BRITISH COLUMBIA | Ministry of Environment

Glen Lake 1981-2009

Water Quality Monitoring Program

(April 2009)

The Importance of Glen 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 Glen Lake has been collected since 1981. This status report provides the results from all data collected up to 2009 and builds upon the work of Bruce Holms (1996) *"State of Water Quality of Glen Lake 1981-1995."* The main focus of this study is to address recent concerns over the fishery resource at Glen Lake and to determine the lake's health in regards to its suitability for fish habitat. Another goal of this report is to determine the current status of the aerator at Glen Lake and to find out whether or not the aerator has improved lake water quality.

Glen Lake lies within the Coastal Douglas-fir biogeoclimatic zone and is located on southern Vancouver Island, in the City of Langford, at an altitude of 67 m. The lake has a surface area of 16.9 hectares, a perimeter of 2113 m, and a mean and maximum depth of 6.4 m, and 14 m (FFSBC, 2008), respectively. The flushing rate for Glen Lake is 1.43 times/year (Perrin, 1995). Figure 1 shows the Glen Lake bathymetric map, including the aerator and water monitoring location, streams, and important geographical features.

Glen Lake's watershed drains an area of 11.9 km^2 (Figure 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. 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 downstream environment.

Photo 1: Wetland habitat and drainage outflow via Colwood Creek

Glen Lake is part of a series of natural lakes on Vancouver Island referred to as "ice kettles" (CRD, 2009a). These lakes were formed by large ice fragments left behind by a melting glacier from the last ice age about 11,000 years ago. Drainage from

Glen Lake occurs at the east-end via Colwood Creek, which in turn drains into the Esquimalt Lagoon through a series of urbanized stream channels, culverts, and Langford Lake. The Lower reaches of Colwood Creek, at Royal Roads University, offer a valuable reference site for research, having rich riparian area and old growth douglas-firs; some over 800 years-old.

There are approximately 58 properties fronting Glen Lake (Figure 2), all of which previously relied on private septic systems for sewage disposal. From December 2005 to April 2009, 48 of these properties have been connected to the City of Langford sewer system. A City Bylaw (1066), adopted July 2007, made it mandatory for all lakefront properties to be connected to the City sewer infrastructure by July 2008. With the bylaw providing for some allowances 12 properties remain to be connected to the City sewer (West Shore Environmental Services, 2009. pers. comm).

Glen Lake provides an important recreational fishery supporting populations of rainbow trout, cutthroat trout, smallmouth bass, brown catfish, and pumpkinseed (FFSBC, 2008). Approximately 12, 500 triploid rainbow trout were stocked in Glen Lake from March 2004 to November 2008 (FFSBC, 2008). In order to preserve the fishery resource and improve water quality a full-lift hypolimnetic aerator was installed in 1985, at the deepest depth (Figure 1). In 2005, due to corrosion and decreased performance, the old aerator was replaced (MoE, 2005). The aerator is inspected annually before start-up and requires uninterrupted performance from May to October. Its purpose is to deliver oxygen to water in the deeper layers of the lake to facilitate survival of trout when high water temperatures result in depleted oxygen levels. The aerator also reduces internal nutrient loading processes by keeping oxygen concentrations above 1 mg/L. In 2008, the aerator was not turned on until July 18^{th}.

The greatest challenge to lake management on Glen Lake will likely be the control of phosphorus (nutrient) loading from non-point source pollution. This loading can promote summer algal blooms and the spread of aquatic vegetation. No reports of fish kills, algal blooms, or aquatic plant problems 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.

