Mary Lake Nature Sanctuary — Lake Stewardship Project

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ENSC 420 — Major Project
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Executive Summary

Mary Lake Nature Sanctuary is a 67-acre property situated in the Millstream Watershed within the Highlands District of the Capital Regional District, traditional territory of the WSÁNEC First Nations. Ownership of the land is currently with the Greater Victoria Greenbelt Society in partnership with Highlands Stewardship Foundation, both of which are responsible for the protection, promotion, and conservation of natural areas such as Mary Lake. Van Isle Eco Consultants in partnership with Royal Roads University were enlisted to obtain baseline water and sediment quality information on the lake and surrounding area. Multiple surveys were conducted to provide environmental information in order to formulate a lake monitoring plan.

Over six months of sampling and analysis, monitoring of the water quality in Mary Lake and its ingoing and outgoing streams was conducted in order to obtain a baseline, and to assess the potential for use of Mary Lake as a habitat for species of ecological and cultural significance to the area. Common water quality parameters (temperature, dissolved oxygen, pH and conductivity) were measured on a bi-weekly basis, and parameters that required laboratory analysis (alkalinity, fecal coliforms, nitrate and phosphate) were performed once in the spring, and again in summer, of 2019. Average dissolved oxygen was found to steadily decrease as the temperature rose over the course of the summer and dropped from as high as 10.8mg/L to as low as 5.4 mg/L by mid summer. Average surface temperatures steadily increased from 12.3°C to 21.3 °C over the same time period. pH did not change as significantly over the summer; however, the lake was found to have an acidifying effect on the water from when it entered to when it left. Conductivity was not found to change seasonally but stayed below 200 µS/cm. Alkalinity was found to be 42.5mg/L $CaCO_3$ and 50.0mg/L $CaCO_3$ on the two days of laboratory testing, indicating a high ability to resist pH change. Nitrate and phosphate concentrations were found to be very low, rarely showing results above detection limits of tests used, which may imply that the lake is nutrient limited, and potential for nutrient pollution may exist. Finally, fecal contamination was examined and was found to be present at levels within the parameters of a healthy lake and are likely present due to activity of mammals in and around the lake.

A depth survey was conducted on the lake and was used to produce a bathymetric map. Depths were found to be shallower than expected, with a maximum depth of 12 feet. Water and sediment samples were examined for copper and lead. While lead was found in

extremely low concentrations, copper was found to be present in both water and sediment samples around expected background levels. Finally, an observational ecological survey was performed to identify the species in and around Mary Lake. The lake was found to contain a number of interesting species and appears to be home to a complex ecosystem.

The team used the data collected to inform the development of a lake monitoring plan for future Greater Victoria Greenbelt Society volunteers. Of key importance in the monitoring plan is continuation of water quality monitoring, ecological monitoring of sensitive species, and control of invasive species.

Acknowledgements

We would like to recognize and acknowledge that Mary Lake Nature Sanctuary is located within the traditional lands of the WSÁNEC (Saanich) Coast Salish Peoples. The ancestors of the WSÁNEC Coast Salish Peoples have played an essential role in the stewardship of Mary Lake and the Highlands for centuries. Mary Lake and the surrounding Highlands were used for hunting, gathering, relaxation, and spiritual practices by the Pauquachin, Tsartlip, Tsawout, Tseycum, Esquimalt and Whyomilth (Songhees) peoples (Greater Victoria Greenbelt Society, n.d.). We had the honor of attending a First Nations meeting at the property led by Elder Tom Sampson, where we obtained insight and knowledge on Mary Lake being more than just a sensitive habitat but also holding very deep cultural and spiritual ties to him and his people. He emphasized that the sensitive flora present on the property were used as medicinal remedies to problems before the introduction of Western medicine, and often times were more effective. We give many thanks and show our appreciation for allowing us to study and be a part of these traditional lands.

To our sponsors at the Greater Victoria Greenbelt Society (GVGS), we would like to thank Bob McMinn, Chair of the GVGS, for enlisting us and allowing us to work on the property; Director Eric Bonham for being our main corridor of communication and organization in terms of work plans; and finally, Vice Chair Koi Neah for her essential role in organizing our attendance at the First Nations meeting with Tom Sampson, who we would not likely have been able to contact otherwise. At the Highlands Stewardship Foundation (HSF), we give thanks to Chairman Neville Griggs, who provided the canoes and proper PFDs for us to safely conduct our lake studies. We would also like to thank Rick Nordin who provided us with a depth sounder which was a major component to our analysis. Finally, the groundskeeper at Mary Lake, Tim Bosenkool, provided helpful insights to species and sensitive areas which aided us in our ecological survey, and helped us experience invasive species management first hand.

Closer to home, we'd like to thank Jonathan Moran for being our advisor on this project and helping us formulate a decisive sampling plan and even indulging in some sampling himself. We would also like to thank Sharon McMillan for helping us during our analysis of water quality by providing us with the proper tools and information for making reagents and necessary media. Finally, we thank Matt Dodd for assisting us in analyzing water and soil samples for heavy metals.

Acronyms & Abbreviations

AAS: Atomic Absorption Spectrophotometry

BCLSS: British Columbia Lake Stewardship Society

CCME: Canadian Council of Ministers of the Environment

DO: Dissolved Oxygen

GVGS: Greater Victoria Greenbelt Society

HSF: Highlands Stewardship Foundation

RRU: Royal Roads University

TDS: Total Dissolved Solids

XRF: X-ray Fluorescence

Glossary of Terms

Alkalinity: Capacity of a water source to neutralize acid measured in milligrams of calcium carbonate ions per litre of water to a specific endpoint (pH of 4.0)

Bathymetry: Measurement of the depth of a body of water (lake, stream, ocean) from a topographic point of view

Conductivity: Measurement of a solution's ability to carry an electric current

Contaminant: A substance released due to human activity

Dissolved Oxygen: Amount of oxygen in a water column; affected by temperature, following Henry's Law

Eutrophication: Series of changes that occur to a lake as a result of increased nutrients from decaying organisms, leading to rapid oxidation of organic matter and depletion of dissolved oxygen

Fecal Coliforms: Lactose fermenting bacteria (*Escherichia coli*) that inhabit the intestinal tract of humans and other warm-blooded animals. Indicators of fecal contamination of water and pathogenicity

Fingerlings: Life stage of a salmonid in which it has developed scales, is no longer dependent on the yolk sac, and has working fins

Flora: Plant life

Henry's Law: Describes the solubility of a gas based on the relationship between the partial pressure of the gas and its concentration in water, which is heavily influenced by temperature

Juvenile Salmonids: Broad term to describe the life cycle stage of salmonids before fully matured

Olfactory: Pertaining to the sense of smell

Salmonids: Broad family of fish (includes trout and salmon)

Spectrophotometry: Method of using light to obtain the concentration of a substance in water by measuring the absorbance of light/amount transmitted at a specific wavelength

Stratification: The separation of the lake into distinct layers due to changes in water temperature

Total Dissolved Solids: Classified as any material in water that will pass through a filter of or less than 2.0 µm in pore size

Total Nitrate: The amount of nitrate and all its species measured in a medium

Total Phosphorus: The amount of phosphorus and all its species measured in a medium

Van-Dorn Bottle: Instrument used to collect water samples at a certain depth without being cross-contaminated

X-ray Fluorescence: The use of high energy electromagnetic waves and their absorbance at a specific wavelength in a medium to obtain the concentration of a metal

1.0 Introduction

1.1 Background and History

Prior to colonization, Mary Lake was the traditional territory of the WSÁNEC (Saanich) Coast Salish Peoples and was used as grounds for hunting, gathering, and spiritual practice. In 1887 the land became privately owned; at this time the house and gardens were located on the eastern side of the property along Millstream Road (Greater Victoria Greenbelt Society, n.d.). Between 1935 and 1947 the property was under the ownership of a logger named Albert Reginald Manzer. During this time the first earthen dam was built which led to the flooding of the hardhack swamp and the creation of a lake affectionately named after his daughter Mary (Greater Victoria Greenbelt Society, n.d.). In 1947, a local artist by the name of Gertrude Mabel Snider purchased the property. Gertrude was responsible for the first conservation efforts on the property in the north half of section 14 (Greater Victoria Greenbelt Society, n.d.). Ownership and full conservation of the property began in 1963 when Peter and Hazel Brotherston purchased the land. The construction of the concrete dam was completed the following year. The construction of this created the easterly and westerly arms of the lake, making Mary Lake the shape it is today. Additionally, they constructed the fish pond and ladder located adjacent to the eastern shore of the lake (Greater Victoria Greenbelt Society, n.d.). Peter and Hazel also removed the previously-existing house and built the house that stands overlooking the lake today (Greater Victoria Greenbelt Society, n.d.). The property was purchased by the Greater Victoria Greenbelt Society in 2016 from the estate of the Brotherstons (Greater Victoria Greenbelt Society, n.d.).

1.2 Scope

This project served to answer two questions: What is the baseline state (2019) of Mary Lake in terms of physical, chemical, and biological parameters? And is Mary Lake currently, or potentially, an ideal protected site for native Vancouver Island amphibious and aquatic species such as Cutthroat Trout, and Coho Salmon? We answered these questions by conducting a series of tests to identify the water chemistry of Mary Lake and surrounding creeks, as well as a bathymetric study of the lake, and an ecological study of the aquatic and riparian areas of the lake and associated creeks. From our findings we were able to construct baseline data which we hope will aid in further research at Mary Lake. In addition to collecting the baseline data, we have created a stewardship and monitoring plan that can be used by the GVGS in partnership with Tsartlip First Nation, the HSF and the community for ongoing monitoring of Mary Lake.

1.3 Lake Monitoring Plan

A basic Lake Monitoring Plan seeks to observe and understand the current status of the lake through conducting a series of tests to analyze the water quality, ecological surveys, and sediment analysis. At Mary Lake we conducted water quality analysis in the lake as well as Earsman Creek, which feeds in and out of the lake, to determine a baseline for water chemistry. The parameters we chose to look at were dissolved oxygen (DO), pH, conductivity, total nitrate, total phosphorus, alkalinity, and fecal coliforms. For heavy metals, we used x-ray fluorescence (XRF) to analyze sediments, and atomic absorption spectrophotometry (AAS) for water samples. From the collection of these data we were able to make recommendations on what parameters should be monitored regularly and which should be looked at seasonally or annually.

A basic monitoring program as described in the British Columbia Lake Stewardship Society Lakekeeper's Field Test manual (BCLSS, 2004) could be conducted in three levels depending on the resources available and the information you are trying to collect. The analysis we have conducted follows the level three design within this manual, which is the most in-depth monitoring plan. For ongoing monitoring at Mary Lake, we suggest that this design is followed so that the results can be compared to the baseline data.

