Environmental Monitoring of Richards Creek, Crofton, BC Based on Water Quality and Stream Invertebrate Sampling

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EXECUTIVE SUMMARY

The 2020 environmental monitoring program conducted at Richards Creek was part of a long-term study by students at Vancouver Island University (VIU) in the Bachelor of Natural Resource Protection (BNRP) program. Richards Creek is situated in North Cowichan, Vancouver Island and is part of the Somenos water basin. The creek, which originates at Crofton

Lake, winds through both residential and agricultural areas before ending in Somenos lake. The creek spans an approximate length of 9.2 kilometers. The project consisted of a proposal, data collection, and data analysis. The proposal was completed and received approval from Owen Hargrove, the project supervisor and VIU professor. To align with previous studies, data was collected from four pre-determined sites on two separate dates, one at low flow and one at high flow. Collected samples were subject to various quality control measures during collection, storage, preservation, transportation, and analysis. Various methods were applied to gather results for hydrology, water quality, and invertebrate communities. Microbiology was not included in the 2020 project as it was in past years. VIU data analysis included turbidity, alkalinity, hardness, nitrate, and phosphate. PH and conductivity were measured in the field. Samples were also shipped for professional analysis at Australian Laboratory Services (ALS) in Burnaby, BC to detect levels of several metals. Results from the 2020 project show that Richards Creek has poor water Quality. One station showed dissolved oxygen levels below the guidelines as well as excessive nutrient loading of phosphorus. Three metals, aluminum, calcium, and iron were present and over the guidelines in some of the sites. Invertebrates communities were sampled and indicated poor water quality. Without restoration and remediation efforts, Richards Creek will likely deteriorate further and continue to decrease in productivity.

1.0 INTRODUCTION AND BACKGROUND

1.1 Project Overview

The 2020 environmental monitoring project of Richards Creek, Crofton, BC, will be undertaken to assess the water quality and invertebrate populations of the stream.
The monitoring project will be run from October 27 - November 18, with a presentation of our findings on November 25. The project will be conducted by Christopher Penner, Torin Evans, and Jeremy Stacey, who are third year students in the Bachelor of Natural Resource Protection Program at Vancouver Island University. The project will be under the direction of Owen Hargrove.

Richards Creek runs for 10 kilometers south of Crofton starting at the Crofton Reservoir and ending at the Northeastern side of Somenos Lake in Duncan, BC (Lanarc Consultants Limited 1999). It has a width of 2 - 18 m and a gradient of <0.1 - 5.0%. The headwaters of Richards Creek begins at Mount Richards and Maple Mountain, with water draining from these sources through a basin into Somenos Lake (Lanarc Consultants Limited 1999). The main source of water flow for Richards Creek comes from the Crofton Reservoir (Lanarc Consultants Limited 1999). Richards Creek has multiple underground springs feeding into the creek which helps maintain a cool water temperature during hot summer months, and helps bolster low summer flows (Lanarc Consultants Limited 1999). The creek hosts a large amount of spawning Coho Salmon, with more than 700 in 1997. It also accommodates populations of cutthroat and rainbow trout (Lanarc Consultants Limited 1999). The waterway runs through agricultural farmland, so there are concerns about run-off and the removal of riparian zones affecting the fish habitat and water quality in the creek.

1.2 Historical Overview

Extensive agriculture activities in the lower portion of Richards Creek have transformed the area. In its natural state, Richards creek is dominated by red osier dogwood and willow shrub forested areas, but much of the natural riparian area has been cleared for agriculture and is purposely flooded for the vegetable and hay fields (Lanarc Consultants Limited 1999). There are sections of the lower creek where the stream can flood more than 600 meters wide. With much of the riparian habitat gone, these areas in the lower Richards Creek system are unable to support the rearing of local salmonid species due to the high temperatures of the water and low dissolved oxygen levels, according to a study put on by Lanarc Consultants Limited in 1999.

