# Cottle Creek Environmental Assessment Final Report

**2017**

**Submitted to:**
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**RMOT 306**
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## Table of Contents:

## Introduction and Background (Nathan Hambrook)

### Project Introduction:

The purpose of this project is to carry out a water and habitat quality monitoring project on Cottle Creek, located in the north-eastern portion of Nanaimo, British Columbia. This project was undertaken by four students from Vancouver Island University (VIU), in RMOT 306-Environmental Monitoring. All activities were completed by the students, with the guidance of Dr. Eric Demers. The project took place between October 23 and November 22 of 2017. During this time the students sampled during two different flow periods, a slow flow period in late October, and a high flow period in November, when the winter rains had started. Water quality, stream macroinvertebrate, and microbiology sampling has been occurring on Cottle Creek annually since 2012. This environmental monitoring project has allowed the continuation of annual data, provided a current assessment on stream health, and will aid in showing any long-term impacts that the surrounding land base of urban development may cause to the watershed.

### Background:

Cottle Creek is in the north-eastern area of Nanaimo, B.C., on the coast of the Salish Sea (Figure 1). Cottle Creek has three segments, or tributaries. The first tributary, upper Cottle Creek, originates near Rutherford road and flows to Cottle Lake; the second, North Cottle Creek, flows from Lost Lake to Cottle Lake; the last tributary empties from Cottle Lake and empties in Departure Bay, near the Pacific Biological Research Station (City of Nanaimo 1999 in Bolland et al. 2013). The Cottle Creek drainage area is approximately 3.8 $km_2$ with Cottle Lake in the middle (Cook and Baldwin 1994). Being so close to the ocean, the median elevation of the creek is 140 m, giving the creek a shallow gradient and low flow rates, with exception of the downstream end near Departure Bay, where waterfall features exist as the creek drops rapidly into the bay (Cook and Baldwin 1994).

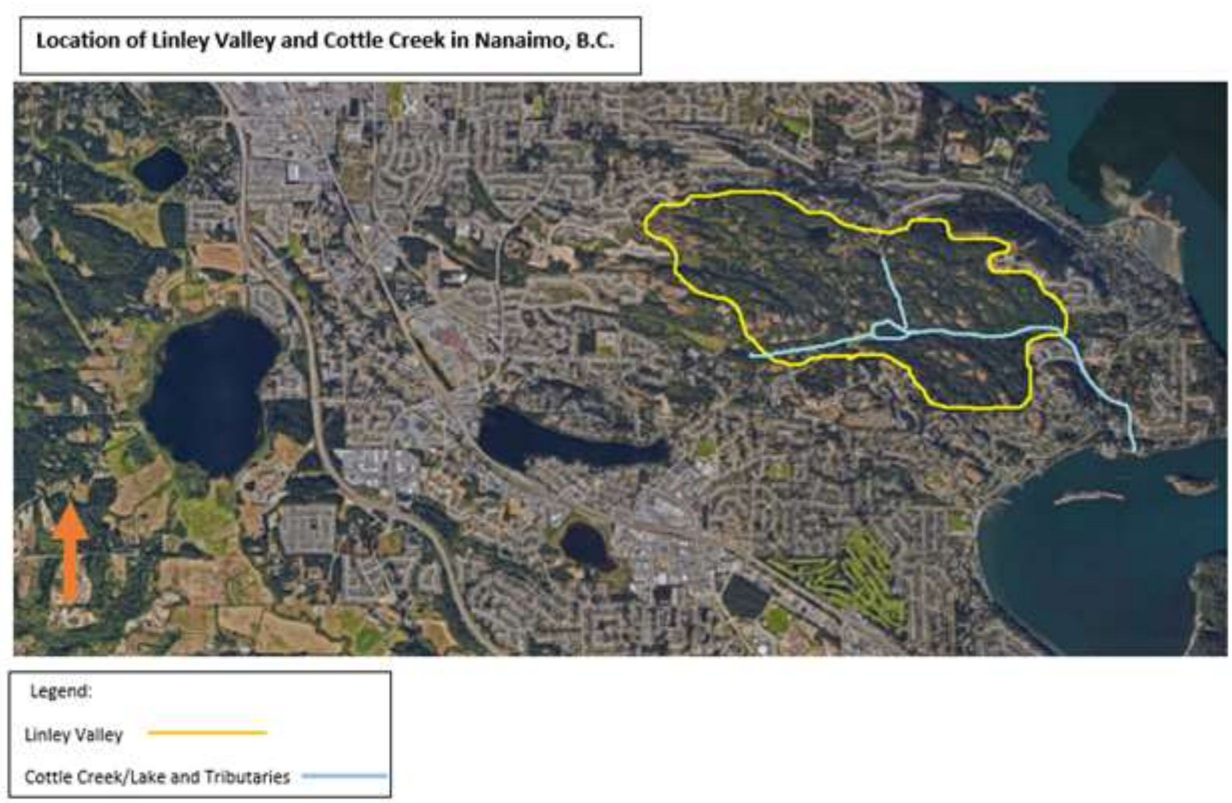


Figure 1: Location of Cottle Creek and the Linley Valley in Nanaimo, BC. (Created in Google maps (2017).

Most of Cottle Creek runs through a large urban park, Linley Valley. At 58.7 hectares, this valley is considered one of the last and largest ecosystems in Nanaimo city limits, and supports abundant wildlife from deer (*Odocoileous hemionus columbianus*), beavers (*Castor canadensis*), migratory birds, healthy insect populations, and amphibians (NALT 2017). The Cottle Creek and lake system supports a cutthroat trout (*Onchorhynchus clarkii*) population (Barlak and Fegan 2014). The ecosystems dominant tree species in the park is the Coastal Douglas Fir (*Pseudotsuga menziesii*), making it a Douglas Fir ecosystem (NALT 2017). Further tree species involved Red Alder (*Alnus rubra*), Western Red Cedar (*Thuja plicata*), individual Big Leaf Maples (*Acer macrophyllum*), and interspersed Arbutus trees (*Arbutus menziesii*). The low-lying vegetation contained Salal (*Gaultheria shallon*), Sword Fern (*Polystichum munitum*), Deer Fern (*Blechnum spicant*), Bracken Fern (*Pteridium aquilinum*), Red Huckleberry (*Vaccinium parvifolium*), Salmonberry (*Rubus spectabilis*) and Trailing Blackberry (*Rubus ursinus*). Himalayan Blackberry (*Rubus armeniacus*) and Daphne (*Daphne laureola*) were a common invasive species observed along the stream.

