B.C. Volunteer Lake Monitoring Program

TABOR LAKE 1994 - 2002

The Importance of Tabor Lake & its Watershed

British Columbians want lakes to provide good water quality, aesthetics and recreational opportunity. When we don't see these features in our local lakes, we want to know why. Is water quality getting worse? Has the lake been polluted by land development? What uses can be made of the lake today? And, what conditions will result from more development within the watershed?

The Ministry of Environments's Volunteer Lake Monitoring Program (VLMP), in collaboration with the non-profit B.C. Lake Stewardship Society, is designed to help answer these questions. Through regular water sample collections, we can come to understand a lake's current water quality, identify the preferred uses for a given lake, and monitor water quality changes resulting from land development within the lake's watershed.

Through regular status reports, the VLMP can provide communities with monitoring results specific to their local lake and with educational material on lake protection issues in general. This useful information can help communities play a more active role in the protection of the lake resource. Finally, the VLMP allows government to use its limited resources efficiently thanks to the help of area volunteers and the B.C. Lake Stewardship Society.

Tabor Lake's VLMP program began in 1993, following a massive fishkill, and has been conducted by the Tabor Lake Cleanup Society. This status report summarizes information derived from this program. The quality of the data has been found to be acceptable. Data quality information is available on request.

A **watershed** is defined as the entire area of land that moves the water it receives to a common waterbody. The term watershed is misused when describing only the land immediately around a waterbody or the waterbody itself. The true definition represents a much larger area than most people normally consider. Tabor Lake's watershed is shown on the next page.

Watersheds are where much of the hydrological cycle takes place and play a crucial role in the purification of water. No "new" water is ever made - water is only cleansed through its continuous natural recycling. The quality of the inland water resource is largely determined by a watershed's capacity to buffer impacts and absorb pollution.

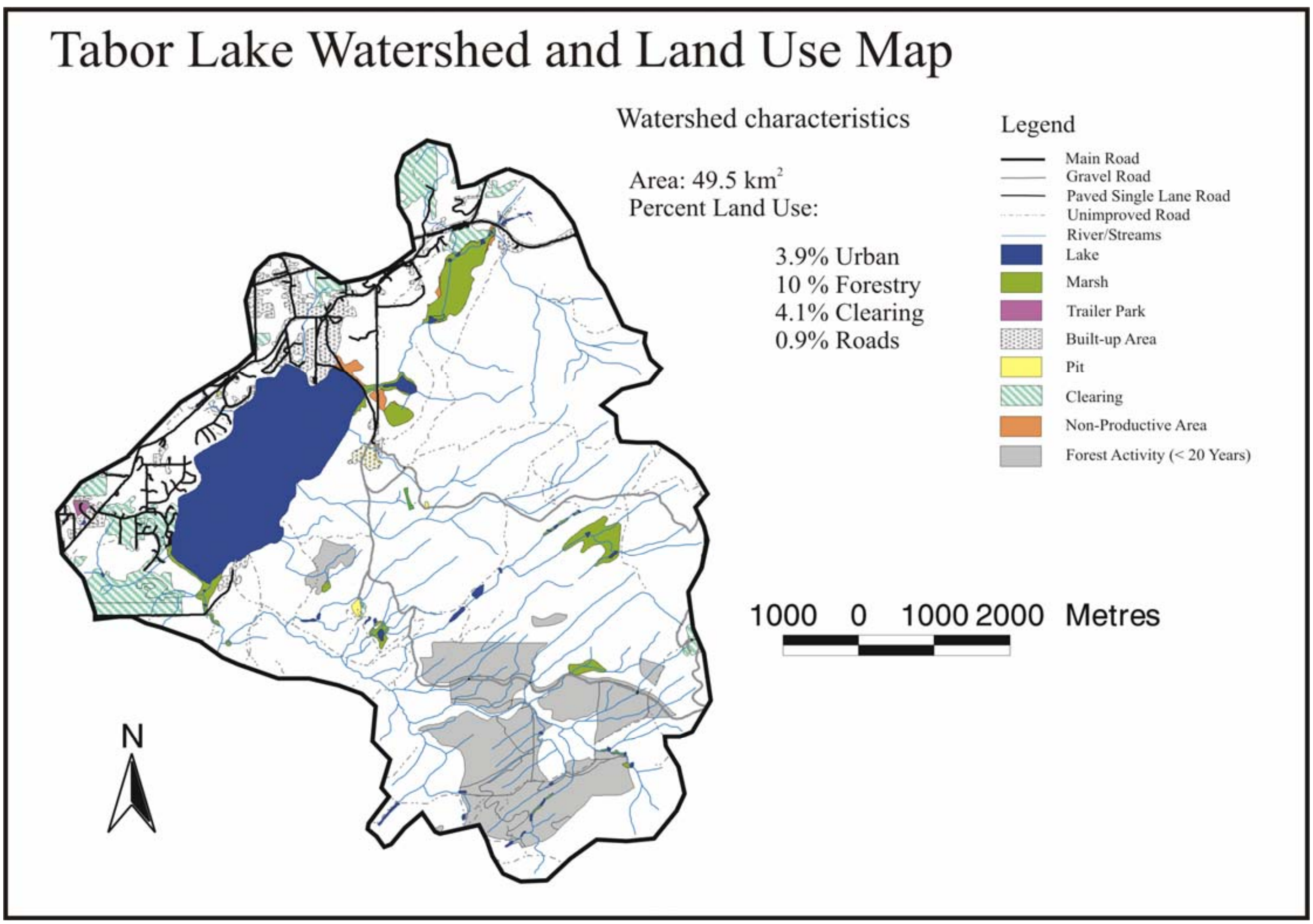
Every component of a watershed (vegetation, soil, wildlife, etc.) has an important function in maintaining good water quality and a healthy aquatic environment. It is a common misconception that detrimental land use practices will not impact water quality if they are kept away from the area immediately surrounding a water body. Poor land-use practices anywhere in a watershed can eventually impact the water quality of the downstream environment.

