th, surface water temperature again increased to 20.17 °C and bottom temperatures measured 17.95 °C. On August 17th, surface water increased slightly to 20.44 °C, while bottom water temperature increased by a couple degrees to 19.47 °C due to the mixing of the water column. Finally, on August 31st, surface water temperature had dropped to 16.61 °C and remained relatively uniform until the bottom where water temperature was 16.20 °C.

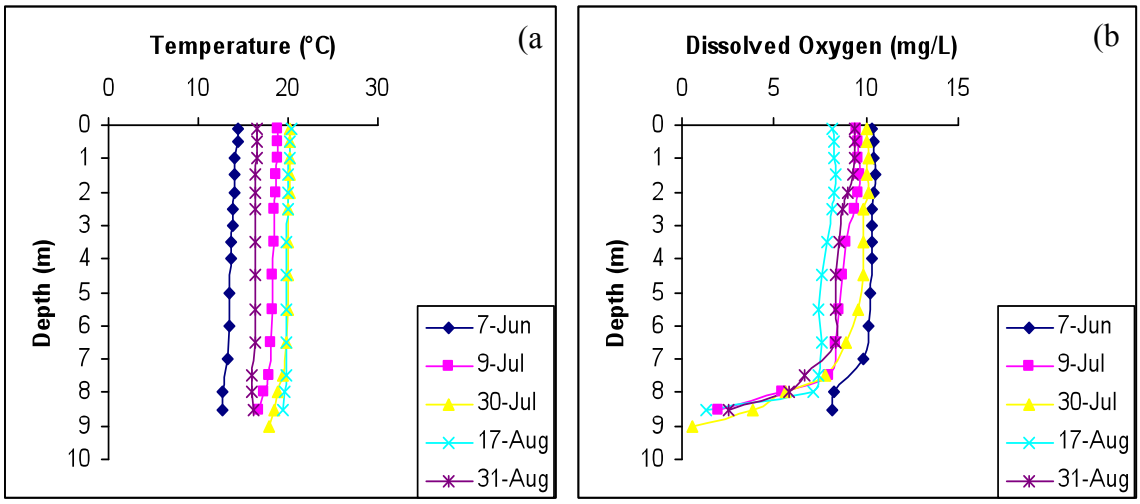

Figure 5 – a) Water temperature and b) dissolved oxygen profiles for South Skeleton Lake measured in 2010.

Despite mixing of the water column, dissolved oxygen in South Skeleton Lake still decreased greatly at the lakebed (Figure 5b). On June 7th, dissolved oxygen measured 10.35 mg/L at the surface and 8.18 mg/L at the lakebed. On July 9th, surface dissolved oxygen decreased to 9.46 mg/L, and dissolved oxygen at the lakebed decreased dramatically to 2.01 mg/L. Similarly, on July 30th, surface dissolved oxygen measured 10.05 mg/L at the surface and 0.55 mg/L at the lakebed. Anoxia at the lakebed is common due to decomposition of algae, which is an oxygen-consuming process. Persistent mixing of the water column, however, helps to maintain higher oxygen levels at shallower depths. On August 17th, surface dissolved oxygen was at a seasonal minimum of 8.13 mg/L and decreased to 1.28 mg/L at the lakebed. Finally, on August 31st, surface dissolved oxygen measured 9.41 mg/L, and concentration at the lakebed measured 2.5 mg/L. The ability of water to hold dissolved oxygen is dependent on water temperature, with warmer waters holding less oxygen. This may help explain the pattern of surface dissolved oxygen concentration seen at South Skeleton Lake. Surface waters were well above the provincial Guidelines for Protection of Freshwater Aquatic Life in South Skeleton Lake for the duration of the summer (DO ≥ 5.0 mg/L).

WATER CHEMISTRY:

ALMS measures a suite of water chemistry parameters. Phosphorous, 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.

Based on average total phosphorous measured in 2010, both north and south basins of Skeleton would be considered eutrophic (47.8 µg/L and 58.8 µg/L, respectively; Table 1). North Skeleton Lake's total phosphorus concentration, compared to previous years, is much higher though not high enough to change the trophic classification of the lake. During the summer, total phosphorous in the north basin was at a seasonal maximum of 79 µg/L on July 27th, and a seasonal minimum of 28 µg/L on August 17th (Figure 6).