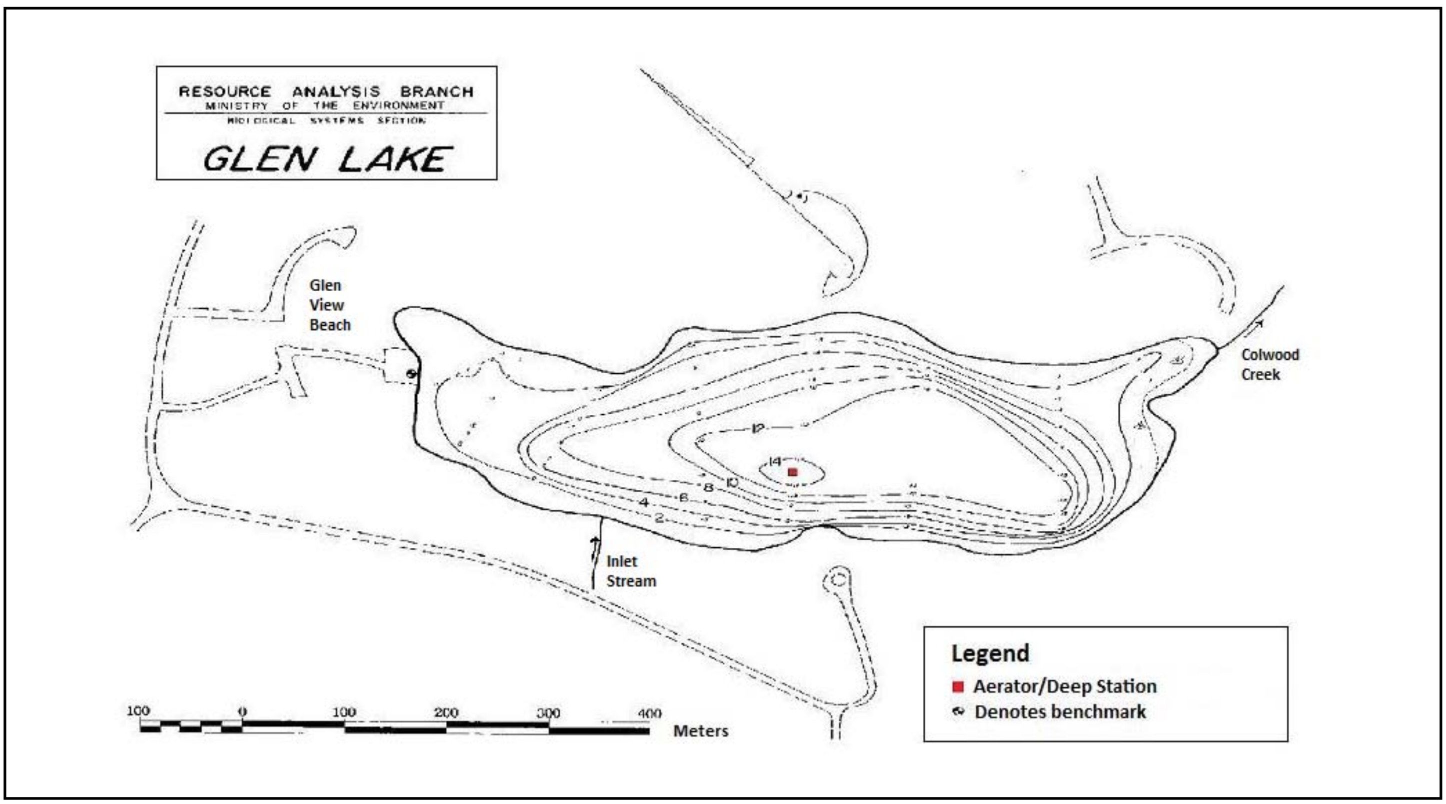


Figure 1: Glen Lake bathymetric map modified from original obtained from Fish Wizard (FFSBC, 2008)