Human activities that impact water bodies range from small but widespread and numerous "non-point" sources throughout the watershed to large "point" sources of concentrated pollution (e.g. effluent pipes or outfalls, spills, etc.). Undisturbed watersheds have the ability to purify water and repair small amounts of damage from pollution and alteration. However, modifications to the landscape and increased levels of pollution impair this ability.

Tabor Lake is located…in the Omineca Peace region near Highway 16, approximately 15 km east of Prince George, B.C. This lake is roughly 3 km long, with maximum and mean depths of 9.2 m and 5.4 m, respectively. Its surface area is 4.08 km^2 and it has a shoreline perimeter of approximately 10 km. The map below shows the Tabor Lake watershed.

Prior to the 1990s, the fish species residing in Tabor Lake included mountain whitefish, rainbow trout (from a 1988 fish stocking), northern squawfish, peamouth chub, lake chub, largescale sucker and longnose sucker. Following the fishkill of 90,000 mountain whitefish (*Prosopium williamsoni*) and other non-sport species in 1993, Tabor Lake now contains mainly rainbow trout (*Oncorhynchus mykiss*). The lake and its watershed is also home to various bird species, moose, deer and black bears.

Land use within the watershed includes lakeshore development (approximately 60 residential units), some forestry and minor agriculture. The lake has good public access and is used for general recreational purposes by residents of Tabor Lake and surrounding communities. The greatest challenge to lake management is the control of phosphorus (nutrient) loading. This nutrient promotes summer algal blooms and the growth of aquatic plants. Reports exist in Ministry of Environment files for Tabor Lake of algae blooms and aquatic plant infestations, with the aquatic plant Canadian pondweed (*Elodea canadensis*) being especially problematic since the early 1980s and possibly, by way of oxygen depletion, being responsible for the 1993 fishkill. Attempts have been made to control phosphorus loading through a harvesting program that involves cutting and removing weeds from Tabor Lake by the Tabor Lake Cleanup Society.



