Lakewatch

THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2010 Crane 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 Bill Lasecki for his dedication to data collection at Crane 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.

CRANE LAKE:

Crane Lake was originally named Moore Lake, after Dr. Bromley Moore, a former president of the College of Physicians and surgeons and a friend of the surveyor Marshall Hopkins. Moore Lake is locally referred to as Crane Lake.

Crane Lake is a medium sized (surface area = 9.28 km^2) and deep (max depth = 26 m, mean depth = 8.3 m) water body located in the Beaver River Watershed (Figure 1, 2). Crane Lake is located in Alberta's Lakeland Region, and is valued for its clear water and natural shoreline. The lake is situated about 280 km northeast of Edmonton in the municipal district of Bonnyville. The town of Bonnyville, south of the lake, and Cold Lake, east of the lake, are the principal urban centers of the area.

Figure 1 – Crane Lake 2011. Photo by Pauline Pozsonyi.

Most of Crane Lake's shoreline is Crown Land. Two former Provincial Areas, Crane Lake East and West, have been disestablished and divested to the Municipal District of Bonnyville. There are two commercial resorts on the south shore.

Crane Lake is a headwater lake with a small drainage basin that is only four times the size of the lake. The only inlets are two minor streams: one on the northeast shore and one on the west shore.

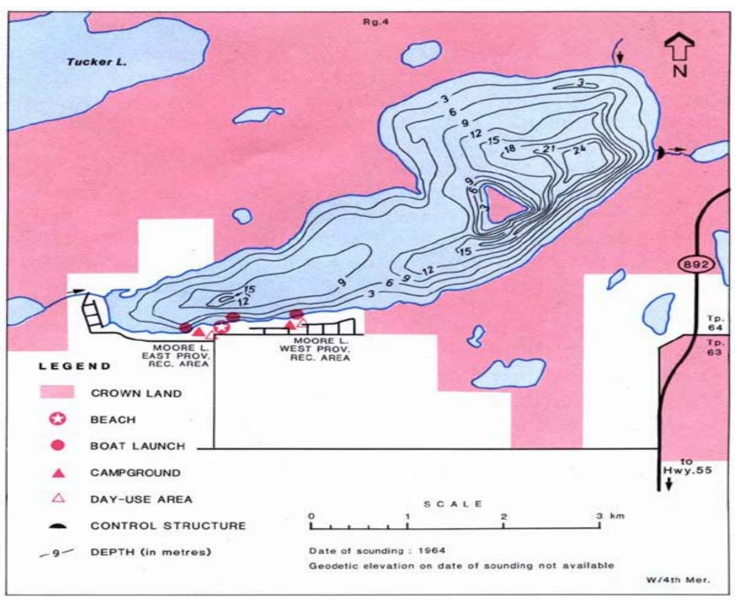

Figure 2. Bathymetry and shoreline features of Moore Lake.
BATHYMETRY SOURCE: Alta. Envir. n.d.[c].

The outlet flows from the east shore into nearby Hilda and Ethel Lakes and eventually into the Beaver River. The eastern basin slopes quite steeply to a maximum depth of 26.0 m northeast of the island. The western basin, with a maximum depth of 15.0 m, is relatively shallow. Its deepest locations are south of the island and north of the campsites. The lake basin drops off very steeply southeast of Doris Island. Sport fish species in the lake are walleye, northern pike, yellow perch, and lake whitefish. Significant growth of aquatic vegetation is limited only to a few areas, such as in the west basin; the lack of extensive vegetation limits fish spawning and feeding habitat in the lake.

Crane Lake is located in the rolling morainal plain in the dry-mixedwood natural subregion of the Boreal Forest natural region (Natural Regions Committee 2006). The main tree species in the watershed include jack pine on well-drained soils, trembling aspen on moderately drained soils, and black spruce and willows on poorly drained soils. Large wetlands are located along the two inflows at the south end of the lake. Agricultural activity in the drainage basin is limited by undesireable soil structure and a relatively short growing season. Most of the cultivated land is located south of the lake. The main agricultural activity is cattle grazing and a limited number of grazing permits and leases have been issued for Crown land in the drainage basin.

