THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2015 Skeleton Lake Report

LAKEWATCH IS MADE POSSIBLE 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.

This report has been published before the completion of the data validation process.

Acknowledgements

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 *Cîpay Sâkâhikan,* which means "place of the skeletons". It is thought that a Cree chief is buried along the shores of the lake.[1]

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. Skeleton Lake used to be the main source of drinking water for the Town of Boyle but has received its drinking water from the Athabasca River since 2007.

The watershed is located in the Dry Mixedwood subregion of the Boreal Mixedwood natural region.[2] Several small intermittent streams flow into the lake and drain a watershed that is four times the size of the lake.[3] 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.
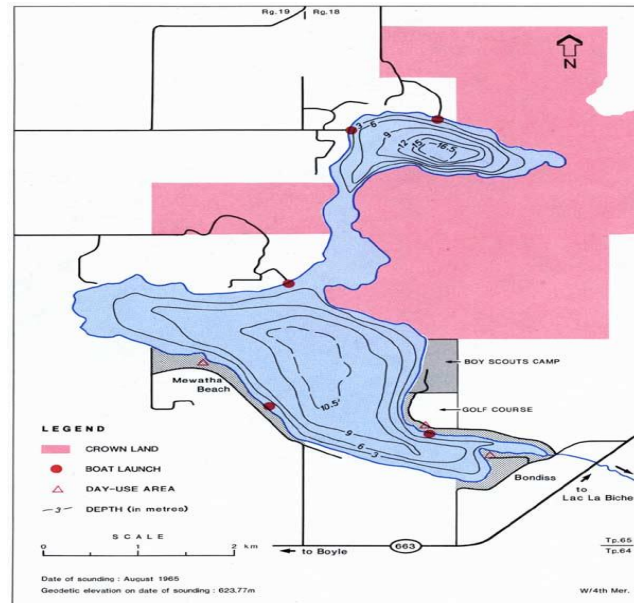
Figure 1 – Bathymetric map of Skeleton Lake obtained from Alberta Environment.

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

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[1] Aubrey, M. K. 2006. Concise place names of Alberta. Retrieved from http://www.albertasource.ca/placenames/resources/searchcontent.php?book=1

[2] Strong, W.L. and K.R. Leggat. 1981. Ecoregions of Alberta. Alta. En. Nat. Resour., Resour. Eval. Plan. Div., Edmonton.

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

Skeleton Lake is divided into two basins. The North basin (Figure 2) is nearly entirely 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 relatively 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.[3] The average concentrations of algae in the South basin are higher than in the North basin. Because the basins are almost disconnected and the morphology and water quality characteristics of the two basins differ, the water quality of the North and South basins are monitored separately. The results for both basins are presented in this report.

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.

Water levels in Skeleton Lake have been monitored in the south basin 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 m since the 1970s, with the exception of 1997, an extremely wet period, during which the water level increased to a historical maximum of 623.9 meters above sea level (m asl). In recent years, water levels in Skeleton Lake have declined to a historical minimum of 621.666 m asl in 2016. Declining water levels are a major stakeholder concern for this lake. In 2011, monitoring of water levels by Alberta Environment and Parks began in the North basin of Skeleton Lake.
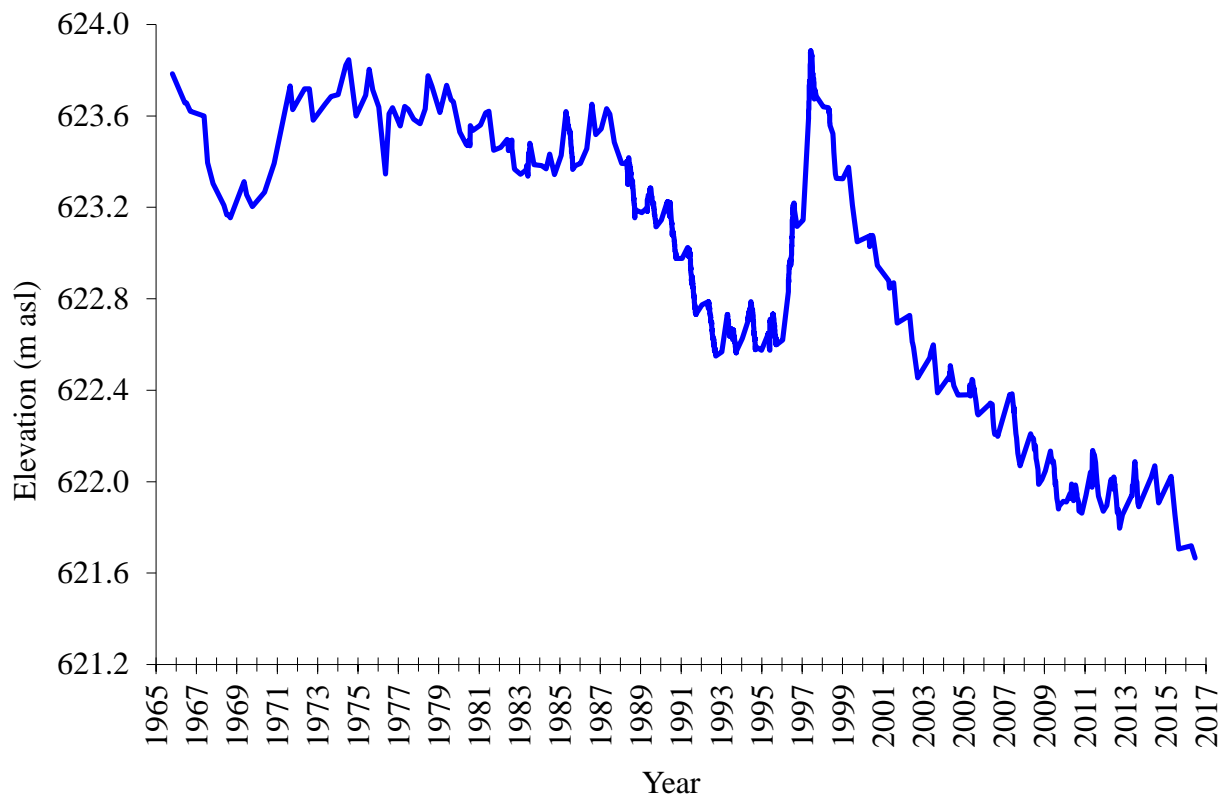
Figure 3 – Water levels at Skeleton Lake (south basin) measured in meters above sea level (m asl). Data obtained from Alberta Environment and Parks.