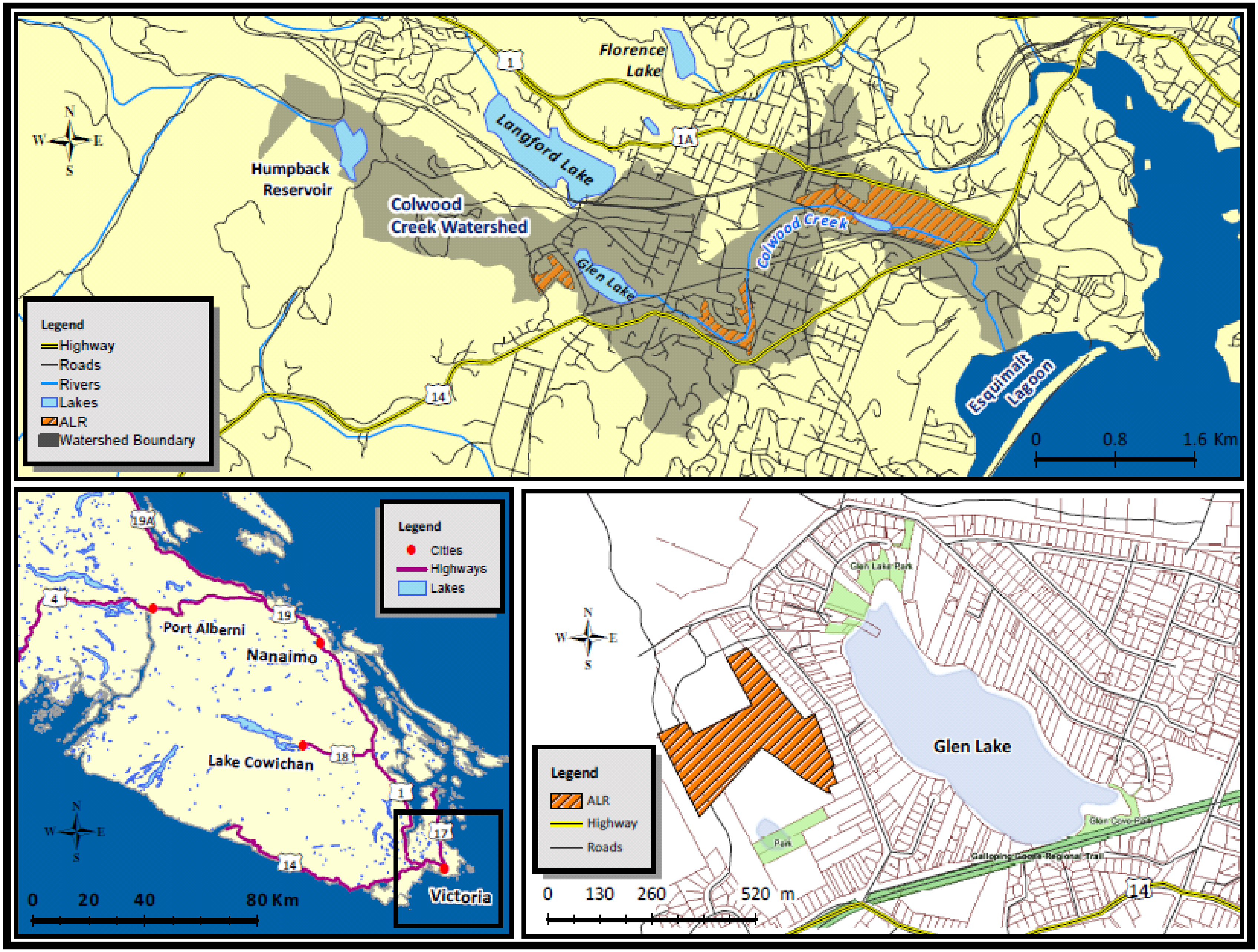


Figure 2: Colwood Creek Watershed, southern Vancouver Island and Glen Lake cadastral map created April 22, 2009, using Natural Areas Atlas (CRD, 2009b) and data layers retrieved from the Land Resource Data Warehouse (www.lrdw.ca). Datum and map projection: NAD 83 UTM Zone 10N.

