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Lakewatch

PINE LAKE (2003)

The Alberta Lake Management Society
Volunteer Lake monitoring report

And you really live by the river? What a jolly life!"

"By it and with it and on it and in it," said the Rat. "It's brother and sister to me. What it hasn't got is not worth having, and what it doesn't know is not worth knowing." *Kenneth Grahame The Wind in the Willows*

"The world's supply of fresh water is running out. Already one person in five has no access to safe drinking water." *BBC World Water Crisis Homepage*

A note from the Lakewatch Coordinator Preston McEachern

Lakewatch has several important objectives, one of which is to document and interpret water quality in Alberta Lakes. Equally important are the objectives of educating lake users about their aquatic environment; enhancing public involvement in lake management; and facilitating a link between aquatic scientists and lake users. The 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. Substantial additional information is generally available on the lakes that have participated in Lakewatch and readers requiring more information are encouraged to seek these sources.

I would like to thank all people who share my love for aquatic environments and particularly those who have helped in the Lakewatch program. These people prove that ecological apathy can be overcome and give us hope that water will not be the limiting factor in the health of our planet.

Acknowledgements

The Lakewatch program is made possible through the dedication of its volunteers and Alberta Environment employees. Leah and John Cottam, with assistance from Lakewatch staff, sampled Pine Lake in 2003. Mike Bilyk, John Willis, Doreen LeClair and Dave Trew from Alberta Environment were instrumental in funding, training people and organizing Lakewatch data. Lakewatch reports on Pine Lake in 2002 and 2003 were prepared by Al Sosiak, with assistance from Bridgette Halbig, and reviewed by Preston McEachern of Alberta Environment. Jean-Francois Bouffard coordinated sampling by Lakewatch in 2003. Without the dedication of these people and the interest of cottage owners, Lakewatch would not have occurred.

Pine Lake

Pine Lake is a small eutrophic lake southeast of Red Deer, Alberta. Pine Lake is subject to severe cyanobacterial blooms. Public concern over deteriorating water quality prompted the Alberta government to initiate a lake restoration program in 1991. The Pine Lake Restoration Program was designed as a pilot project for future lake and watershed projects in Alberta.

An advisory committee that represented all members of the community directed early planning and problem diagnosis by the Alberta government. A diagnostic study in 1992 (Sosiak and Trew 1996) determined that approximately 61% of the total phosphorus (TP) loading was from sediment release and other internal sources, compared to about 36% from surface runoff, and determined that algal growth in Pine Lake was mainly limited by the supply of phosphorus. Four critical areas for watershed restoration were identified on four streams affected by livestock operations and sewage release (Sosiak and Trew 1996). These streams contributed 72% of the phosphorus loading from streams in 1992.

The advisory committee later formed the Pine Lake Restoration Society, a non-profit organization with representatives from all stakeholders, which raised funds and worked with technical advisors from the Alberta government. The Pine Lake Restoration Society implemented a four-year work plan in 1995 that addressed phosphorus loading from all sources. The main objective of the restoration program was to restore Pine Lake to a "natural" level of algal productivity. The Pine Lake Restoration Society and other individuals in the basin completed beneficial management practices (BMPs) projects at various agricultural sites. Other organizations also improved wastewater treatment at a resort and two camps near the shoreline of Pine Lake.

Following an evaluation of the different alternatives to remove or treat phosphorus released from lake sediments, hypolimnetic withdrawal was selected as the preferred method of treatment. Hypolimnetic withdrawal has been successfully used to reduce TP concentration in various lakes, mainly in Europe, but has never been attempted in Alberta. Two different designs for the Pine Lake system were prepared and evaluated and, following public notice and licensing, the system was installed in September 1998.

The system at Pine Lake consists of a weir that maintains head and regulates lake level, and a gravity-fed pipeline that withdraws cool, phosphorus-rich water from the hypolimnion of the south basin, and discharges through a vault with control valves to a stilling basin on Ghostpine Creek. Locations and other details on the projects and results of water quality sampling to 2001 are in Sosiak (2002).