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.

North: Average Secchi disk depth measured 2.00 m in 2015 (Table. This average was comprised of a season minimum of 1.25 m on June 4th and a maximum of 2.75 m on July 3rd. Unlike other lakes across the province, Skeleton Lake North experienced its highest chlorophyll-*a* concentrations in June and September, which helps to explain why water clarity was highest in July and August. Compared to historical variation observed in the North basin of Skeleton Lake, an average of 2.00 m falls on the low end of Skeleton Lake North's historical observations.

Figure 4 – Secchi depth values measured five times over the course of the summer at Skeleton Lake North in 2015.

South: In 2015, only three samples were collected from the South basin of Skeleton Lake due to scheduling complications. This has resulted in an average Secchi disk depth (2.50 m) which is likely skewed high compared to historical data.
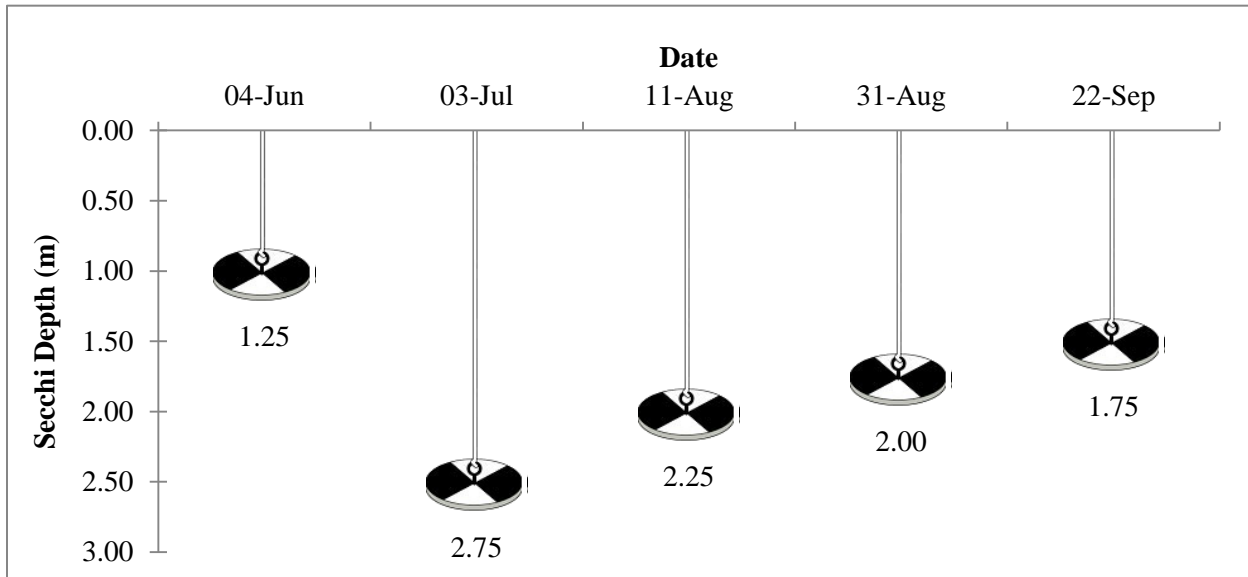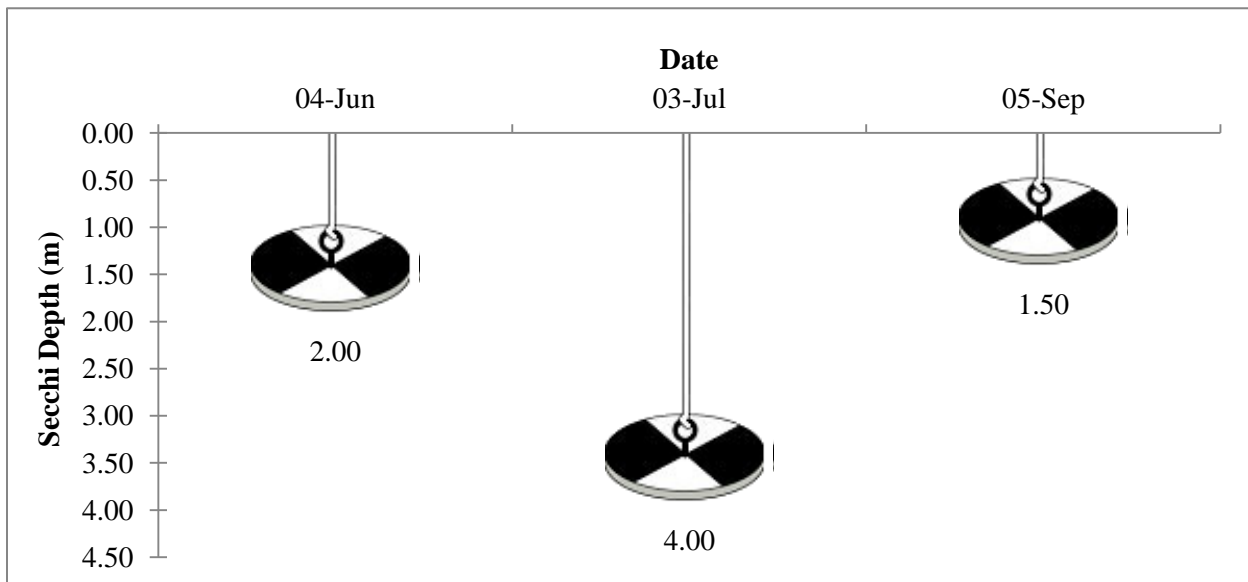

Figure 4 – Secchi depth values measured five times over the course of the summer at Skeleton Lake South in 2015.