South Skeleton Lake's 2010 total phosphorous concentration appears higher than its long-term average of about 40 µg/L, though is not high enough to change the trophic classification of the lake. This is also higher than the 2010 average measured in North Skeleton Lake. Total phosphorous increased throughout the course of the summer, with a seasonal minimum of 51 µg/L on June 6th, a seasonal maximum of 65 µg/L on July 30th, and a final measurement of 64 µg/L on August 31st (Figure 7).

Average 2010 total Kjeldahl nitrogen (TKN) in North Skeleton Lake was 1.61 mg/L, which falls into the hypereutrophic classification (Table 1). In this basin total Kjeldahl nitrogen followed a similar pattern as the phosphorous, reaching a seasonal maximum of 1.75 mg/L on July 27th, and a seasonal minimum of 1.50 mg/L on August 31st (Figure 6). Average 2010 TKN in South Skeleton Lake was 1.56 mg/L, characteristic of a hypereutrophic lake and higher than previous year's averages. TKN in the south basin

was at a seasonal minimum of 1.33 µg/L on June 6th and a seasonal maximum of 1.78 µg/L on August 31st (Figure 7).

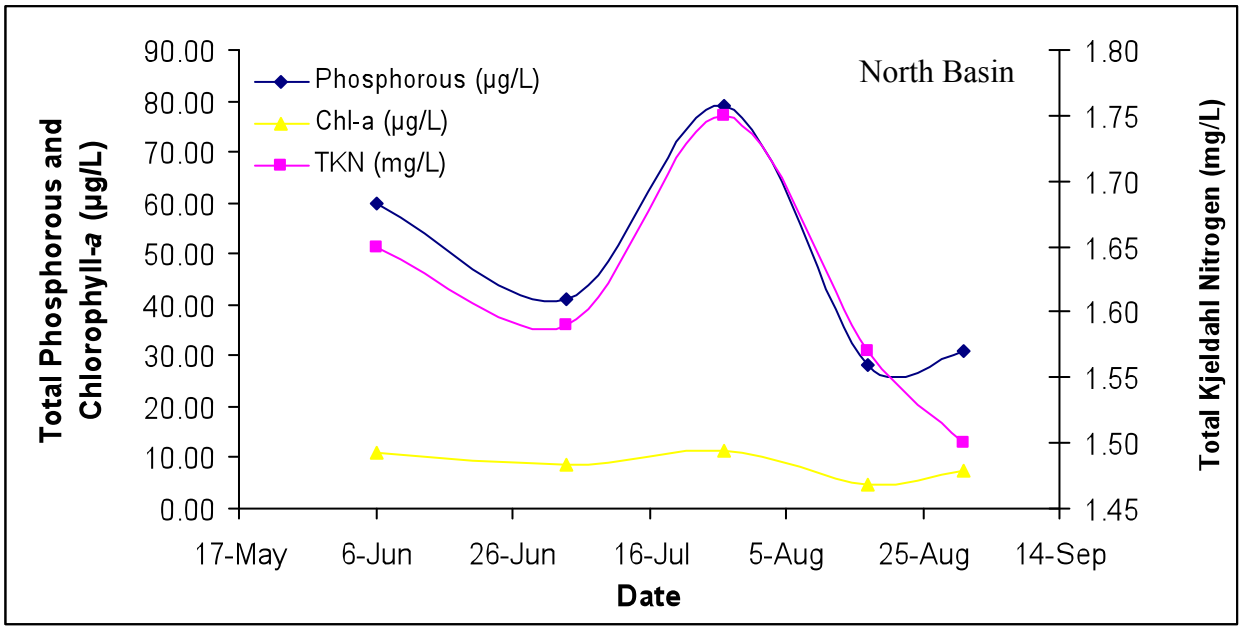

Figure 6 – Total phosphorous (µg/L), chlorophyll-*a* (µg/L), and total Kjeldahl nitrogen (mg/L) measured five times over the course of the summer in 2010.