This report presents results of a volunteer sampling of Pine Lake in 2003. This sampling program was designed to monitor changes in water quality in Pine Lake following the completion of all watershed and lake projects in 1998. In 1978 to 2002, euphotic zone composite samples for all variables were collected in the same three sub-basins that have been sampled since 1978, and water temperature and dissolved oxygen concentrations throughout the water column were measured at deep locations in each of the three sub-basins. In 2003, Lakewatch volunteers collected a single euphotic zone composite sample on each sampling date during June to September from the entire lake. Chlorophyll *a* in the three basins did not differ significantly between the three basins in any of the 15 sampling years from 1978 to 2000, and total phosphorus was only higher in the middle basin in one year (1986)(Sosiak 2002). Accordingly, the composite samples collected from the entire lake in 2003 were probably representative of conditions in individual basins. This report consists of a comparison of 2003 data with results collected by the Alberta government and Lakewatch since 1978.

Fig. 1: Bathymetry of Pine Lake. From Sosiak and Trew (1996).

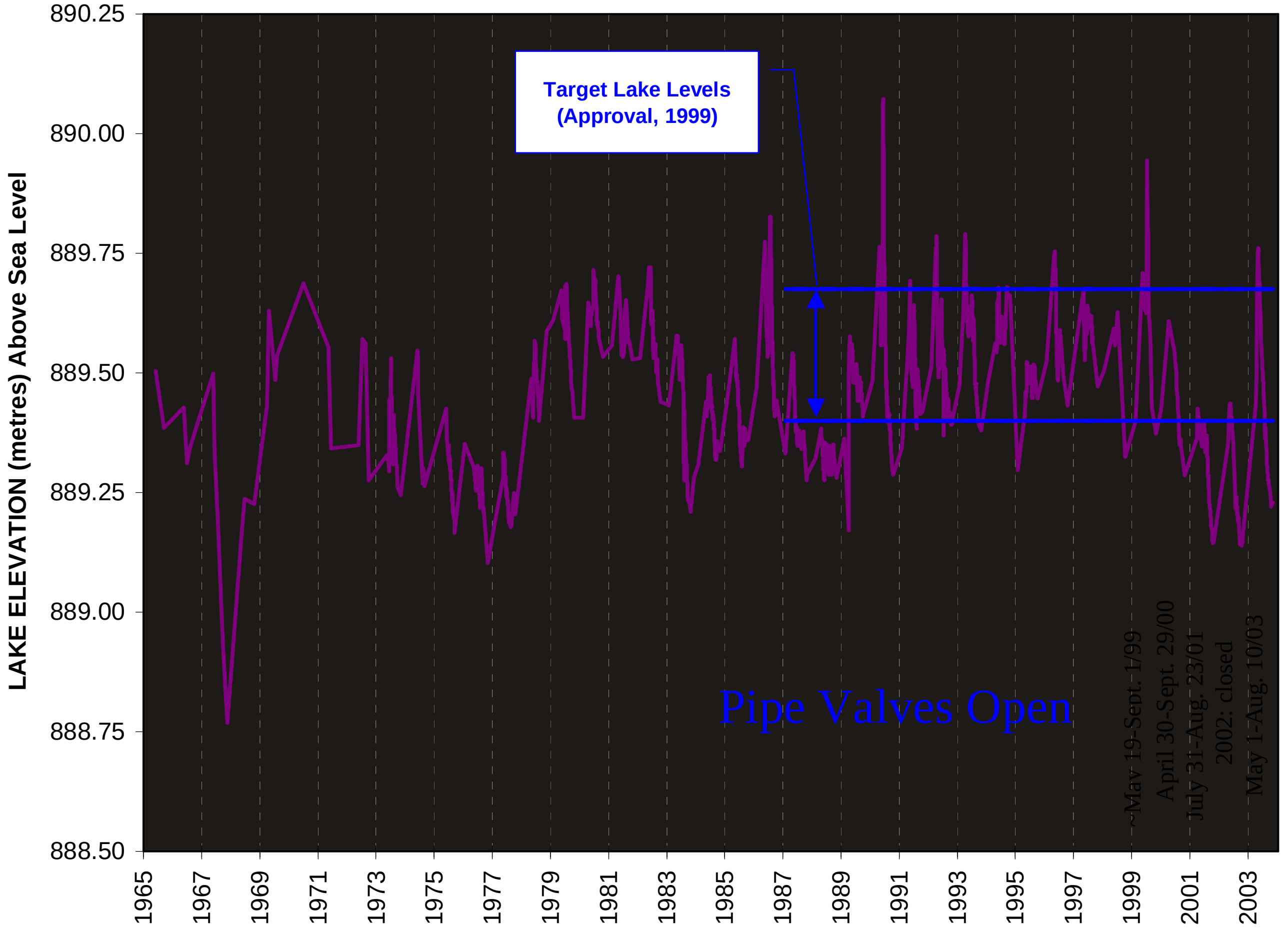


Figure 2. Historic Lake Levels for Pine Lake (05CE902).