WATER LEVELS:

Water levels in Crane Lake have shown a general trend towards decline since sampling began in 1980. Periods of high surface run-off have offered temporary reprieve from declining levels, namely in 1997 when a maximum of 549.7 meters above sea level (m asl) was reached, and in 2007, when the lake was restored to 549.5 m asl. Water levels in 2010 increased from the previous year to 549.4 m asl, and are likely to increase further given the high run-off seen in 2011.

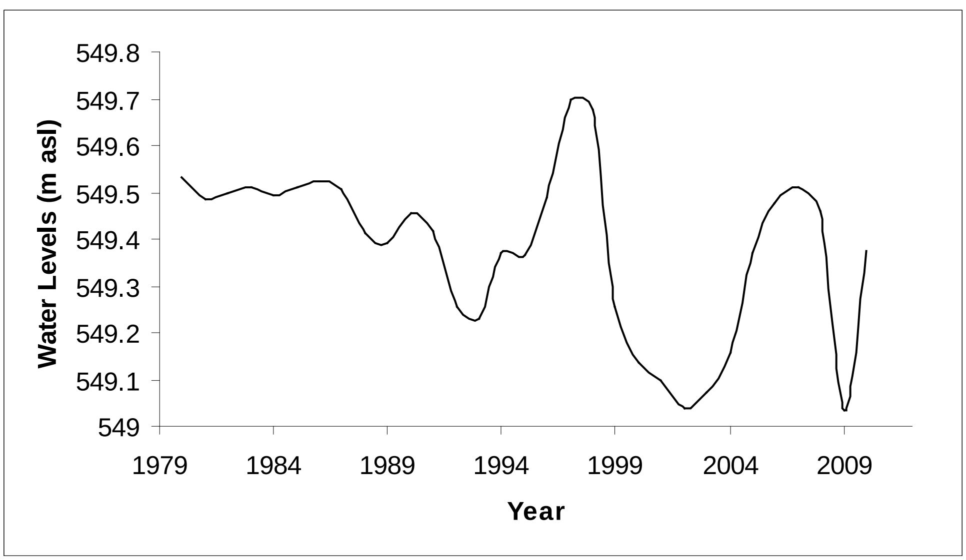

Figure 3 – Water levels for Crane Lake in meters above sea level (m asl). Data obtained from Environment Canada.

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.

Water clarity at Crane Lake is quite good in comparison to other lakes in the region. Though secchi disc depth was only measured three times from July 8th to August 20th (generally the period of lowest water clarity due to algal blooms), average secchi depth was still 3.75 m (Table 1). Secchi depth was at a maximum of 4.75 m on July 8th and a minimum of 3.25 m on August 20th. Compared to previous years, an average secchi depth of 3.75 m is well within the natural variation of the lake, though probably skewed towards a lower value due to the absence of measurements in June and September.

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.

Water temperature at Crane Lake changed very little during the short period of monitoring in 2010 (Figure 4a). Surface water temperature on July 8th measured 18.63 °C, with stratification present between 7.0-11.0 m. At the lakebed, water temperature had decreased to 6.08 °C. On August 5th, surface water temperature had increased to 21.49 °C, with stratification present between 7.0-11.5 m, and a final bottom temperature of 7.29 °C. Finally, on August 20th, surface water temperature decreased slightly to 19.64 °C, with stratification being pushed deeper to 9.5-12.5 m. At the lakebed, water temperature was 8.13 °C.