Non Point Source Pollution and Tabor Lake

"Point source" pollution originates from municipal or industrial effluent outfalls. Other pollution sources exist over broader areas and may be hard to isolate as distinct effluents. These are referred to as "non-point" sources of pollution (NPS). Shoreline modification, urban storm water runoff, onsite septic systems, agriculture and forestry are common contributors to NPS pollution. One of the most detrimental effects of NPS is phosphorous loading to water bodies. The amount of total phosphorus (TP) in a lake can be greatly influenced by human activities. If local soils and vegetation do not retain this phosphorus, it will enter watercourses where it will become available for algal production.

Onsite Septic Systems and Grey Water

Onsite septic systems effectively treat human wastewater and wash water (grey water) as long as they are properly located, designed, installed, and **maintained**. When these systems fail they become significant sources of nutrients and pathogens. Poorly maintained pit privies, used for the disposal of human waste and grey water, can also be significant contributors.

Tree Harvesting

Harvesting can include clear cutting, road building and land disturbances, which may alter water flow and increase sediment and phosphorous inputs to water bodies.

Storm water Runoff

Lawn and garden fertilizer, sediment eroded from modified shorelines or infill projects, oil and fuel leaks from vehicles and boats, road salt, and litter can all be washed by rain and snowmelt from properties and streets into watercourses. Phosphorus and sediment are of greatest concern, providing nutrients and/or rooting medium for aquatic plants and algae. Pavement prevents water infiltration to soils, collects hydrocarbon contaminants during dry weather and increases direct runoff of these contaminants to lakes during storm events.

Agriculture

Agriculture is economically and culturally important. When these practices are poorly managed, however, significant NPS impacts to water can result, such as nutrient and pathogen introductions from manure and habitat damage from livestock access to shorelines.

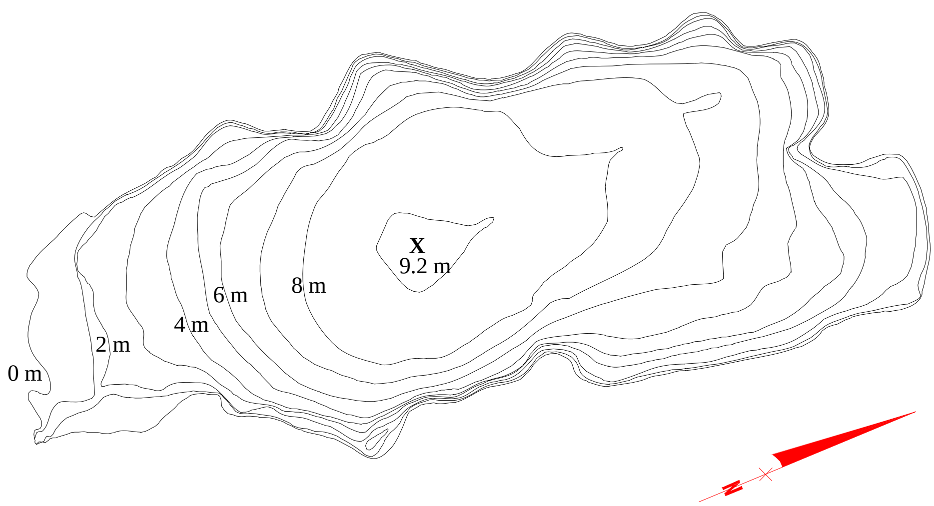
Boating

Oil and fuel leaks are the main concerns of boat use on small lakes. With larger boats, sewage and grey water discharges are issues. Other problems include litter, the spread of aquatic plants, and the churning up of bottom sediment and nutrients in shallow water operations.