Results

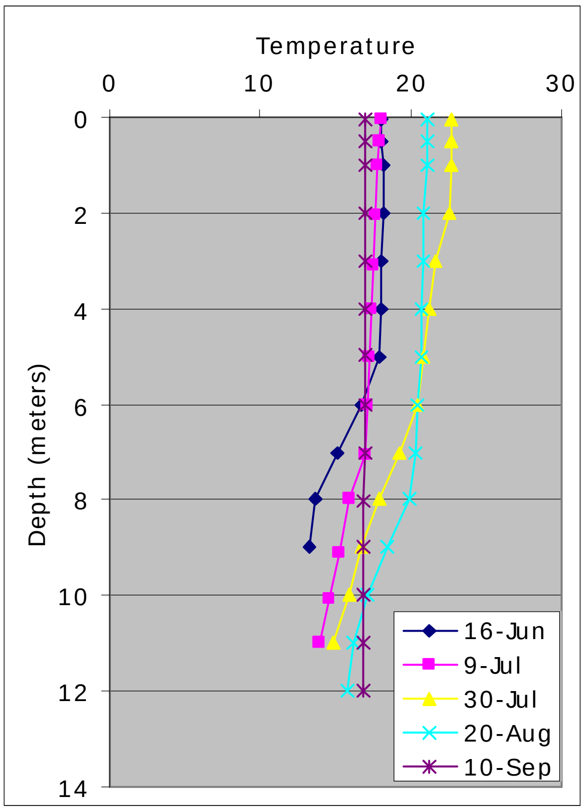
Water levels

Water levels in Pine Lake have been monitored since 1965. Under the approval to operate the hypolimnetic withdrawal system, the Pine Lake Restoration Society tries to maintain water levels within a range (Figure 2) that was recommended in the engineering report for the system. The weir operator for the Society accomplishes this by adding or removing boards to the weir at the lake outfall and by operating the control valves. There was sufficient water to operate the hypolimnetic withdrawal system in 1999, 2000 and briefly in 2001, but there was not sufficient water to operate the system during the drought in 2002, which was one of the worst droughts that have occurred in this region. During planning for the project, it was assumed that there would be insufficient water to operate the system three years of 10 (Sosiak 1997). With the control valves shut and all boards in the weir, lake levels declined to 889.147, which is the third lowest on record (Figure 2).

Lake levels were higher at the start of the 2003-operating season, up to 889.755, but rapidly declined to a low of 889.221 by October 25. The summer of 2003 was relatively warm and dry, and records from the weir master indicate that the valves were open from May 1 to August 10 (Figure 2).