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: The north basin of Skeleton Lake reached a maximum observed temperature of 23.29 degC. Due to the depth of the north basin, temperature dropped quickly in the water column, regularly measuring ~6 degC at the lakebed. The north basin of Skeleton Lake remained stratified throughout the summer, beginning as early as 3 m on July 3rd and as deep as 8.5 m on September 22nd. In late September, the temperature of the entire water column dropped dramatically, measuring only 12.93 degC at the surface.

South: Weak thermal stratification was observed on June 4th beginning at 5.5 m. On subsequent sampling trips, thermal stratification was not observed – historical data, however, suggests that the south basin of Skeleton Lake experiences intermittent periods of weak thermal stratification throughout the open-water season.
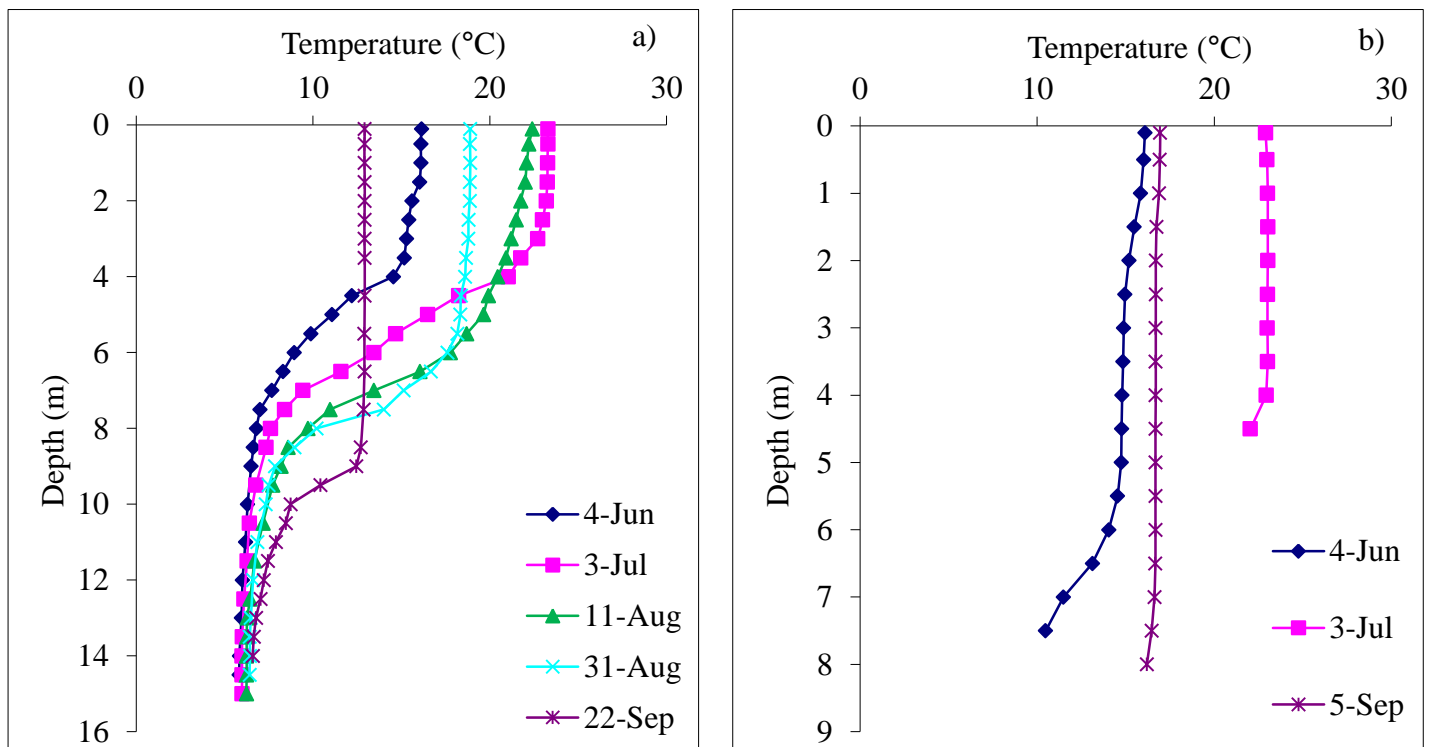
Figure 6 – Temperature profiles from the North a) and South basins b) of Skeleton Lake.

North: While the north basin of Skeleton Lake was well oxygenated at the surface, regularly measuring above the Canadian Council for Ministers of the Environment guideline for the Protection of Aquatic Life of 6.5 mg/L, dissolved oxygen concentrations dropped dramatically at the thermocline. Anoxia was observed as early as 8 m on August 11th and present at the lakebed on each sampling trip. Isolation from oxygen rich surface waters and the oxygen-consuming process of decomposition contribute to the lack of oxygen in deeper waters. The temperature and oxygen patterns observed in the north basins of Sekelton Lake are not unusual for a small and deep Alberta Lake.

South: Likely due to its intermittent periods of thermal stratification, the south basin of Skeleton Lake did show a decrease in oxygen with depth, particularly near the lakebed. While the surface of the south basin was well oxygenated on both June 4th and July 3rd, on September 5th, nearly the entire water column fell below the Canadian Council for Ministers of the Environment guideline for the Protection of Aquatic Life of 6.5 mg/L. Low concentrations of oxygen near the lake sediments may contribute to the release of phosphorus from the sediments.

Figure 6 – Dissolved oxygen profiles from the north a) and south basins b) of Skeleton Lake.