Tabor Lake Bathymetric

Contour Interval – 1 m
Scale – 1:11,878

Lake Characteristics
Area: 4.1 km^2
Volume: 21,950,000 m^3
Max. Depth: 9.2 m
Mean Depth: 5.4 m
Shoreline Length: 10 km
Elevation: 698 masl
Water Quality Sampling Site: X



TABOR LAKE TROPHIC CHARACTERISTICS

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	
Max. surface temp. (°C):	-	24.0	20.0	22.0	24.0	24.0	21.5	22.5	25.0	22.0	
Min. near-bottom oxygen (mg/L):	-	1.0	0.2	1.0	0.8	0.1	1.5	0.3	0.3	0.3	
Spring overturn TP (ug/L):		31.0	29.0	-	41.0	32.0	20.0	29.0	24.0	15.1	-
Summer average TP (ug/L)	-	66.1	50.2	47.3	53.9	78.3	29.0	57.0	43.4	37.2	
Avg. chlorophyll a (ug/L):	-	16.0	41.0	8.3	13.7	11.9	8.6	8.1	8.1	7.2	
Avg. secchi depth (m):	-	3.9	3.5	3.8	4.3	4.0	3.3	3.1	3.0	2.5	

What's Going on Inside Tabor Lake?

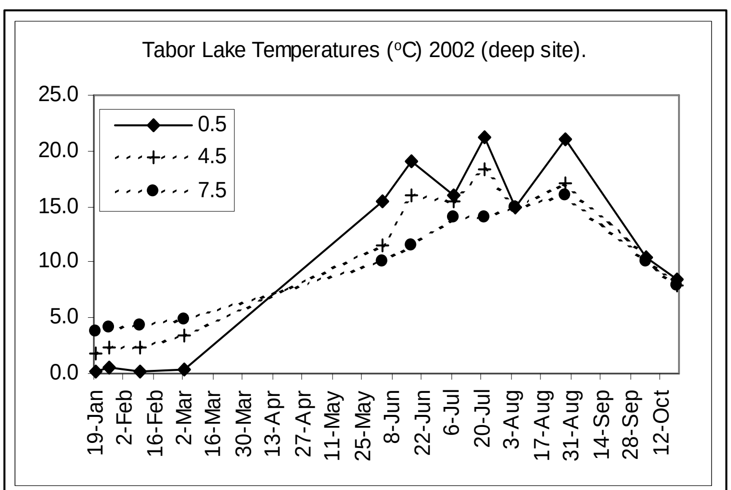
Temperature

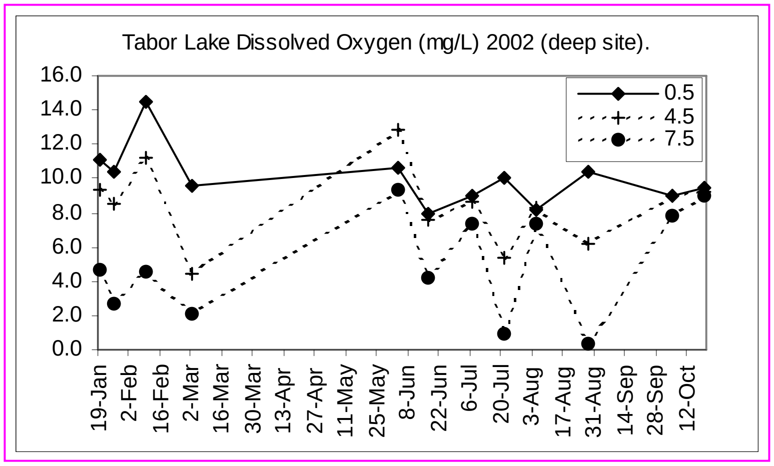
Lakes show a variety of annual temperature patterns based on each lake's location and depth. In the summer, most B.C. interior lakes form layers (stratify), with the coldest water near the bottom because it is denser, and therefore, resists mixing into the warmer, upper layer for much of the summer. In spring and fall, these lakes usually mix from top to bottom as wind energy overcomes the reduced temperature and density differences between the surface and bottom waters. This process is called spring and fall overturn and is very important, as it tends to homogenize the characteristics of the total water column, including temperature, density and chemical concentrations. In the winter, lakes re-stratify under ice with the densest water (4°C) near the bottom.

Lakes of only a few metres depth tend to overturn throughout the summer or stratify only temporarily, depending on wind conditions. In winter, the temperature pattern of these lakes is similar to that of deeper lakes.