1.4 Species at Risk Habitat Suitability

It is hoped that by establishing a baseline for water quality and overall ecosystem health at Mary Lake, the information can be used to determine the suitability of the lake as a potential habitat for aquatic species native to Vancouver Island. In particular, the sponsor is interested in the potential for Mary Lake and its streams to act as salmon and cutthroat trout spawning areas as part of a network within the Millstream Watershed due to their ecological and cultural significance for the area. There is concern that the seasonal changes in the lake that occur in late summer may affect this suitability. The sponsor has observed a steep change in water level during the dry summer months and believes that changes in water quality that affect spawning salmonid species may accompany this change. Salmonids can be sensitive to changes in water quality and so may avoid areas that do not meet their requirements. Temperature and DO are major factors for salmon and trout health, and some may only spawn in streams that have readings within a certain range. For example, during spawning, Coho Salmon (*Oncorhynchus kisutch*) and Coastal Cutthroat Trout (*O. clarkii clarkii*) prefer temperatures between 4.4-9.4 °C and 6.1-17.2 °C, respectively (Ice, 2008). Dissolved Oxygen also has an effect on salmonid health and behaviour (Ice, 2008); in particular, to the situation at Mary Lake, dropping DO levels have been observed and could adversely affect the growth of salmonid embryos and fingerlings. The initial symptoms of DO deprivation in salmon occur at about 6mg/L (Government of B.C., 1993). Salmonids can still survive below this concentration, but they may experience reduced growth, efficiency and swimming performance (Government of B.C., 1993). Oxygen solubility is inversely related to temperature; therefore, as water temperature increases over the summer, the concentration of DO will decrease (Baird & Cann, 2015).

Due to the long history of Mary Lake as a settlement and logging site, there is potential that human activity in the past may affect the lake's suitability as salmon and trout habitat. Specifically, copper is a contaminant with known adverse effects on salmonid health and behaviour. Dissolved copper primarily affects salmonid olfactory senses, reducing their ability to sense prey and avoid predators, and other key behaviours like migrating upstream or downstream depending on their lifecycle stage. This olfactory toxicity is more exaggerated in juvenile salmonids, thus making the issue of further concern for Mary Lake, as the hope is that the habitat will be used for spawning (Hecht et. al, 2007).

2.0 First Nations Perspectives

Mary Lake lies in the Highlands area within the traditional territory of the WSÀNEC (Saanich) Coast Salish People. On June 27, 2019, the team had the opportunity to meet with Tom Sampson, a respected Elder of the nearby Tsartlip First Nation, as well as his fellow Elders and extended family members representing other nearby First Nations. The Elders spoke to how the Highlands was used as a hunting ground, for medicine collection, as a place of both physical and spiritual cleansing, and is a key area of cultural significance.

Among the Elders' concerns was the loss of plant and animal species integral to traditional First Nations practices. Tom Sampson mentioned that deer are being found more often in the cities than in traditional hunting grounds and impeding their ability to hunt as they did formerly. This highlights the importance of protecting pristine natural areas where deer and other animals can flourish. Also mentioned was the use of native plants as medicines, and indicators of harvesting times and changing of the seasons. Some of these have been identified by our team to be present in the area. The Elders said that these important traditional medicines were now hard to find in some areas due to the degradation of natural areas in which those plants formerly thrived. Another issue raised was the complete loss of spawning salmon and trout in the highlands and surrounding watersheds. The group mentioned that as children they would eat salmon daily, but the fish is now much more limited in availability. The return of this important food source to the area would be a key step toward maintaining cultural practices of First Peoples.

The key take-away from our meeting was the overall cultural significance of the Highlands to the First Nations people. There was a strong spiritual connection to the land and species at Mary Lake that was evident in the stories told by the Elders. It is clear that the conservation of Mary Lake and areas like it is not only of ecological importance, but cultural and spiritual importance as well. In order to properly care for the land at the Lake, it will be important to keep in mind the sacredness of having a deep and honouring relationship with nature and the ways in which it can support both the spiritual and physical aspects of a healthy life. A key step moving forward with the conservation of Mary Lake will be including First Nations voices in decision making surrounding monitoring and use of the property in order to properly acknowledge the area's true significance. It is the hope of this team that this report can be used in order to inform these decisions, and that our results can be merged with traditional ecological knowledge and First Nations perspectives and the integrity and health of Mary Lake maintained.

3.0 Materials & Methods

3.1 Bathymetric survey

The bathymetric survey was performed using a Hummingbird 200xd Fishfinder attached to the side of a canoe, alongside a handheld Garmin GPS unit. The team recorded lake depth at 315 waypoints around the Lake and imported the data to ArcMAP. The data points were converted to a raster image and made into a contour map using a contour mapping tool.

3.2 Water Quality

Water quality parameters were measured by a combination of field measurements using probes and laboratory analysis. Water was analyzed at surface and at a depth of 2 m in areas of the lake that were deep enough. Water samples were collected and preserved according to the B.C. Water Sampling Field Manual (Government of British Columbia, 2013). Deeper water samples were collected using a Van Dorn bottle and placed into either a rinsed beaker for field analysis or a rinsed sample bottle for laboratory analysis. Surface samples were taken using a clean, rinsed beaker and measured immediately using probes. All samples requiring laboratory analysis except metals samples were tested on the same day as sampling, and so did not require preservation past refrigeration. Heavy metal samples were preserved using nitric acid and refrigerated. Analytical methods for each water chemistry parameter are listed in Table 1. Sample sites were chosen in order to be representative of the lake as a whole. The sites Lake 1, Lake 2, and Lake 3 were chosen to cover the deeper sections of the lake, the Dock site was chosen to represent the beach and Nature House area in order to detect any changes due to human activity, and the stream sample sites were chosen to be as close to the lake as possible. The sample site coordinates can be found in Table 2, and the approximate sites can be found on the map in Appendix III.

Table 1: Analytical Methods and Equipment Used for Testing the Water Chemistry at Mary Lake Nature Sanctuary

Water Quality Parameter	**Method**	**Description/Equipment**
pH	Probe measurement	Oakton PCTSTestr 50 field probe
Temperature	Probe measurement	Cole-Parmer temperature-corrected dissolved oxygen probe
Conductivity	Probe measurement	Oakton PCTSTestr 50 field probe
DO	Probe measurement	Cole-Parmer temperature-corrected dissolved oxygen probe
Alkalinity	Potentiometric Titration (Noble, 2018)	Titrated with 0.1M HCl and 0.1M NaOH, measured using Accumet pH meter to produce a potentiometric curve
Nitrates	Spectrophotometry (Noble, 2018)	Samples reduced using Zn and reacted with sulfanilic acid and naphthylamine hydrochloride to produce colour. Colour intensity measured using a Genesys 10vis spectrophotometer
Phosphates	Spectrophotometry (Noble, 2018)	Samples reacted with molybdate and stannous chloride to produce blue precipitate. Colour intensity measured using a Genesys 10vis spectrophotometer
Fecal Coliforms	Membrane Filtration (Noble, 2019)	Samples filtered through Millipore paper and incubated on m-FC Agar
Metals (Lead, Copper)	Atomic Absorption Spectrophotometry	Atomic absorption spectrophotometry assisted by Matt Dodd

Table 2: Water Quality and Sediment Sample Sites used for Primary and Secondary Tests on Mary Lake

Coordinate	Lake 1	Lake 2	Lake 3	Dock	Dead Deer Creek	North Earsman	South Earsman
Lat (N)	48°29.972	48°29.939	48°29.972	48°29.994	48°29.991	48°30.036	48°29.916
Long (W)	123°31.143	123°31.126	123°31.019	123°31.130	123°31.132	123°31.084	123°30.947

3.3 Sediment Survey

Lake sediments were collected from the lake bottom using an Eckman grab in accordance with the B.C. Field Sampling Manual (Government of British Columbia, 2013). The grab sampler was dropped from the side of the canoe and collected into plastic bags, dried in laboratory fume hoods, sifted, and analyzed by X-ray Fluorescence (XRF) for lead and copper content.

3.4 Ecological Survey

An ecological survey was performed on an observational basis, and presence of species was recorded. Plant, fish, and amphibian species were identified from both lake shore and canoe. Observations and photographs were compared against field guides (Pojar and Mackinnon, 2004), online resources, and personal communication with Jonathan Moran, Alison Moran, and Sharon McMillan.

4.0 Results

4.1 Mary Lake Baseline Water and Sediment Quality

The seasonal pH levels of the lake water and surrounding creeks were found to be relatively neutral, with Earsman Creek entering the lake being slightly higher. The decrease in pH could be a result of biological activity breaking down carbon at the bottom of the lake where oxygen is expected to be low. Because of this, the reactions that occur will result in a slight acidifying effect. The trends of DO and temperature found in and around the lake were observed to have significant seasonal changes. The relationship between DO and temperature found on the property follow Henry's Law quite closely when considering Figure 1. Warmer water will dissolve less oxygen; as the lake warms in the summer months, the amount of dissolved oxygen naturally decreases. The oxygen levels did however spike on July 23rd, possibly due to increases of plant activity, and thereby increased levels of oxygen released during photosynthesis. Upon inspecting the difference within the lake, the different depths proved not to have a significant effect on pH, DO, or temperature (See data in Appendix I). This is likely due to the fact that the lake is fairly shallow and therefore allows for even mixing to occur.

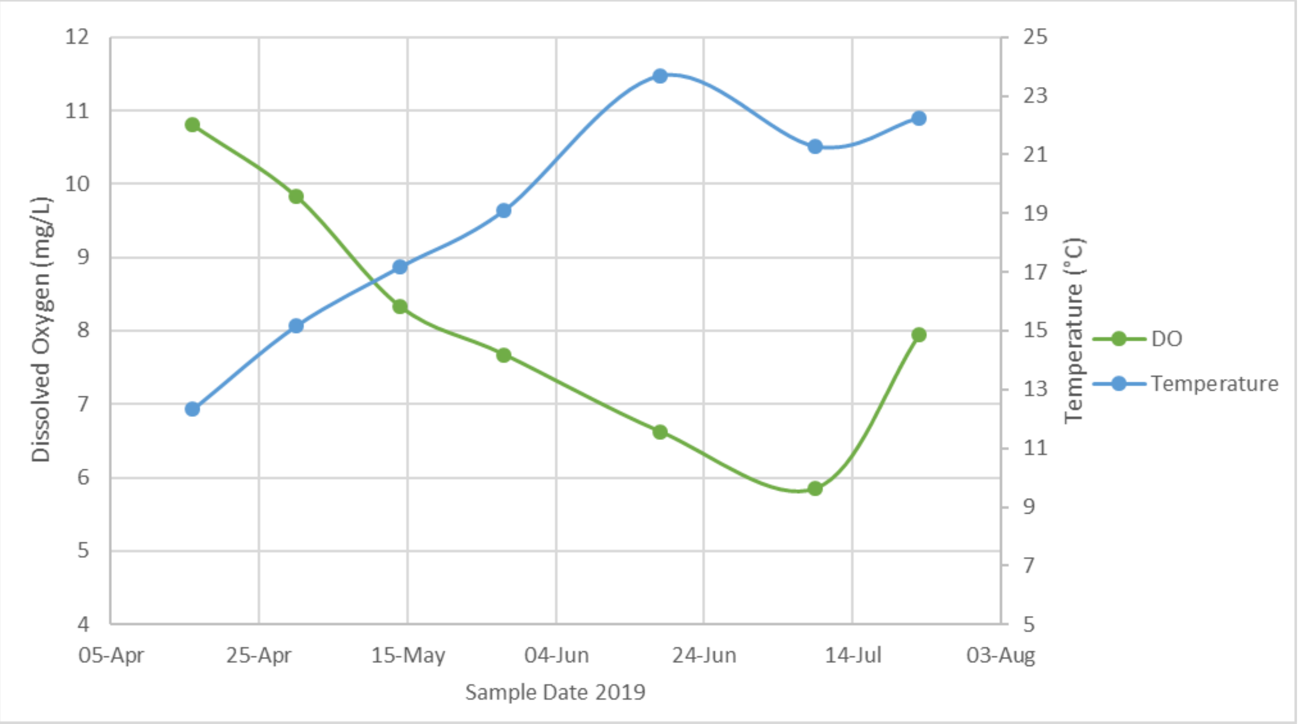

Figure 1: Average dissolved oxygen and temperature measurements from the surface of Mary Lake from April 16, 2019 to July 23, 2019 sampled using a Cole-Parmer probe.