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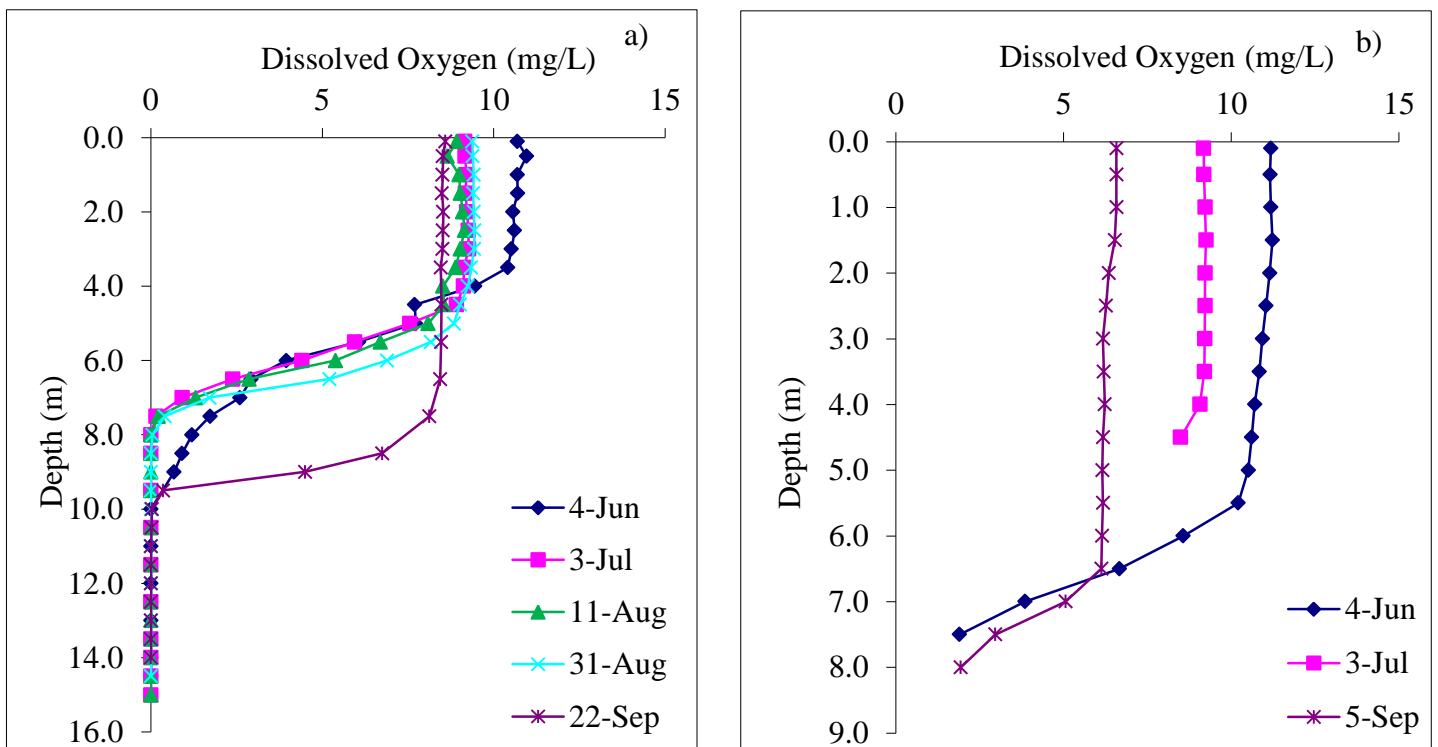 nutrients, which can lead to harmful algal/cyanobacteria blooms. One direct measure of harmful cyanobacteria blooms are Microcystins, a common group of toxins produced by cyanobacteria. See Table 1 for a complete list of parameters.

North: Total phosphorus concentration measured an average of 26 µg/L in 2015 (Table 3). This average falls into the mesotrophic, or moderately productive, trophic classification and lies at the low end of the historical variability previously observed in the north basin of Skeleton Lake. The 2015 average is comprised of a minimum concentration of 17 µg/L on August 11th and a maximum of 40 µg/L on June 4th (Figure 5).

Chlorophyll-*a* concentration showed peaks both early and late in the open-water season in the north basin of Skeleton Lake. On June 4th, chlorophyll-*a* concentration measured 11.6 µg/L, and only one month later, chlorophyll-*a* concentration had decreased to 2.4 µg/L. A seasonal maximum chlorophyll-*a* concentration was then observed on September 22nd measuring 13.5 µg/L. In total, average chlorophyll-*a* concentration measured 7.5 µg/L – this concentration falls on the low end of the historical variability previously observed in the north basin of Skeleton Lake. An average value of 7.5 µg/L falls into the mesotrophic, or moderately productive, classification.