Water temperature and dissolved oxygen

As in previous years (Sosiak 2002), thermal stratification occurred in the middle basin of Pine Lake in 2003 (Figure 3). Water temperatures in bottom water ranged down to 13.3° C, which was warmer than bottom temperatures in 2002, but similar to the previous minimum of 13.5° C during the summer of 1997. Surface temperatures ranged up to 22.7° C on July 30, 2003. This suggests that stable stratification of Pine Lake occurred in 2003. As in previous years about the bottom 4 m of the water column was anoxic in the middle basin (Sosiak 2002) in 2003. Electronegative redox (≥ 73 mV), an indicator of strong reducing conditions associated with anoxia, occurred on the August 20, 2003 sampling trip alone.



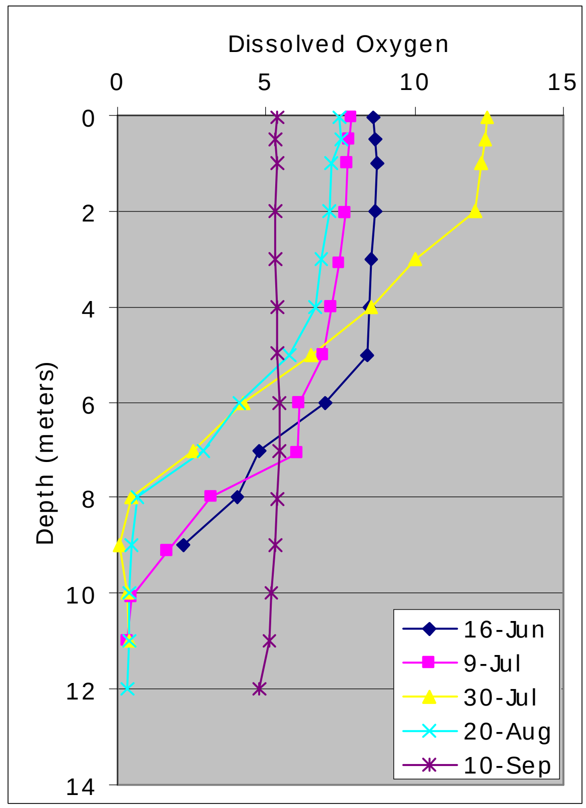


Fig. 3: Water temperature and dissolved oxygen profiles for Pine Lake during 2003.

Water clarity and Secchi Depth

Water clarity is influenced by suspended material, both living and dead, as well as some coloured dissolved compounds in the water column. The most widely used measure of lake water clarity is Secchi depth. Lake water usually clears in the spring but then becomes less clear as algae grow throughout the summer.

Median Secchi depth measurements collected by volunteers in the middle basin of Pine Lake in 2003 (3.0 m)(Figure 4) were much higher than in 2002, which indicates the lake had greater water clarity in 2003 than in recent years. Minimum and maximum measurements were within the range that has occurred in recent years. The median Secchi depth in 2003 was at the boundary between mesotrophic and eutrophic states. One of the goals of the restoration program has been to achieve a natural level of productivity. Since the lake is thought to have been naturally mesotrophic, the 2003 Secchi depth measurements are encouraging. However, it should be noted that only five Secchi depths were collected in 2003, and these results may not represent the complete range of conditions that occurred that year.