Non-Point Source Pollution and Glen 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 3). 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: Lake-shore homes surrounding Glen Lake

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 waterbodies. 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 Greywater

As long as onsite septic systems are properly located, designed, installed and **maintained**, they can effectively treat human wastewater and wash water (greywater). 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.

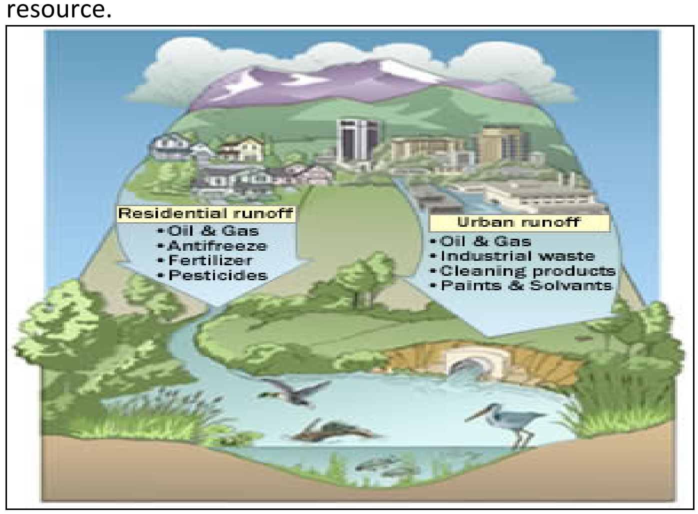


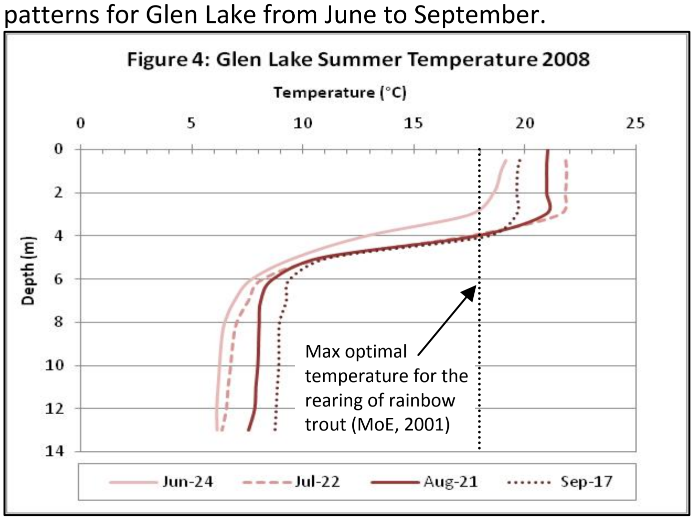
Figure 3: Non-point sources of pollution within a watershed. Obtained from http://www.ci.fort-collins.co.us/stormwater/stormwater-images/quality.jpg

What's Going on Inside Glen 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) in the summer 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 these might affect water quality over time.

Glen Lake temperature data for 2008 were collected at the deep monitoring station 7 times from March to September. Figure 4 shows the summer temperature stratification patterns for Glen Lake from June to September.



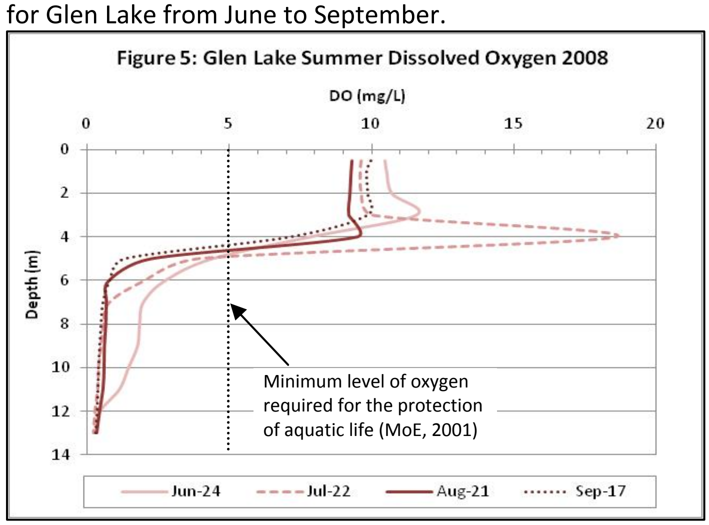
A maximum temperature of 21.9˚C was observed on July 22nd, at 1 m, and a minimum temperature of 6.09˚C was measured on June 24th at 12 m. Almost all surface temperatures during the summer, with the exception of June, were over the maximum optimal temperature for the rearing of rainbow trout. Surface (0-4 m), middle (5-9 m), and bottom (10-14 m) temperatures ranged from 12.8-21.9, 6.29-11.2, and 6.09-8.89˚C, respectively, with means of 19.5, 8.43, and 7.32˚C, respectively.