Total Kjeldahl nitrogen (TKN) measured an average of 1.5 mg/L in 2015. This average falls well into the historical variability previously observed in the north basin of Skeleton Lake.
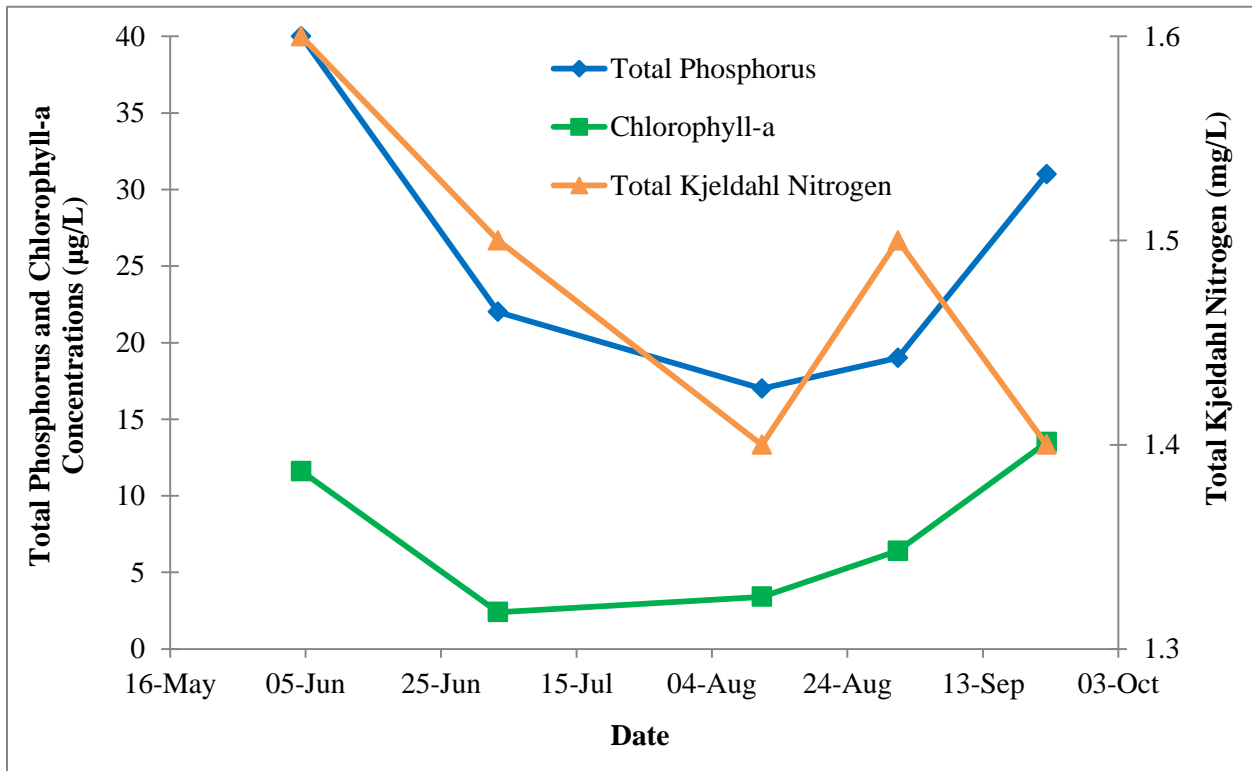
Figure 5 – Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentration measured five times over the course of the summer in the north basin of Skeleton Lake.

South: Due to the frequent mixing of the south basin of Skeleton Lake, nutrients appeared to increase throughout the summer. TP measured an average of 27 µg/L in 2015, though this average is likely skewed low due to the lack of August samples (Table 3).

Samples were not collected during the peak time for chlorophyll-*a* in the south basin of Skeleton Lake. However, a bloom was observed on September 5th, measuring 29 µg/L of chlorophyll-*a*. Field observations suggest there was streaking cyanobacteria along the surface of the lake and significant build-up of cyanobacteria along the shores.

Average TKN measured 1.4 mg/L in the south basin in 2015. TKN does not typically change dramatically throughout the summer in Alberta's lakes.
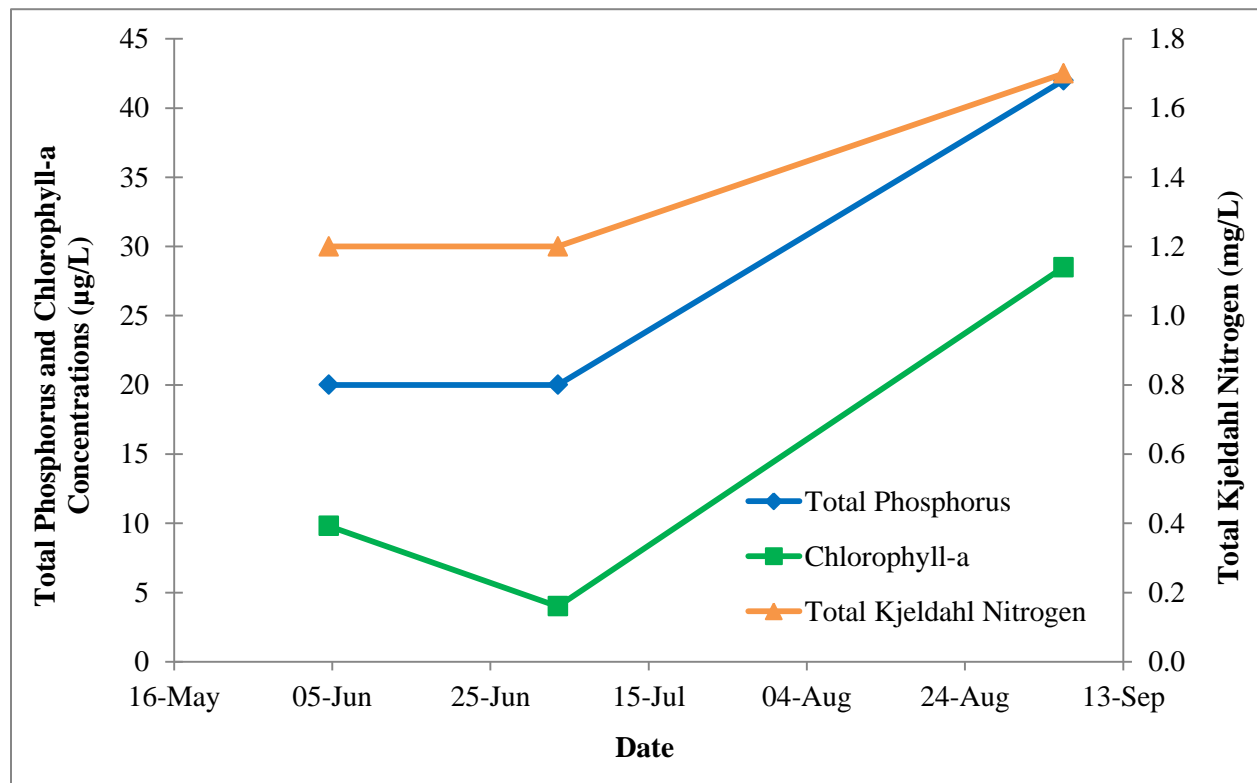
Figure 5 – Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentration measured five times over the course of the summer in the north basin of Skeleton Lake.