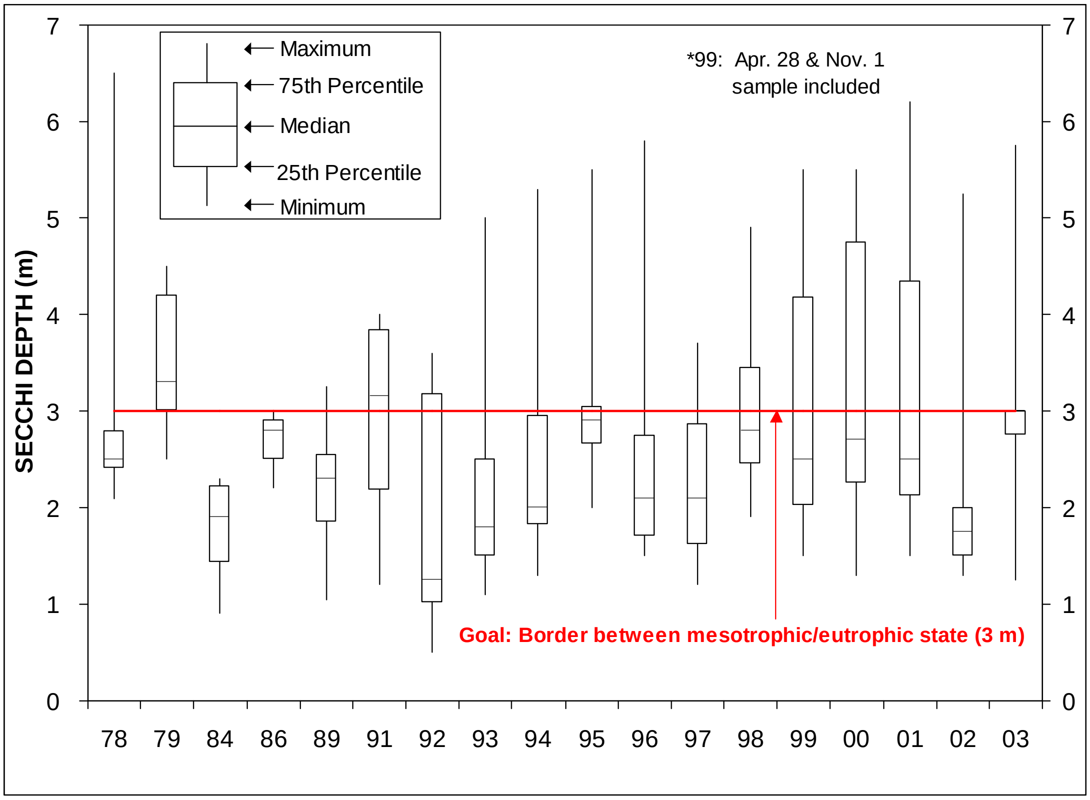


Fig. 4: Secchi depth (May-Oct) in the middle basin of Pine Lake, 1978 – 2003.

