B.C. Volunteer Lake Monitoring Program

CHIEF LAKE 2000 - 2002

The Importance of Chief 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 Environment'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.

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. Chief Lake's watershed, shown on the next page, is 202 square kilometers.

Watersheds are where much of the ongoing hydrological cycle takes place and play a crucial role in the purification of water. Although no "new" water is ever made, it is continuously cleansed and recycled as it moves through watersheds and other hydrologic compartments. The quality of the water resource is largely determined by a watershed's capacity to buffer impacts and absorb pollution.

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.

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 down stream environment.

Chief Lake's VLMP program began in 2000 and has been conducted by the Chief Lake Volunteer Water Testing Group. This status report summarizes information derived from the program and compares it to 1976 government data. Quality of the data has been found to be acceptable. Data quality information is available on request.

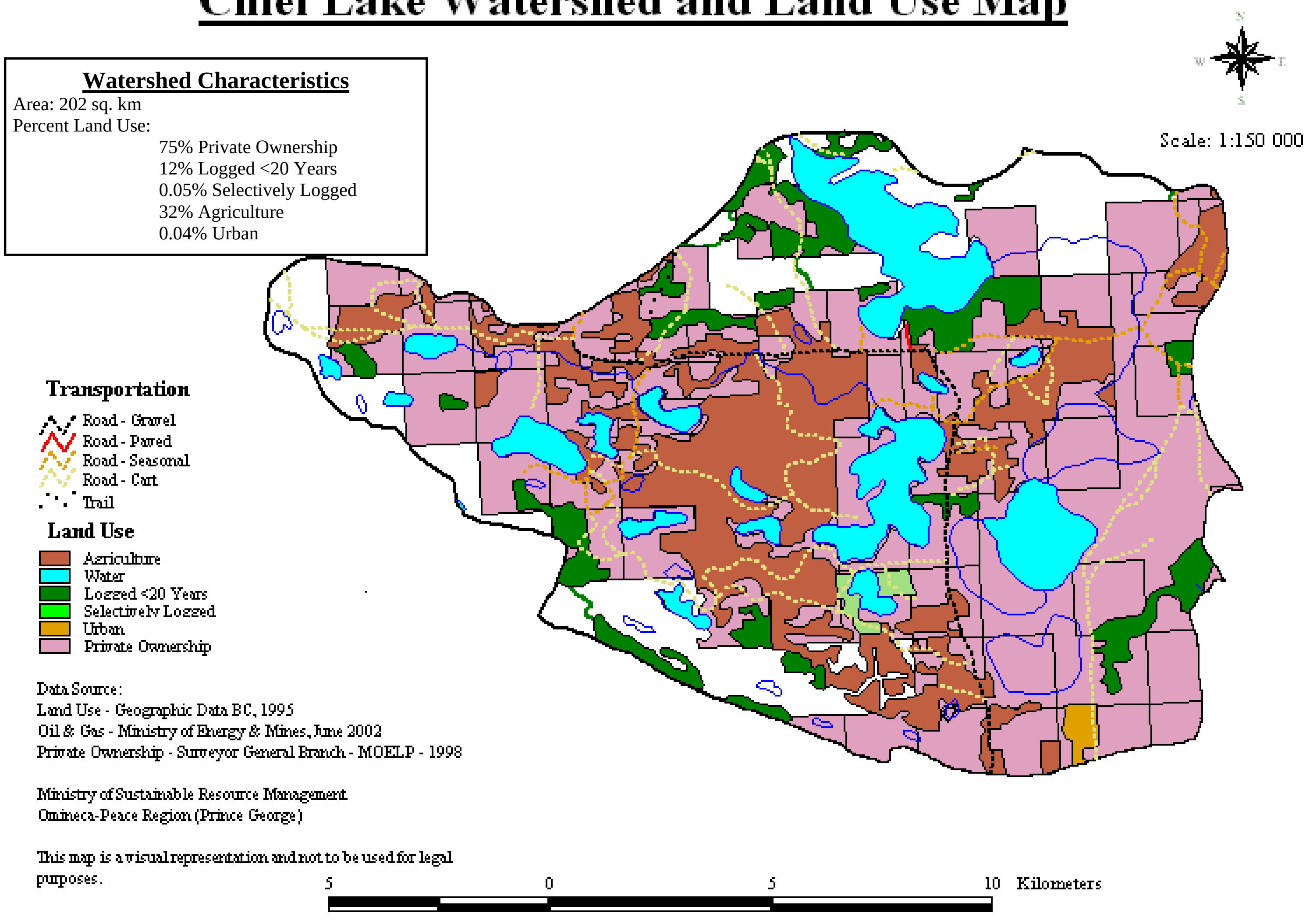
Human activities that impact water bodies range from small but widespread and numerous "non-point" sources throughout the watershed to large "point" sources of concentrated pollution (e.g. outfalls, spills, etc.). Undisturbed watersheds have the ability to purify water and repair small amounts of damage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