Habitat restoration was undertaken via the process of dredging the section above Richards Trail on the Van Eeuwen farm in 1983 and putting in farm fencing to restrain the cattle from foraging the riparian zone of the creek. Bank restoration was also conducted (Lanarc Consultants Limited 1999). Unfortunately, the owner did not maintain the cattle fencing. Part of Richards Creek has also been ditched, this section starts at Somenos Lake and goes upstream to a point 35 meters below Richards Trail (Lanarc Consultants Limited 1999). This section of steam has a very flat gradient and the minimal flow in this area does not allow enough dissolved oxygen in the water to support fish during the summer period (Lanarc Consultants Limited 1999). Water permits are also allowed from the creek and withdrawal of water below Richards Trail is used for crop watering. This has contributed to cease of flow and dry up of the stream (Lanarc Consultants Limited 1999).

1.3 Potential Environmental Concerns

Widespread agricultural use in the area is a cause of concern for the creek. Agriculture use has caused a multitude of problems, mainly: loss of riparian areas through cattle feeding and flooding fields. Ditching the creek, causing reduced flow in turn causing high water temperatures and reduced dissolved oxygen levels, all of which are bad for the local salmonid species. Removal of water from the creek for crop and cattle watering, causing low levels and no water in some areas. Runoff from agriculture fields in the area, contributing to pollution and eutrophication of the creek. Pollution from urban sources are also a cause of concern. Although not a densely populated area, trash can be found near bridges and roadways, polluting the stream. Lastly, there are some concerns about point source pollution from storm drain runoff in the creek, namely around site 3.

1.4 Project Objectives

The objective of the stream assessment of Richards Creek is to contribute to the years of data collected by former VIU students to help build a long-term stream assessment of Richards Creek. Water quality, basic hydrology, and stream invertebrate assessments will be conducted so the overall health of the stream can be assessed. These tests will be conducted at our four chosen sites within the stream. Laboratory analysis by ALS will also be used to garner a better insight into the chemical composition of the stream. This report, as well as past reports will be of interest to the District of North Cowichan, the Department of Fisheries and Oceans, agriculture landowners in the area, and anyone who cares about the health of our local streams in B.C.

2.0 METHODS

2.1 Sampling Stations

2.1.1 Locations and Site Descriptions

As the project objective is to continue the long-term environmental monitoring project at Richards Creek, sampling sites 1-4 were predetermined by past studies. The location for each site were provided with UTM coordinates as well written descriptions, photos, map references and field sketches. Figure 1 shows an approximate location for sampling locations 1-4

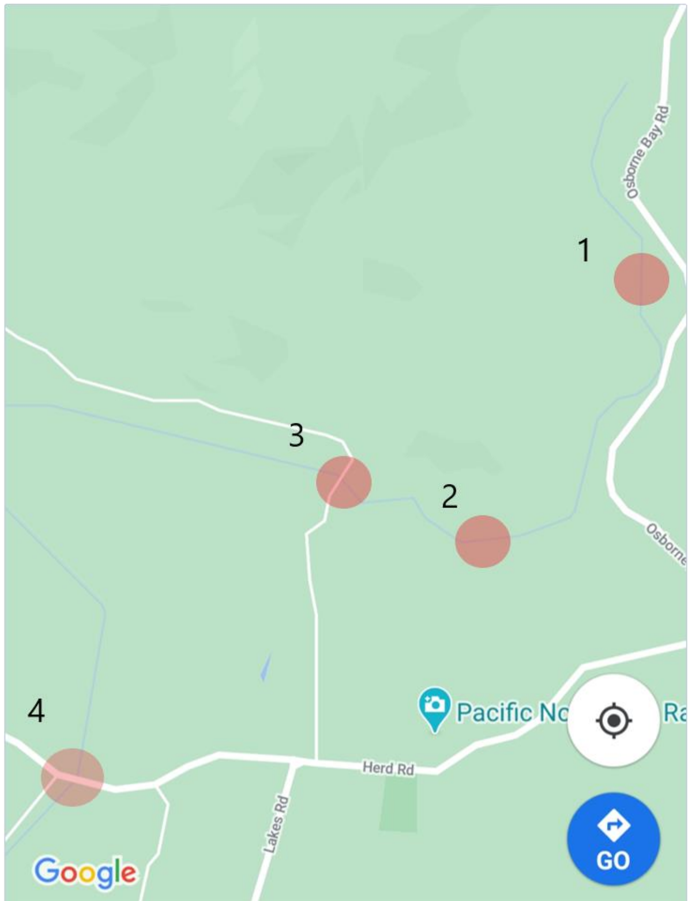

Figure 1: Approximate Sampling locations 1-4 on Richards creek. Site 1 is furthest upstream and site 4 is furthest downstream (photo modified from google maps).