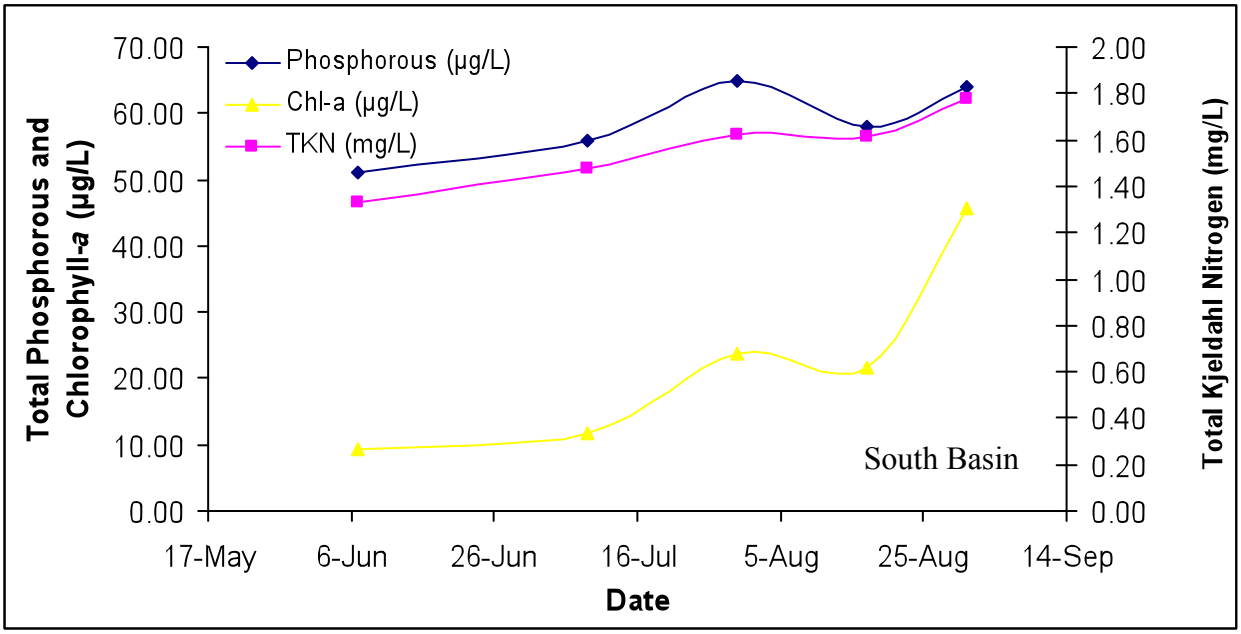

Figure 7 – Total phosphorous (µg/L), chlorophyll-*a* (µg/L), and total Kjeldahl nitrogen (mg/L) measured five times during the summer of 2010.

Average 2010 chlorophyll-*a* concentration for North Skeleton Lake was 8.62 µg/L (Table 1). This is less than seen in previous years and falls under the mesotrophic classification.

Chlorophyll-*a* concentration in the north basin closely followed the pattern of phosphorous concentration, reaching a maximum of 11.5 µg/L on July 27th and a minimum of 4.54 µg/L on August 17th (Figure 6). This pattern indicates that North Skeleton Lake is phosphorous limited, as are many lakes throughout the province.

Average 2010 chlorophyll-*a* concentration for South Skeleton Lake measured 22.3 µg/L and falls under the eutrophic classification (Table 1). Although higher than recent years, this is within the historical variation for the lake, as seen in 1986 when the average was 24.0 µg/L. Chlorophyll-*a* concentration was at a seasonal minimum of 9.32 µg/L on June 7th and a seasonal maximum of 45.60 µg/L on August 31st (Figure 7).

Concentrations of chlorophyll-*a* are notably different between the north and south basins, with the south having almost three times greater concentrations than the north (Table 1). The frequent mixing of the water column at South Skeleton Lake, versus the strong stratification in North Skeleton Lake, likely contributes to this difference.

Average pH measured in 2010 at North and South Skeleton Lakes was 8.71 and 8.80, respectively. Both lakes have pH levels well above neutral (7.00; Table 1). Ion concentrations in both basins of Skeleton Lake are quite low, with the dominant ions being magnesium, calcium, and bicarbonate. Since the first measurement in 1985, there is no obvious pattern with regard to ion concentration change. Metals were measured twice in both basins in 2010 and all concentrations fell within their respective guidelines (Table 2).