Temperature stratification patterns are very important to lake water quality. They determine much of the seasonal oxygen, phosphorus and algal conditions. When abundant, algae, or free-floating small plants, can create problems for lake users.

Temperature was measured at the deepest part of Tabor Lake during 2002 (see figure below). Slight stratification was noted under the ice during the winter months and then stronger stratification by early June. A period of destratification would have occurred after ice-off in late April early May when the lake would have mixed to uniform temperature. The maximum surface temperature, reached by mid July, was 21.2 °C at the deep site. Loss of stratification was noted in early August. A uniform temperature of 15.0 °C may have been due to a strong wind event. Wind and water turbulence can increase heat exchange between warm surface and cooler underlying waters. Shorter days and cooling air temperatures through September caused a loss of lake stratification, leaving the water temperature nearly uniform with depth at 10.0 °C by early to mid-October.





Dissolved Oxygen

Oxygen is essential to life in lakes. It enters lake water from the air by wind action and plant photosynthesis. Oxygen is consumed by respiration of animals and plants, including the decomposition of dead organisms by bacteria. A great deal can be learned about the health of a lake by studying oxygen patterns and levels.

Lakes that are unproductive (oligotrophic) will have sufficient oxygen to support life at all depths through the year. But as lakes becomes more productive (eutrophic), and increasing quantities of plants and animals respire and decay, more oxygen consumption occurs, especially near the bottom where dead organisms accumulate.

In productive lakes oxygen in the isolated bottom layer may deplete rapidly (often to anoxia), forcing fish to move into the upper layer (fish are stressed when oxygen falls below about 20% saturation). Fish kills occur when decomposing or respiring organic matter (algae or weeds) use up the oxygen. In summer this can happen on calm nights after a period of high plant productivity, but most fish kills occur during late winter or at initial spring mixing when under-ice oxygen levels are depleted over the winter.

The figure above shows the oxygen patterns of the deep site for 2002. Surface water oxygen remained near saturation, not dropping below 8 mg/L. The mid- and bottom-layers displayed varying levels of oxygen throughout the sampling period with the bottom waters exhibiting near zero oxygen concentrations (termed anoxia or anoxic conditions) on two occasions in the summer. In both cases, the bottom waters are replenished with oxygen by destratification and mixing of the lake by the next sampling date. This can be determined from the similarity of the temperature data for the full water column on the sampling dates following the anoxic conditions.

Vertical mixing and the aeration of bottom waters occurred with the onset of cooler fall temperatures (Oct.) resulting in the saturation of the lake prior to freeze-up.

What's Going on Inside Tabor Lake?

Trophic Status and Phosphorus

The term "trophic status" is used to describe a lake's level of productivity that is generally characterized by the amount of aquatic plant growth. This growth depends on the amount of nutrients available for both weeds and tiny floating algae called phytoplankton. Algae are important to the overall ecology of a lake because they are food for zooplankton, which in turn are food for other organisms, including fish. In most lakes, phosphorus is the nutrient in shortest supply and thus acts to limit the production of aquatic life. When in excess, phosphorus stimulates plant growth resulting in algal blooms and/or extensive weed growth. As mentioned earlier (page 3), total phosphorus (TP) in a lake can be greatly influenced by human activities.

The trophic status of a lake can be determined by using a variety of surrogate measures of productivity. Generally, the more productive a lake is, the higher the algal growth and therefore the less clear the water becomes. Water clarity is measured using a ***Secchi disc***. Productivity is also characterized by measuring nutrient levels and ***chlorophyll a*** (the green photosynthetic pigment of algae). In many lakes, phosphorus concentrations during spring overturn can be used to predict summer algal productivity.