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 can become stressed when oxygen levels fall below 5 mg/L, the instantaneous minimum level recommended for the protection of aquatic life (MoE, 2001).

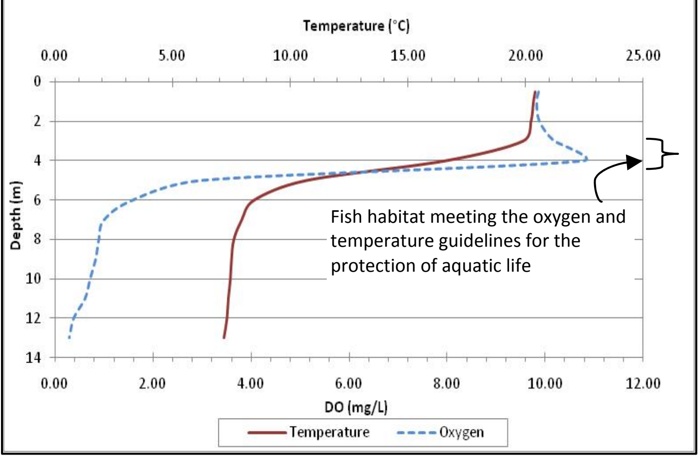
Glen Lake dissolved oxygen data for 2008 were monitored at the deep station 7 times from March to September. Figure 5 shows the summer oxygen stratification patterns for Glen Lake from June to September.



A maximum oxygen level of 18.6 mg/L was observed on July 22nd, at 4 m, and a minimum oxygen level of 0.25 mg/L was measured on July 22nd, at 13 m. The oxygen spike observed at 4 m can likely be attributed to oxygen produced by phytoplankton (algae). During the summer of 2008 almost all oxygen concentrations below 5 m failed to meet the guideline for the protection of aquatic life. Surface (0-4 m), middle (5-9 m), and bottom (10-14 m) oxygen concentrations ranged from 7.15-18.6, 0.44-4.42, and 0.25-1.46 mg/L, respectively, with means of 10.1, 1.47, and 0.51 mg/L, respectively. The late start-up date of the aerator likely resulted in the severe anoxic conditions observed at the water/sediment interface.

In order to summarize summer temperature and oxygen stratification trends for the summer of 2008 a mean profile was created using data from Figures 4 and 5. Figure 6 displays the 2008 zone of optimal habitat for rainbow trout (3.4-4.8 m), where temperatures are below the criteria for max optimal temperature for the rearing of rainbow trout (18˚C) and where oxygen levels are above the recommended level for the protection of aquatic life (5 mg/L). Outside of their optimal habitat zone, fish could become stressed.