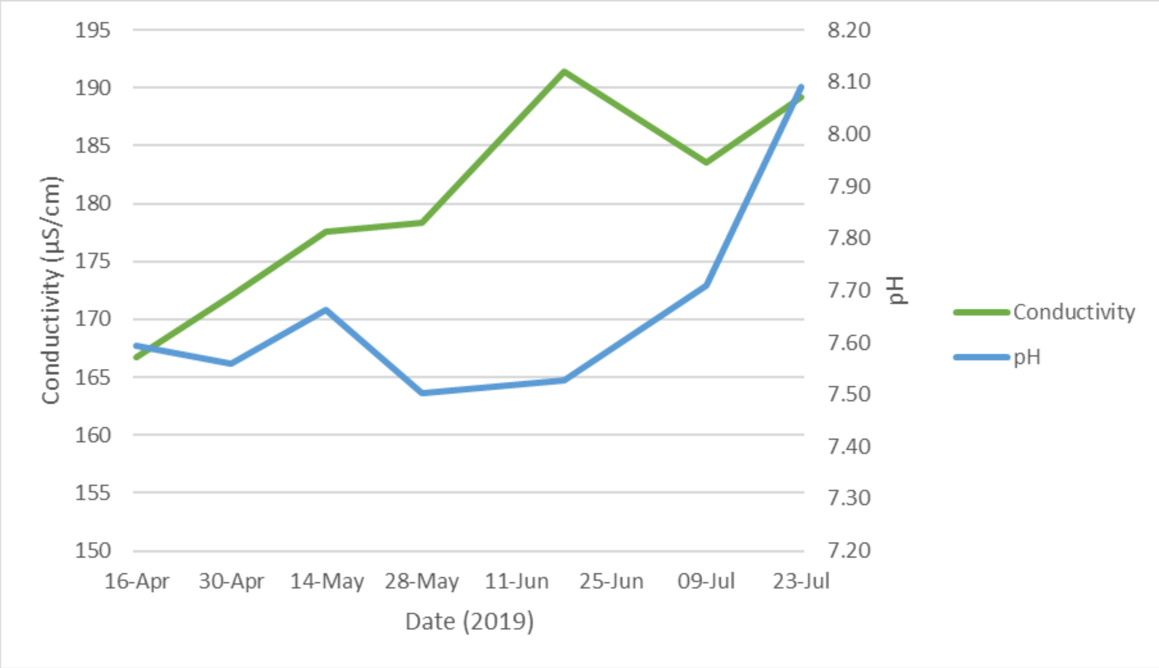

Figure 2: Average conductivity and pH measurements from the surface of Mary Lake from April 16, 2019 to July 23, 2019 sampled using a Cole-Parmer probe.

Mary Lake was found to have a significant impact on the water chemistry of Earsman Creek as it left the lake, as seen with dissolved oxygen in Figure 3. The temperature of the creek water leaving the lake was found to increase, while pH and DO decreased seasonally (See Appendix I). This is likely due to biological activity within the lake and the residence time between entering and leaving. As spring and summer arrive, organisms begin spawning and using up the nutrients in the lake. High traffic and nutrient mixing allow for microorganisms to break down nutrients as they reach the lake floor, again acidifying the water. Looking directly at the effect of temperature on DO, Figure 3 describes a nearly linear relationship, which falls in line with Henry's Law in which the solubility of a gas in a liquid will be influenced by temperature.

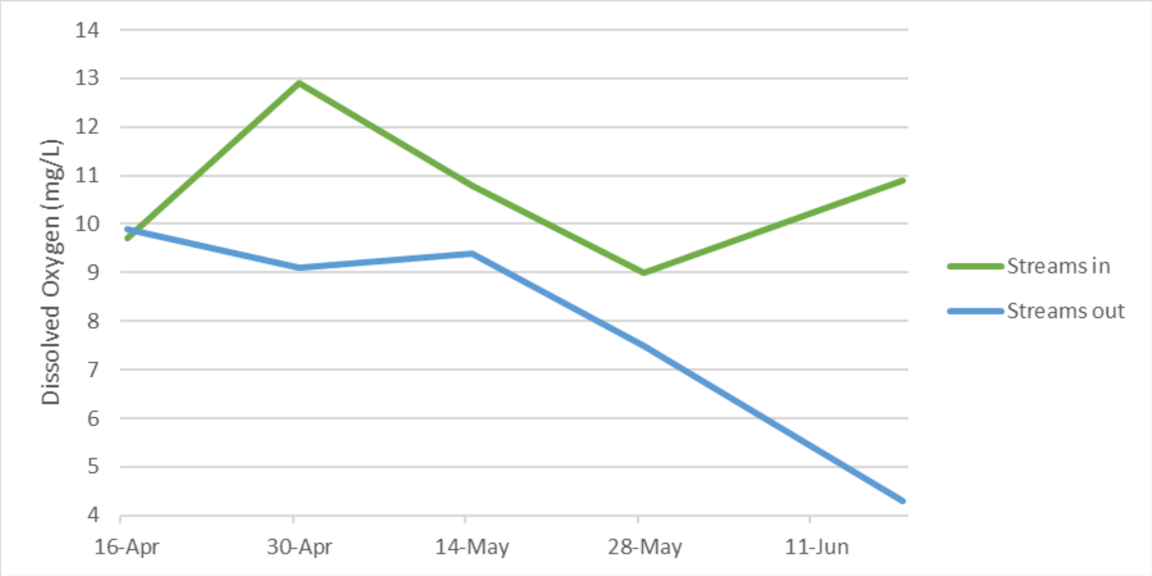

Figure 3: Line graph displaying change in dissolved oxygen in water in Earsman Creek before entering Mary Lake and after exiting. Measurements show that the lake causes a slight decrease in dissolved oxygen. Measured using Cole-Parmer dissolved oxygen probe.

Heavy metal contamination can affect the ability of salmonids to locate spawning areas as their olfactory senses are fairly sensitive to metals such as copper (Hecht et. al, 2007). Lead is a heavy metal toxic to humans and other organisms when available in water (Baird & Cann, 2015). However, lead contamination is associated with human activity and as such, testing for it would reveal whether or not human activity on and around the site has resulted in contamination and release of lead. In a shallow lake, we would assume that the metals settle to the bottom and therefore we sampled the sediments of the creeks and the lake floor. However, looking at the XRF data for the sediments, copper proved to be more prevalent with lead levels either under detection limits or at very low concentrations (Table 3). Additionally, heavy metals can exist in ionic form and therefore may be observed in the liquid phase. Testing revealed that this, however, is not the case for copper or lead as the concentrations were very low when compared to the sediment concentrations (Appendix I).

Table 3: X-ray fluorescence analysis of sediment obtained from Mary Lake and inlet and outlet creeks for copper and lead content. June 25, 2019

Sample Site	Heavy Metals Concentrations	
	Cu Concentration (ppm)	Pb Concentration (ppm)
Dock	50.17	Below detection limit
North Earsman	48.02	Below detection limit
South Earsman	40.03	Below detection limit
Lake 1	47.49	5.36
Lake 2	41.61	8.33
Lake 3	30.06	Below detection limit

Conductivity is used to measure the number of dissolved ions in the water. It is a measure of how easily electricity flows through the water, and therefore changes in conductivity can be used to determine if there are any significant increases in the runoff of sediments (Government of the Northwest Territories, n.d). Water conductivity has been relatively steady, with North Earsman Creek having the highest values (Appendix I). As water temperature increases, so does the conductivity. Evaporation can also increase the conductivity because as the lake loses water, ions and salts will become more concentrated. Low conductivity has a range between 0 and 200 µS/cm and is an indicator of pristine conditions (Government of the Northwest Territories, n.d). All readings taken from Mary Lake were below 200 µS/cm. Two readings from the North Earsman were above 200 µS/cm; one was 204 µS/cm on June 18, 2019 and one was 210 µS/cm on May 28, 2019.

Nitrate is found in most natural waters and is produced by oxidation of nitrogen by microorganisms (CCME, 2012). High nitrate concentrations may indicate contamination from anthropomorphic sources such as manures, wastewater treatment, and fertilizers. Phosphate is a critical nutrient in water that supports the growth of aquatic plants and algae (Government of Canada, 2015). However, an excess of phosphates in water can lead to increased algal growth. As algae build in an ecosystem, they begin to sink and decay. This process creates anoxic conditions which can lead to fish kills. Toxic cyanobacteria can also develop in environments with excessive phosphorus, which poses a serious health concern to animals and humans (Government of Canada 2015). Common sources of phosphates in natural waters are lawn and garden fertilizers, agricultural runoff, soil erosion, wind and decaying organic matter. Mary Lake was found to have no detectable levels of nitrate or phosphate. The North Earsman had the highest level of nitrate with a maximum value of 0.28mg/L which is well below the Canadian water quality guideline of 13 mg/L (CCME, 2012).

Alkalinity describes water's capacity to resist changes in pH that would make the water more acidic (Water Research Center, 2014). In most rivers and lakes, this buffering system is composed of carbonate-bicarbonate ions which mainly come from rocks and sediments. Mary Lake had an average of 42.5 mg $CaCO_3$/L on April 26, 2019 and 50.0 mg $CaCO_3$/L on July 9, 2019, as seen in Appendix I. The Earsman had an average of 43.8 mg $CaCO_3$/L on April 16 and was too dry to test on July 9, 2019. Natural waters with alkalinity values > 20 mg $CaCO_3$/L have low sensitivity to acid inputs (Ministry of Environment, 2017).

Fecal coliforms are a commonly used indicator of microbial water contamination in recreational waters (Madigan, Bender, Buckley, Sattley, & Stahl, 2018). They are useful indicators because they inhabit the intestinal tracts of humans and other warm-blooded animals. Their presence can indicate fecal contamination and the possible presence of pathogens (Madigan et al., 2018). Referring to Appendix I, raw data collected show that fecal coliforms were low in overall counts. Counts ranged between 0 CFC/ 100 mL and 50 CFU/100 mL using membrane filtration. These numbers are well below the safe limits stated within the British Columbia guidelines for fecal coliforms in recreational waters, which is ≤ 200 fecal coliforms /100 ml (British Columbia, 2001).