Chief Lake is located...in the Omineca Peace region approximately 27 km northwest of Prince George, B.C. This lake is roughly 6 km long, with maximum and mean depths of 6.1 m and 3.8 m, respectively. Its surface area is 7.37 km^2 and it has a shoreline perimeter of 21 km. The map below shows the Chief Lake watershed and its associated land use practices. It is believed that land use practices in the Chief Lake watershed are integral to the health of the lake. Because the lake has a slow flushing rate (0.1 times/year), poor land use practices causing an influx of possible contaminants are more likely to be held within the lake for a long period of time compared to other lakes with faster flushing rates. Nukko Creek, as well as many of the other tributaries entering Chief Lake, are fed by many of the lakes in the surrounding area. Therefore, water quality in Chief Lake is affected by activities on Nukko Lake and the other lakes in the watershed, as well as those activities on Chief Lake itself.

Chief Lake contains the following sport fish: lake whitefish (*Coregpmis clupeaformis)*, brook trout (*Salvelinus fontinalis)*, and rainbow trout (*Oncorhynchus mykiss*). Despite successful natural reproduction in these species, the lake does not provide a satisfactory sports fishery, primarily due to the overabundance of undesirable coarse fish species and extensive weed growth.

Land use within the watershed includes lakeshore development (more than 50 lots), forestry and agriculture. The lake has little public access and is used for general recreational purposes by residents of Chief Lake and surrounding communities. The greatest challenge to lake management is likely the control of phosphorus (nutrient) loading. This loading promotes summer algal blooms and the spread of aquatic plants. Reports do exist in MOE files of algae blooms and aquatic plant infestations around the entire lake, especially in the shallow littoral areas.

Chief Lake Watershed and Land Use Map



Non-Point Source Pollution and Chief 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 stormwater runoff, onsite septic systems, agriculture and forestry are common contributors to NPS pollution. One of the most detrimental effects of NPS pollution is phosphorus 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 waste water 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.

Stormwater 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 includes grains, livestock and mixed farming. These practices can alter water flow and increase sediment and chemical/bacterial/parasite inputs to water bodies.

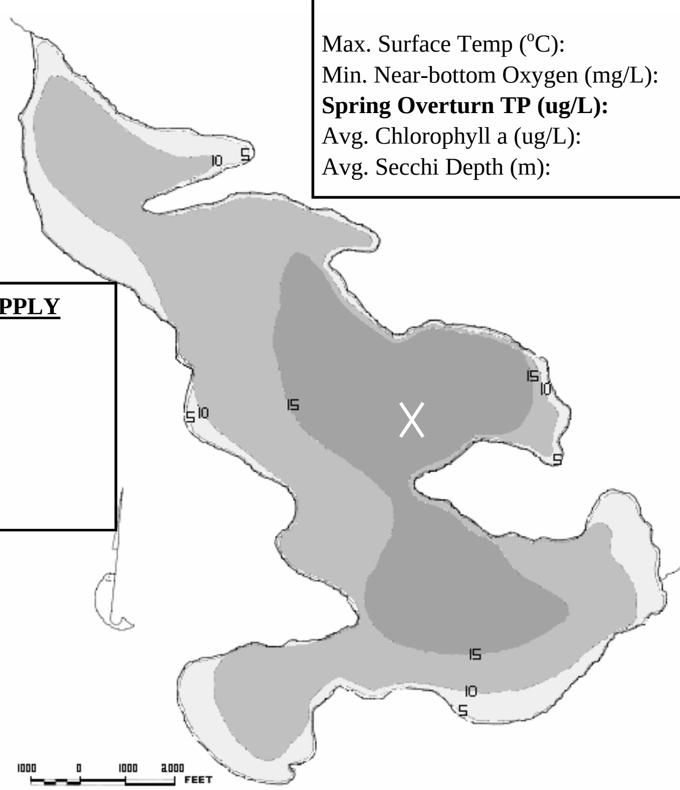
Boating

Oil and fuel leaks are the main concerns of boat operation 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 sediments and nutrients in shallow water operations.