Figure 6: Glen Lake Average Summer DO and Temperature 2008



Trophic Status and Phosphorus

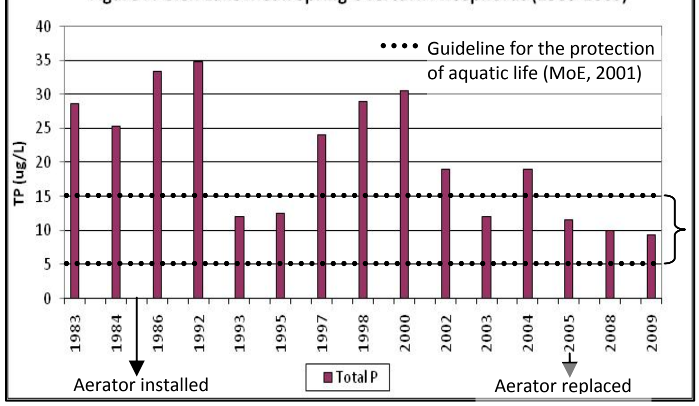
The term trophic status is used to describe a lake's level of productivity and depends upon the amount of nutrients available for plant growth, including tiny floating algae called phytoplankton. Algae are important to the overall ecology of the lake because they are food for zooplankton, which in turn are food for other organisms, including fish. In many lakes phosphorus is the nutrient in shortest supply, acting as the nutrient limiting aquatic life production. When in excess, phosphorus accelerates growth and may artificially advance a lake towards a higher trophic status. As mentioned on Page 4, 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 in plants). The more productive a lake is the higher the algal growth and the less clear the water. Phosphorus concentrations measured during spring overturn can be used to assess current productivity and 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 called ***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) (Nordin, 1985). Mesotrophic lakes generally encompass the characteristics 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. The release of TP from sediments can cause algal blooms and lead to further oxygen depletion when algae die. 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 phosphorus guideline recommended for the protection of aquatic life is 5-15 µg/L TP (MoE, 2001).

Glen Lake spring overturn TP data were collected from 1983-2009. A mean TP histogram (Figure 7) was created by averaging TP results for all depths (surface, middle, and bottom) during spring overturn sampling for each year.

Figure 7: Glen Lake Mean Spring Overturn Phosphorus (1983-2009)



From this figure, TP values appeared to have decreased slightly over time with a mean TP value of 29.1 µg/L in the 80's (n=3), 22.5 µg/L in the 90's (n=5), and 15.9 µg/L in the 00's (n=7). From these TP values Glen Lake displayed nutrient characteristics of a eutrophic lake (TP > 30 µg/L) in 1986, 1992, and 2000 with mesotrophic conditions dominating for the rest of the years. The TP guideline for protecting aquatic life was exceeded 9 out of the 15 years during spring overturn sampling. The recent decrease in spring overturn TP may be attributed to the aerator reducing phosphorus release from lake sediments, or to a decrease in phosphorus input from connecting lake-side septic systems to the City sewer.

Confounding factors such as timing of sample collection and seasonal variations in weather must also be taken into consideration.

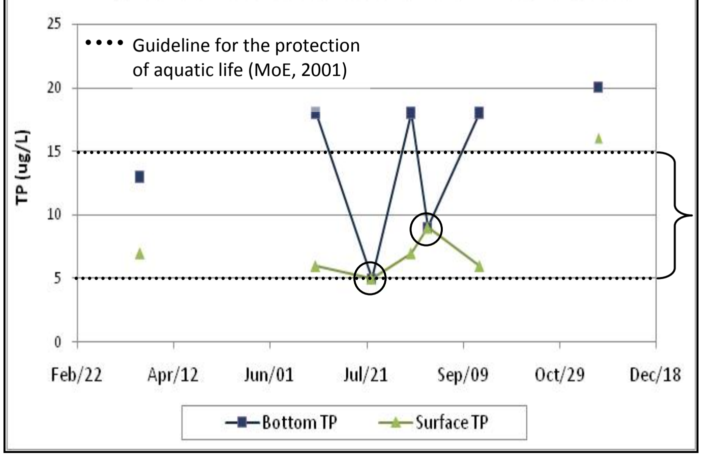
In general, nutrients tended to increase with depth, further indicating the possibility of internal phosphorus loading. For example, six individual bottom TP values, taken from May-August 1984, ranged from 83-201 µg/L. These high values were likely the result of internal phosphorus loading and contributed to the decision to install an aerator. No extreme TP values have been observed during the summer since the aerator has been in operation.