North: Average pH in the north basin of Skeleton Lake measured 8.70 which is well above neutral (Table 3). The North basin of Skeleton Lake is buffered against changes to pH due to its alkalinity (204 mg/L $CaCO_3$) and bicarbonate concentrations (228 mg/L HCO_3). Conductivity in the north basin of Skeleton Lake is also moderate, measuring an average of 402 µS/cm in 2015. Conductivity has been increasing over the years at Skeleton Lake, likely due to the concentration of salts increasing with decreasing water levels. Contributing to the north basin's conductivity are the dominant ions of magnesium (26 mg/L), calcium (25 mg/L) and sodium (19 mg/L).

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

South: Average pH in the south basin of Skeleton Lake measured 8.72 which is well above neutral (Table 3). The south basin of Skeleton Lake is buffered against changes to pH due to its alkalinity (220 mg/L $CaCO_3$) and bicarbonate concentrations (243 mg/L HCO_3). Conductivity in the south basin of Skeleton Lake is moderate, measuring an average of 413 µS/cm in 2015. Conductivity has been increasing over the years at Skeleton Lake, likely due to decreasing water levels. Contributing to the south basin's conductivity are the dominant ions of magnesium (26 mg/L), calcium (24 mg/L) and sodium (21 mg/L).

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 2015, no zebra or quagga mussels were detected in Skeleton Lake.

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.

In 2015, concentrations of microcystin were low in both basins of Skeleton Lake (Table 1; Table 2). However, cyanobacteria blooms should always be treated with caution as microcystin is not the only toxin produced by cyanobacteria, and grab sample concentrations may be higher than the composite samples collected by ALMS.

Table 1 – Microcystin concentrations measured in the north basin of Skeleton Lake in 2015.

Date	Microcystin (µg/L)
4-Jun	<0.1
3-Jul	<0.1
11-Aug	<0.1
31-Aug	<0.1
22-Sep	0.16

Table 2 – Microcystin concentrations measured in the south basin of Skeleton Lake in 2015.

Date	Microcystin (µg/L)
4-Jun	0.14
3-Jul	<0.1
5-Sep	0.93

Table 3 - Average Secchi disk depth and water chemistry values for Skeleton Lake. Previous years averages are provided for comparison.

Parameter	South													North								
	1985	1986	2005	2006	2008	2009	2010	2011	2012	2013	2014	2015*		1985	1986	2005	2010	2011	2012	2013	2014	2015
TP (µg/L)	31.4	46.7	28.8	39.8	45.4	40.3	58.8	44.5	40.3	39.6	50.7	27		24.3	36.3	32.7	47.8	44.5	36.0	47.6	25.2	26
TDP (µg/L)	7.8	10.7	8.4	12.6	13.4	13.5	14.8	11.8	11.8	20.2	59.0	9.0		7.8	10.7	11.0	16.0	11.8	14.4	28.2	10.6	11
Chlorophyll-a (µg/L)	14.8	24.2	12.1	15.0	19.3	12.4	22.3	17.2	17.3	12.12	29.8	14.1		9.2	10.7	11.0	8.6	17.2	8.6	7.56	5.76	7.46
Secchi depth (m)	2.00	1.60	2.28	1.60	1.65	1.63	1.40	1.40	1.81	1.59	1.56	2.50		2.50	2.50	2.63	1.75	1.40	2.45	2.35	2.81	2.00
TKN (mg/L)	1.1	1.3	1.2	1.2	1.3	1.1	1.6	1.4	1.4	1.3	1.4	1.4		1.2	1.1	1.3	1.6	1.4	1.5	1.5	1.2	1.5
NO$_2$ and NO$_3$ (µg/L)	2.1	2.8	6.0	14.0	12.7	12.5	24.8	6.0	3.5	2.5	38.0	2.0		2.25	3.67	3.0	4.4	6.0	2.50	2.5	22	2.3
NH$_3$ (µg/L)	13.6	37.2	12.8	27.0	19.2	26.8	22.0	24.3	21.0	21	55.6	25		21.2	32.5	12.7	82.8	24.3	21.2	23.2	33.4	25
DOC (mg/L)	13.6	14.6	14.4	14.9	16.5	14.6	15.8	14.3	14.2	14.3	17.4	16		14.8	14.6	16.6	18.6	14.3	17.8	18.2	18.97	17
Ca (mg/L)	26.3	25.0	23.4	25.5	22.8	23.6	21.3	22.1	25.8	25	21.3	24		23.3	24.3	21.3	23.0	22.1	25.1	24.17	31	25
Mg (mg/L)	19.0	19.0	23.4	23.0	26.9	24.4	25.1	26.7	25.7	25.6	25.8	26		18.7	18.8	23.5	25.9	26.7	25.0	26.9	21.23	26
Na (mg/L)	13.6	13.8	19.2	20.1	20.2	21.3	21.7	19.6	20.9	21.77	24.4	21		13.3	13.5	17.5	18.7	19.6	17.6	18.7	20.8	20
K (mg/L)	8.59	8.64	10.85	11.50	11.50	12.50	11.93	11.60	13.25	17.7	14.1	13		8.43	8.45	10.60	10.77	11.60	11.90	13.5	12.24	13
SO$_4^{2-}$ (mg/L)	2.5	2.5	3.0	3.7	3.0	5.0	2.9	1.5	1.5	4.83	2.2	2.0		2.5	2.5	5.0	6.3	1.5	4.2	7.5	2.17	7.6
Cl$^-$ (mg/L)	1.8	1.4	3.1	3.4	3.8	4.2	4.7	4.4	4.8	4.33	5.3	5.8		1.5	1.3	3.2	3.4	4.4	5.6	5.1	6	6.8
CO$_3$ (mg/L)	4.6	9.0	5.7	9.7	8.8	10.1	9.0	11.8	9.4	16	21.88	13		4.1	10.8	12.0	9.7	11.8	8.7	17.4	9.78	11
HCO$_3$ (mg/L)	208.40	191.62	226.00	232.50	223.67	231.33	229.33	229.25	246.75	227.8	255.2	243		198.08	194.43	204.00	217.67	229.25	226.40	212.8	235.6	228
pH	8.53	8.72	8.66	8.71	8.73	8.76	8.80	8.72	8.64	8.75	8.8	8.72		8.533	8.58	8.79	8.71	8.72	8.67	8.86	8.58	8.70
Conductivity (µS/cm)	333.4	327.2	360.0	389.3	374.3	381.3	390.7	388.0	405.8	410.2	398.0	413		318.3	323.7	334.5	372.3	388.0	388.4	390.4	390	402
Hardness (mg/L)	143.4	140.4	152.0	158.3	168.0	159.0	156.7	165.0	170.0	168	159	167		134.8	138.0	150.0	164.0	165.0	165.7	171	165	170
TDS (mg/L)	181.1	178.1	204.0	213.8	211.3	218.3	214.0	210.0	222.0	230.3	233	227		172.2	174.5	192.5	205.0	210.0	210.0	217.3	214.667	222
Microcystin (µg/L)	/	/	0.148	0.178	0.240	0.340	0.306	0.230	0.218	0.2356	0.402	0.370		/	/	0.078	0.142	0.230	0.169	0.129	0.08	0.08
Total Alkalinity (mg/L CaCO$_3$)	178.2	175.2	202.5	210.0	205.3	211.0	210.3	208.0	218.0	213.6	209.2	220		169.8	171.5	186.5	195.0	208.0	200.0	204	192.6	204