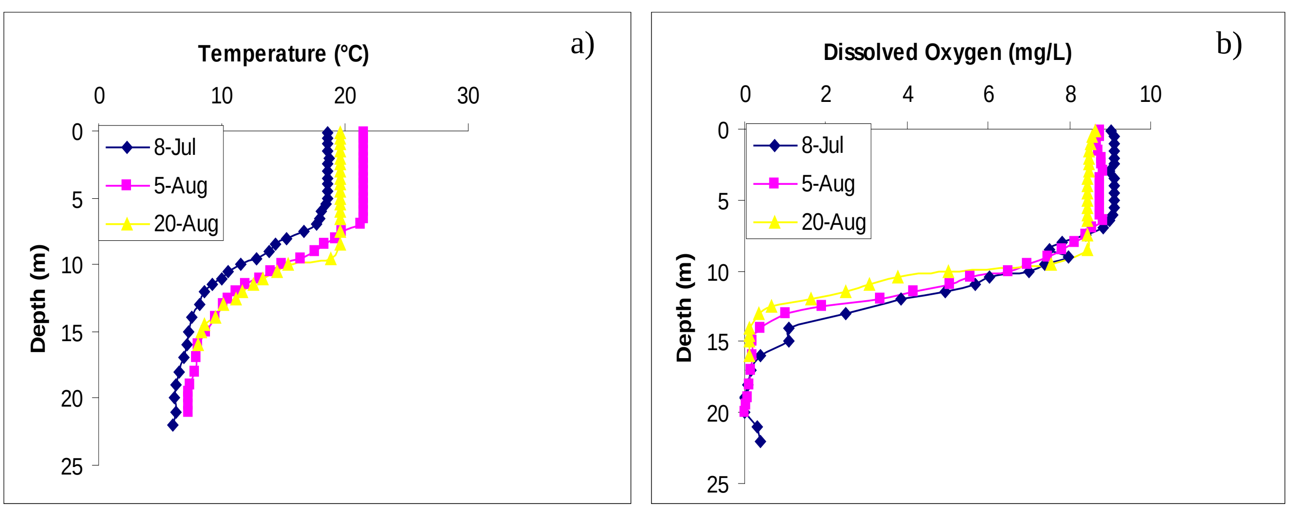

Figure 4 – a) Water temperature (°C) and b) dissolved oxygen (mg/L) profiles for Crane Lake measured three times during the summer of 2010.

Dissolved oxygen at Crane Lake also changed very little over the course of sampling (Figure 4b). On July 8th, surface dissolved oxygen measured 9.04 mg/L, decreasing steadily to anoxia by 14.0 m. Because Crane Lake is so deep, it is difficult for the wind to mix oxygen-rich surface waters to deeper depths. This, coupled with the oxygen-consuming decomposition that occurs on the lakebed, result in anoxic conditions at deeper depths. On August 5th, dissolved oxygen measured 8.74 mg/L at the surface and again decreased steadily to anoxia at ~13.0 m. Finally, on August 20th, surface dissolved oxygen was 8.64 mg/L and anoxic conditions began around 12.5 m. Though anoxia was present in the bottom waters, the water column at Crane Lake was well oxygenated for often more than half its depth.

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 total average phosphorous measured in 2010 (28.67 μg/L) (Table 1), Crane Lake would be considered mesotrophic, or moderately productive. Total phosphorous changed dramatically in the summer of 2010, measuring 23 μg/L on July 8th, 42 μg/L on August 5th, and 21 μg/L on August 20th (Figure 5). Compared to previous years (Table 1), the average total phosphorous falls on the high end of Crane Lakes natural variation, likely because data was only collected from July and August. When water over the bottom sediments is anoxic, as seen in July and August of 2010, phosphorus is released from the sediments into the overlying water. Unlike phosphorous, total Kjeldahl nitrogen showed little change during sampling, measuring a maximum of 0.97 mg/L on July 8th, and a minimum of 0.94 mg/L on August 20th (Figure 5). Based on historical averages, an average total nitrogen of 0.96 mg/L is typical for Crane Lake (Table 1). Finally, average chlorophyll-*a* at Crane Lake in 2010 was 2.31 μg/L (Table 1). A value of 2.31 μg/L falls within the oligotrophic classification, meaning low productivity, and is typical of Crane Lake during the past decade. A seasonal maximum of 2.76 μg/L was recorded on July 8th, and a seasonal minimum of 1.64 μg/L was measured on August 5th (Figure 5).