4.2 Bathymetric Map

A bathymetric survey was conducted, and a depth map was constructed by Taylor Jones (Figure 8). The survey indicated that at the deepest, the lake is 12 feet (3.66 m) deep, and more commonly 10 feet (3.05m). The survey shows that the lake depth is distributed fairly evenly, with many pockets of very shallow (< 1 m) areas. The west shore is characterized by steep cliffs that drop to 10 feet in depth. Some more shallow areas were often filled with aquatic plants. Some individual data points had measurements that were much shallower than the surrounding area. These can be explained by boulders and tree remains left on the lake bottom when the lake was originally flooded. Note that the depth sounder used was only able to take measurements in one-foot increments; therefore, the entire map was kept in imperial units for the sake of consistency and to avoid misleading information following the conversion to metric. Future surveys may wish to use more accurate sounders capable of measurement in metric units in order to obtain a more precise survey.

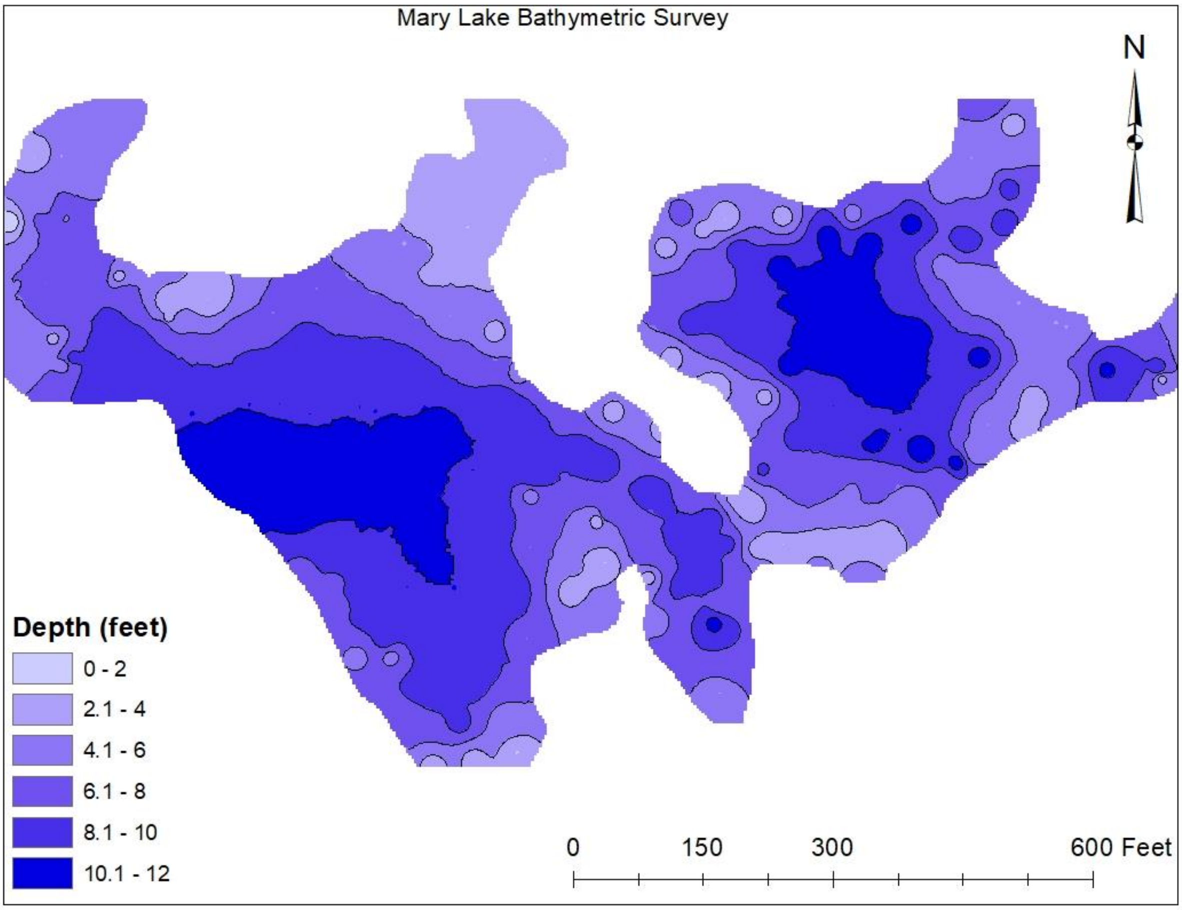

Figure 4: Bathymetric contour map of Mary Lake measured using Hummingbird 200xd Fishfinder and Garmin GPS unit. Raster image and map produced using ArcMAP 10.2. Data collected April 9, 2019, map produced April 23, 2019 by Van Isle Eco Consulting.

4.3 Ecological Survey

Our observation-based ecological survey was conducted on an ongoing basis over the course of the project. A summary of our findings can be found in the Appendices (Appendix II, Table 2 and 3); we have also included in Appendix II a list of aquatic and semi-aquatic plant species that were previously identified at Mary Lake by Hans Roemer, from an ecological survey conducted in 2010. Previous surveys of the Mary Lake property indicated that there are seven distinct ecosystems that are representative of almost all habitat types found within the Highlands. Due to this, the protection and preservation of the Mary Lake property and its flora and fauna is extremely important. Because we were unable to obtain an animal care certificate, we could not collect data on all of the species found within the lake.

Further study would have to be conducted to collect data on current aquatic species populations within the lake and streams. A more in-depth ecological survey was beyond the scope for this project. Amongst the expected native species observed on the property, several uncommon and interesting plant species were identified (See Figures 5, 6, and 7 below)

Figure 5: Allotropa virgata (Candystick or Sugarstick)
Candysticks are saprophytic herbs, meaning they are actually heterotrophs and do not photosynthesize (MacKinnon, and Pojar, 2004). They instead get their energy through parasitism of fungi that feed on leaf litter beneath coniferous forests (Klinkenberg, B., 2017). This is the only species within its genus, and is restricted to western North America (MacKinnon, and Pojar, 2004).

Figure 6: *Boschniakia hookeri* (Ground Cones)
Ground Cones are a parasitic herb on Salal. They attach themselves to the roots of a host plant and take up their nutrients (MacKinnon, and Pojar, 2004). This plant has a cultural significance to the First Nations of B.C. The Kwakwaka'wakw and Nuu-chah-nulth peoples would eat the root base of the plant. It was also used as a good luck charm (MacKinnon, and Pojar, 2004).

Figure 7: *Utricularia* sp. (Bladderwort)
Bladderwort is a carnivorous aquatic plant. Tiny bladders are equipped with valve-like doors and four stiff trigger bristles (MacKinnon, and Pojar, 2004). When small crustaceans, or other small aquatic organisms activate the trigger bristles the bladder walls expand creating a vacuum to suck the prey into the bladder (MacKinnon, and Pojar, 2004). Once inside they become trapped and decay, allowing the plant to absorb the nutrients.

5.0 Discussion

Mary Lake is a healthy ecosystem as evidenced by the multitude of species and generally acceptable water quality results. However, it remains susceptible to drastic changes in water quality and ecological diversity from anthropogenic sources, seasonal change, and climate change. Alkalinity was found to be relatively high, suggesting a strong ability to resist acidification. Further, the very low levels of nitrate and phosphate indicate that the lake may be vulnerable to effects from nutrient increases due to human activity which can result in eutrophication of the lake. Eutrophication can be associated with the creation of anoxic conditions in water, as well as the release of toxins by blue-green algae (Baird, 2012).

Lead was chosen as a potential indicator of lake contamination due to human activity in the past. Total lead concentrations in water samples determined via atomic absorption spectrophotometry were found to be below detection limits, and further analysis of sediments by XRF analysis found that lead concentrations were either very low or below detection limits. Lead can therefore be considered to be at natural levels and is not a concern at Mary Lake. Copper concentrations were also examined by AAS, and the metal was present in detectable concentrations, ranging between 0.118ppm and 1.723ppm. These values were far above the upper limits for dissolved copper to have adverse effects on salmonids. Olfactory responses in juvenile Coho salmon can be severely affected between 0.001ppm and 0.020ppm dissolved copper (Baldwin et al. 2003), and reduction in predator avoidance behaviour has been observed in salmonids in the range of 0.00018 and 0.0021ppm dissolved copper (Hecht et. al, 2007). However, the AAS test was detecting total copper in the water rather than dissolved as was tested in the cited studies; therefore, further analysis would be required to determine the exact level of dissolved copper in Mary Lake. XRF analysis was also performed, to determine the amount of copper present in the sediments in the bottom of Mary Lake, as well as its streams in and out. This revealed even higher levels of copper, ranging between 30.06ppm and 50.17ppm. While this level is concerning considering the limits for adverse effects mentioned above, background concentrations of copper in Canada are typically around 31ppm in lake sediments, which fits well with our results (Canadian Council of Ministers of the Environment, 1999 A). Further, the sediment in Mary Lake was observed to have a high level of organic matter, which can greatly lessen the adverse effects of copper (Canadian Council of Ministers of the Environment, 1999 A). Further studies regarding the potential for copper to harm salmon may be required in Mary Lake and the Millstream

Watershed as reintroduction efforts continue; however, at present we believe fish are not at danger as lake conditions presently stand.

Conductivity, pH, dissolved oxygen, and temperature were recorded at two-week increments over the duration of the study. During the time of testing the team observed seasonal changes in dissolved oxygen, temperature, and pH. The concern with these changes is that they may degrade the potential of Mary Lake as a habitat for important species, such as salmon. Dissolved oxygen is considered the most fundamental water quality parameter, and the abundance of life in any water body is dependent on it. In general, dissolved oxygen levels less than 5mg/L would be considered to be unsuitable for fish (Canadian Council of Ministers of the Environment, 1999 B). By May 28, 2019, the lowest observed dissolved oxygen measurement was 4.7mg/L, at a temperature of 21.6 °C (see Appendix I), which is below the CCME guideline. Following the trend of decreasing dissolved oxygen, there is potential for oxygen levels to decrease to unacceptable levels during hot summer months. However, data collected from the July 23rd sample date indicated there was an increase in DO within the lake which could be a result of photosynthetic activity from the abundant aquatic plant life. pH has been found to be decreasing over the summer; however, changes are not as dramatic as with temperature. Significant decreases in pH may have effects on the species in Mary Lake, but this does not appear to be of major concern at present. Conductivity results appeared to indicate that Mary Lake is healthy, and no significant changes in conductivity have been observed over the course of the study. Conductivity should continue to be monitored following the conclusion of this study however, because it can be used to monitor pollution such as sediment addition due to upstream construction activities. Monitoring of temperature, dissolved oxygen, and pH should also be continued beyond this study.

Fecal coliforms were measured in the water in Mary Lake in order to assess the potential for fecal contamination. While coliforms were found to be present, levels were well within recreational water quality guidelines (British Columbia, 2001). The fecal coliforms were likely present due to the activity of otters, beavers, and mink that have been observed to use the lake, and so the results we obtained are not high enough to warrant concern regarding water quality in Mary Lake.

The ecological survey built upon the previous study by Hans Roemer in 2010. The property contains several distinct ecosystems: open and closed Douglas Fir forests, Douglas Fir/ Garry Oak/Arbutus forest, aquatic habitats (lake, streams, wetlands), Red Alder/Skunk Cabbage swamps, and rocky outcrop habitats. These are all home to a high abundance of flora and fauna. The high level of plant productivity and the high numbers of animals spotted in and around the lake, particularly native amphibian species like Red-Legged Frogs and Roughskin Newts, suggest that the Lake is in very good health. Due to this, indicator species should be chosen, and the presence of these more sensitive species should be closely monitored in order to continue the assessment of lake health.