Chief Lake Contour Map

CHIEF LAKE TROPHIC CHARACTERISTICS

	1976	1986	2000	2001	2002
Max. Surface Temp (°C):			20.5	18.5	21.0
Min. Near-bottom Oxygen (mg/L):			5.0	4.0	2.0
Spring Overturn TP (ug/L):	**32.0**	**28.0**	**37.0**	**37.3**	**38.7**
Avg. Chlorophyll a (ug/L):			15.0	27.8	23.2
Avg. Secchi Depth (m):			1.4	1.2	1.2



THEORETICAL PHOSPHORUS SUPPLY

Spring Overturn TP (ug/L): 37.7*
Sedimentation Rate Coefficient: (0.6-0.8)
Flushing Rate (#/yr): (0.1)
Yearly TP Loading (gm/m^2/yr): 0.1-0.13
*Using VLMP data 2000-2002
-Flushing rate based on regionalization calculations and field observations.

LAKE CHARACTERISTICS

Area: 7.37 km^2
Volume: 28,086,500 m^3
Max. Depth: 6.1 m
Mean Depth: 3.8 m
Shoreline Length: 21 km
Elevation: 792 m
X = water quality sampling site

What's Going on Inside Chief Lake?

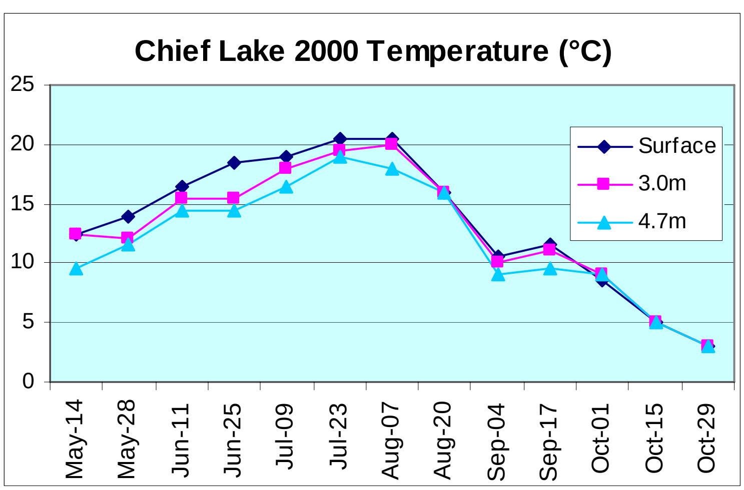
Temperature

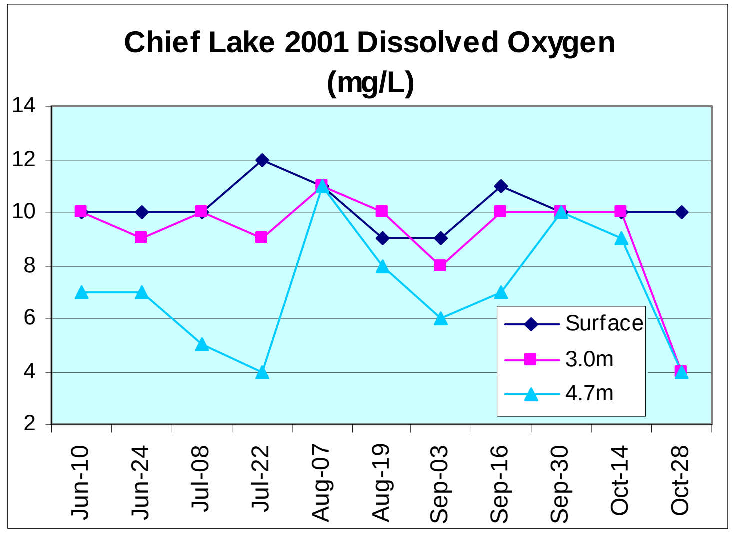
Lakes show a variety of annual temperature patterns based on each lake's location and depth. Most interior lakes form layers (stratify), with the coldest summer water near the bottom. Because colder water is denser, it resists mixing into the warmer, upper layer for much of the summer. In spring and fall, these lakes usually mix from top to bottom (overturn) as wind energy overcomes the reduced temperature and density differences between surface and bottom waters. In the winter, lakes re-stratify under ice with the most dense water (4°C) near the bottom.