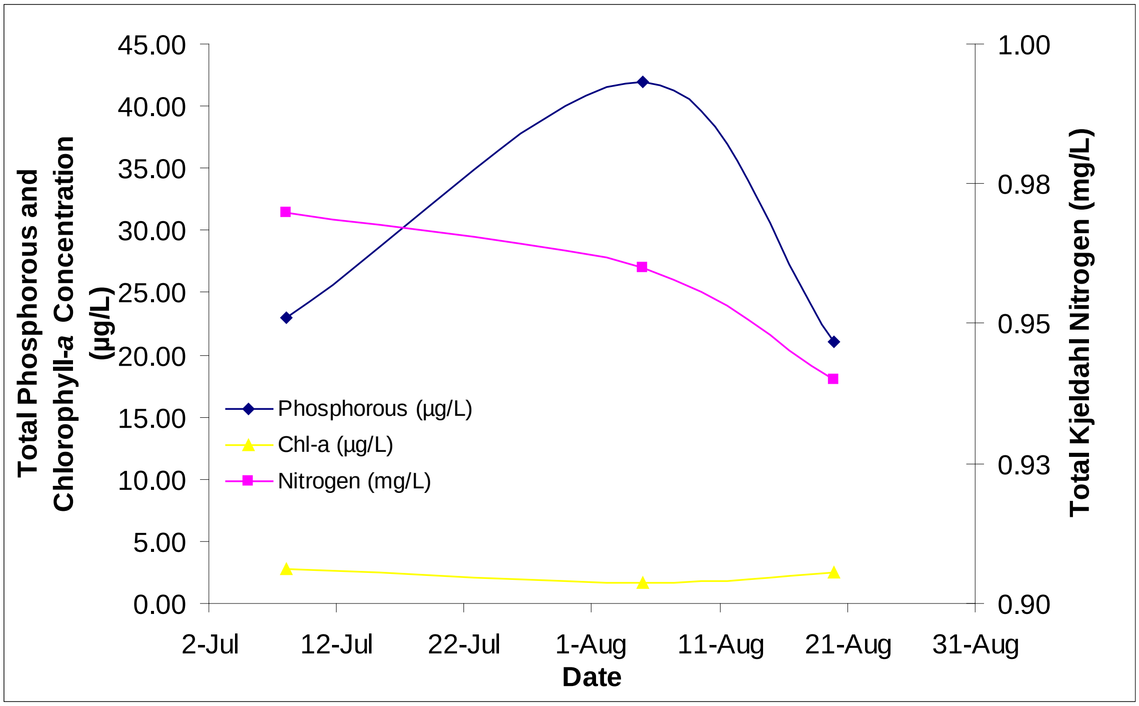

Figure 5 – Total phosphorous (µg/L), chlorophyll-*a* (µg/L) and total Kjeldahl nitrogen (mg/L) measured three times at Crane Lake during the summer of 2010

The average pH at Crane Lake in 2010 was 8.9 (Table 1), well above that of pure water (7.0). As a hard water lake, Crane Lake is well buffered against changes to pH due to high alkalinity (456 mg/L $CaCO_3$). The total dissolved solids concentration is moderately high for a freshwater lake. The dominant cation in Moore Lake is sodium, whereas in most other lakes in the area it is calcium. Because the ionic composition of groundwater in the immediate area is similar to the composition of Moore Lake water, it is likely that Moore Lake has substantial groundwater inflow (Mitchell and Prepas 1990). Dominant ions in Crane Lake include bicarbonate, sodium, magnesium, and carbonate. Concentrations of many ions have increased throughout the years, potentially due to increased input from groundwater and a reduction in water levels due to decreased surface runoff. Metals were also sampled for at Crane Lake, and all concentrations fell within their respective guidelines (Table 2).

Table 1 – Average secchi depth and water chemistry values for Crane Lake. Previous years are provided for comparison.