In addition, safety and ease of access governed our site choice on a micro level. Considering that we would be required to transport bulky equipment, it was not practical to choose an area that required us to travel on technical terrain. Additionally, we wanted areas where we could avoid disturbing the natural habitat or private property. Unfortunately, like in the previous years' studies, we were required to use someone’s private driveway in order to reach a suitable sample location. The property owner was contacted over the phone and granted permission to access the stream via their driveway. All our sites are located close to houses or a main road, so in the event of an emergency would be easy for a first responder to find and reach us. An initial site visit was conducted on 14-10-2020 to confirm each site and address safety concerns. Field notes, sketches, and map references can be found in the appendix (tab A and B) of this report.

Sites 1 is located alongside Escarpment Way, North Cowichan (UTM 10 452478.75E 5409477.68N, see appendix tab B). This site is a small segment of Richards Creek that flows between two farms and through a culvert under the road. The substrate of this site is made up 80% by small rocks with the remaining 20% divided between silt and fragments of wood and other organic material. The streams surrounding vegetation consist mainly of cedar trees, salmon berry bushes and sword ferns. In-stream cover is around 50%. Our entrance point is at the mouth of the culvert that runs under the road, which opens into a pool. Further upstream is a slow ripple (see appendix tab C for photos of the site).

Site 2 is located just beyond the north end of Rice Road, North Cowichan (UTM 452060.77 E 5408585.36 N, see appendix tab B). It sits between two properties, a farm to the north and a driveway to the south. The site requires us to walk about 30 meters through some light bush to access it. The vegetation in the surrounding area on the southern bank consists of alders, sword ferns, and several bamboo stalks. The stream itself is dominated by alders, cedar, ferns and some tall grasses. The canopy cover is around 80% with mature trees providing shade for most of the day. The substrate composition was 70% large gravel and small rocks with 30% sediment. Our entire site is made up of a single, gentle but steadily flowing ripple. A glide in present at the end of our sampling site. (see appendix tab C for photos of the site).

Site 3 is located off the road of Richards Trail, North Cowichan (UTM 10 451322.93E 5408806.28N, see appendix tab B). Being bordered on both sides by farmland, site 3 is enclosed, 5 with roughly 20% canopy cover. The canopy is made mainly alder trees while the banks are mostly moss and grasses with the occasional salmon berry bush. Site 3's substrate is dominated by small rocks which make up 80% of the stream bed, followed by 15% cobblestone and large woody debris and the final 5% is fine sediment and gravel. Our entrance to the stream at this site is a shallow pool with a gentle but steady ripple. Downstream is a culvert where the water passes under Richards Trail road (see appendix tab C for photos of the site).

Site 4 is located under a bridge on Herd Road, North Cowichan UTM 10 450291.79 E 5407631.55. This site is much different than the previous three, with almost no visibly detectable flow, initial water depth tests with a walking stick indicate a sheer drop off at least five feet. The substrate is unidentifiable aside from mud and reeds. The surrounding vegetation is mostly reeds and different kinds of grasses and bushes. There is a complete absence of canopy cover and limited in stream cover. The surface of the water is covered in a thick layer of duckweed. On the west side of the bank there is a road leading to residential development and on the eastern side of the bank there is forest and bush for several hundred meters before the first residential neighborhood. There is virtually no detectable flow to the surface of the water (see appendix tab C for photos of the site).

2.1.2 Habitat Characteristics

The habitat characteristics for sites one through four are summarized below on table 1. On each site visit photographs were taken (see appendix tab C) and on the initial site visit field notes were taken to ensure accurate recall of the characteristics of each site (see appendix tab A).

Table 1: Summarized Habitat Characteristics for Richards Creek, Crofton, BC

	Site 1	**Site 2**	**Site 3**	**Site 4**
Water Character	Rifle/Glide	Rifle/Glide	Rifle/Glide	Pool
Canopy Cover (+/-10%)	~50	~85	~20	0
Dominant Instream Cover	Terrestrial vegetation	LWD	Boulders	Aquatic Vegetation
Substrate Type	Fines, gravel	Pebbles, gravel, cobble	Pebbles, gravel, cobble, boulders	N/A
Dominant Flora Types	Grasses, Red Alder	Ferns, Salal, Red Alder, Big Leaf Maple, moss	Red Alder, Western Red Cedar, grasses	Grasses, cattail, duckweed, shrubs

2.1.3 Sampling Frequency

Sampling frequency was based on suspected low flow and high flow conditions and to align with past studies. The first sampling event was on 27-10-2020 with VIU laboratory analysis on 28-10-2020. The second sampling event took place on 17-11-2020 with VIU laboratory analysis on 18-11-2020. See table 2 below for a summary of the sampling frequency.

