Ministry of Environment

Green Lake 1983-2008

Water Quality Monitoring Program

(April 2009)

The Importance of Green Lake and its Watershed

British Columbians want lakes to provide good water quality, aesthetics and recreational opportunity. When we do not see these features in our local lakes, we want to know why. Through regular monitoring programs the Ministry of Environment (MoE) can come to understand a lake's current water quality, identify the designated uses for a given lake, and monitor water quality changes resulting from land development within the lake's watershed. The MoE can work in partnership with local government, land owners, and the BC Lake Stewardship Society (BCLSS) to develop lake specific monitoring programs and provide educational materials on general lake protection issues. This useful information can help communities play a more active role in the protection of the lake resource.

Monitoring data for Green Lake has been collected since 1983. This status report provides the results from all data collected up to 2008 and builds upon the works of David Kelly, *Water Quality Green Lake: the Effects of Sewage Contamination on the Aquatic Ecosystem* (Kelly, 1991). The main focus of this study is to address recent concerns over the fisheries resource at Green Lake and to determine the lake's health in regards to its suitability for fish habitat.

Green Lake's watershed (defined as the entire area of land that moves the water it receives to a common waterbody) drains an area of 4.2 km^2. Watersheds play a crucial role in the purification of water, retaining water and releasing it to the environment as required for the proper maintenance of ecosystem functions. Water 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.

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.

Green lake lies within the Coastal Douglas-fir biogeoclimatic zone and is located on Vancouver Island, in the northwest region of the City of Nanaimo, at an altitude of 93 m. The lake is shaped like a rounded-square, with a surface area of 13.4 hectares, a perimeter of 1400 m, and a mean and maximum depth of 5.7 m, and 10 m, respectively. Figure 1 shows the bathymetric map for Green Lake, including water monitoring locations, streams, and important geographical features.

Photo 1: E & N railway trestle at north-end of Green Lake (MoE, 2008)

Green Lake is located in a depression sheltered by surrounding hills. Around it are residential homes, hobby farms, and one agricultural property. All lake-side residences rely on private septic fields for sewage disposal but the City of Nanaimo is investigating the possibility of connecting Green Lake residences to the City of Nanaimo sewer (Hickey, T., pers. comm., 2009). Green Lake supports populations of rainbow trout, cutthroat trout, small mouth bass, prickly sculpin, and stickleback (FFSBC, 2008). It has been stocked with rainbow trout since 1984 and stocked with cutthroat trout since 1989. Approximately 12,750 rainbow trout have been released into Green Lake between April 2004 and November 2008 (FFSBC, 2008). Several bird species including mallards, cormorants, and Canada geese are also supported at Green Lake.

Drainage from Green Lake occurs at the north-end via Bloods Creek, which in turn flows into the Straight of Georgia. Bloods Creek supports various fish types including chum salmon, coho salmon, cutthroat trout, rainbow trout, and smallmouth bass (FFSBC, 2008). No anadromous salmonids reach the lake due to limited water flow through Bloods Creek (Kelly, 1991). The principle inlet, Copley Brook, is located at the west side of the lake and some local run-off also enters the Lake through a bog located at the north end, underneath the E & N railway trestle (Photo 1). Copley Brook is said to be an ephemeral stream since it flows mostly after rainfall or snowmelt events and is dry for the majority of the year. Seasonal variations in weather can influence lake water levels causing them to fluctuate above or below the mean or maximum depth.

The greatest challenge to lake management on Green Lake will likely be the control of phosphorus (nutrient) loading from non-point source pollution. This loading could promote summer algal blooms and the spread of aquatic plants. No reports of algal blooms or aquatic plant problems for Green Lake have been found in MoE files. However, increased nutrients can lead to decreased oxygen levels and warmer temperatures, which can affect the aquatic life, including fish.