In most lakes, the ratio of nitrogen (N) to phosphorus (P) 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. This can have major impacts on the amount and species of algae present. The mean N:P ratio from all lake data collected during spring overturn between 1983-2009 was 35:1. Looking at all available N and P data the N:P ratio appears to have increased over the decades with a mean N:P ratio of 26:1 in the 80's (n=37) and a mean N:P ratio of 50:1 in the 00's (n=31). Increase in the N:P indicates that P is still the limiting nutrient to algal production. An increase in the N:P ratio could be due to either an increase in Total N or a decrease in TP, or both.

TP data for 2008 were collected seven times from March-November. Figure 8 shows the surface (0.1-0.5 m) and bottom (9-13 m) TP values for 2008. Four of the seven bottom TP values were above the guidelines for the protection of aquatic life, while only one surface value taken on November 18th (16 µg/L) was over the criteria. The high November surface TP value is likely a result of fall mixing, when the nutrient rich bottom water mixes with the surface.

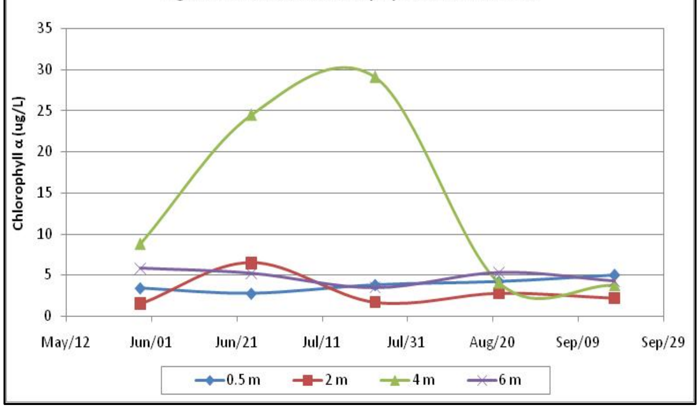
In the spring and summer, as thermal stratification develops and sets in, phosphorus values usually increase with depth. This trend can be seen in the 2008 TP data, with the exception of two samples taken on July 22nd and August 21st, where bottom TP decreased. On July 22nd, at 4 m depth, oxygen (Figure 5) and chlorophyll α (Figure 9) concentrations were elevated at 18.6 mg/L and 29.1 µg/L, respectively, indicating that oxygen was probably being produced by plant biomass present at about 4 m depth. The decline of bottom TP on July 22nd can likely be attributed to the uptake of P by increased amounts of algae. A similar event probably occurred August 21st but was not completely captured by the sample data.

Figure 8: Glen Lake Total Surface and Bottom Phosphorus 2008



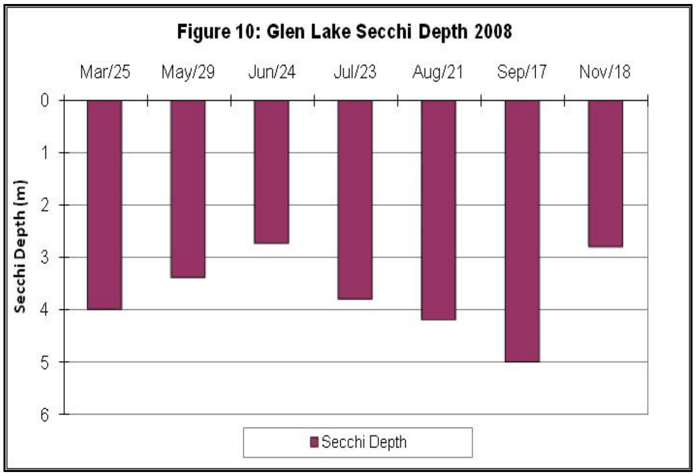
Summer plant life samples, as measured by chlorophyll α, were collected from June-September at various depths. Figure 9 displays Glen Lake chlorophyll α concentrations for the summer of 2008. The summer average (June-September) for chlorophyll α was 6.55 µg/L. The maximum chlorophyll α value of 29.1 µg/L was observed on July 22nd, at a depth of 4 m, while the minimum chlorophyll α value of 1.70 µg/L was also measured on July 22nd but at a depth of 2 m. This provides further evidence that a bloom was likely occurring at about 4 meters on this day.