6.0 Recommendations

In this project, we were able to determine baseline data for Mary Lake over the spring and early summer seasons of 2019. Laboratory procedures were performed on water samples for the parameters of alkalinity, nitrate, phosphate and fecal coliforms. Due to the lake being so shallow, turbidity measures using a Secchi disc were ineffective because the disc could still be seen once it reached the bottom of the lake. Future monitoring measurements could include alternate tests for turbidity and total dissolved solids (TDS) in the form of appropriate meters. Additional water quality observations that could be included for Mary Lake are water hardness, which may affect the toxicity of some heavy metals, and a benthic invertebrate survey. Also, continuation of monitoring during the late summer (when there is no in and out flows), fall and winter months would be helpful in getting a full seasonal profile for Mary Lake.

In order to determine the suitability of Mary Lake and the Earsman Creek for salmon habitat, stream surveys, invertebrate surveys, and habitat mapping could be carried out. This would give information on substrate conditions and potential spawning habitat along Earsman Creek.

Invasive species such as American Bullfrogs (*Lithobates catesbeianus*), Scotch Broom (*Cytisus scoparius*), and European Black Slugs (*Arion ater*) are all present on the property. Currently there are efforts being made to control and remove Scotch Broom and American Bullfrogs. The continued removal of Bullfrogs is extremely important for the health of the lake as bullfrogs pose a threat to native species. We hope that by reducing the bullfrog population, native frog populations (and therefore, species diversity) will increase. As well, the continued removal of Scotch Broom will reduce stress on the native plant species and encourage higher species diversity throughout the property.

The installment of wildlife cameras around the property of Mary Lake would allow for a more in-depth study of wildlife activity on the property. There have been signs of Cougar activity in several locations on the property as well as evidence of Bear activity. The installation of wildlife cameras would allow for the confirmation and ongoing observation of these species on the property and it might provide information on the presence and activities of other species.

To gain a better understanding of the species of fish present within the lake we recommend setting up fish traps. This will allow for a more thorough understanding of the species present to better inform future management plans. In order to do this an animal care certificate will have to be obtained prior to setting up the traps.

One of the things we were interested in at the start of the project was the suitability of the lake as habitat for Western Painted turtles. Due to time and resources we decided to focus on other aspects of the project more pertinent to the deliverables outlined by the GVGS. Now that we have a baseline of the lake, we recommend that habitat suitability for Western Painted turtles be revisited and future studies conducted to determine if the lake would sustain a population.

7.0 Monitoring Plan

To continue the preservation of Mary Lake and ensure the protection of its wildlife and ecosystem health, continuous monitoring of the site should occur. This is to provide GVGS and HSF the adequate amount of information if there were to be a contamination event from upstream developmental sources. Likewise, it can be used to monitor the water quality to support existing biota. Our baseline survey will set the framework for future monitoring and we have outlined parameters of interest, as well as how and when to obtain them.

7.1 Parameters of Interest

Our baseline survey centered around rapidly changing factors, and it is imperative to continue monitoring these parameters:

- DO
- pH
- Temperature

These three are essential to lake monitoring due to the fact that they can indicate relative health of a water system, are related to one another and therefore can affect one another, and can be obtained fairly quickly. Because these parameters are rapidly changing, they can indicate whether contamination from upstream sources is occurring before adverse effects are observed.

Parameters less likely to be affected as easily or have a higher tolerance to inputs can be monitored less frequently; however, this does not discount their importance. These are:

- Phosphate
- Nitrate
- Alkalinity
- Hardness
- Heavy metals (water & sediments)
- TDS
- Turbidity

These are dependent mainly on anthropogenic inputs from rural upstream activities. Phosphates and nitrates are responsible for eutrophication of water bodies, which can suffocate organisms living in such an environment. Additionally, alkalinity of the lake should be monitored as it reflects the ability of the lake to withstand acidification from upstream sources. Contaminants specific to human activity such as copper and lead should be monitored as well, because the property is in close proximity to heavy development occurring in the Highlands District. However, some heavy metals such as copper are heavily influenced in their availability by factors such as water hardness. TDS and turbidity can be included as they can be used as proxies to indicate changing levels of particulates that may contain heavy metals.

In terms of ecological surveys, the presence or absence of certain organisms is the main parameter; a proxy for ecosystem health depending on the requirements of certain organisms (e.g. Cutthroat Trout). This can be done via a benthic survey in which invertebrates are captured, identified, and enumerated. Because some invertebrates are sensitive to ecosystem perturbation and require a narrow range of environmental conditions, their presence/abundance can be an indicator of ecosystem health.

7.2 Procedural Guidelines

For future monitoring of Mary Lake and its tributaries, certain procedural guidelines adapted from our baseline report should be used as to allow for appropriate comparison of data. The results obtained from these procedures should be compared against our baseline survey of Mary Lake to see if and how changes in water or sediment quality have occurred. Collection of the water should be done as outlined in the LakeKeeper's Field Test manual (BCLSS, 2004) to ensure proper techniques are followed and avoid error in analysis. Monitoring of either rapid or non-rapid changing parameters should be conducted with these in mind:

- At least three lake locations
- North Earsman
- South Earsman

Sampling of the lake should be done at surface, with depth readings being optional, as our research showed no stratification of the water column. For not so rapid changing parameters, sampling once every three months would be sufficient as the change in between would likely not be significant enough, unless an event in which a pollutant had been released occurred. This should be carried out in the same locations within Mary Lake and at the North and South Earsman creeks. Sediment samples should be collected from each lake site and creek site quarterly.

Some of the parameters can be measured on site and therefore require field equipment. Others will require a laboratory that can provide the proper reagents, glassware, and devices for accurate calculations and analysis. The equipment that can be used in the field are as follows:

- Canoe, paddles, PFD
- Nalgene sampling bottles
- Van Dorn Bottle sampler
- pH meter capable of reading from at least 2.0 to 12.0
- DO meter
- Thermometer
- Turbidimeter
- Conductivity meter
- Handheld GPS

These will be used to analyze for the majority of the rapidly-changing parameters, along with turbidity and conductivity. For the non-rapid parameters, we suggest outsourcing to a professional lab or back to RRU for analysis due to the requirements of laboratory equipment such as:

- Proper glassware (beakers, volumetric flasks, burettes, pipettes, etc.)
- Proper reagents (KHP, HCl, NaOH pellets, etc.)
- Proper analytical equipment (pH meters, XRF, AAS, spectrophotometers, etc.)

With regard to sampling of water and sediments, be sure to schedule sampling dates ahead of time to ensure consistency and avoid days that rain has occurred or is occurring as it can affect the results drastically. Ecological surveying will require that GVGS and HSF obtain an animal care certificate in order to perform a survey of lake organisms such as fish. Assuming this has already been procured, the necessary equipment may be is as follows:

- Mesh nets
- Benthic invertebrate survey protocol for B.C.
- Field guides
- Fish traps
- Wildlife cameras
- Plastic buckets
- Ice cube trays (for invertebrates)
- Waders and rubber boots
- Blunt tweezers

- Hand lens
- Plastic spoons

Because the essence of the ecological survey is to examine the presence or absence of organisms, this should be conducted as non-invasively as possible. Wildlife cameras are beneficial due to no direct interaction being required between humans and wildlife.

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APPENDIX I:
Results from Primary and Secondary Sampling Procedures for Water Quality

Table 1: Secondary field sampling data measured from Mary Lake Nature Sanctuary on April 16, 2019 Using a Cole-Parmer Probe and an Oaklon PCTSTestr 50

Sample	Depth	pH	Conductivity (µS/cm)	Temp (°C)	DO (mg/L)
“Dead Deer Creek”	Surface	7.47	191.6	8.5	8.4
Earsman NORTH	Surface	7.64	184.9	8.3	9.7
Earsman SOUTH	Surface	7.57	162.1	10.8	9.9
Dock	Surface	7.69	167.4	11.3	9.9
Lake 1	Surface	7.54	169.8	12.0	11.7
Lake 1	2 m	7.54	171.8	13.0	10.2
Lake 2	Surface	7.55	167.6	12.6	10.8
Lake 2	2m	7.48	174.5	11.7	8.2
Lake 3	Surface	7.60	162.1	13.4	10.8
Lake 3	2m	7.56	163.2	12.7	9.5

Table 2: Secondary field sampling data measured from Mary Lake Nature Sanctuary on April 30, 2019 Using a Cole-Parmer Probe and an Oaklon PCTSTestr 50

Sample	Depth	pH	Conductivity (µS/cm)	Temp(°C)	DO (mg/L)
“Dead Deer Creek”	Dried up				
Earsman NORTH	Below surface	8.19	193.9	11.2	12.9
Earsman SOUTH	Below surface	7.69	169.1	14.5	9.1
Dock	surface	7.74	173.1	15.6	10.2
Lake 1	Surface	7.54	167.0	14.8	9.8
Lake 1	2 m	7.64	179.9	16.7	8.3
Lake 2	Surface	7.52	176.2	14.7	9.5
Lake 2	2m	7.51	167.4	14.5	9.0
Lake 3	Surface	7.44	171.9	15.6	9.8
Lake 3	2m	7.40	171.4	13.9	8.6

Table 3: Secondary field sampling data measured from Mary Lake Nature Sanctuary on May 14, 2019 Using a Cole-Parmer Probe and an Oaklon PCTSTestr 50

Sample	Depth	pH	Conductivity (µS/cm)	Temp(°C)	DO (mg/L)
“Dead Deer Creek”	Dried up				
Earsman NORTH	Below surface	8.13	196.6	13.8	10.8
Earsman SOUTH	Below surface	7.56	176.2	15.3	9.4
Dock	surface	7.61	177.1	18.0	8.6
Lake 1	Surface	7.82	180.2	16.3	8.9
Lake 1	2 m	7.54	182.7	16.2	7.4
Lake 2	Surface	7.60	177.0	16.8	7.8
Lake 2	2m	7.62	180.1	16.2	8.2
Lake 3	Surface	7.62	176.2	17.6	8.0
Lake 3	2m	7.58	176.6	17.4	7.4

Table 4: Secondary field sampling data measured from Mary Lake Nature Sanctuary on May 28, 2019 Using a Cole-Parmer Probe and an Oaklon PCTSTestr 50

Sample	Depth	pH	Conductivity (µS/cm)	Temp(°C)	DO (mg/L)
“Dead Deer Creek”	Dried up				
Earsman NORTH	Below surface	8.10	210.0	15.3	9.0
Earsman SOUTH	Below surface	7.44	178.8	17.5	7.5
Dock	surface	7.59	179.6	18.8	9.3
Lake 1	Surface	7.5	177.8	19.8	6.8
Lake 1	2 m	7.36	179.6	18.0	9.7
Lake 2	Surface	7.48	178.5	18.5	6.8
Lake 2	2m	7.31	180.0	18.3	6.1
Lake 3	Surface	7.44	177.3	19.3	7.8
Lake 3	2m	7.36	177.4	18.3	6.3

Table 5: Secondary field sampling data measured from Mary Lake Nature Sanctuary on June 18, 2019 Using a Cole-Parmer Probe and an Oaklon PCTSTestr 50