The land base surrounding Linley Valley and along Cottle Creek is comprised of heavily populated residential areas. As Nanaimo grows, development is ever increasing. The development has brought in more roads, houses, and people to the area. The more development and habitation that takes place around the creek, the higher the stressors are on the creek system, like fertilizer from properties and oils from roads. These stressors may affect stream sedimentation, and water quality as yard fertilizers filter into the stream. The stream has been negatively affected by the clearing of trees and the neglect of any kind of erosion maintenance (City of Nanaimo 1999 in Bolland et al. 2013).

The objectives of this project are to collect and analyze data about the health and water quality of Cottle Creek. This project will gather data from four different sites of the creek. The same four sites have been sampled annually, following similar parameters, since 2012. The data will be analyzed by VIU students, at VIU, and at the Australian Laboratory Services (ALS) center in Burnaby. The types of data collected include macroinvertebrates, water quality, and microbiology. When results are returned, they will be reviewed to ascertain the current stream health and compare to previous years to see if there are any impacts that are chronically affecting the stream, or if any acute stressors have arisen in the last year.

## Proposed Environmental Sampling and Analytical Procedures (A.Dignan)

### Proposed Sampling Program:

Since 2012, VIU students of the of Bachelor of Natural Resource Protection program have conducted annual environmental monitoring assessments of Cottle Creek, Nanaimo, BC under the guidance and instruction of Dr. Eric Demers. It was crucial that the continuity of already established and previously used protocols and procedures be utilized to maintain consistency throughout the entirety of the project.

## Locations (A. Dignan)

### Habitat Characteristics:

Upon visiting and reviewing various locations along Cottle Creek on October 18, 2017, four sites shown in figure 2 were selected as sampling stations to conduct assessments for water quality, microbiology and stream invertebrates. The four sites were chosen based on characteristics which were deemed to be representative of the entire creek. These characteristics include canopy cover, flow, and substrate composition, which allows for proper stream invertebrate sampling. Ease of safe accessibility was also a factor which was considered when selecting the four sites. Furthermore, assessments have been conducted at these sites in previous years; by continuing to study in the same locations, comparisons can accurately be made with current and past data. All four sites displayed shallow depth and moderate to slow flow characteristics during the initial site visit. However, depths and rate of flow increased with continued rainfall during later sampling events.

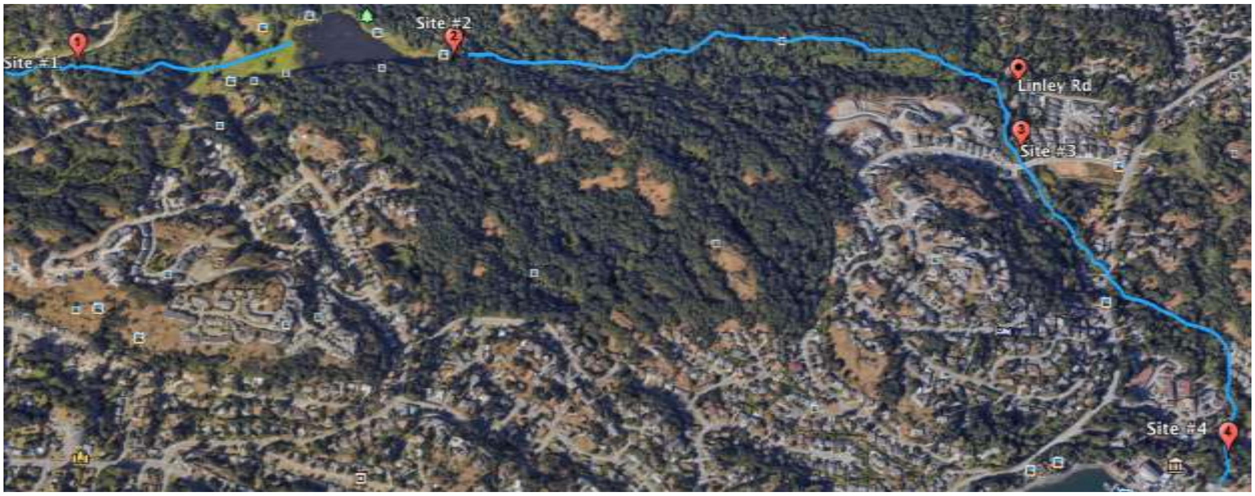


Figure 2: Overview of the four sites within Cottle Creek utilized as sampling stations. Water flows from station 1 downstream to station 4 where it is discharged in Departure Bay (Google Earth 2017).

Site #1 (UTM 10 U 0428025 m E; 5452201 m N) (Figure 3) is located downstream of Landalt Rd and runs parallel with Arrowsmith Rd. This site is located upstream of Cottle Lake and displays a variety of different flow characteristics which are representative of the rest of the creek. Additionally, the area around the site is relatively flat and easy to walk around which proved beneficial while sampling. However, to access this site, it is required to walk down a steep gully from Arrowsmith Rd followed by climbing over 2 m high wire fence and requires caution to avoid any risk of injury. Vegetation in this site primarily consists of young Western Red Cedar, Sword Fern and some Deer Fern. Substrate composition consists of roughly 60% gravel and 40% cobble.


Figure 3: Site #1 (Google Earth 2017)

Site #2 (UTM 10 U 0428587 m E; 545262 m N) (Figure 4) is located at the east end of Cottle Lake where the lake drains downstream towards Departure Bay. The site is located approximately 10 m from the main trail bridge and was selected as it has characteristics which are representative of the other three sites. Furthermore, this site is easy to access from the main lake trail, although a 10-minute walk is required from the main parking lot. Site 2 consists of approximately 40% cobble, 60% gravel. Vegetation consists of sword fern, deer fern, bracken fern, Pacific willow (*Salix lucida*), cedar, skunk cabbage (*Symplocarpus foetidus*), and red huckleberry.


Figure 4: Site #2 (Google Earth 2017).

Site #3 (UTM 10 U 0430184 m E; 5452037 m N) (Figure 5) is located approximately 20 m north of the upstream side of Nottingham Dr. This site is easily accessible and has little to no risks associated with it. There is a variety of different flow characteristics within this area of the creek. Substrate composition consists of 80% fine silt and 20% cobble. Vegetation within the site includes Red Alder, Skunk Cabbage and a variety of grasses.

Figure 5: Site #3 (Google Earth 2017).

Site #4 (UTM 10 U 0430573 m E; 5451345 m N) (Figure 6) is Located approximately 20 m south off Stephenson Point Rd on the downstream side of where the road intersects the creek. This site is the furthest downstream site to be assessed and is located very close to where the system discharges into Departure Bay. This site displays a variety of stream characteristics such as pools, riffles, and small waterfalls. Substrate composition consists of 80% boulder, 20% cobble and contained some large chunks of concrete left behind by past construction. Site vegetation comprised of a variety of ferns, Oregon Grape (*Mahonia aquifolium*), Red Huckleberry, Red Cedar and Arbutus.


Figure 6: Site #4 (Google Earth 2017).