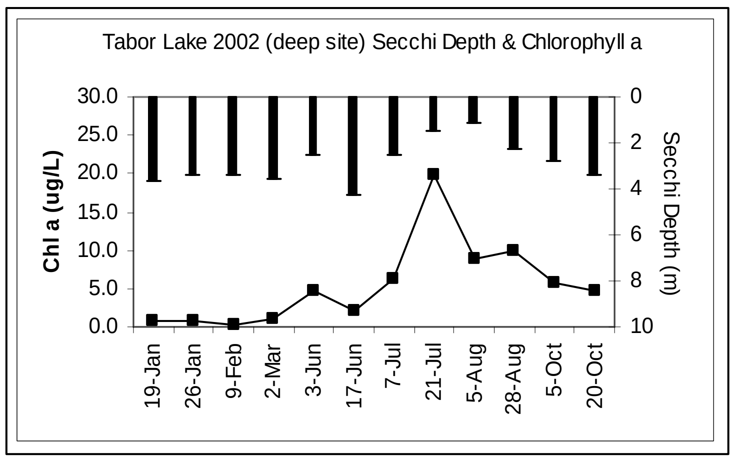
Lakes of low productivity are referred to as ***oligotrophic***, meaning they are typically clear water lakes with low nutrient levels (1-10 ug/L TP), sparse plant life (0-2 ug/L Chl a), and low fish production. Lakes of high productivity are termed ***eutrophic***, due to abundant plant life (>7 ug/L Chl a), including algae, because of higher nutrient levels (>30 ug/L TP). Lakes with an intermediate productivity are called ***mesotrophic*** (10-30 ug/L TP and 2-7 ug/L Chl a) which combine the qualities of oligotrophic and eutrophic lakes.

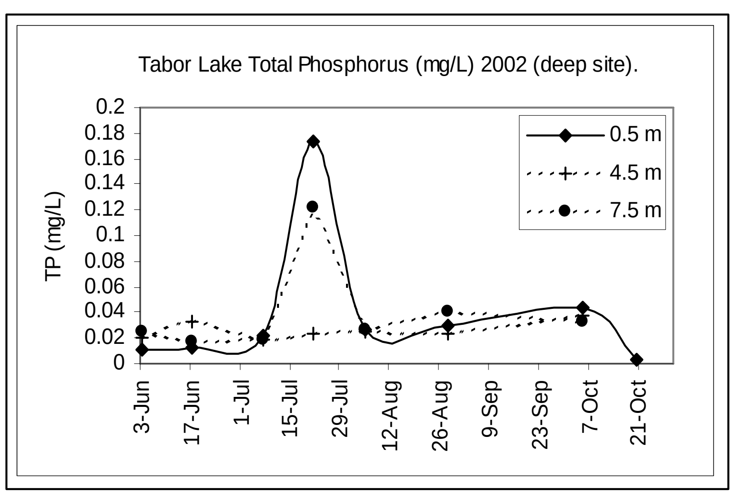
Lake sediments can themselves be a major source of phosphorus. If deep-water oxygen becomes depleted, a chemical shift occurs in bottom sediments. This shift causes sediment to release phosphorus to overlying waters. This "internal loading" of phosphorus can be natural but is often the result of phosphorus pollution. Lakes displaying internal loading and summer overturns generally have elevated algal levels and often lack recreational appeal.

Tabor Lake spring TP levels (page 3) have remained somewhat stable since 1993 (average of 29.4 ± 6.6 ug/L) implying a mesotrophic nature bordering on eutrophy. However, in lakes that exhibit internal phosphorus loading the spring overturn TP values are not a good indicator of the following summer's trophic condition. Therefore to assess the changing conditions of Tabor Lake we need to evaluate the history of summer phosphorus, chlorophyll a and secchi disc changes. The data suggest that summer algal concentrations are improving somewhat and water clarity has been generally stable over this 9-year period (page 3). However, older algal chlorophyll and secchi data are lacking and therefore restrict a longer-term comparison with present conditions.

The first figure below displays the 2002 Tabor Lake algal chlorophyll concentrations and water clarity, as measured by Secchi disc. For this period, secchi was a very good indicator of chlorophyll. Overall chlorophyll averaged 5.4 ug/L at the deep site, but summer chlorophyll averaged 7.8 ug/L, suggesting the lower range of eutrophy.