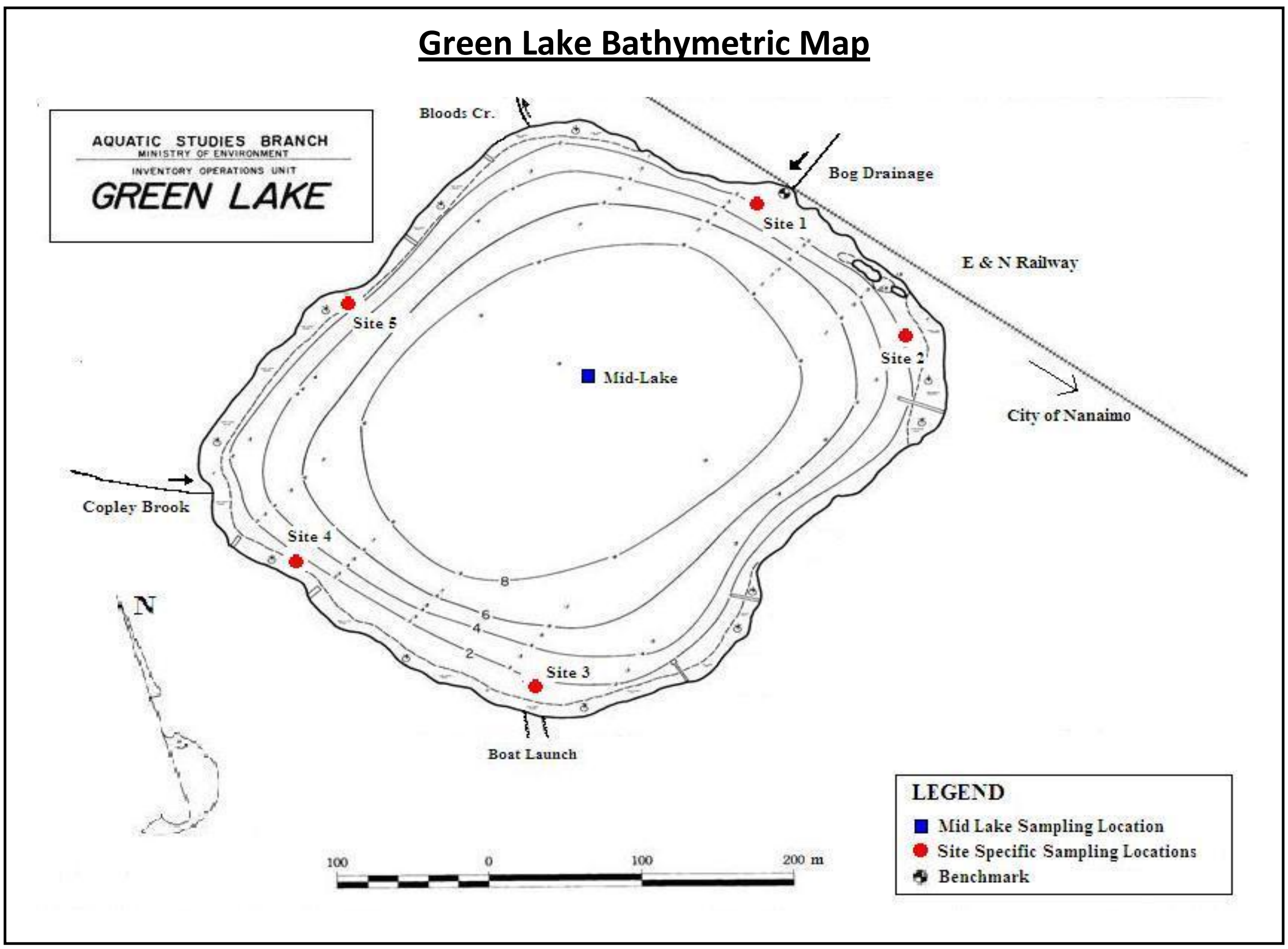


Figure 1: Green Lake bathymetric map obtained from Fish Wizard (FFSBC, 2008) and modified by Simon Allard February 4, 2009

Non-Point Source Pollution and Green 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 (NPS) of pollution (Figure 2). 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 water courses where it will become available for algal production. Watersheds have the ability to buffer against pollution in time but this ability is impeded with landscape modifications and/or significant increases in pollution.

Photo 2: Picture of Green Lake obtained from
http://www.nanaimoinformation.com/forum/showthread.php?p=26620

Land Use

Lakeshore property owner's rights and increasing land values can promote high land use expectations at the expense of lake-shore riparian areas. Residential development generally includes clear-cutting and other vegetation removal for placement of structures. This can be limited to just the building site requirements or can include removal of riparian vegetation, land clearing for lawns or agricultural activities, shoreline protection structures, and docks. All of these land disturbance activities can alter water flow, and potentially increase sediment and phosphorus inputs to water bodies.