**Sampling Frequency (A.Dignan):**

As previously stated, hydrology, water quality and microbiology were all assessed throughout the duration of the project. Discharge was assessed at two of the four stations to determine rate of flow. Water samples were collected from all four stations to determine water temperature, dissolved oxygen, pH, conductivity, turbidity, alkalinity, hardness, nitrate, phosphate and other aspects further outlined in section 3.3. Furthermore, samples from sites 1, 2 and 4 were collected and sent to Vancouver for ALS analyses to test for a wide variety of components. Microbiology sampling took place at all four sites during the first sampling event. Finally, stream invertebrate sampling was done at site 1, 2 and 4 during this first sampling event. A total of 9 invertebrate samples (3 replicate samples per site) were collected during this process and used to help assess water quality.

**Basic Hydrology (A. Zimich start):**

Stream discharge was done at both stations 2 and 3 for both sampling events. Stream discharge was measured using the cross-sectional area of the stream and current speed. To find the cross-sectional area, we measured the wetted width and took the average depth from 7-10 convenient increments across the stream. The cross-sectional area is equal to the average depth multiplied by the wetted width. To measure velocity, we took the time taken by a float to travel a set distance. We then multiplied our cross-sectional area by velocity to figure out discharge in $m^3/s$.

**Water quality**

**Field Measurements Parameters:**

In the field, we measured water temperature (ºC) and dissolved oxygen (mg/L) with an electronic probe for all stations on both sampling events.

### Water sample collection:

Water samples were taken from all four stations, and at two separate times to account for hypothesized low (late October) and high flow (mid-November) events. Water sampling followed guidelines set by the *Ambient freshwater and effluent sampling manual* (MWLAP 2003). Water samples were collected using 1L plastic bottles provided by Vancouver Island University.

### VIU Lab Analysis:

Water samples were taken from all four locations for both events on Cottle Creek and were transported to VIU for laboratory analysis. There, we tested for pH, hardness (mg/L as CaCO2), conductivity (µS/cm), nitrate (mg/L as $NO_3^-$), alkalinity (mg/L), phosphate (mg/L $PO_4^3$), and turbidity (NTU). Laboratory analysis were done within 24 hours of taking the samples.

### ALS Lab Analysis:

ALS laboratory analysis happened in Burnaby, BC. Samples were sent in from both sampling events and included stations 1, 2 and 4. ALS samples were taken using 3 pre-rinsed bottles (two 250ml bottles and one 1L bottle). At the lab, they tested for general parameters, total metals, and nutrients. The 3 samples from stations 1, 2 and 4 were cooled at 4$^o$C until they were sent in for analysis.

### Quality Control/ Quality Assurance:

For quality assurance, we ensured that the samples were taken from the same area for both events. We used clean VIU containers that were rinsed 3 times onsite and the samples were taken from mid water column level. Our team faced upstream when we took samples and made sure not to stir up debris. In the lab all members of the team wore clean latex gloves and rinsed all test beakers and containers with distilled water before use. Furthermore, these samples matched the parameters, procedures, and intervals as previously done studies on Cottle Creek since 2012. For quality control, we took a replicate sample from station one and also used a trip blank. Furthermore, we took three replicate samples at each station 1, 2, and 4 with the Hess sampler. This was done on the first sampling event only and ensured more accurate results for stream invertebrates.

**Data analysis comparison to guidelines:**

The results from the analysis done by VIU and ALS were compared to the maximum guidelines for BC aquatic life (MWLAP 1998).

**Microbiology (A. Zimich end):**

All four stations were tested for coliforms during the first sampling session. Procedures used for microbiology tests followed the *TOTAL COLIFORMS AND E. COLI MEMBRANE FILTRATION METHOD* (USEPA 2003). Sampling was done to check for the presence of non-fecal and warm blooded fecal coliforms. Samples were taken with 100ml Whirlpak bags and were incubated before lab analysis.

## Results and Discussion (Mikey Boudreau and Nathan Hambrook):

This section will go over the results of the 2017 Cottle Creek monitoring project completed by VIU students. The results will be described, and any trends will be highlighted for each parameter of water quality, stream macroinvertebrates, and microbiology for Cottle Creek.

**Water Quality:**

**PH (Nathan):**

| **Table 1:** Ph of Cottle Creek Sites, measured in both sampling events. | | |
|---|---|---|
| **Site Samples:** | **First Sample Event, October 30, 2017** | **Second Sample Event, November 20, 2017** |
| Trip Blank | 7 | 8 |
| CCS1R | 7.6 | 7.5 |
| CCS1 | 7.3 | 8.1 |
| CCS2 | 7.2 | 8.1 |
| CCS3 | 7.4 | 7.5 |
| CCS4 | 7.8 | 7.2 |

Table one shows the pH (potential Hydrogen) of each site with a trip blank and replicate sample for the high and low flow sample period. Between sample period one and two the overall trend is an increase in pH for samples, except for site four. There also could have been possible contamination with the trip blank in the second event, because the trip blank has a change in pH from seven to eight. Our pH rage is from 7.2-8.1, which is within the aquatic life guidelines of 6.5-9 as set out by MOE (1998). The decrease in acidity between sample events could be due to exposure to basic minerals in the sample sites, or the increase in rainfall has diluted the acidic ions in the water column.

**Conductivity (Nathan Hambrook):**

**Table 2:** Conductivity of Cottle Creek Sites, measured in Microsemens per Centimeter in both sampling events.

| Site Samples: | First Sample Event, October 30, 2017 | Second Sample Event, November 20, 2017 |
|---|---|---|
| Trip Blank | <0.01 µ/cm | <0.01 µ/cm |
| CCS1R | 186 µ/cm | 97 µ/cm |
| CCS1 | 182 µ/cm | 97 µ/cm |
| CCS2 | 191 µ/cm | 84 µ/cm |
| CCS3 | 197 µ/cm | 93 µ/cm |
| CCS4 | 203 µ/cm | 94 µ/cm |

Table two shows the difference in the conductivity, which is the ability of electricity to pass through the water based on the amount of dissolved ions present, of the two sample periods for each of the sample sites, replicate and trip blank. The trip blank is below discernable numbers which is what is to be expected from treated water. The conductivity of the first sample event is higher than the second, ranging from 182-203 micro-siemens per centimeter. Whereas, the second event ranges from 83-97 micro-siemens per centimeter. The parameter for coastal streams is around 100 µ/cm (MOE 1998). The first event exceeds this parameter, but it balances out with higher flows. The slow flow rates allow more exposure for ions to dissolve and stay present in the system, but the high flow rates of the second period diluted the ions in the water, reducing the conductivity.