The second diagram below displays 2002 phosphorus concentrations in Tabor Lake. Winter phosphorus data was not collected in 2002. Summer TP at the deep site fluctuated between 10 – 40 ug/L over most of the open water season except for a sharp increase in surface and bottom TP levels on the 21st of July. On this date surface TP rose to 174 ug/L, reflecting the algal bloom that can be identified by the increase in chlorophyll a in the first diagram below. Bottom water TP also rose extremely on July 21st, to 122 ug/L. This change is associated with an episode of internal loading as very low oxygen concentrations in the bottom waters on this date resulted in a large release of sediment-stored phosphorus. The strong thermal stratification of the lake on this date restricted movement of the high surface and bottom phosphorus content thereby maintaining previous low TP concentrations in the middle layers. A mixing of the entire lake on Aug. 5 resulted in a lowering of TP levels at both the top and bottom levels to pre-peak and middle layer concentrations.





Historical Look at Tabor Lake

Lake Coring; what does it Mean?

The Tabor Lake VLMP was initiated well after local land development and other possible impacts to the lake began. So, although this monitoring program can accurately document current lake quality, it cannot reveal historical "baseline" conditions or long-term water quality trends. Here lies the value in coring lake sediments. Past changes in water quality can be inferred by studying the annual deposition of algal cells, specifically diatoms, on the lake bottom.

The deep site of Tabor Lake was cored and sectioned by the Ministry of Environment in 1991. The 40 cm cores, dating back 200 years, were analysed by Dr. Brian Cummings of Queen's University. His report is available on request.

Historical changes in relative diatom abundance were measured directly by microscopy. By knowing the age of various core sections and the phosphorus preference of the specific diatom algae in each section, historical changes in lake phosphorus concentrations, chlorophyll, and water clarity can be estimated.

Dating processes indicated that the Tabor Lake core was generally of good quality and would provide reliable records of environmental history over the past 150 years.

Interpretations were somewhat hindered however, by one diatom species that can be found in a wide range of nutrient environments making ecological classification problematic.

Historically, Tabor Lake maintained relatively stable inferred phosphorus concentration of between 35 and 40 ug/L until the 1970s. Over the past 30 years however, there has been an increase in the variability of inferred phosphorus concentration with a trend towards increasing phosphorus concentrations indicating progressive eutrophication. This compares well with the recent average summer water phosphorus measurements that exhibit values of 29.0 ug/L and greater since 1994 (see page 3). However, there appears to have been declines in average summer TP and chlorophyll in recent years.

The cores exhibit unusually high rates of sedimentation since 1950. This indicates increased lake productivity and/or increased delivery of sediments from the landscape associated with watershed activities. Charcoal deposits found in the Tabor Lake core corresponded to the severe watershed fire in 1961. Increased nutrients delivered to the lake following the fire may have been due, in part, to the lack of a vegetation buffer along that steeper side of the lake.

Current Management Approaches

Two approaches for water quality management of Tabor Lake are currently available. Macrophyte harvesting of the littoral zone has occurred in most years from 1995 to 2002. As well, a weir has been installed at the lake outlet to assist in water level management. While the weir has not actually been used to regulate water quality in response to increase nutrient levels, it is possible to do so. Calculations of the amount of phosphorus that has been, and could be removed from the lake as compared to the amounts that have been internally loaded have been reported by Dr. Ellen Petticrew of the University of Northern B.C. Between 1995 and 2002, summer weed harvesting was found to remove between 336 to 760 kg of phosphorus each year while the weir could have potentially removed between 139 to 300 kg during summer nutrient peaks. In contrast the summer contribution of TP from internal sediment loading ranged from 260 to 1411 kg over the 6-year period. As lake phosphorus contributions from internal loading depend on both the condition of the sediment as well as on weather conditions (temperature and wind) it is hard to predict what significance this process will have each summer. Therefore it would be useful to use both weed harvesting and weir management as long term approaches to reducing the total lake phosphorus load.