Agriculture

Agriculture, including livestock, the production of grains, and mixed farming can alter water flow and increase sediment, chemical, bacterial, and parasitic input into water bodies.

Agricultural runoff is a potential source of freshwater eutrophication – a process where organic and inorganic compounds such as nitrogen and phosphorus, not normally present in such abundance, are introduced to a lake. The usual result of eutrophication is an overabundance of algae growth on the lake surface.

Onsite Septic Systems and Grey Water

As long as onsite septic systems are properly located, designed, installed and **maintained**, they can effectively treat human waste water and wash water (grey water). Failure of onsite septic systems can cause significant nutrient and pathogenic waste to enter the water body and can be dangerous to human and animal health.

Stormwater Runoff

Lawn and garden fertilizer, sediment eroded from modified shorelines or infill projects, lawn chemicals, 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. Paved structures prevent infiltration of water to soils, collect hydrocarbon contaminants during dry weather, and increase direct runoff of these contaminants to lakes during heavy rain events. Severe stormwater runoff can cause soils to erode and can result in property loss. As a common resource, it is the responsibility of everyone to ensure that the freshwater resources remain clean. The control of runoff pollution, at the source, is vital to the protection of this precious resource.

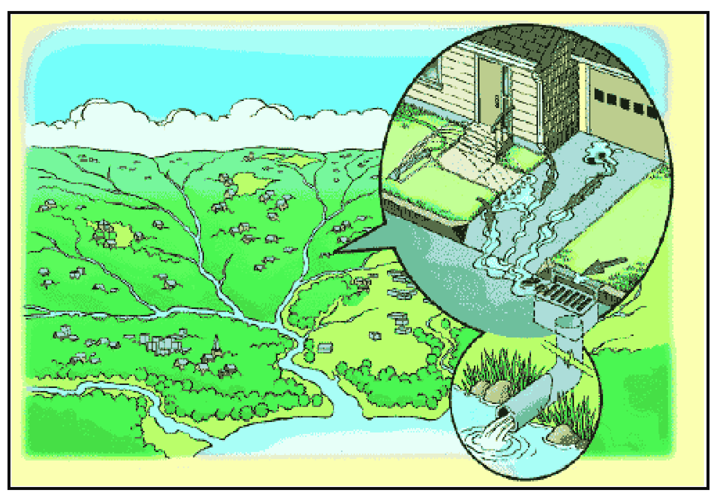


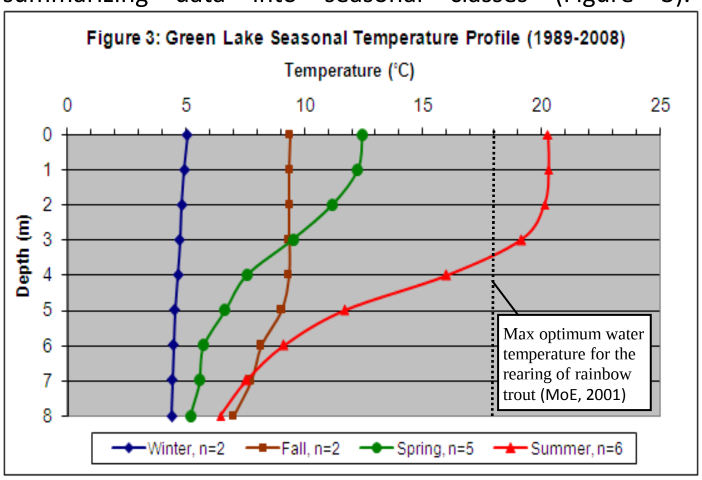
Figure 2: Non-point sources of pollution within a watershed. Obtained from
http://counties.cce.cornell.edu/onondaga/002_environment/001_water_quality/000065.php

What's Going on Inside Green Lake?