Lakes of only a few metres depth tend to mix throughout the summer or layer 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 can create problems for most lake users.

Temperature was measured in the central basin of Chief Lake during 2000-02. The figure below illustrates Chief Lake water temperatures in this basin during 2000. This figure is representative of the data collected during the following two years. Given the lake's shallow depth, it appears to stratify in early May. This stratification is weak, however, and the lake appears to experience a uniform temperature profile more than once throughout the summer and early fall. This is likely due to the shallow depth and open surface of Chief Lake (thus being more susceptible to wind action and water turbulence), which can cause mixing of the stratified layers. The maximum surface temperature, reached by late July/early August, was 20.5 ^{o}C. Shorter days and cooling air temperatures through late August caused a loss of lake stratification in late September, leaving the water temperature nearly uniform with depth, as water temperatures continued to decrease throughout early/late fall.





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 become 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 - no oxygen), forcing fish to move into the upper layer (fish are stressed when oxygen falls below about 20% saturation). Fish kills can occur when decomposing or respiring algae use up the oxygen. In summer, this can happen on calm nights after an algal bloom, but most fish kills occur during late winter or at initial spring mixing.

The figure above shows the oxygen patterns for Chief Lake in 2001, which represents other years of study. Surface water oxygen remained near saturation, not dropping below 9 mg/L. There were three declines in deep oxygen levels, with a low of 4 mg/L on July 22nd. Shortly after each of these drops, recoveries are visible where the oxygen levels became uniform with those at the surface. This was caused by lake overturn, which itself likely resulted from the lake's shallow nature and strong water turbulence formed by wind action. The multiple overturns experienced by Chief Lake are characteristic of a polymictic lake (i.e. it has more than two annual vertical mixings). This differs from most lakes in British Columbia which usually experience only two annual mixings and are termed dimictic.

What's Going on Inside Chief Lake?

Trophic Status and Phosphorus

The term "trophic status" is used to describe a lake's level of productivity and depends on the amount of nutrient available for plant growth, including tiny floating algae called phytoplankton. Algae are important to the overall ecology of the 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 accelerates growth and may artificially age a lake. As mentioned earlier (page 3), total phosphorus (TP) in a lake can be greatly influenced by human activities.

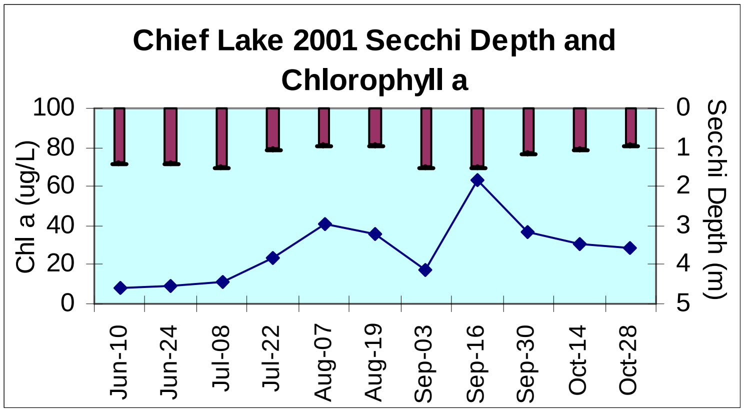
The trophic status of a lake can be determined by measuring productivity. The more productive a lake is the higher the algal growth and therefore the less clear the water becomes. Water clarity is measured using a ***Secchi disc***. Productivity is also determined by measuring nutrient levels and ***chlorophyll***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