Parameter	**1980**	**1981**	**1997**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
TP (μg/L)	/	26.8	23.0	20.0	23.2	22.8	22.5	19.3	28.7
TDP (μg/L)	/	11.0	10.0	10.0	10.8	10.8	12.3	11.5	11.3
Chlorophyll-*a* (μg/L)	7.90	8.20	7.00	7.00	4.77	3.90	2.45	2.28	2.31
Secchi depth (m)	2.7	3.3	3.5	3.2	2.9	2.8	4.0	3.8	3.8
TKN (μg/L)	1.24	0.94	0.97	0.99	0.98	0.85	0.93	0.75	0.96
NO_2 and NO_3 (μg/L)	5	3	8	6	7.8	<5	<5	7	3.67
NH_3 (μg/L)	29	22	7	10	14	13.5	9.75	15	15.3
DOC (mg/L)	14.5	13.8	/	13.7	13.7	13.9	13.4	13.8	13.2
Ca (mg/L)	16.6	16.7	15.7	13.7	15.2	15.4	15.4	14.7	12.7
Mg (mg/L)	41	39.8	48	41.8	47.7	49.3	50.4	47.2	51.4
Na (mg/L)	89	81	116	125	112.2	123.7	124.3	125.3	133.3
K (mg/L)	6.6	7.7	7.8	8.1	8.2	8.4	8.13	8.27	7.83
SO_4^{2-} (mg/L)	18.0	20.5	27.9	24.0	28.0	25.7	29.7	34.7	26.7
Cl^- (mg/L)	20.7	21.0	26.2	29.3	29.7	30.4	30.3	30.6	30.8
CO_3 (mg/L)	/	/	39.0	41.0	40.5	43.3	42.7	42.3	37
HCO_3 (mg/L)	/	/	415	457	459	461	469	467	480
pH	8.7	8.5	8.9	8.9	8.9	8.9	8.9	8.9	8.9
Conductivity (μS/cm)	724	704	822	842	873	862	868	867	893
Hardness (mg/L)	/	/	233	240	234	240	246	231	243
TDS (mg/L)	405	/	482	509	507	523	532	533	563
Microcystin (μg/L)	/	/	/	0.16	0.39	0.17	0.10	0.13	0.09
Total Alkalinity (mg/L $CaCO_3$)	354	356	400	443	444	450	455	454	456

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 – Average concentration of metals measured in Crane Lake on August 5th and August 20th 2010. Average metal concentrations from 2005 to 2009 also shown for comparison. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference.

Metals (Total Recoverable)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Guidelines**
Aluminum µg/L	2.1	9.07	5.36	8.86	7.95	4.365	100[a]
Antimony µg/L	0.03	0.03	0.029	0.0423	0.0308	0.0308	6[e]
Arsenic µg/L	4.27	3.02	3.66	4.48	3.67	3.06	5
Barium µg/L	13.4	14.4	14.4	13.8	14	13.25	1000[e]
Beryllium µg/L	0.003	0.003	<0.003	<0.003	<0.003	0.00475	100[d,f]
Bismuth µg/L	0.0005	0.001	0.002	0.004	0.0019	0.0005	/
Boron µg/L	255	327	276	289	310.5	300.5	5000[e,f]
Cadmium µg/L	0.01	0.005	0.01	0.0131	0.0117	0.0129	0.085[b]
Chromium µg/L	0.24	0.359	0.217	0.405	0.472	0.1824	/
Cobalt µg/L	0.01	0.025	0.013	0.015	0.0203	0.0089	1000[f]
Copper µg/L	0.25	0.38	0.238	1.31	0.294	0.24	4[c]
Fluoride (mg/L)	0.22	/	/	/	/	/	1.5
Iron µg/L	6.5	6	6.81	8.8	19.9	5.175	300
Lead µg/L	0.05	0.066	0.1	0.0345	0.0132	0.01405	7[c]
Lithium µg/L	65.7	72.5	61.8	62.1	73.1	66.05	2500[g]
Manganese µg/L	1.8	1.7	2.45	1.87	1.32	1.36	200[g]
Molybdenum µg/L	3.19	3.59	3.15	3.23	3	2.9	73[d]
Nickel µg/L	0.01	0.092	0.064	<0.005	0.132	0.06375	150[c]
Selenium µg/L	0.19	0.52	0.416	0.721	0.433	0.364	1
Silver µg/L	0.001	0.001	<0.0005	0.0014	0.0038	0.000875	0.1
Strontium µg/L	68	75.2	73.8	69	69.9	69.2	/
Thallium µg/L	0	0.01	0.002	0.0018	0.0031	0.00125	0.8
Thorium µg/L	0.004	0.006	0.018	0.0197	0.0008	0.005075	/
Tin µg/L	0.02	0.03	<0.03	<0.03	<0.03	0.015	/
Titanium µg/L	0.61	0.79	0.07	0.744	0.574	0.5875	/
Uranium µg/L	0.19	0.21	0.206	0.208	0.179	0.1815	100[e]
Vanadium µg/L	0.15	0.25	0.21	0.235	0.268	0.181	100[f,g]
Zinc µg/L	2.08	2.5	0.751	0.362	0.329	0.66	30