Temperature

Temperature can affect the solubility of many chemicals and can therefore influence the effect of pollutants on aquatic life. Colder water is denser and heavier and lies on the bottom overlain by subsequent warmer, less dense layers. Most Vancouver Island lakes form layers (stratify) and, like coastal lakes, are typically monomictic overturning (mixing from top to bottom) once during late winter or spring as wind energy overcomes the reduced temperature and density differences between surface and bottom waters. Temperature stratification patterns are important to lake water quality because they determine much of the seasonal oxygen, phosphorus, and algal conditions. Increased temperatures elevate the metabolic oxygen demand of organisms and reduce the solubility of oxygen in water. Optimum temperature ranges for rainbow trout during incubation, rearing, and spawning life history stages are 10.0-12.0˚C, 16.0-18.0˚C, and 10.0-15.5˚C (MoE, 2001), respectively. Monitoring lake water temperature over the long-term can also help to determine potential effects of climate change and how it might affect water quality over time.

Green Lake temperature data were collected at the deep mid-lake station (Figure 1) 15 times from 1989 to 2008. A seasonal depth profile for temperature was created by summarizing data into seasonal classes (Figure 3).

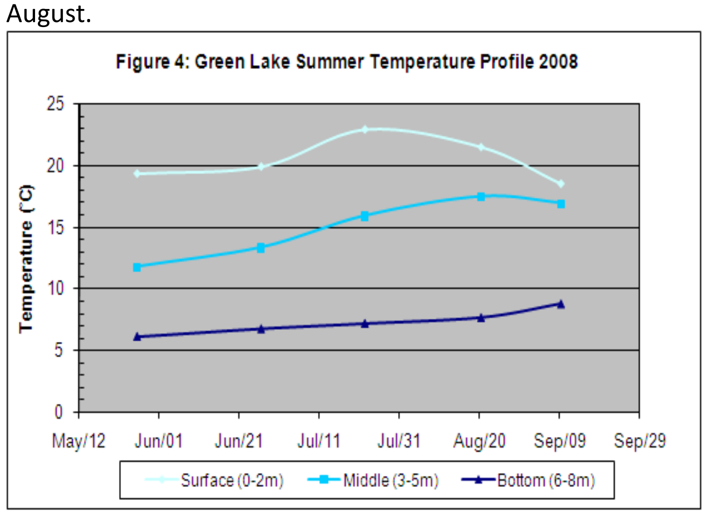


The seasons are classified to represent seasonal temperature trends for our region and have been divided into fall (Sept 21-Dec 19), summer (June 21- Sept 20), winter (Dec 20 - Feb 20), and spring (Feb 21- June 20). A maximum temperature of 22.92˚C was reached in the summer of 2008, on July 22, at a depth of 2 m and a minimum temperature of 4.00˚C was achieved on March 8, 2001 at the bottom depths of 8 and 9 m.

The average summer surface (0-2m), middle (3-5m), and bottom (6-8m) water temperatures for Green Lake from 1991-2008 data were 20.62, 15.59, and 7.69˚C, respectively.

In the seasonal temperature profile (Figure 3) it can be seen that water temperatures are nearly isothermal with very little stratification in the fall and winter. A distinct thermocline develops during the summer at a depth of 3-5 m. The bottom temperatures do not change dramatically throughout the seasons, ranging from an average of 4.43˚C in the winter to an average of 7.69˚C in the summer. Beyond temperatures of 18˚C fish become stressed; leading to a higher risk of parasitic infection, disease, and ultimately death. In the summer, upper waters, from 0-3.5 m depth are above the optimum temperature range for the rearing of rainbow trout. This restricts suitable fish habitat to below 3.5 m.

Figure 4 shows the summer stratification trends from May-September 2008. The average 2008 summer temperature at the surface, middle, and bottom depths was 20.69, 15.89, and 7.58˚C, respectively. Bottom waters (hypolimnion) temperatures remained consistently cool, ranging from 6.13˚C in May to 8.75˚C in September. Overall, as expected, lake temperatures increased throughout the summer with surface temperatures cooling towards the end of July and middle-depth temperatures cooling towards the end of August.