Sample	Depth	pH	Conductivity (µS/cm)	Temp(°C)	DO (mg/L)
"Dead Deer Creek"	Dried up				
Earsman NORTH	Below surface	7.81	204	17.5	10.9
Earsman SOUTH	Below surface	7.11	185.7	16.1	4.3
Dock	surface	7.68	192.5	23.8	6.5
Lake 1	Surface	7.54	192.2	24.2	6.3
Lake 1	2 m	7.43	191.2	23.2	6.1
Lake 2	Surface	7.5	191.2	23.7	7.6
Lake 2	2m	7.52	189.9	21.3	8.8
Lake 3	Surface	7.39	189.6	23	6.1
Lake 3	2m	7.37	189.4	22.3	6.3

Table 6: Secondary field sampling data measured from Mary Lake Nature Sanctuary on July 9, 2019 Using a Cole-Parmer Probe and an Oaklon PCTSTestr 50

Sample	Depth	pH	Conductivity (µS/cm)	Temp(°C)	DO (mg/L)
“Dead Deer Creek”	Dried up				
Earsman NORTH	Dried up				
Earsman SOUTH	Dried up				
Dock	surface	8.04	196.6	21.1	7.5
Lake 1	Surface	7.66	180.5	21.6	5.4
Lake 1	2 m	7.74	178.8	21.5	6.6
Lake 2	Surface	7.65	180.8	20.8	5.8
Lake 2	2m	7.61	179.7	21.3	5.7
Lake 3	Surface	7.49	176.5	21.6	4.7
Lake 3	2m	7.40	192.3	21.8	7

Table 7: Secondary field sampling data measured from Mary Lake Nature Sanctuary on July 23, 2019 Using a Cole-Parmer Probe and an Oaklon PCTSTestr 50

Sample	Depth	pH	Conductivity (µS/cm)	Temp(°C)	DO (mg/L)
“Dead Deer Creek”	Dried up				
Earsman NORTH	Dried up				
Earsman SOUTH	Dried up				
Dock	surface	8.81	200	21.4	9.3
Lake 1	Surface	8.07	192.7	22.2	7.9
Lake 1	2 m	7.98	175.8	22	7.7
Lake 2	Surface	7.83	188.9	22.4	8.5
Lake 2	2m	7.75	191.2	22.2	6.5
Lake 3	Surface	7.65	191.9	23	6.1
Lake 3	2m	7.51	192.3	22.1	5.8

Table 5: Alkalinity, phosphate, and nitrate using potentiometric titrations and spectrophotometry at the Royal Roads University laboratory using water samples collected on February 26, 2019 by Van Isle Eco Consulting

Sample	Alkalinity (mg $CaCO_3$ /L)	Phosphate (ppm)	Nitrate (ppm)
"Dead Deer Creek"	31	< 0.1	0.25
North Earsman	45	< 0.1	0.27
South Earsman	41	< 0.1	0.25
Dock	43	< 0.1	0.030

Table 6: Alkalinity, phosphate, and nitrate using potentiometric titrations and spectrophotometry at the Royal Roads University laboratory using water samples collected on April 16, 2019 by Van Isle Eco Consulting

Sample	Alkalinity (mg $CaCO_3$ /L)	Phosphate (ppm)	Nitrate (ppm)
"Dead Deer Creek"	34.64	< 0.1	0
North Earsman	44.83	0.028	0.282
South Earsman	42.79	< 0.1	0
Lake 1: Surface	43.81	< 0.1	0
Lake 1: 2m	42.79	< 0.1	0
Lake 2: Surface	44.83	< 0.1	0
Lake 2: 2m	42.79	< 0.1	0
Lake 3: Surface	42.79	< 0.1	0
Lake 3: 2m	43.81	< 0.1	0
Dock	42.79	< 0.1	0

Table 7: Alkalinity, phosphate, and nitrate using potentiometric titrations and spectrophotometry at the Royal Roads University laboratory using water samples collected on July 9th, 2019 by Van Isle Eco Consulting

Sample	Alkalinity (mg $CaCO_3$ /L)	Phosphate (ppm)	Nitrate (ppm)
Lake 1: Surface	49.32	< 0.1	0
Lake 1: 2m	48.23	< 0.1	0
Lake 2: Surface	51.52	< 0.1	0
Lake 2: 2m	51.52	< 0.1	0
Lake 3: Surface	50.42	< 0.1	0
Lake 3: 2m	49.32	< 0.1	0

Table 8: Fecal Coliform plate count performed on April 17, 2019 by Van Isle Eco Consulting

Plate sample	Dilution	Sample 1	Sample 2	Average
Lake 1	10^{-1}	0	0	0
Lake 1	10^{-2}	0	0	0
Lake 2	10^{-1}	0	0	0
Lake 2	10^{-2}	0	0	0
Lake 3	10^{-1}	0	0	0
Lake 3	10^{-2}	0	0	0
Dead Deer	10^{-1}	0	0	0
Dead Deer	10^{-2}	0	0	0
North Earsman	10^{-1}	6	4	5
North Earsman	10^{-2}	0	0	0
South Earsman	10^{-1}	1	1	1
South Earsman	10^{-2}	1	0	0.5

Table 9: Copper concentration of water samples obtained from Mary Lake and Earsman Creek before and after entering the lake. Samples were analyzed using AAS in the Royal Roads Laboratory by Van Isle Eco Consulting, and Dr. Matt Dodd

Sample Site	Cu Concentration (mg/L)
North Earsman	0.448
South Earsman	0.118
Dock	0.553
Lake 1	1.483
Lake 2	1.723
Lake 3	0.610

Additional Figures

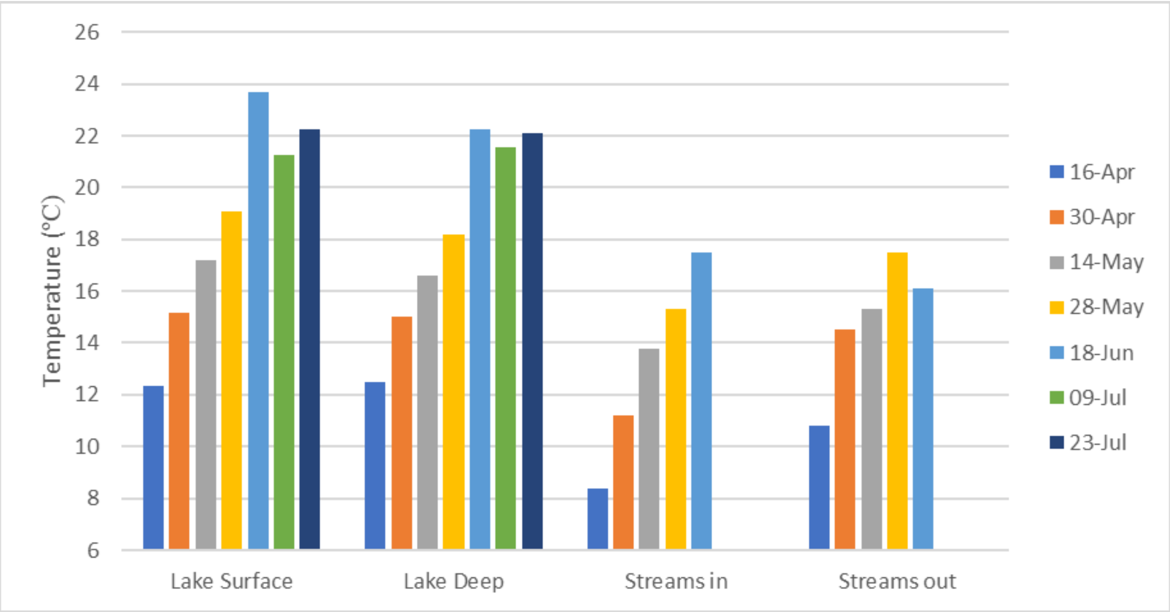

Figure 8: Average temperature readings from Mary Lake from 16 April, 2019 to 23 July, 2019 by Van Isle Eco Consulting using Cole-Parmer temperature corrected dissolved oxygen probe.

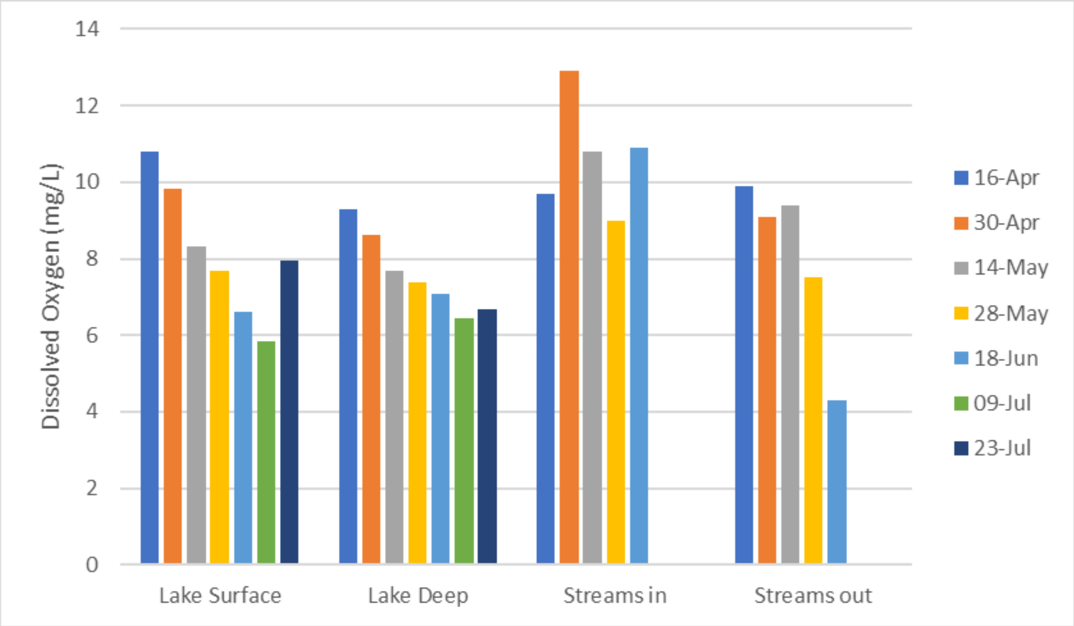

Figure 9: Average dissolved oxygen readings from Mary Lake from 16 April, 2019 to 23 July, 2019 by Van Isle Eco Consulting using Cole-Parmer temperature corrected dissolved oxygen probe.