Values represent means of total recoverable metal concentrations.

[a] Based on pH ≥ 6.5; calcium ion concentrations $[Ca^{+2}]$ ≥ 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.

References Cited

Natural Regions Committee 2006. Natural Regions and Subregions of Alberta. Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta. Pub. No. T/852. Online at http://www.tpr.alberta.ca/parks/heritageinfocentre/docs/NRSRcomplete%20May_06.pdf

Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes. University of Alberta Press. Online at: http://sunsite.ualberta.ca/Projects/Alberta-Lakes/

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:

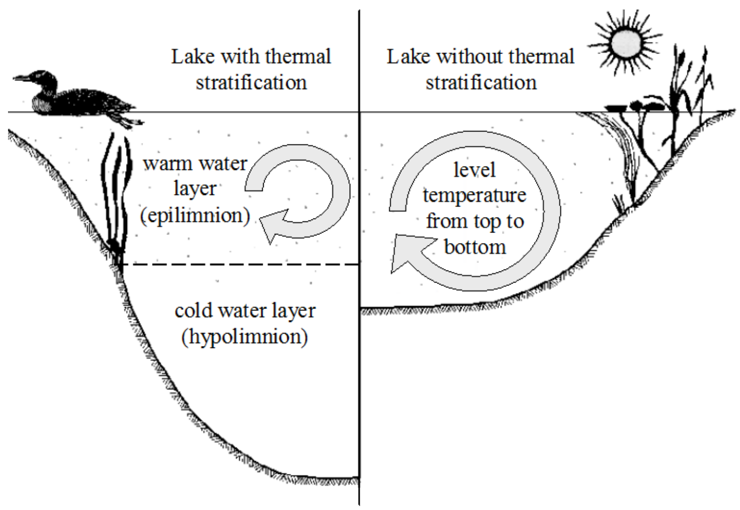

Figure A: Difference in the circulation of the water column depending on thermal stratification.

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.

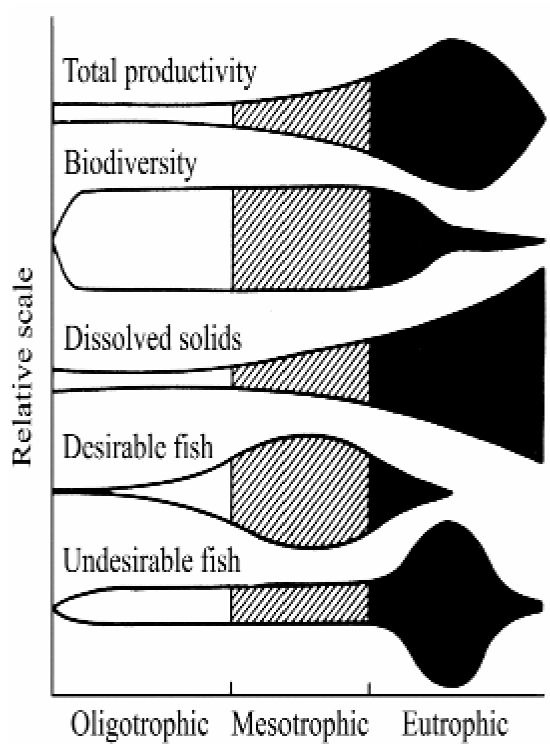

Figure B: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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

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.