Figure 9: Glen Lake Chlorophyll α Summer 2008



The 2008 chlorophyll α data indicated that Glen Lake was likely experiencing a summer algae bloom during June and July, in the approximate location of the thermocline. Based on summer chlorophyll α results Glen Lake was primarily mesotrophic with some tendencies for eutrophic (> 7 chl α) conditions at depth.

Glen Lake water clarity data for 2008 were measured seven times from March-November (Figure 10). Water clarity, or visibility, was measured using a secchi disc, a black and white disc that measures the depth of light penetration.



The 2008 secchi depth average was 3.8 meters, while the summer average was 4.1 meters. Measuring secchi depth can help to determine the depth of bloom occurrences and increase the chances of capturing a eutrophic event with chlorophyll α sampling. For example, secchi data from June and July showed that light did not appear to penetrate past 4 m, the depth at which a bloom was likely occurring. Secchi readings ranged from a minimum of 2.8 m with the maximum amount of light penetration (5.0 m) occurring in September, at the end of the summer season.

Bacteriological

Bacteriological data for Glen Lake has been collected at Glen View Beach since 1980. Fecal coliforms (FC) are bacteria from warm blooded animal droppings, including human sewage. These bacteria can cause gastrointestinal illnesses when contaminated water in ingested. Advisory notices are posted when FC counts exceed the guideline (based on 5 weekly samples in 30 days) for primary contact recreation (200 CFU/100 mL of water, geometric mean), when values fluctuate dramatically, or if there is suspicion of beach contamination (CRD, 2009c). Fecal coliform data collected from 1980-1995, by the Capital Regional District's Health Environmental Protection Division, ranged from < 3 MPN/100 mL to 2400 MPN/100 mL (Holms, 1996). Several advisory notices, warning the risk to bather's health, were posted at Glen View Beach from 1980-1995, (Holms, 1996). Bacteriological data collected from 1999-2008, by the Vancouver Island Health Authority (VIHA), has shown similar trends with FC values ranging from < 1 CFU/100 mL to 1800 CFU/100 mL. From 1999-2008 the guideline was never exceeded; however, temporary advisory notices were posted on several occasions during the summer due to high single sample values.

Recommendations for Water Quality Management at Glen Lake

Lake monitoring results suggest that Glen Lake has moderate water quality conditions with some high summer 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 depths where temperature is cooler and oxygen is saturated. Chlorophyll α and phosphorus values mostly indicated that Glen Lake is mesotrophic with some tendencies of eutrophic status in the summer. Spring overturn sampling is recommended to measure trends and predict summer productivity. Summer bacteriological sampling should continue at Glen View Beach to ensure that fecal coliform values do not exceed the criteria for primary contact recreation. Inspection and maintenance of the aerator should occur yearly and prior to start-up in May to ensure uninterrupted performance. Fish health and numbers should be monitored closely to ensure that the recreational fishery remains stable. A summer monitoring program should be put into place, possibly by volunteers, to collect temperature, oxygen, and secchi data at the deep station monthly from May-October. These data are critical for determining whether or not continuous operation of the aerator will result in significant increases in hypolimnetic oxygen concentrations.

Tips to Keep Glen 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 food 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
- Conserve water: run the washing machine and dishwasher only when full and use only low-flow showerheads, faucets, and toilets.
- 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

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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Email: bclss@shaw.ca
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Acknowledgements

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