Table 1. Average secchi depth and water quality variables for North and South Skeleton Lake basins collected in 2010. Data collected in earlier years is shown for comparison.

	North Skeleton Lake				South Skeleton Lake						
Parameter	**1985**	**1986**	**2005**	**2010**	**1985**	**1986**	**2005**	**2006**	**2008**	**2009**	**2010**
TP (µg/L)	/	36	33	48	/	47	29	41	45	40	58
TDP (µg/L)	/	10	11	16	/	11	8.4	12.5	13.4	13.5	14.8
Chlorophyll-*a* (µg/L)	9.2	11	11	8.6	16	24	12	17	19.3	12.4	22.3
Secchi depth (m)	2.5	2.5	2.6	1.8	2	1.6	2.3	1.4	1.7	1.6	1.4
TKN (µg/L)	1160	1140	1300	1612	1139	1318	1158	1290	1324	1135	1564
NO_2 and NO_3 (µg/L)	<3	<4	4	5.2	<3	<3	6.8	<5	<5	12.5	24.8
NH_3 (µg/L)	21	32	13	83	13	37	14	29	19	26	22
DOC (mg/L)	15	/	17	18.6	14	/	13	/	16.4	14.6	15.8
Ca (mg/L)	23	/	21	23	26	/	22	25	22.8	23.6	21.3
Mg (mg/L)	19	/	24	25.9	19	/	23	23	26.9	24.4	25.1
Na (mg/L)	13	/	18	18.7	14	/	19	20	20.2	21.3	21.7
K (mg/L)	8	/	11	10.8	9	/	11	11	11.5	12.5	11.9
SO_4^{2-} (mg/L)	<5	/	5	6	<5	/	3	6	5	6	2.8
Cl^- (mg/L)	<2	/	3.2	3.4	<2	/	3.1	3.4	3.8	4.2	4.7
CO_3 (mg/L)	<5	/	12	10	<6	/	11	15	13	12.7	13.3
HCO_3 (mg/L)	198	/	204	218	208	/	226	231	223	231	229
pH	8.40-8.80	/	8.8	8.7	8.5-8.8	/	8.7	8.7	8.7	8.8	8.8
Conductivity (µS/cm)	/	/	/	372	/	/	/	389	374	381	391
Hardness (mg/L)	/	/	/	164	/	/	/	158	168	159	157
TDS (mg/L)	172	/	193	205	181	/	204	213	211	218	214
Microcystin (µg /L)	/	/	0.08	0.14	/	/	0.14	0.18	0.24	0.34	0.31
Total Alkalinity (mg/L $CaCO_3$)	170	/	/	195	178	/	226	210	205	211	210

Note: TP = total phosphorous, TDP = total dissolved phosphorous, 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 North and South Skeleton Lake during 2010. Values shown for 2010 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.

	South			North	
Metals (Total Recoverable)	**2008**	**2009**	**2010**	**2010**	**Guidelines**
Aluminum µg/L	24.1	12.8	22.95	26.04	100
Antimony µg/L	0.033	0.032	0.03335	0.03635	6
Arsenic µg/L	1.01	0.983	1.065	0.8565	5
Barium µg/L	55.8	57.3	55.55	48.95	1000
Beryllium µg/L	0.0045	<0.003	0.0015	0.00585	100
Bismuth µg/L	0.0036	0.004	0.002	0.00195	/
Boron µg/L	102.5	109.6	97	122.5	5000
Cadmium µg/L	<0.002	0.0023	0.00695	0.0057	0.085
Chromium µg/L	0.115	0.188	0.1395	0.242	/
Cobalt µg/L	0.023	0.0203	0.01325	0.01845	1000
Copper µg/L	0.171	0.27	0.1303	0.1633	4
Iron µg/L	49.2	70.4	41	7.73	300
Lead µg/L	0.0285	0.0283	0.02505	0.0151	7
Lithium µg/L	30.6	36.1	28.05	31.7	2500
Manganese µg/L	44.5	62.1	49.75	35.4	200
Molybdenum µg/L	0.103	0.114	0.09395	0.0627	73
Nickel µg/L	<0.005	0.204	0.0025	0.0025	150
Selenium µg/L	0.144	0.12	0.076	0.05	1
Silver µg/L	0.0036	0.0069	0.00255	0.0013	0.1
Strontium µg/L	185	185	188	176	/
Thallium µg/L	0.00115	0.00185	0.001	0.000725	0.8
Thorium µg/L	0.0093	0.0017	0.0096	0.008025	/
Tin µg/L	0.0483	<0.03	0.03015	0.015	/
Titanium µg/L	1.21	0.762	0.904	0.336	/
Uranium µg/L	0.121	0.11	0.1145	0.1965	100
Vanadium µg/L	0.207	0.208	0.2095	0.214	100
Zinc µg/L	0.373	0.996	0.5025	0.3085	30