**Hardness (Nathan Hambrook):**

**Table 3:** Hardness of Cottle Creek sites, measured as $CaCo_3$ in mg/L during both sampling events.

| **Site Samples:** | **First Sample Event, October 30, 2017** | **Second Sample Event, November 20, 2017** |
|---|---|---|
| CCS1R | 84 mg/L | 38 mg/L |
| CCS1 | 76 mg/L | 40 mg/L |
| CCS2 | 80 mg/L | 32 mg/L |
| CCS3 | 73 mg/L | 34 mg/L |
| CCS4 | 76 mg/L | 35 mg/L |

Hardness is a measure of the amount of Calcium and Magnesium in the water, measured in $CaCo_3$. Table three shows the hardness levels with the October and November sample periods. Soft water is <60 mg/L $CaCo_3$ and hard water is >120 mg/L $CaCo_3$. Metals are more toxic in softer water. Metals are less toxic in hard water, as the $CaCo_3$ (MOE 1998). The Nanaimo geology is not very soluble as it is more sandstone and conglomerate that are not rich in calcium. The decrease in $CaCo_3$ between the two events is solely due to the high flow rates that wash away dissolved minerals.

**Turbidity (Mike Boudreau):**

Turbidity is the amount of light that is permitted to travel through a liquid. This measurement indicates the clarity of water. When water bodies receive water from a large precipitation event, solids become washed off the environment and suspended in the water column. A highly unclear or turbid water sample has the capacity to affect the gills of aquatic life by obstructing respiratory (gill) function (Alaska Department of Environmental Conservation 2013). Waters with high turbidity allow for increased microbial biomass due to the suspended solids in the unclear water serving as a substrate for microbial attachment.

It was found that in general, sites had a higher turbidity during the second sampling event than samples taken during the first sampling event (table 4). Turbidity values in Nephelometric Turbidity Units (NTU) for the first sampling event had a range from 1.10 NTU (site 3) to 7.29 NTU (site 2). The 7.29 NTU value is a very apparent outlier in the data. Other samples during sampling event 1 ranged from 1.10 NTU (site 3) to 3.2 NTU with an average, excluding the 7.29 NTU value of 1.9525 NTU, with all stations sampling event 1 resulted in an average turbidity of 3.02 NTU. Sampling event 2 resulted in an average turbidity of 2.71 NTU, which is indeed of a lower water clarity that sampling event 1.

Site 2 during sampling event 1 presented an outlier in the data due to its location, on the outflow of Cottle Lake, a shallow productive lake. The high NTU value was highly influenced by eutrophic lake derived suspended solids accentuated by the time of year (end of growing season) and low rainfall. The sample taken from site 1 during the first sampling event appears to be an outlier albeit less than site 2 may show an inaccurate result because of improper sampling techniques and/or extreme low water flows causing the sample bottle to become fouled with sediment. Although turbidity increased between sampling events, the increase was well below BC Ministry of Environment (1998) standards of maximum turbidity increase 5NTU; if background ≤50 NTU.

**Table 4:** Turbidity of Cottle Creek Sites, measured in Nephelometric Turbidity Units (NTU), during both sampling events.

| **Site Samples:** | **First Sample Event, October 30, 2017** | **Second Sample Event, November 20, 2017** |
|---|---|---|
| CCS1R | 1.55 NTU | 2.81 NTU |
| CCS1 | 3.20 NTU | 3.04 NTU |
| CCS2 | 7.29 NTU | 2.95 NTU |
| CCS3 | 1.1 NTU | 2.54 NTU |

| | | |
|---|---|---|
| CCS4 | 1.96 NTU | 2.21 NTU |
| Mean | 3.02 NTU<br>**Excluding CCS2: 1.9525 NTU** | 2.71 NTU |

**Alkalinity (MB):**

Alkalinity is a water quality parameter measuring the acid buffering ability of a water sample. This ability to buffer acid is highly dependent on the quantities of $Ca^{2+}$and $Mg^{2+}$ present in the water, higher concentrations of these ions will increase alkalinity (U. Mass. Amherst 2017). Alkalinity is measured in mg/L of calcium carbonate ($CaCO_3$).Water with high alkalinity >20 mg/L is considered to be of low acid sensitivity. Water with low alkalinity: 0-10 mg/L is of high acid sensitivity. Water with 10-20 mg/L is considered to have moderate acid sensitivity (MOE 1998).

During the first sampling event, all samples possessed a high alkalinity ( >20 mg/L) which is a low acid sensitivity . Values during sampling event 1 ranged from 46 to 60 mg/L with the highest alkalinity at the lake outflow site, site 2 and the lowest alkalinity being found at site 1 (table 5).

During sampling event 2, samples were deemed to be of low acid sensitivity or very slightly under that in the moderate acid sensitivity category. Alkalinity Values in the second sampling event ranged from 17.9 to 23.5 mg/L. The highest alkalinity coming from site 1, and the lowest alkalinity coming from site 2.

The observed drop in alkalinity between sampling events is a product of the increased flow rate due to a large rainfall event. Water during high flow rates possesses a less dense composition of acid buffering components (Murdoch & Shaneley 2006). In low flow periods water is able to interact with the substrate to a much higher extent, picking up more acid buffering components.

**Table 5:** Measurement of Alkalinity of each site on Cottle Creek, measured in mg/L of $CaCo_3$.

| **Site Samples:** | **First Sample Event, October 30, 2017** | **Second Sample Event, November 20, 2017** |
|---|---|---|
| CCS1R | 49 mg/L | 22.1 mg/L |
| CCS1 | 51 mg/L | 23.5 mg/L |
| CCS2 | 60 mg/L | 17.9 mg/L |
| CCS3 | 46 mg/L | 19.5 mg/L |
| CCS4 | 50 mg/L | 19.7 mg/L |

**Phosphate (Nathan Hambrook):**

| **Table 6: Phosphate measurement of each site on Cottle Creek, measured in mg/L of $PO_4^{3-}$, during both sampling events.** | | |
|---|---|---|
| **Site Samples:** | **First Sample Event, October 30, 2017** | **Second Sample Event, November 20, 2017** |
| **Trip Blank** | **0.03 mg/L** | **.02 mg/L** |
| **CCS1R** | **0.04 mg/L** | **0.06 mg/L** |
| **CCS1** | **0.12 mg/L** | **0.2 mg/L** |
| **CCS2** | **0.04 mg/L** | **0.19 mg/L** |
| **CCS3** | **0.04 mg/L** | **0.07 mg/L** |
| **CCS4** | **0.03 mg/L** | **0.24 mg/L** |

Table five shows the measure of phosphate for the October and November sampling periods. Phosphate ($PO_4^{3-}$) is measured in for mg/L. Phosphate is the soluble form of phosphorus (MOE 1998). It enters the stream naturally through the weathering of minerals and certain organic debris. It also enters through human activity, such as, wastewater effluent, and fertilizers that artificially increase the $PO_4^{3-}$. There are no water quality guidelines for phosphate; however it plays a large role in the eutrophication of a lake. Phosphate and nitrate will combine in a ratio of 16 Nitrat to 1 Phosphate, the Redfield Ratio, to form nutrients that will allow biological organisms to feed and grow. Phosphate is usually limited in an ecosystem; therefore, when it is increased rapidly it can lead to eutrophication of a water body and an accelerated growth period for algae and create harmful algal blooms.