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.
*Based on only three samples.

Table 4 - Concentrations of metals measured at the north and south basins of Skeleton Lake. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference.

Metals (Total Recoverable)	South								North						Guidelines
	2008	2009	2010	2011	2012	2013	2014	2015	2010	2011	2012	2013	2014	2015	
Aluminum µg/L	24.1	12.8	22.95	23.2	7.88	12.655	18.5	/	26.04	13.9	14.75	11.735	10.75	16.2	100[a]
Antimony µg/L	0.033	0.032	0.03335	0.0326	0.0236	0.02795	0.0455	/	0.03635	0.02885	0.0307	0.0326	0.032	0.0315	6[e]
Arsenic µg/L	1.01	0.983	1.065	0.948	0.367	1.0065	1.36	/	0.8565	0.8685	0.574	0.8165	0.7735	0.828	5
Barium µg/L	55.8	57.3	55.55	56.2	44	57.7	45.8	/	48.95	50.85	51.1	49.05	48.5	53.75	1000[e]
Beryllium µg/L	0.0045	<0.003	0.0015	0.0048	0.0015	0.0015	0.004	/	0.00585	0.0052	0.00645	0.0015	0.004	0.004	100[d,f]
Bismuth µg/L	0.0036	0.004	0.002	0.0014	0.0057	0.0038	0.0005	/	0.00195	0.00215	0.0321	0.0143	0.00225	0.00925	/
Boron µg/L	102.5	109.6	97	106	87.2	100.9	94.75	/	122.5	105.5	104.85	93.5	97.05	94.3	5000[ef]
Cadmium µg/L	<0.002	0.0023	0.00695	0.0045	0.0035	0.0024	0.008	/	0.0057	0.001	0.001	0.001	0.002	0.002	0.085[b]
Chromium µg/L	0.115	0.188	0.1395	0.15	0.106	0.196	0.215	/	0.242	0.0765	0.1535	0.28	0.105	0.075	/
Cobalt µg/L	0.023	0.0203	0.01325	0.0171	0.0084	0.0285	0.022	/	0.01845	0.01115	0.00955	0.02615	0.007	0.0185	1000[f]
Copper µg/L	0.171	0.27	0.1303	0.181	0.508	0.1805	0.535	/	0.1633	0.154	0.3698	0.1402	0.13	0.175	4[c]
Iron µg/L	49.2	70.4	41	53.4	48.5	40.2	13.45	/	7.73	3.59	7.2	21.95	2.875	7.5	300
Lead µg/L	0.0285	0.0283	0.02505	0.0327	0.0126	0.02665	0.0265	/	0.0151	0.0137	0.01055	0.0168	0.0135	0.0275	7[c]
Lithium µg/L	30.6	36.1	28.05	33.2	21.9	29.15	39.7	/	31.7	33	28.1	26.65	27.95	28.7	2500[g]
Manganese µg/L	44.5	62.1	49.75	58.1	40.3	50.15	34.15	/	35.4	43.9	29	16.05	12.55	31.55	200[g]
Molybdenum µg/L	0.103	0.114	0.09395	0.103	0.0643	0.0823	0.087	/	0.0627	0.05335	0.02955	0.03915	0.037	0.041	73[d]
Nickel µg/L	<0.005	0.204	0.0025	0.0025	0.0025	0.16175	0.0595	/	0.0025	0.0025	0.0025	0.05425	0.004	0.004	150[c]
Selenium µg/L	0.144	0.12	0.076	0.138	0.05	0.05	0.07	/	0.05	0.096	0.05	0.082	0.03	0.03	1
Silver µg/L	0.0036	0.0069	0.00255	0.00025	0.0022	0.02725	0.001	/	0.0013	0.003175	0.001525	0.007125	0.001	0.001	0.1
Strontium µg/L	185	185	188	186	134	197.5	208.5	/	176	187	166	180	180	194.5	/
Thallium µg/L	0.00115	0.00185	0.001	0.001	0.00015	0.000365	0.00068	/	0.000725	0.0006	0.001225	0.0004	0.00045	0.0104	0.8
Thorium µg/L	0.0093	0.0017	0.0096	0.0066	0.0084	0.00655	0.00563	/	0.008025	0.00625	0.0313	0.01075	0.001175	0.00045	/
Tin µg/L	0.0483	<0.03	0.03015	0.015	0.0327	0.015	0.0195	/	0.015	0.015	0.38175	0.0377	0.0065	0.026	/
Titanium µg/L	1.21	0.762	0.904	1.1	0.26	1.43	0.985	/	0.336	0.676	0.2735	0.7785	0.2025	0.73	/
Uranium µg/L	0.121	0.11	0.1145	0.12	0.0612	0.09055	0.196	/	0.1965	0.202	0.18	0.1995	0.211	0.205	100[e]
Vanadium µg/L	0.207	0.208	0.2095	0.217	0.101	0.145	0.265	/	0.214	0.1855	0.2035	0.1865	0.19	0.19	100[f,g]
Zinc µg/L	0.373	0.996	0.5025	0.399	0.361	0.346	1.3	/	0.3085	0.41	0.4175	0.2805	0.55	0.25	30