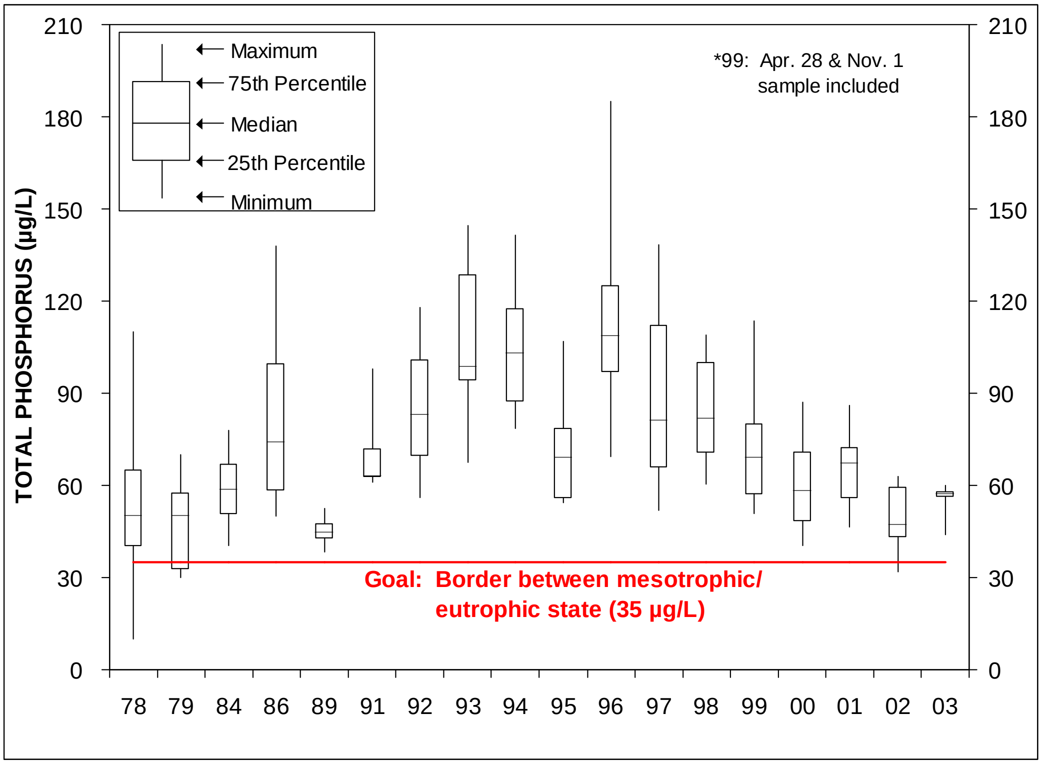


Fig. 5: Euphotic zone composite total phosphorus in Pine Lake (1978 – 2003).

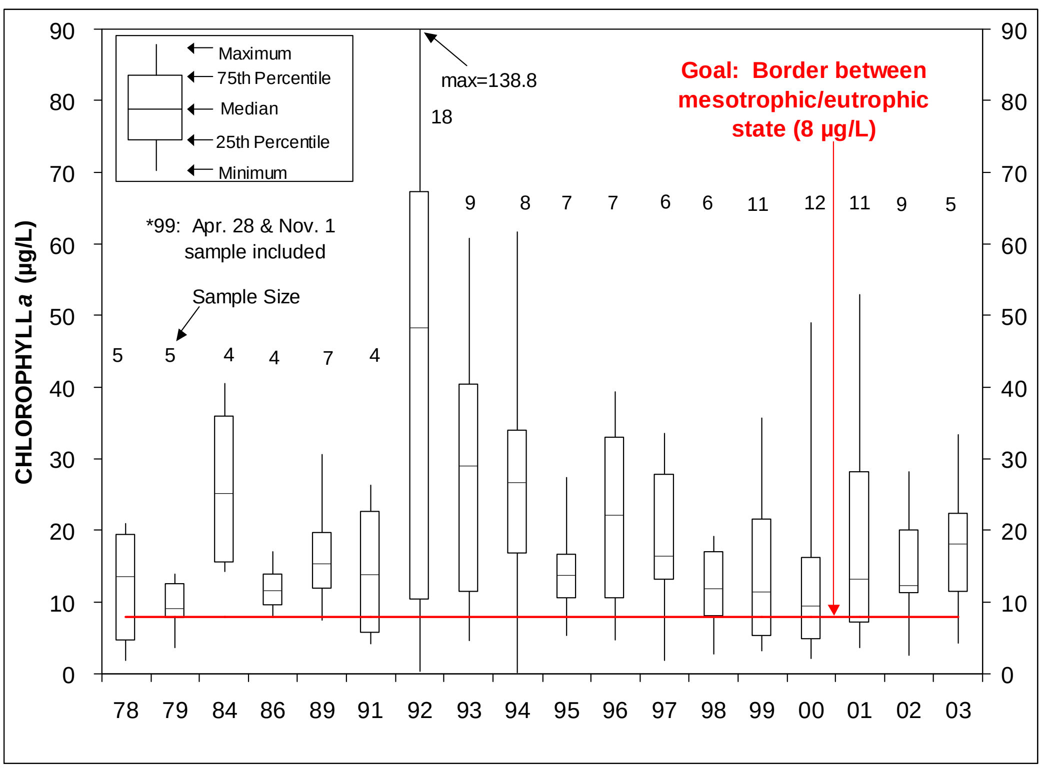


Fig. 6: Euphotic zone composite chlorophyll *a* in Pine Lake (1978 – 2003).