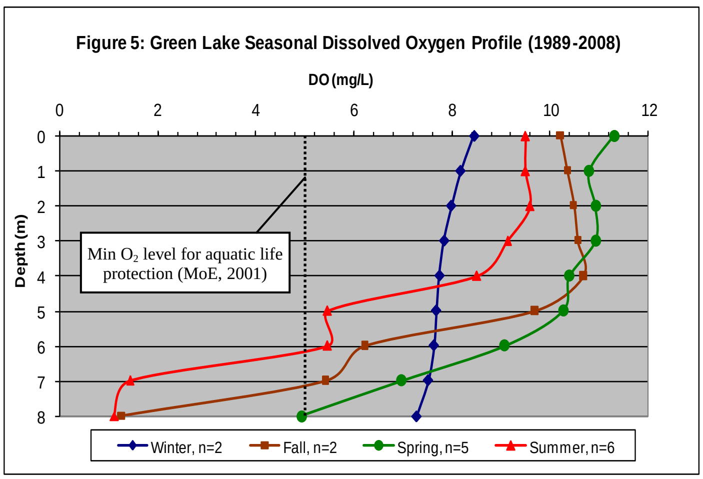


Dissolved Oxygen

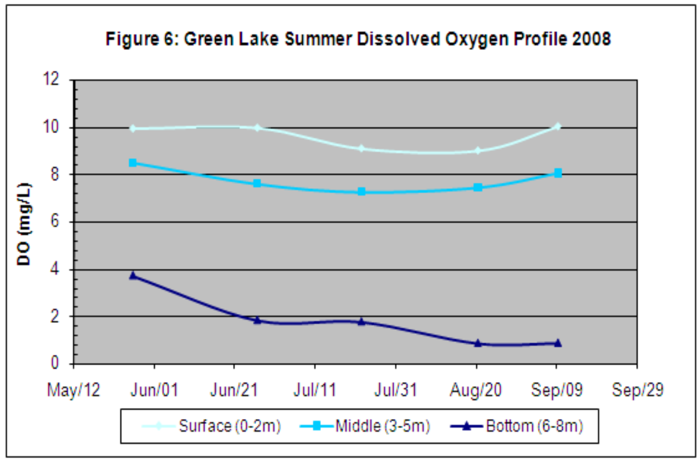
The availability of oxygen in water is critical to the maintenance of aquatic life. Oxygen enters the water as dissolved oxygen (DO) from many sources including air, wind action, and through plant photosynthesis. Oxygen is consumed by the respiration of plants and animals and through the decomposition of dead organic material by bacteria (Carter & Roumiew, 2008).

Lakes that are low in productivity (oligotrophic) typically offer sufficient levels of oxygen to support life at all depths. As lakes become more productive (eutrophic), oxygen availability becomes limited and may only accommodate life at certain depths. Fish, for example, become stressed when oxygen saturation levels fall below 20% (BCLSS, 2008). The instantaneous minimum level recommended for the protection of aquatic life, to be maintained at all times, is 5 mg/L (MoE, 2001).

The historical seasonal DO profile in Figure 5 summarizes data from 1989-2008. In winter, oxygen levels of between 7-9 mg/L can be observed at all depths. As the seasons progressed towards the summer, surface DO levels remained high at the surface and decreased with depth. Anoxic conditions occurred in the hypolimnion during fall and summer; limiting fish habitat to middle and upper depths. In summer months, warm surface temperatures further limited fish habitat to a depth of 3-5 m where oxygen and temperature are tolerable.



Summer 2008 DO data (Figure 6) shows that DO levels remained saturated at the middle and surface depths but reached anoxic conditions at the bottom (6-8 m) in early June, lasting till the end of the summer and extending into the fall season. During the summer of 2008, the average DO levels found at the surface, middle, and bottom depths were 9.61, 7.77, and 1.81 mg/L, respectively, with a minimum DO measurement of 0.35 mg/L occurring on June 22, at 8 m. The average DO at 8 m depth, from May to September, was 0.53 mg/L. Bottom waters appeared unsuitable for fish habitat for almost half of the year in 2008.