For sample event one, the levels of phosphate ranged from 0.02 mg/L to 0.12 mg/L. The 0.12 mg/L from sample site one is an outlier for the sample sites, as the next highest is 0.04 mg/L. This outlier could be the result of improper sample techniques due to the variation in the replicate sample, or site one being close to a culvert, a road, and houses, where nutrients and fertilizers could funnel through the culvert and concentrate into the site. The rest of the levels are relatively low, which is due to the low flow amounts, that do not move the nutrients around as aggressively.

For sample event two, the levels of phosphate ranged from 0.02 mg/L to 0.24 mg/L. Overall these numbers are still low. Site one, two, and four are the highest at 0.2 mg/L, 0.19 mg/L, and 0.24 mg/L respectively. Site one would be a similar situation as sampling event one, because of the variation in the replicate, which could indicate sampler error, or variability in the flow of nutrients. Site two is up from 0.04 mg/L, in event one, to 0.19 mg/L in event two. This would be from the high flow period that created a larger movement of water out of Cottle Lake, which is eutrophic and carries a lot of nutrients. Site four was the highest in the second sampling event at 0.24 mg/L. Site four is the farthest sample station downstream, and encompasses the largest stretch with urban development. The increased precipitation on the area, presumably, washed more nutrients off the roads, and property, and funneled them into the end of the stream where site four exists.

**Nitrate (Nathan Hambrook):**

| **Table 7:** Nitrate measurement, of $NO^{-}_{3}$, in mg/L during both sampling events | | |
|---|---|---|
| **Site** | **First Sample Event, October 30, 2017** | **Second Sample Event, November 20, 2017** |
| CCS1 | N/A | 0.67 mg/L |
| CCS1R | N/A | 1.02 mg/L |
| CCS2 | N/A | 1.11 mg/L |
| CCS3 | N/A | 1.26 mg/L |
| CCS4 | N/A | 1.50 mg/L |
| Trip Blank | N/A | 0.07 mg/L |

Table seven shows the Nitrate ($NO^{-}_{3}$) measurements for the November sample event only. The data for the first sample event was lost due to a clerical error, but is assumed that values are lower in the first event than the second event. This would be consistent with the results from the rest of the water quality variables. Nitrate is the most common form of nitrogen that is used for growth stimulus. In large quantities Nitrate can be toxic to toddlers. The guideline for streams is a maximum amount of 200 mg/ L with a 40 mg/L average (MOE 1998). Nitrate enters a stream through atmospheric diffusion of nitrogen, and other terrestrial sources like organic material. Like phosphate, it also is delivered to a water body in higher quantities when there are pollution events like wastewater discharge.

When assuming that Nitrate levels from event one are lower than event two, it makes sense that the level two Nitrate levels range from 0.07 mg/L to 1.50 mg/L. Even at these increased rates, the Nitrate levels are far below the guidelines. The trip blank is expected to be low in Nitrogen, and at 0.07 mg/L it falls within the drinking water guidelines of a maximum of 10 mg/L (MOE 1998). The levels of Nitrate have a general increasing trend from site one to four. Site four has the highest amount of Nitrate because, like Phosphate, it is in the largest urban area of the stream, which will collect a large amount of nutrients from the houses and roads. Since Nitrate can enter the stream through atmospheric deposition, site four also acts as a funnel for the watershed and all the Nitrate falling with the rain.

**Coliforms (MB):**

During the first sampling event, water from all four sites was tested for the presence of coliform bacteria. The presence of coliform bacteria, especially fecal coliforms indicate that the water may contain harmful bacteria, parasites, or viral pathogens such as *E. coli*, giardia and hepatitis (Donovan et al. 2008, Health Canada 2017). Coliforms are measured by colony counts, 1 coliform referenced in this report is 1 colony.

Coliform analysis revealed that all sites had non-fecal coliforms present, and 3 out of 4 sites had fecal coliforms present (table 8). The general trend of coliform numbers was the headwaters had less coliform bacteria than the reaches farther downstream. There is more total exposure to inputs in the case of lower elevation (downstream) reaches. Site 2, the site at the outflow of Cottle Lake showed outlying 322 non-fecal coliforms and no fecal coliforms. This outlying value showcases again the unique nature of site 2 due to its proximity to the productive lake.

There are no guidelines for coliforms in respect to aquatic life. If someone were to explore the Cottle Creek watershed for drinking water, they would need to seek applicable water treatment as coliforms were present all 100ml samples. There should be no total coliforms present in a 100ml sample for drinking water (Health Canada 2017).

**Table 8:** Measure of Coliform activity in all four test sites on Cottle Creek during the first sample event only.

| **Site Samples:** | **First Sample Event, October 30, 2017** | |
|---|---|---|
| **Coliform Colour** | Red (non-fecal) | Blue (fecal) |
| CCS1 | 13 | 3 |
| CCS2 | 322 | 0 |
| CCS3 | 52 | 3 |

| | | |
|---|---|---|
| CCS4 | 441 | 10 |

**Dissolved Oxygen (MB):**

Dissolved oxygen is the amount of free O2 in water. Aquatic life in general requires oxygen dissolved in water to live. Influences on dissolved oxygen levels include rate of atmospheric deposition and flow rate (Michaelis 2006). Dissolved oxygen is measured in mg/L.

It was found that dissolved oxygen levels during the first sampling event ranged between 10.18 and 12.11mg/L (table 9). During the second sampling event dissolved oxygen ranged from 11.43 to 12.47mg/L. The higher dissolved oxygen levels observed in the second sampling event are likely due to increase flow rate and thus increased atmospheric interaction. Site 2, the lake outflow site had the lowest dissolved oxygen levels throughout the sampling events, this is expected due to its proximity to a stagnant body of water.