Household Tips to Keep Tabor Lake Healthy

Yard Maintenance, Landscaping & Gardening

- Minimize the disturbance of shoreline areas by maintaining natural vegetation cover.
- Minimize high-maintenance grassed areas.
- Replant lakeside grassed areas with native vegetation. Do not import fine fill.
- Use paving stones instead of pavement.
- Stop or limit the use of fertilizers and pesticides.
- Don't use fertilizers in areas where the potential for water contamination is high, such as sandy soils, steep slopes, or compacted soils.
- Do not apply fertilizers or pesticides before or during rain due to the likelihood of runoff.
- Hand pull weeds rather than using herbicides.
- Use natural insecticides such as diatomaceous earth. Prune infested vegetation and use natural predators to keep pests in check. Pesticides can kill beneficial and desirable insects, such as ladybugs, as well as pests.
- Compost yard and kitchen waste and use it to boost your garden's health as an alternative to chemical fertilizers.

Agriculture

- Locate confined animal facilities away from waterbodies. Divert incoming and treat outgoing runoff from these facilities.
- Limit the use of fertilizers and pesticides.
- Construct adequate manure storage facilities.
- Do not spread manure during wet weather, on frozen ground, in low-lying areas prone to flooding, within 3 m of ditches, 5 m of streams, or 30 m of wells, or on land where runoff is likely to occur.
- Install barrier fencing to prevent livestock from grazing on streambanks.
- If livestock cross streams, provide gravelled or hardened access points.
- Provide alternate watering systems, such as troughs, dugouts, or nose pumps for livestock.
- Maintain or create a buffer zone of vegetation along a streambank, river or lakeshore and avoid planting crops right up to the edge of a waterbody.

Auto Maintenance

- Recycle used motor oil, antifreeze, and batteries at collection centres.
- Use phosphate-free biodegradable products to clean your car. Wash your car over gravel or grassy areas, but not over sewage systems.
- Use a drop cloth if you fix problems yourself.

Onsite Sewage Systems

- Inspect your system yearly, and have the septic tank pumped every 2 to 5 years by a septic service company. Regular pumping is cheaper than having to rebuild a drain-field.
- Use phosphate-free soaps and detergents.
- Don't put toxic chemicals (paints, varnishes, thinners, waste oils, photographic solutions, or pesticides) down the drain because they can kill the bacteria at work in your onsite sewage system and can contaminate waterbodies.
- Conserve water: run the dishwasher only when full and use only low-flow showerheads and toilets.

Boating

- Do not throw trash overboard or use lakes or other waterbodies as toilets.
- Use biodegradable, phosphate-free cleaners instead of harmful chemical.
- Conduct major maintenance chores on land.
- Use 4 stroke engines, which are less polluting than 2 stroke engines, whenever possible. Use an electric motor where practical.
- Keep motors well maintained and tuned to prevent fuel and lubricant leaks.
- Use absorbent bilge pads to soak up minor oil and fuel leaks or spills.
- Recycle used lubricating oil and left over paints.
- Check for and remove all aquatic plant fragments from boats and trailers before entering or leaving a lake.
- Do not use metal drums in dock construction. They rust, sink and become unwanted debris. Use styrofoam or washed plastic barrel floats. All floats should be labeled with the owner's name, phone number and confirmation that barrels have been properly emptied and washed.

SUMMARY

Recent VLMP sampling and sediment coring results suggest that Tabor Lake has been showing progressive eutrophication over the past 20 years and yet still has fairly to good recreational water quality. While there are periods of good water clarity and low TP in Tabor Lake during most summers indicating early stages of improvement, it does not appear that on average the water quality of Tabor Lake is improving. This is due to the problem of internal phosphorus loading for which the frequency and duration are difficult to predict. The weed harvesting program should be continued and the weir should be used in a manner that allows water quality management in the future. Additional years of VLMP data are recommended to monitor the effects of the internal loading events in comparison to the longer term management approaches of weed harvesting and water level control at the weir. Regardless, all residents and land developers within the watershed are advised to practice good land management such that nutrient or sediment additions to the lake and its tributaries are minimized.

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Acknowledgements

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Photo Credit:
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