Trophic Status and Phosphorus

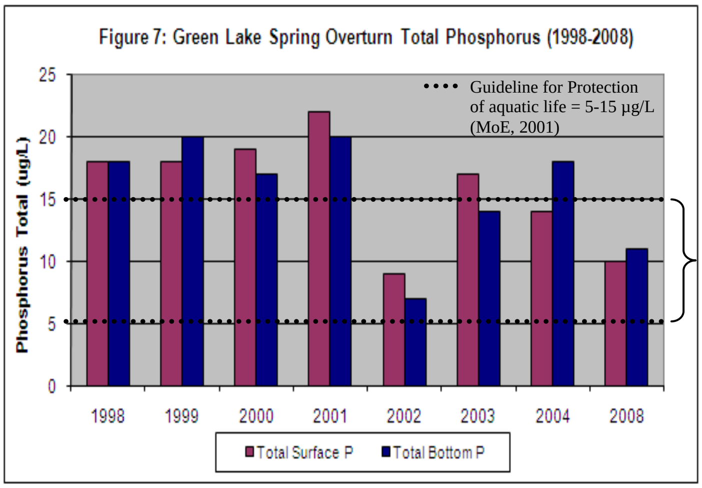
The term trophic status is used to describe a lakes level of productivity and depends upon the amount of nutrients available for plant growth, including tiny floating algae called phytoplankton. Algae are important to the overall ecology of the lake because they are food for zooplankton, which in turn are food for other organisms, including fish. In many BC lakes, phosphorus is the nutrient in shortest supply and thus acts to limit aquatic life production. When in excess, phosphorus accelerates growth and may artificially advance a lake towards a higher trophic status. As mentioned on Page 3, TP in a lake can be greatly influenced by human activities.

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

Lakes of low productivity, referred to as ***oligotrophic,*** are typically clear water lakes with low nutrient levels (1-10 µg/L TP), sparse plant life (0-2 µg/L chl. α), and low fish production. Lakes of high productivity are ***eutrophic***. They have abundant plant life (> 7 µg/L chl. α), including algae, due to higher nutrient levels (> 30 µg/L TP). Lakes with an intermediate productivity are called ***mesotrophic*** (10-30 µg/L TP and 2-7 µg/L chl. α) and generally encompass the characteristics of oligotrophic and eutrophic lakes (Nordin, 1985).

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 usually have elevated algal levels and typically lack recreational appeal. The recommended guideline for the protection of aquatic life is 5-15 µg/L TP (MoE, 2001).

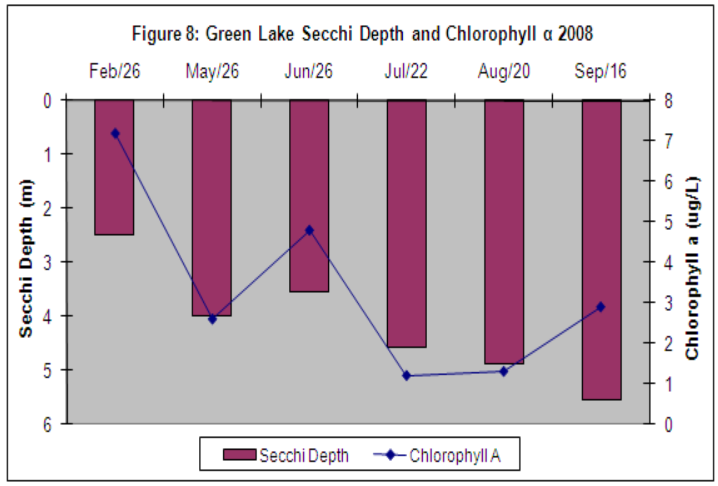
Green Lake surface spring overturn total phosphorus (TP) data were collected every year from 1998-2004, and again in 2008 (Figure 7). The minimum, maximum and average spring overturn TP at 0.5 m was 9.00 (2002), 22.0 (2001), and 18.5 µg/L TP (1998-2008), respectively. This surface TP average indicates that during spring overturn (Feb-March) Green Lake displays nutrient characteristics of a mesotrophic lake. Four phosphorus values (115, 162, 111, and 730 µg/L) taken from the bottom during 1989, 1990, July 2008, and August 2008 were removed entirely due to possible disturbance of bottom sediment by the sampler. These values were deemed outliers but indicate that there is an overabundance of nutrients available in bottom sediments.



In most lakes, the ratio of nitrogen to phosphorus is well over 15:1, meaning excess nitrogen is present. In lakes where the N:P ratio is less than 5:1, nitrogen becomes limiting to algae growth and can have major impacts on the amount of algae present. The N:P ratio average from all lake data collected during spring overturn between 1998-2008 was 46:1 at the surface and 47:1 at the bottom, indicating that phosphorus is the limiting nutrient.