The BC Ministry of Environment (1998) has a minimum guideline for dissolved oxygen in respect to long term and on an acute, instantaneous minimum for 2 different life stages of aquatic life (fish). The long term minimum guideline for all life stages other than buried embryo / alevin is 8mg/L and for this life stage the instantaneous minimum guideline is 5 mg/L. The other life stage in the guideline, buried embryo/ alevin require long term minimum of 11 mg/l and for this life stage the instantaneous minimum guideline is 9mg/l. The only value that is violating these guidelines is site 2 during the first sampling event. Site 2 during the first sampling event is in accordance with all dissolved oxygen minimum requirements except for in the case of the long-term average for buried embryo/ alevin life stage.

| **Table 9:** Dissolved $O_2$ rating for the first and second sampling events on Cottle Creek | | |
|---|---|---|
| **Site** | **First Sample Event, October 30, 2017** | **Second Sample Event, November 20, 2017** |
| CCS1 | 11.56 mg/L | 12.47 mg/L |
| CCS2 | 10.48 mg/L | 11.43 mg/L |
| CCS3 | N/A | 12.14 mg/L |
| CCS4 | 12.11 mg/L | 12.7 Mg/L |

**Stream Macroinvertebrates:**

Invertebrates were used because they are effective indicators of stream health, and can show long-term conditions of a stream. If invertebrates can be found in a stream, they are useful because they do not move far like fish, and they are sensitive to changes in pollution levels. There are three levels of invertebrates that can be found in a stream to indicate stream health: the pollution intolerant, like mayflies, the somewhat pollutant tolerant, like freshwater shrimp, and the pollution tolerant, like leeches. As a stream becomes increasingly polluted, the pollutants clog the gills of the sensitive invertebrates and they die off, leaving the more robust invertebrates, like worms. This section will review results for site one, two, and four for the first sample event. The section will detail the following: the density, diversity, and site rating.

**CCS1 (Nathan Hambrook):**

| **Table 10:** Site one (CCS1) assessment rating on the first sampling event with invertebrate samples via Hess sampler with triplicate samples. | |
|---|---|
| **Assessment** | **Rating** |
| Invertebrate Density Per Sample Area | $107.4/m^2$ |
| EPT Index | 2 |
| Average rating of site | 2.5 (marginal) |
| Diversity Index | 0.2 |

Table ten shows the invertebrate sampling site assessment ratings based on the types of invertebrates found. The average density of invertebrates at site one are $107.4/m^2$. Species diversity is measured between 0.0 and 1. The species diversity is 0.2, which means that there are is not a great amount of diversity of invertebrates at this site, it is quite simple. The EPT index is two, which means that there is only a marginal number of invertebrates that are pollution sensitive. The overall site rating is marginal at 2.5. The marginal site rating means that there are higher amounts of invertebrates that belong to more pollutant tolerant categories, and indicates that the stream health in site one is not terrible, but it is not healthy enough to support a high number of sensitive taxa. This could indicate that there are certain pollutants that build up over time in the stream that does not make it very suitable habitat.

**CCS2 (Nathan Hambrook)**

| **Table 11:** Site Two (CCS2) assessment rating on the first sampling event with invertebrate samples via Hess sampler with triplicate samples. | |
|---|---|
| **Assessment** | **Rating** |
| Invertebrate Density per Sample Area | 112.53/$m^2$ |
| Diversity Index | 0.14 |
| EPT Index | 1 |
| Average rating of site | 1.25 (poor) |

Table eleven shows the invertebrate sampling site assessment ratings of site two on Cottle Creek. The invertebrate density for the area that we sampled at this site are 112.53/$m^2$. Comparatively, the diversity index is quite low. This section of stream does not have a very diverse number of organisms. The EPT index has lowered from the first site, of marginal, down to one, which is poor for the number pollution sensitive organisms that should be present. The average site rating is 1.25, which is representative of a poor assessment rating. With the low diversity of invertebrates, the low amount of EPT taxa, and the poor assessment rating, this site shows poor stream health and is unable to support abundant taxa. This is most likely due to some build-up of pollutant in the system, or something is present that makes this unsuitable habitat.

**CCS4 (Nathan Hambrook):**

| **Table 12:** Site Four (CCS4) assessment rating on the first sampling event with invertebrate samples via Hess sampler with triplicate samples. | |
|---|---|
| **Assessment** | **Rating** |
| Invertebrate Density per Sample Area | 229/$m^2$ |
| Diversity Index | 0.16 |
| EPT Index | 2 |
| Average rating of site | 1.5 (poor) |

Table twelve shows the invertebrate assessment rating for site four on Cottle Creek. This site had the highest density at 229 organisms per square meter. Even with the highest density, like the other sites, the diversity is low at .16. The EPT index is also low at 2. These with the poor site rating of 1.5, makes this site another site that demonstrates poor health, because the lack of pollution sensitive invertebrates in the system. A probable reason for the poor system health would be linked to some pollutant that may build up over time and renders it as an inhospitable environment to thrive in.

**ALS Lab Results (MB):**

The results from the ALS laboratory provided a valuable quality assurance in our results from the VIU laboratory, all results were within reasonable scientific similarity.

Results from both sampling events reflected similar values to that of the VIU laboratory analysis. The majority of parameters tested during both sampling events were below the lowest detection limit or LDL (tables 13& 14). Detectable values are bolded in both tables and values exceeding guidelines for aquatic life set out by the BC Ministry of Environment (1998) are in red as well as bold.

The analysis completed by the ALS Laboratory resulted in one breach in the BC MoE (1998) guidelines. Site 2 (Cottle lake outflow) exceeded the guideline for iron (table 13). An iron content of 1.19mg/L was observed, the guideline maximum is 1 mg/L. Possible natural sources for this iron level are weathered rocks and soil around watershed, deposition from air (rain, dust, gravity) (Xing & Liu 2011). Anthropogenic sources include storm water discharge, waste. A natural iron cycle exists, and it is possible that a high point in this cycle was occurring during this sampling event and low flow rate culminated with high natural iron level to breach the parameter. Iron levels during the second sampling event were well below guideline maximums at all sites (table 14).

Levels of all other detectable water quality parameters are below the guideline limits and are benign to aquatic life.

Table 13: ALS Laboratory Results from Sampling Event 1. Results exceeding LDL are bolded. Results exceeding guidelines for aquatic life are in red

| **Physical Tests (Water)** | **Lowest Detection Limit** | **Untits** | **Cottle Cr. S1** | **Cottle Cr. S2** | **Cottle Cr. S4** |
|---|---|---|---|---|---|
| Conductivity | 2.0 | uS/cm | **189** | **194** | **206** |
| Hardness (as CaCO3) | 0.50 | mg/L | **70.2** | **70.7** | **72** |
| pH | 0.10 | pH | **7.83** | **7.77** | **7.90** |
| **Anions and Nutrients (Water)** | | | | | |
| Ammonia, Total (as N) | 0.0050 | mg/L | **0.0085** | **0.0137** | <0.0050 |
| Nitrate (as N) | 0.0050 | mg/L | **0.0588** | <0.0050 | **0.862** |
| Nitrite (as N) | 0.0010 | mg/L | **0.0011** | <0.0010 | **0.0017** |
| Total Nitrogen | 0.030 | mg/L | **0.408** | **0.402** | **1.07** |
| Orthophosphate-Dissolved (as P) | 0.0010 | mg/L | **0.0035** | **0.0028** | **0.0015** |
| Phosphorus (P)-Total | 0.0020 | mg/L | **0.0094** | **0.0106** | **0.0049** |
| N:P | N/A | N/A | **43.4** | **37.9** | **218.4** |
| **Total Metals (Water)** | | | | | |
| Aluminum (Al)-Total | 0.20 | mg/L | <0.20 | <0.20 | <0.20 |
| Antimony (Sb)-Total | 0.20 | mg/L | <0.20 | <0.20 | <0.20 |