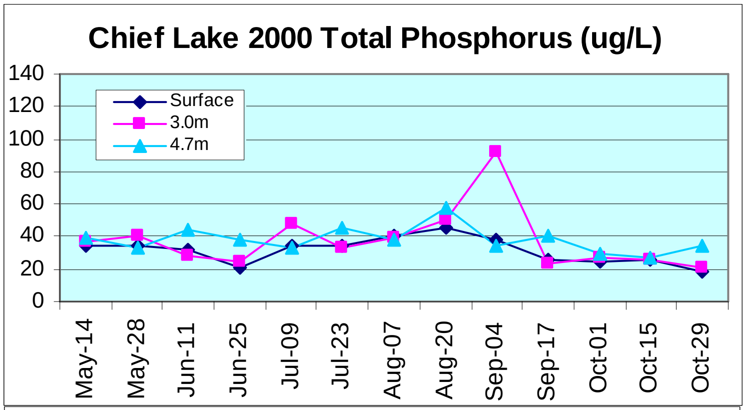
Lakes of low productivity are referred to as ***oligotrophic***, meaning they are typically clear water lakes with low nutrient levels (1-10 ug/L TP), sparse plant life (0-2 ug/L Chl. a), and low fish production. Lakes of high productivity are ***eutrophic***. They have abundant plant life (>7 ug/L Chl. 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) and generally combine the qualities of oligotrophic and eutrophic lakes.

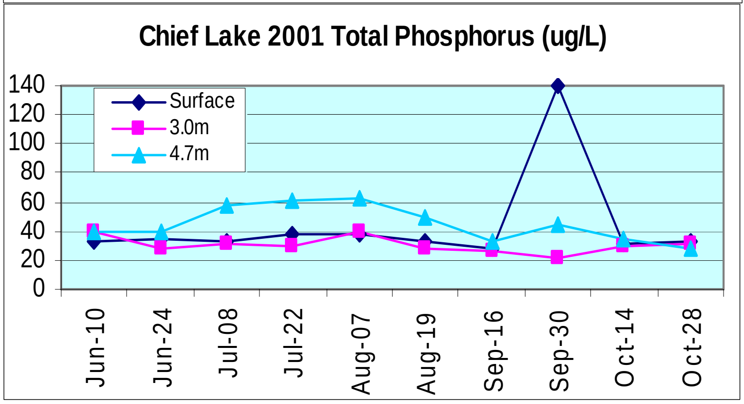
Lake sediments can themselves be a major source of phosphorus. If deep-water oxygen becomes depleted, a chemical shift occurs in bottom sediments. This shift causes sediment to release phosphorus to overlying waters. This "internal loading" of phosphorus can be natural but is often the result of phosphorus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

Chief Lake spring TP levels (page 3) have remained stable since 2000 (average of 37.7 ug/L), implying eutrophic conditions. These values are higher than those found in both 1976 and 1986, however, those samples were collected at different stations so may be slightly biased. The data also suggest that summer algal densities and water quality have recently been stable. Some older chlorophyll and secchi data from 1976 government files generally show similar conditions to those found during this study. The figure to the upper right displays Chief Lake algal chlorophyll concentrations and visibility, as measured by Secchi disc. Secchi was a reasonable indicator of chlorophyll in all of the study years. Chlorophyll averaged 27.8 ug/L in the central basin in 2001, again suggesting eutrophy.

The latter diagrams below display 2000/01 phosphorus cycling in Chief Lake. Summer average surface TP for 2000 was 31 ug/L and it was 44 ug/L in 2001. A large TP peak on September 30th, 2001 (140 ug/L) is the dominant reason for the difference between the two years. Excluding this data point gives a surface TP value for 2001 of 34 ug/L. This large peak on September 30th may be due to the churning up of the lake sediments during the turnover event that occurred at the same time. The different depths within Chief Lake appear to show similar concentrations of TP throughout the summer. This is likely due to the shallow depth of the lake and the frequent mixing of water via wind activity and water turbulence. The slight elevation in deep TP for 2001 may be attributed to an increase in algal settling. Increases in chlorophyll occurred during this same period, which may have resulted in more algal fallout to the lake bottom. It is unlikely that this increase in deep TP resulted from internal phosphorus loading, as dissolved oxygen levels didn't drop below 4 mg/L during this period and ortho-phosphorus values were measured below the detection limit.