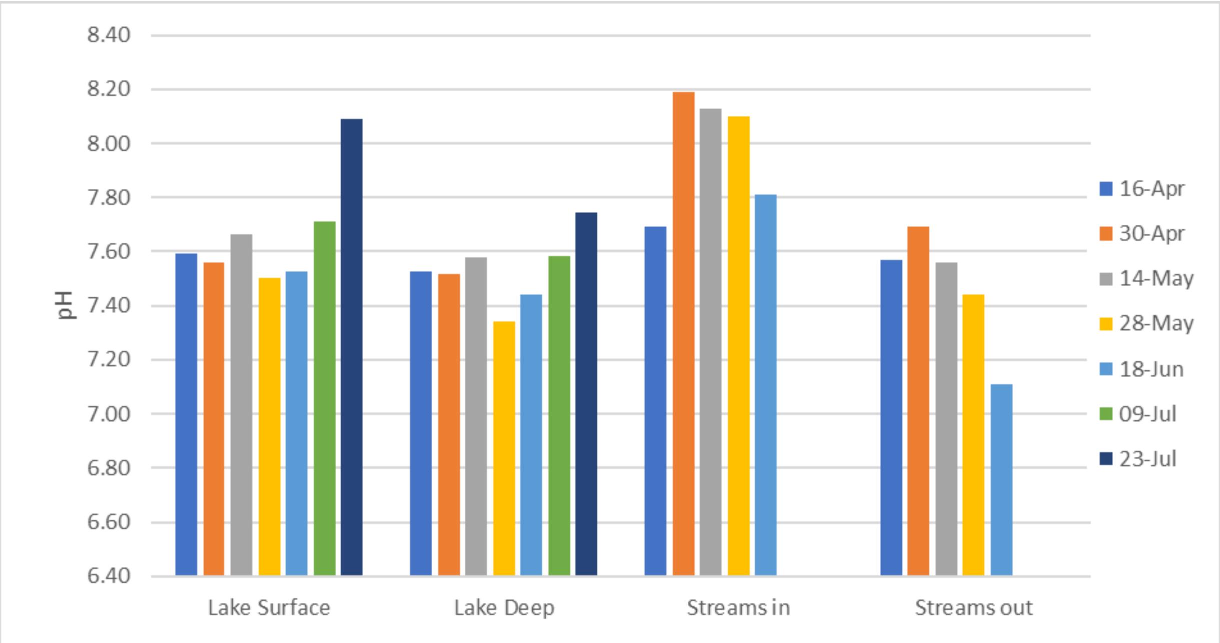

Figure 10: Average pH readings from Mary Lake from 16 April, 2019 to 23 July, 2019 by Van Isle Eco Consulting using Oakton PCTSTester 50 field probe.

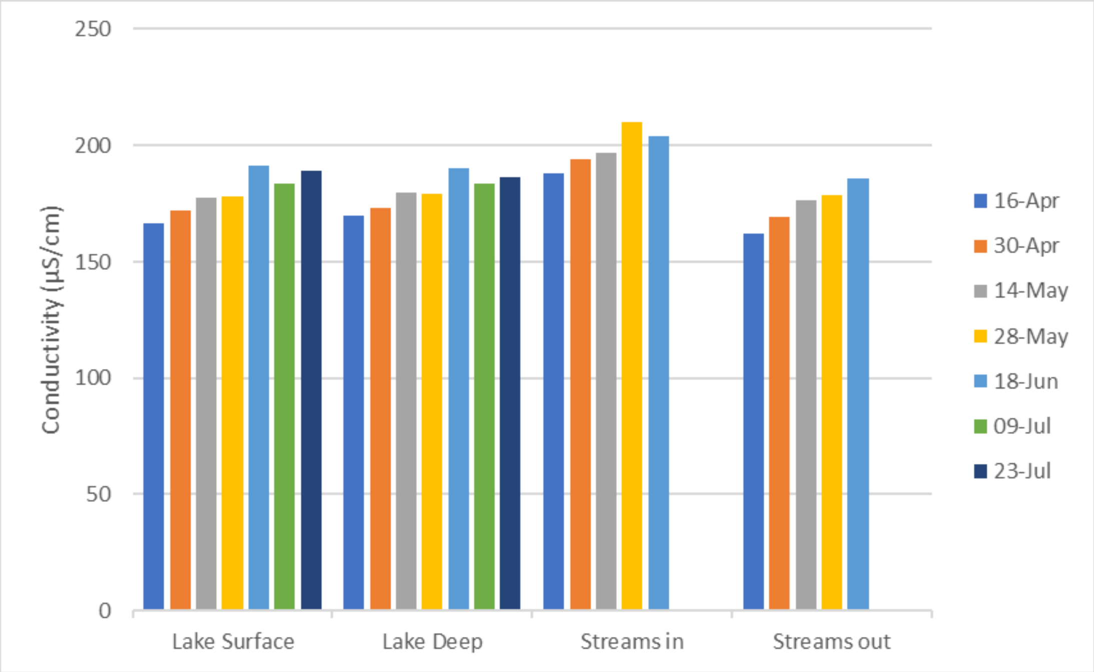

Figure 11: Average conductivity readings from Mary Lake from 16 April, 2019 to 23 July, 2019 by Van Isle Eco Consulting using Oakton PCTSTester 50 field probe.

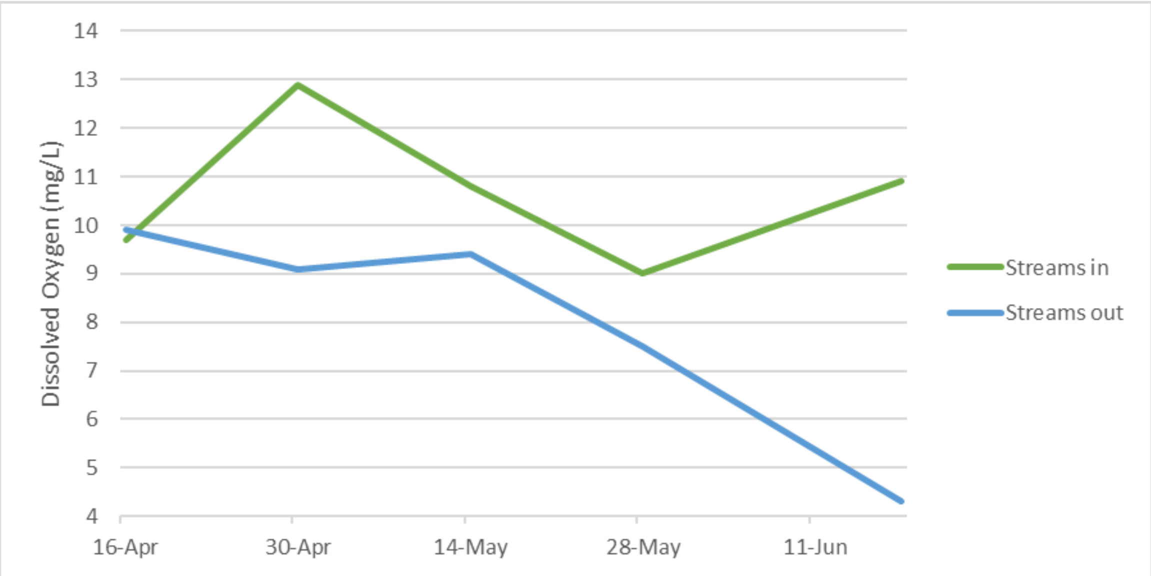

Figure 12: The effect of Mary Lake on dissolved oxygen in Earsman Creek measured 16 April, 2019 to June 2019 by Van Isle Eco Consulting using Cole Parmer temperature corrected dissolved oxygen probe.

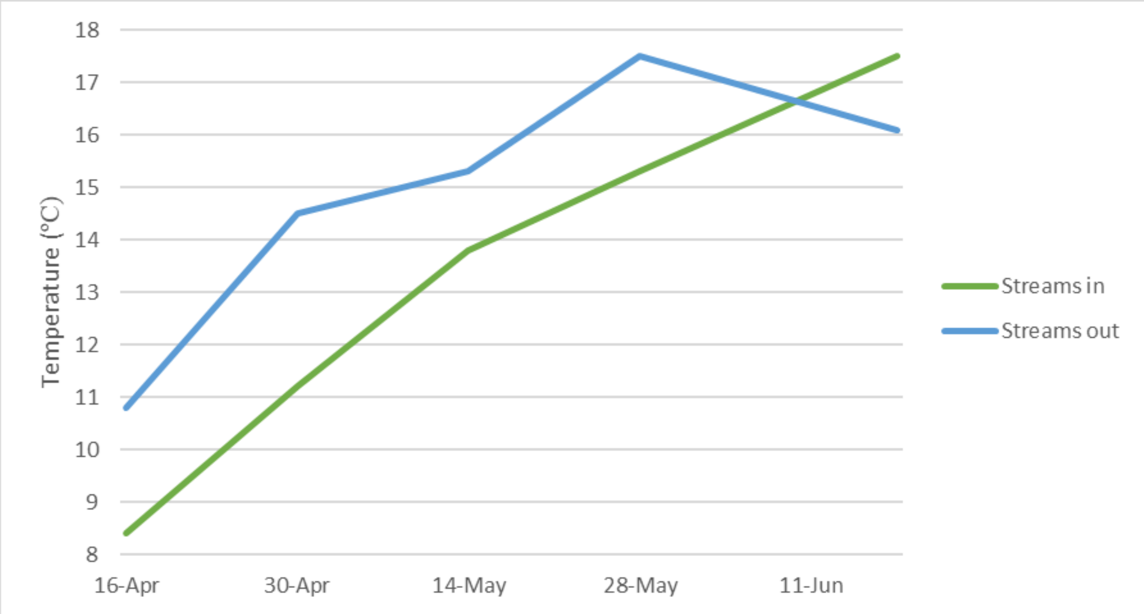

Figure 13: The effect of Mary Lake on temperature in Earsman Creek measured 16 April, 2019 to June 2019 by Van Isle Eco Consulting using Cole Parmer temperature corrected dissolved oxygen probe.

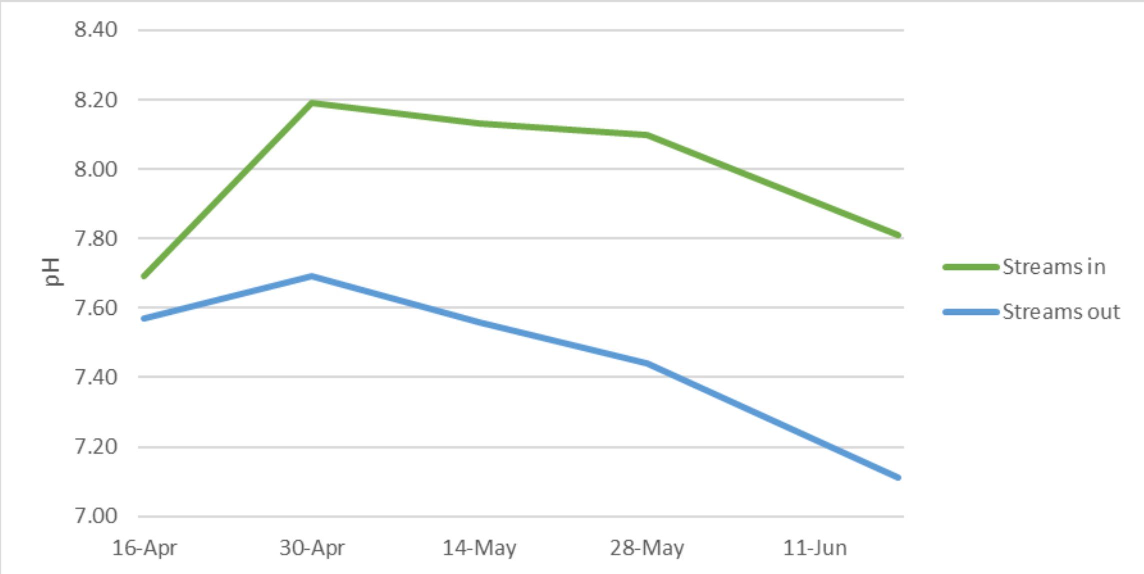

Figure 14: The effect of Mary Lake on pH in Earsman Creek measured 16 April, 2019 to June 2019 by Van Isle Eco Consulting using Oakton PCTSTester 50 field probe.