| | | | | | |
|---|---|---|---|---|---|
| Arsenic (As)-Total | 0.20 | mg/L | <0.20 | <0.20 | <0.20 |
| Barium (Ba)-Total | 0.010 | mg/L | <0.010 | <0.010 | <0.010 |
| Beryllium (Be)-Total | 0.0050 | mg/L | <0.0050 | <0.0050 | <0.0050 |
| Bismuth (Bi)-Total | 0.20 | mg/L | <0.20 | <0.20 | <0.20 |
| Boron (B)-Total | 0.10 | mg/L | <0.10 | <0.10 | <0.10 |
| Cadmium (Cd)-Total | 0.010 | mg/L | <0.010 | <0.010 | <0.010 |
| Calcium (Ca)-Total | 0.050 | mg/L | **18.7** | **19.8** | **19.8** |
| Chromium (Cr)-Total | 0.010 | mg/L | <0.010 | <0.010 | <0.010 |
| Cobalt (Co)-Total | 0.010 | mg/L | <0.010 | <0.010 | <0.010 |
| Copper (Cu)-Total | 0.010 | mg/L | <0.010 | <0.010 | <0.010 |
| Iron (Fe)-Total | 0.030 | mg/L | **0.715** | **1.19** | **0.367** |
| Lead (Pb)-Total | 0.050 | mg/L | <0.050 | <0.050 | <0.050 |
| Lithium (Li)-Total | 0.010 | mg/L | <0.010 | <0.010 | <0.010 |
| Magnesium (Mg)-Total | 0.10 | mg/L | **5.67** | **5.15** | **5.46** |
| Manganese (Mn)-Total | 0.0050 | mg/L | **0.0276** | **0.0495** | **0.0245** |
| Molybdenum (Mo)-Total | 0.030 | mg/L | <0.030 | <0.030 | <0.030 |
| Nickel (Ni)-Total | 0.050 | mg/L | <0.050 | <0.050 | <0.050 |
| Phosphorus (P)-Total | 0.30 | mg/L | <0.30 | <0.30 | <0.30 |
| Potassium (K)-Total | 2.0 | mg/L | <2.0 | <2.0 | <2.0 |
| Selenium (Se)-Total | 0.20 | mg/L | <0.20 | <0.20 | <0.20 |

| | | | | | |
|---|---|---|---|---|---|
| Silicon (Si)-Total | 0.10 | mg/L | **6.76** | **4.81** | **5.72** |
| Silver (Ag)-Total | 0.010 | mg/L | <0.010 | <0.010 | <0.010 |
| Sodium (Na)-Total | 2.0 | mg/L | **12.6** | **12.6** | **14.2** |
| Strontium (Sr)-Total | 0.0050 | mg/L | **0.0786** | **0.0785** | **0.0753** |
| Thallium (Tl)-Total | 0.20 | mg/L | <0.20 | <0.20 | <0.20 |
| Tin (Sn)-Total | 0.030 | mg/L | <0.030 | <0.030 | <0.030 |
| Titanium (Ti)-Total | 0.010 | mg/L | <0.010 | <0.010 | <0.010 |
| Vanadium (V)-Total | 0.030 | mg/L | <0.030 | <0.030 | <0.030 |
| Zinc (Zn)-Total | 0.0050 | mg/L | <0.0050 | <0.0050 | <0.0050 |

Table 14: ALS Laboratory Results from Sampling Event 2. Results exceeding LDL are bolded

| Physical Tests (Water) | Lowest Detection Limit | Units | Cottle Cr. S1 | Cottle Cr. S2 | Cottle Cr. S4 |
|---|---|---|---|---|---|
| Conductivity | 2.0 | uS/cm | **108** | **93.8** | **104** |
| Hardness (as CaCO3) | 0.50 | mg/L | **37** | **31.7** | **35.4** |
| pH | 0.10 | pH | **7.50** | **7.33** | **7.49** |
| **Anions and Nutrients (Water)** | | | | | |
| Ammonia, Total (as N) | 0.0050 | mg/L | **0.0085** | <0.0050 | **0.0070** |
| Nitrate (as N) | 0.0050 | mg/L | **0.851** | **0.773** | **0.932** |
| Nitrite (as N) | 0.0010 | mg/L | **0.0019** | **0.0020** | **0.0017** |
| Total Nitrogen | 0.030 | mg/L | **1.09** | 0.993 | **1.16** |
| Orthophosphate-Dissolved (as P) | 0.0010 | mg/L | **0.0018** | <0.0010 | <0.0010 |
| Phosphorus (P)-Total | 0.0020 | mg/L | **0.0110** | **0.0106** | **0.0075** |
| N:P | N/A | N/A | **99.1** | **93.7** | **154.7** |
| **Total Metals (Water)** | | | | | |
| Aluminum (Al)-Total | 0.20 | mg/L | <0.20 | <0.20 | 0.20 |
| Antimony (Sb)-Total | 0.20 | mg/L | <0.20 | <0.20 | <0.20 |
| Arsenic (As)-Total | 0.20 | mg/L | <0.20 | <0.20 | <0.20 |

| | | | | | |
|---|---|---|---|---|---|
| Barium (Ba)-Total | 0.010 | mg/L | <0.010 | <0.010 | <0.010 |
| Beryllium (Be)-Total | 0.0050 | mg/L | <0.0050 | <0.0050 | <0.0050 |
| Bismuth (Bi)-Total | 0.20 | mg/L | <0.20 | <0.20 | <0.20 |
| Boron (B)-Total | 0.10 | mg/L | <0.10 | <0.10 | <0.10 |
| Cadmium (Cd)-Total | 0.010 | mg/L | <0.010 | <0.010 | <0.010 |
| Calcium (Ca)-Total | 0.050 | mg/L | **10.2** | **8.61** | **9.69** |
| Chromium (Cr)-Total | 0.010 | mg/L | <0.010 | <0.010 | <0.010 |
| Cobalt (Co)-Total | 0.010 | mg/L | <0.010 | <0.010 | <0.010 |
| Copper (Cu)-Total | 0.010 | mg/L | <0.010 | <0.010 | <0.010 |
| Iron (Fe)-Total | 0.030 | mg/L | **0.450** | **0.313** | **0.363** |
| Lead (Pb)-Total | 0.050 | mg/L | <0.050 | <0.050 | <0.050 |
| Lithium (Li)-Total | 0.010 | mg/L | <0.010 | <0.010 | <0.010 |
| Magnesium (Mg)-Total | 0.10 | mg/L | **2.81** | **2.47** | **2.72** |
| Manganese (Mn)-Total | 0.0050 | mg/L | **0.0441** | **0.0102** | **0.0196** |
| Molybdenum (Mo)-Total | 0.030 | mg/L | <0.030 | <0.030 | <0.030 |
| Nickel (Ni)-Total | 0.050 | mg/L | <0.050 | <0.050 | <0.050 |
| Phosphorus (P)-Total | 0.30 | mg/L | <0.30 | <0.30 | <0.30 |
| Potassium (K)-Total | 2.0 | mg/L | <2.0 | <2.0 | <2.0 |
| Selenium (Se)-Total | 0.20 | mg/L | <0.20 | <0.20 | <0.20 |
| Silicon (Si)-Total | 0.10 | mg/L | **4.73** | **4.76** | **5.29** |