Values represent means of total recoverable metal concentrations.
[a] Based on pH $\geq$ 6.5; calcium ion concentrations $[Ca^{+2}] \geq$ 4 mg/L; and dissolved organic carbon concentration $[DOC] \geq$ 2 mg/L.
[b] Based on water Hardness of 300 mg/L (as $CaCO_3$)
[c] Based on water hardness > 180mg/L (as $CaCO_3$)
[d] CCME interim value.
[e] Based on Canadian Drinking Water Quality guideline values.
[f] Based on CCME Guidelines for Agricultural use (Livestock Watering).
[g] Based on CCME Guidelines for Agricultural Use (Irrigation).
A forward slash (/) indicates an absence of data or guidelines.

A BRIEF INTRODUCTION TO LIMNOLOGY

INDICATORS OF WATER QUALITY:

Water samples are collected in LakeWatch to determine the chemical characteristics that characterize general water quality. Though not all encompassing, the variables collected in LakeWatch are sensitive to human activities in watersheds that can cause degraded water quality. For example, nutrients such as phosphorus and nitrogen are important determinants of lake productivity. The concentrations of these nutrients in a lake are impacted (typically elevated) by land use changes such as increased crop production or livestock grazing. Elevated nutrient concentrations can cause increases in undesirable algae blooms resulting in low dissolved oxygen concentrations, degraded habitat for fish and noxious smells. A large increase in nutrients over time may also indicate sewage inputs which in turn may result in other human health concerns associated with bacteria or the protozoan *Cryptosporidium.*

TEMPERATURE AND MIXING:

Water temperature in a lake dictates the behavior of many chemical parameters responsible for water quality. Heat is transferred to a lake at its surface and slowly moves downward depending on water circulation in the lake. Lakes with a large surface area or a small volume tend to have greater mixing due to wind. In deeper lakes, circulation is not strong enough to move warm water to depths typically greater than 4 or 5 m and as a result cooler denser water remains at the bottom of
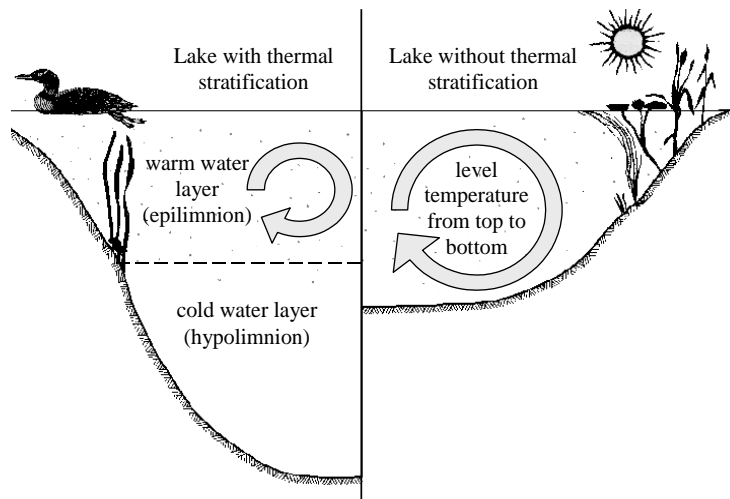

Figure A: Difference in the circulation of the water column depending on thermal stratification.

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•L^{-1} and should not average less than 6.5 mg•L^{-1} over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 mg•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.
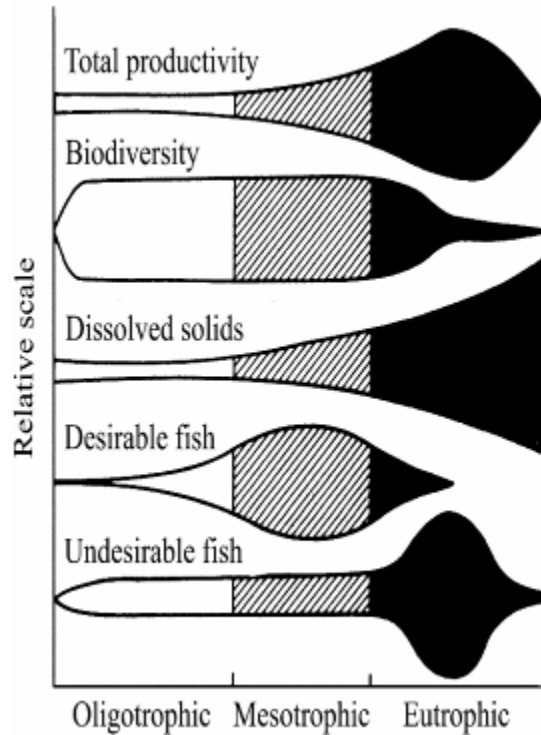

Figure B: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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