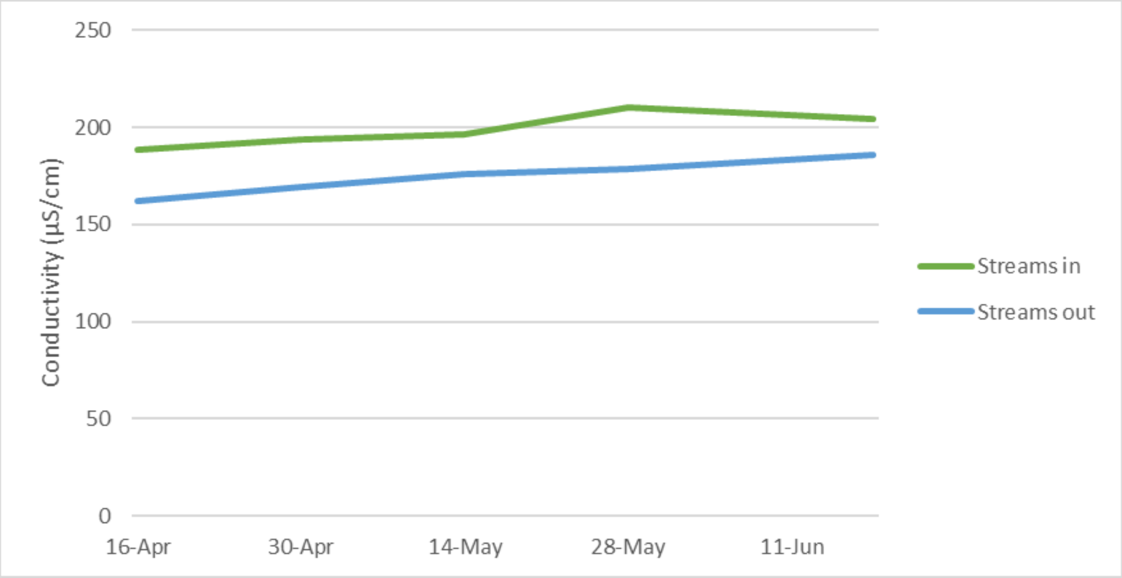

Figure 15: The effect of Mary Lake on conductivity in Earsman Creek measured 16 April, 2019 to June 2019 by Van Isle Eco Consulting using Oakton PCTSTester 50 field probe.

APPENDIX II:

Adapted table of known species observed to be present in aquatic habitats, wetlands, and streamside areas within Mary Lake

Table 1: Modified table of organisms found within aquatic habitats, wetlands, and stream sides as identified by Hans Roemer, 2010.

Scientific Name	Common Name	Habitats
Abies grandis	Grand fir	Streamside
Acer macrophyllum	Big-leaf maple	Streamside
Adiantum aleuticum	Maidenhair fern	Streamside
Alisma triviale	Water plantain	Aquatic
Alnus rubra	Red alder	Wetlands/Streamside
Athyrium filix-femina	Ladyfern	Wetlands/Streamside
Callitriche (palustris?)	Spring water-starwort	Aquatic
Carex deweyana	Dewey's sedge	Streamside
Carex hendersonii	Henderson's sedge	Streamside
Carex obnupta	Slough sedge	Wetlands
Carex utriculata	Beaked sedge	Wetlands
Cornus stolonifera	Red-osier dogwood	Wetlands/Streamside
Dryopteris expansa	Spiny woodfern	Streamside
Eleocharis palustris	Common spike-rush	Aquatic
Equisetum arvense	Common horsetail	Wetlands
Galium trifidum	Small bedstraw	Wetlands
Gaultheria shallon	Salal	Streamside
Glyceria elata	Tall mannagrass	Wetlands
Helenium autumnale var. grandiflora	Mountain sneezeweed	Wetlands
Hypericum anagalloides	Bog St.John's wort	Wetlands
Juncus articulatus	Jointed rush	Wetlands
Juncus effusus var. *pacificus*	Common rush	Wetlands
Lysichiton americanum	Skunk cabbage	Wetlands/Streamside

Scientific Name	Common Name	Habitats
Malus fusca	Pacific crabapple	Wetlands/Streamside
*Mentha spicata**	Spearmint	Wetlands
Nuphar lutea	Pond lily	Aquatic
Oemleria cerasiformis	Indian plum	Streamside
Oenanthe sarmentosa	Water parsley	Wetlands
*Phalaris arundinacea**	Canary reedgrass	Wetlands
Physocarpus capitatus	Ninebark	Wetlands/Streamside
Polystichum munitum	Sword fern	Streamside
Populus tremuloides var *vancouveriana*	Vancouver Island trembling aspen	Wetlands
Potamogeton natans	Floating pondweed	Wetlands
Pseudotsuga menziesii	Douglas-fir	Streamside
Pteridium aquilinum	Bracken	Streamside
Ribes bracteosum	Stink currant	Streamside
Rosa nutkana	Nootka rose	Wetlands
Rubus spectabilis	Salmonberry	Wetlands/Streamside
Rubus ursinus	Trailing blackberry	Streamside
Salix lucida	Pacific willow	Wetlands/Streamside
Salix scouleriana	Scouler’s willow	Wetlands/Streamside
Salix sitchensis	Sitka willow	Wetlands
Spiraea douglasii	Hardhack	Wetlands
Stachys chamissonis var. *cooleyae*	Cooley’s hedgenettle	Wetlands
Thuja plicata	Western redcedar	Streamside
Typha latifolia	Cat tail	Aquatic
Urtica dioica	Stinging nettle	Streamside
Veronica scutellata	Marsh speedwell	Wetlands

Table 2: *Plant species identified through observational surveys and organized into terrestrial, aquatic, and lichens and mosses.*

Terrestrial		
Scientific Name	**Common Name**	**Habitats**
Corallorhiza mertensiana	Western Coralroot Orchid	Forest edge
Lychnis coronaria	Rose Campion	Lake- riparian area
Aquilegia formosa	Western Red Columbine	Swamp edge
Calypso bulbosa	Lady Slipper Orchid	Forest edge
Allotropa virgata	Candy Stick	Forest edge
Boschniakia hookeri	Ground Cones	Lake-riparian area
Digitalis purpurea	Common foxglove	Open meadow
Pyrola picta	White-veined Wintergreen	Forest edge
Rumex acetosella	Sheep Sorel	Lake-riparian area
Claytonia perfoliata	Miner's Lettuce	Forest edge
Achlys triphylla	Vanilla leaf	Forest/ riparian
Polypodium glycyrrhiza	Licorice Fern	Forest- elevated microsite
Holodiscus discolor	Ocean Spray	Forest
Piperia teransversa	Royal rein Orchid	Forest edge
Aquatic & Semi Aquatic		
Polygonum amphibium	Water Smartweed	Lake-near shore
Myriophyllum sp.	Milfoil	Lake
Potamogeton natans	Broad-leaved Pondweed	Lake
Utricularia vulgaris	Common Bladderwort	Lake
Sparganium eurycarpum	Common burreed	Lake- near shore
Callitriche heterophylla	Diverse-leaved star-wort	Lake- near shore
Mentha aquatica	Water mint	Lake- near shore
Lichens & Mosses		

Scientific Name	Common Name	Habitats
Hypogymnia heterophylla	Seaside Bone lichen	On trunk of tree or logs
Hypogymnia enteromorpha	Beaded Bone lichen	On conifers, in open and shady forests
Pulmonaria loberia	Lungwort	Coniferous/deciduous humid forests
Peltigera britannica	Freckle Pelt	On moss/rocks, open forest
Platismatia herrei	Tattered Rag lichen	Douglas Fir, open forest
Plasmatia glauca	Ragbag lichen	Open & Shady forest
Hypogymnia physodes	Hooded Bone lichen	Tress, moss, rocks, open/shad forest
Evernia prunastri	Antlered Perfume	Deciduous/coniferous trees & shrubs in open sites
Cladonia fimbriata	Pixie Cup lichen	Acid & mineral soil, open sites tree bases
Cladonia squamosa	Dragon Cladonia	Mossy ground, decaying wood, open/shady sites
Cladina portentosa	Coastal Reindeer lichen	Open sites
Cladonia furcata	Cup Lichen	Soil, moss, & humus
Sphaerophorus globosus	Globe Ball lichen	Bark and \wood
Neckera douglasii	Douglas Neckera	Trunks/branches of trees
Kindbergia oregana	Oregon Beaked Moss	Lowland forest; logs, humus, tree bases
Rhytidiadelphus triquetrus	Rough goose neck moss	Logs and tree bases
Hylocomium splendens	Step Moss	Western redcedar and hemlock forests
Plagiomnium venustum	Magnificent Moss	Rotting logs/lower tree trunk
Polytrichum juniperinum	Juniper Haircap Moss	Disturbed mineral soils
Porella navicularis	Tree-ruffle Liverwort	Tree trunks and branches
Kindbergia praelonga	Slender Beaked Moss	Logs, humus and tree bases

Table 3: *Animal species identified by observation of the animal or evidence of its presence.*

Scientific Name	Common Name	Evidence
Ursus americanus	Black Bear	Feces, claw marks
Odocoileus hemionus	Black-tailed Deer	Observed
Lontra canadensis	River Otter	Observed
Puma concolor	Cougar	Claw marks, and deer remains
Castor canadensis	Beaver	Observed
Neovison vison	Mink	Observed
Tamiasciurus douglasii	Douglas Squirrel	Observed
Cathartes aura	Turkey Vulture	Observed
Tachycineta thalassina	Violet Green Swallow	Observed
Monadenia fidelis	Pacific Sideband Snail	Observed
Podarcis muralis	Euopean Wall Lizard	Observed
Lithobates catesbeianus	American Bullfrog	Observed
Taricha granulosa	Rough-Skinned Newt	Observed
Arion ater	European Black Slug	Observed
Ariolimax sp.	Pacific Banana Slug	Observed
Lepomis gibbosus	Pumpkinseed Sunfish	Observed
Ardea herodias	Blue Heron	Observed
Hirundo rustica	Barn Swallow	Observed
Mergus merganser	Common Merganser	Observed
Lophodytes cucullatus	Hooded Merganser	Observed
Aix sponsa	Wood Duck	Observed
Aythya collaris	Ring-necked Duck	Observed
Anas platyrhynchos	Mallard	Observed
Agelaius phoeniceus	Redwing Blackbird	Observed
Myotis lucifugus	Little Brown Bat	Observed

Scientific Name	Common Name	Evidence
Pacifastacus leniusculus	Signal Crayfish	Observed
Rana aurora	Red-Legged Frog	Observed
Thamnophis sp.	Garter Snake	Observed
Haliaeetus leucocephalus	Bald Eagle	Observed

APPENDIX III:
Map of sampling locations at Mary Lake Nature Sanctuary