| | | | | | |
|---|---|---|---|---|---|
| Silver (Ag)-Total | 0.010 | mg/L | <0.010 | <0.010 | <0.010 |
| Sodium (Na)-Total | 2.0 | mg/L | **7.8** | **7.5** | **8.0** |
| Strontium (Sr)-Total | 0.0050 | mg/L | **0.0415** | **0.0356** | **0.0376** |
| Thallium (Tl)-Total | 0.20 | mg/L | <0.20 | <0.20 | <0.20 |
| Tin (Sn)-Total | 0.030 | mg/L | <0.030 | <0.030 | <0.030 |
| Titanium (Ti)-Total | 0.010 | mg/L | **0.013** | <0.010 | **0.014** |
| Vanadium (V)-Total | 0.030 | mg/L | <0.030 | <0.030 | <0.030 |
| Zinc (Zn)-Total | 0.0050 | mg/L | <0.0050 | <0.0050 | <0.0050 |

## Conclusion and Recommendations

### Conclusion (A.Zimich)

Cottle creek is a moderately healthy stream that demonstrates good water quality. The only exceeding guideline was iron for site 2 (first sampling event). Our aquatic invertebrate quality was lower than expected as we noticed many category 2 and 3 species in the more downstream sampling sites. We expect that the decline in both water quality and invertebrates is due to the fact that Cottle creek is in a highly urbanized area. Near site 3 and 4 (downstream) we noticed the encroachment of houses and properties on Cottle creeks riparian zones. Cottle creek is in a highly urban area and must be monitored to ensure water quality is maintained.

### Recommendations (A.Dignan)

It is highly recommended that annual monitoring projects be continued within Cottle Creek to ensure consistency of available record for water quality parameters. Cottle Creek helps sustain a wide variety of flora and fauna species within Nanaimo and is certainly a valuable asset to local ecosystems and overall biodiversity. Given that Cottle Creek is situated within an area of Nanaimo which is currently undergoing constant construction and development, it would prove beneficial to monitor any potential negative alterations to water quality. Furthermore, monitoring for a variety of anthropogenic stressors associated with highly urbanized areas such as this is necessary to support the continued health of Cottle Creek.

**References:**

Alaska Department of Environmental Conservation. 2013. Frequently Asked Questions: Turbidity in Surface Waters <https://dec.alaska.gov/water/wqsar/wqs/pdfs/Attachment_F_FAQ_Turbidity_in_Surface_Waters_110813.pdf> Acessed Dec.10 2017.

Barlak R. 2012. Regional District of Nanaimo Community Watershed Monitoring Network 2012 Data Summary [internet]. Nanaimo (BC): Ministry of Environment; [cited 2017 Oct 19]. Available from: http://www.rdn.bc.ca/cms/wpattachments/wpID2844atID5562.pdf

Bolland A, Krenz D, Peake B, Sinitsin C. 2013. Cottle Creek Environmental Monitoring Program Final Report. RMOT 306. Nanaimo (BC): Vancouver Island University. Available from: https://wordpress.viu.ca/rmot306/wq_reports/

British Columbia Ministry of Environment [Internet]. (1998). Guidelines for Interpreting Water Quality Data. Resources Inventory Committee. Available from: https://www.for.gov.bc.ca/hts/risc/pubs/aquatic/interp/index.htm

Cook B, Baldwin J. 1994. Chase to Nanoose Water Allocation Plan [Internet]. Nanaimo (BC): Ministry of Environment, Lands and Parks; [cited 2017 Oct 19]. Available from: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/water-planning/water_allocation_chase_nanoose.pdf

Donovan, E., Unice, K., Roberts, J. D., Harris, M., & Finley, B. (2008). Risk of gastrointestinal disease associated with exposure to pathogens in the water of the lower passaic river. Applied and Environmental Microbiology, 74(4), 994-1003.
Filtration Method. No. 10029. Revision 3.

Health Canada (2017). Guidelines for Canadian Drinking Water Quality—Summary Table. Water and Air Quality Bureau, Healthy Environments
and Consumer Safety Branch, Health Canada, Ottawa, Ontario.

Linley Valley [Internet]. 2017. Nanaimo (BC): Nanaimo Area and Land Trust; [cited 2017 Oct 19]. Available from: https://www.nalt.bc.ca/1_4_contact.html

Michaelis, B. (2005). Dissolved oxygen dynamics in a shallow stream system
Ministry of Water, Land, and Air Protection (MWLAP). (1998). Guidelines for interpreting water quality data. Retrieved from: https://www.for.gov.bc.ca/hts/risc/pubs/aquatic/interp/intrptoc.htm

Ministry of Water, Land, and Air Protection (MWLAP). (2003). Part E water and wastewater sampling: Ambient freshwater and effluent sampling. Retrieved from: https://www.for.gov.bc.ca/hts/risc/pubs/aquatic/ambient/part_e_water_and_waste water_sampling_ambient_freshwater_and_effluent_sampling_simulate_template. pdf

Murdoch, P. S., & Shanley, J. B. (2006). Flow-specific trends in river-water quality resulting from the effects of the clean air act in three mesoscale, forested river basins in the northeastern united states through 2002. Environmental Monitoring and Assessment, 120(1), 1-25.

U Mass Amherst. 2017. Analysis Method for pH and Alkalinity. <https://wrrc.umass.edu/research/projects/acid-rain-monitoring-project/analysis-method-ph-and-alkalinity> Acessed Dec.10 2017.

U.S. Environmental Protection Agency (USEPA). (2003). Total Coliforms and E.Coli Membrane

Xing, W., & Liu, G. (2011). Iron biogeochemistry and its environmental impacts in freshwater lakes. Fresenius Environmental Bulletin, 20(6), 1339-1345.