Values represent means of total recoverable metal concentrations.

[a] Based on pH ≥ 6.5; calcium ion concentrations $[Ca^{+2}] \geq 4.0$ mg/L; and dissolved organic carbon concentration [DOC] ≥ 2.0 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

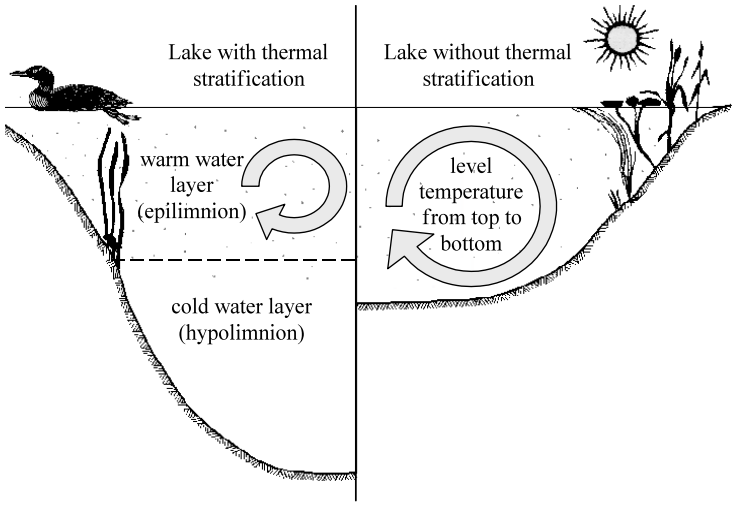

Figure A: Difference in the circulation of the water column depending on thermal stratification.

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.

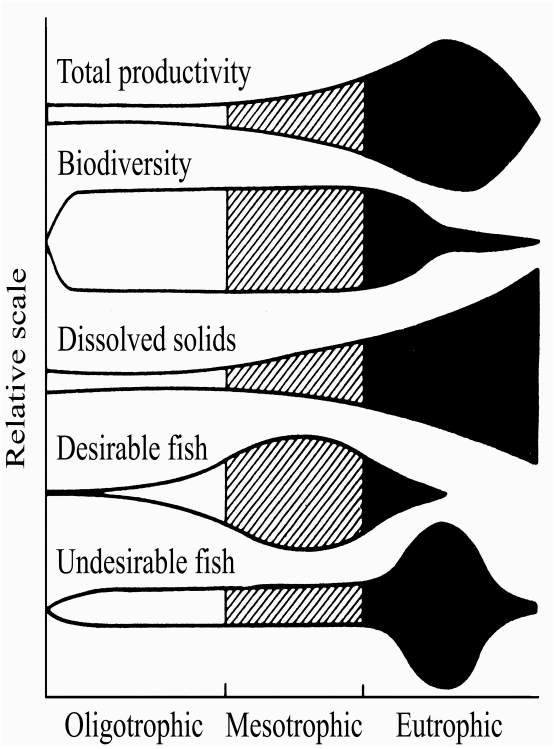

Figure B: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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

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

Note: These values are from a detailed study of global lakes reported in Nurnberg 1996. Alberta Environment uses slightly different values for TP and CHL based on those of the OECD reported by Vollenweider (1982). The AENV and OECD cutoffs for TP are 10, 35 and 100; for CHL are 3, 8 and 25. AENV does not have TN or Secchi depth criteria. The corresponding OECD exists for Secchi depth and the cutoffs are 6, 3 and 1.5 m.