Historical Look at Chief Lake

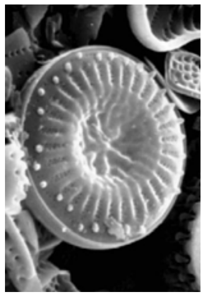
Lake Coring; What does it Mean?

The Chief Lake VLMP was initiated well after local land development and 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 (in this case diatoms) on the lake bottom.

Chief Lake's central basin was cored and sectioned by the Ministry, with help from the VLMP, during the winter of 2002/2003. The 46.5 cm, 400-year core, was analyzed 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 in each section, historical changes in lake phosphorus concentrations, chlorophyll, and water clarity can be estimated.

Dating processes indicated that the lead 210 activity of the Chief Lake core was low, however it did show evidence that the core was of good quality. This was substantiated by a good organic matter profile. Both suggest that the results of the core should be reliable, and hence give an accurate description of the lake's history.



Diatoms are type of phytoplankton commonly found in lake environments. Their glass-like shell (known as a frustule) is composed of silicon. This frustule leaves a permanent record of diatom history in lake bottoms. There are two main types of diatoms, the Centrales which have radial symmetry (e.g. *Cyclotella stelligera* seen in the left photo) and the Pennales which have bilateral symmetry (e.g. *Navicula miniscula* seen in the right photo).

The central basin core indicates that Chief Lake has undergone only minor changes in diatom assemblage during the past 400 years. Thus, it appears that human activities during the last century have likely had little impact on the 'average' trophic status of the lake; however, this does not necessarily rule out small scale impacts along the lake shoreline, that were not large enough to be detected in the core.

The core also suggests that sedimentation rates have increased since the late 1990's. However, because sedimentation rates can vary across a lake basin, caution must be taken when interpreting the results from just one core. The core also shows the sediment to have a relatively high organic matter content. This organic matter content has increased since 1600 AD from 35% to 46% since 1970. This may be due to increased in-lake production of organic matter, increased inwash of organic matter from tributaries (land use?), or decreased loading of inorganic matter to the lake. Because there was little change in diatom assemblage throughout the core, it is difficult to determine which of the factors may be of the greatest influence.

SUMMARY

Recent VLMP results as well as 1976 and 1986 government data suggest that Chief Lake is eutrophic, has stable water quality parameters, and has not changed significantly during the past three decades. VLMP sampling is not recommended for this lake over the next 5-10 years, as the data collected during this study were of good quality, and show a stable trend. The lake core collected during the winter of 2002/2003 shows that the algal profile has remained stable during the past 400 years, and there has been no major shift in trophic status. Hence, water quality in the lake has not fluctuated to any great extent during the core's history. Regardless, all residents and land developers within the watershed are advised to practice good land management such that nutrient or sediment addition to the lake and its tributaries are minimized.

Household Tips to Keep Chief 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 lady bugs, 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 water and treat outgoing effluent 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, 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.

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 washing machine and dishwasher only when full and use only low-flow showerheads and toilets.

Auto Maintenance

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

Boating

- Do not throw trash overboard or use lakes or other waterbodies as toilets.
- Use biodegradable, phosphate-free cleaners instead of harmful chemicals.
- 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.

Who to Contact for More Information

Ministry of Environment
Contact: Bruce Carmichael or James Jacklin
Public Feedback Welcomed
3rd Floor, 1011-4th Ave
Prince George, BC, V2L 3H9
Ph: (250)-565-6455 or (250)-565-4403
Email: Bruce.Carmichael@gov.bc.ca
James.Jacklin@gov.bc.ca

Chief Lake Volunteer Water Quality Testing Group
Contact: Tom Wood
Ph: (250) 967-4357
Email: woodt@pgonline.com

Regional District of Fraser-Fort George
Contact:
155 George St.
Prince George BC, V2L 1P8
Ph: 250-960-4400
Fax: 250-960-4466

The B.C. Lake Stewardship Society
Contact:
#4 552 West Ave,
Kelowna, BC, V1Y 4Z4
Ph: 1-877-BC-LAKES
Fax: (250)-717-1226
Email: BCLSS@hotmail.com
Website: www.bclss.org

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Tom Wood, Kelvin Mudle, Tim Wood

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