Table1: Mean values from summer 2003 samples compared to values from those reported in the Atlas of Alberta Lakes (Mitchell and Prepas 1990).

Parameter	1979	1984	1992	1996	2002	2003
TP ($\mu g \bullet L^{-1}$)	-	56	84.7	104.0	49.3	55
Chl ($\mu g \bullet L^{-1}$)	11.3	26.3	50.4	22.1	15.6	17.9
Secchi (m)	3.4	1.8	1.8	2.1	1.7	3.1
TKN ($\mu g \bullet L^{-1}$)	1293	1302	2052	1360	1442	1474
TN ($\mu g \bullet L^{-1}$)	-	-	2088	1385	1445	1484
NO_2+NO_3N ($\mu g \bullet L^{-1}$)	13	<10	36	11	3	10
NH_4^+ N ($\mu g \bullet L^{-1}$)	-	59	146	120	11	98
Ca ($mg \bullet L^{-1}$)		23	25	28	20	21
Mg ($mg \bullet L^{-1}$)		25	25	24	26	24
Na ($mg \bullet L^{-1}$)		108	99	103	112	124
K ($mg \bullet L^{-1}$)		10	9	10	11.5	10
SO_4^{2-} ($mg \bullet L^{-1}$)		84	69	63	90	79
Cl^- ($mg \bullet L^{-1}$)		6	7	8	11	10
Total Alkalinity ($mg \bullet L^{-1}$ $CaCO_3$)		319	308	313	321	331

Water chemistry

The median total phosphorus concentrations reported for the middle basin of Pine Lake in 2003 (57 μg/L, Figure 5) was slightly higher than in 2002, but similar to other median concentrations since 2000 (58 μg/L). Total phosphorus remains much lower than prior to completion of the lake restoration program in 1998. Peak total phosphorus concentrations have declined to levels similar to the early 1980s, about one third the highest concentrations observed when water quality in Pine Lake was poorest in 1992 to 1996. Also important in this marked improvement is that the range in total phosphorus concentrations has become narrower, which may reduce the possibility of bloom conditions.

Median chlorophyll *a* concentrations were slightly higher in 2003 (median 18.1 μg/L) than in other years since 1998 (Figure 6), but well within the range that occurred in recent years and much lower than occurred most years prior to the lake restoration program. Peak concentrations have decreased by half since 1994 and by four-fold compared to the year with the poorest water quality (1992). This reduction in the occurrence of algal blooms is likely the result of lower peak phosphorus concentrations, attesting to the success of the management activities at Pine Lake.

These low phosphorus and chlorophyll *a* concentrations probably reflect the combined effects of reduced external phosphorus loadings and algal production following the restoration program (Sosiak 2002) and low runoff in recent years. These phosphorus and chlorophyll *a* results suggest that Pine Lake is now at the lower end of the eutrophic range of algal productivity. These indicators remain near the borderline between mesotrophic and eutrophic productivity, which was the stated objective of the lake restoration program. Algal blooms still occur in the late summer, but conditions have improved greatly in recent years.

Alkalinity, chloride, and sodium levels have increased slightly since 1984-1992, and most forms of nitrogen have declined since 1992 (Table 1). However, other variables have changed little over time (Table 1).

The results of the 2003 volunteer sampling of Pine Lake provide a valuable ongoing assessment of changes in this lake since the lake restoration program. This lake was intended to serve as a model for future lake management programs in Alberta, and some of the lake and watershed methods used at Pine Lake are unique in this province. It would be valuable to continue this monitoring program, to evaluate the operation of the hypolimnetic withdrawal system and the response of the lake to normal variations in precipitation and runoff.

References

Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes. University of Alberta Press.

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Sosiak, A. 2002. Initial results of the Pine Lake restoration program. Science and Standards, Alberta Environment.

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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 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**. 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.

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

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.