From 1990 to 2000 the average TP at the surface (n=7), middle (n=5), and bottom (n=5) was 11.14, 11.80, and 18.80 µg/L, respectively. From 2000-2008 TP increased at the surface (n=11) with an average value of 13.36 µg/L but decreased slightly at the bottom (n=11) with an average measurement of 17.33 µg/L. In general, nutrients tended to increase with depth further indicating the possibility of internal phosphorus loading.

Figure 8 displays Green Lake water clarity, and surface (0.5 m) chlorophyll α concentrations during 2008. Water clarity, or visibility, is measured using a Secchi disc, a black and white disc that measures the depth of light penetration. Secchi disc depth appeared to be a reasonable indicator of chlorophyll α in 2008. The average 2008 chlorophyll α was 3.33 µg/L and the 2008 average Secchi depth was 4.18 meters. The summer averages (June-Sept) for chlorophyll α and Secchi depth were 2.55 µg/L and 4.65 meters, respectively. A maximum chlorophyll α value of 7.2 µg/L was observed during the spring overturn sampling on February 26, 2008 with a minimum chlorophyll α value of 1.2 µg/L measured on July 22, 2008.



The 2008 Chlorophyll α data indicated that Green Lake exhibited eutrophic lake conditions in February with mesotrophic conditions dominating for the rest of the sampling year. Green Lake was likely experiencing a spring bloom, which can occur when the lake surface waters initially warm up and nutrient concentrations are still well mixed throughout the water column.

Bacteriological data for Green Lake has not been collected since 1991. Intense bacteriological sampling occurred during 1990-1991 to locate potential sources of pathogenic waste from failing septic systems. A paper released in July of 1990 by the city of Nanaimo concluded that 15 to 40% of residences in the Green Lake area have experienced septic tank problems (In Kelly, 1991). From 1990-1991 fecal coliform results ranged from less than 2 to 520 CFU/100mL with an average of 32.20 CFU/100mL. A map of the site specific sampling locations (Site 1 to Site 5) used for bacteriological data collection can be found in Figure 1.

Should Further Monitoring be done on Green Lake?

Lake monitoring results suggest that Green Lake has adequate recreational water quality with the exception of some high phosphorus values and fecal coliform counts. Summer 2008 data showed that elevated surface temperatures and bottom anoxic conditions are not optimal for fish. Fish habitat is restricted to mid-depths where temperature is cooler and oxygen is saturated. Chlorophyll α and phosphorus values mostly indicated that Green Lake is mesotrophic with some tendencies of eutrophic status in the spring/summer. Spring overturn sampling is recommended to observe changes and confirm the lake's nutrient status. Fish health and numbers should be monitored closely to ensure that the recreational fishery remains stable. Furthermore, bacteriological sampling at the site specific locations is recommended to determine whether water quality currently meets the guidelines for primary recreational contact (less than or equal to 200 CFU/100mL geometric mean) (MoE, 2001). Regardless, all lake-side residents and developers in the watershed are advised to practice good land management such that nutrient or sediment addition to the lake and its tributary is minimized. The transplanting of aquatic plants into Green Lake is also to be avoided.

Tips to Keep Green Lake Healthy

Yard Maintenance, Landscaping & Gardening

- Minimize the disturbance of shoreline areas by maintaining natural vegetation cover
- Minimize high-maintenance grassed areas
- Replant lake-side 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
- Do not apply fertilizers or pesticides before or during rain due to the likelihood of runoff
- Compost yard and kitchen waste and use it to boost your garden's health as an alternative to chemical fertilizers
- 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

Agriculture

- Locate confined animal facilities away from waterbodies and 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 stream banks and lake-shores
- 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 stream bank, river or lake-shore 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. They can kill the bacteria at work in your on-site sewage system and can contaminate waterbodies
- Conserve water: run the washing machine and dishwasher only when full and use only low-flow showerheads, faucets, 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 and 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
- Use absorbent bilge pads to soak up minor leaks or spills
- Check for and remove all aquatic plant fragments from boats and trailers before entering or leaving a lake. Eurasian milfoil is an aggressive invasive aquatic weed. Be sure to familiarize yourself with this plant and remove and discard any fragments
- Do not use metal drums in dock construction. They rust, sink and become unwanted debris. Use blue or pink closed-cell extruded polystyrene billets or washed plastic barrel floats and label them with owner's name and phone number in case they wash away.

Who to Contact for More Information

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