Table 2: Summary of Sampling Frequency for Richards Creek, Crofton, BC

Site #	**Sampling Event 1** **27-10-2020 (Field Collection)** **28-10-2020 (Lab Analysis)**	**Sampling Event 2** **17-11-2020 (Field Collection)** **18-11-2020 (Lab Analysis)**
1	• VIU laboratory Samples • 1 Invertebrate Sample • Hydrology	• VIU laboratory Samples • Triplicate Invertebrate Sample • Hydrology
2	• VIU laboratory Samples • ALS laboratory Samples • 1 Invertebrate Sample • Hydrology	• VIU laboratory Samples • ALS laboratory Samples • Triplicate Invertebrate Sample • Hydrology
3	• VIU laboratory Samples • ALS laboratory Samples • 1 Invertebrate Sample • Hydrology	• VIU laboratory Samples • ALS laboratory Samples • Triplicate Invertebrate Sample • Hydrology
4	• VIU laboratory Samples • ALS laboratory Samples	• VIU laboratory Samples • ALS laboratory Samples

2.2 Basic Hydrology

For sites one through four, basic hydrology was collected on both sampling events. To calculate flow, the stream width and the average depth was measured. We then conducted a flow tests using the ping pong method. A measuring tape and stopwatch were used to time the ping pong ball traveling 5m. These tests were conducted twice, once in October and again in November. This data was used to calculate discharge and change in flow.

2.3 Water Quality

2.3.1 Field Measurements

Field measurements were taken at each site during both sampling events. These included water temperature and dissolved oxygen which were measured to the nearest 0. 1° C and

0.1mg/L, respectively. To measure these, an electronic probe (from VIU) was rinsed with first distilled water and then with water from the creek before being held in the creek (as close to the centre and we could get) until the readings stabilized (approximately 30 seconds).

2.3.2 Water Sample Collection

The samples for conducting the water quality tests were taken using proper procedure as outlined below. First off proper PPE was utilized as to not contaminate the sample. In addition, sterilized containers issued by VIU were used. To collect the actual sample, the team rinsed each bottle and lid three times before approaching the sampling location from a downstream direction. The container was then placed in the water column as close to the center (horizontal and vertical) as possible. Special care was taken to not disturb any sediment. Each sample was then labelled appropriately and placed in the cooler. The water samples were stored in the cooler with ice to preserve the integrity until our return to the school where they were placed in a refrigerator at 4°C. Water samples were analysed within 24hrs of collection at the VIU laboratory. Refer to table two for the sampling frequency.

2.3.3 VIU Laboratory Analysis

The specific parameters that we will be testing in the VIU lab are: conductivity (μs/cm), pH, turbidity, alkalinity (mg/L CACO3), hardness (mg/L CACO3), nitrate and phosphate (mg/L PO4 3). Each of these tests will be conducted twice over the course of the project, once in October and again in November. The water quality parameters we tested for, as well as the equipment used, are summarized below in table 3.

Table 3: Water quality Parameters Measured, Including Units and Equipment used, for Samples Analysed in the VIU Laboratory

Parameter	Unit	Equipment
Conductivity	µS/cm	Pinpoint Conductivity Meter
pH	N/A	Oakton pHTestr 10 pH
Turbidity	mg/L	HACH 2100 Potable Turbidimeter
Alkalinity (as $CaCO_3$)	mg/L	HACH AL-DT digital titration method
Hardness (as $CaCO_3$)	mg/L	HACH HA-4P test kit
Nitrate	mg/L	HACH DR2800 Spectrophotometer Method 8192
Phosphate	mg/L	HACH DR2800 Spectrophotometer Method 8048

Each parameter included in table 3 was analysed using the detailed instructions supplied in the VIU laboratory. Each of the methods were approved and have been tested by years of past students for accuracy. For access to the instructions, contact the RMAP department at VIU.

2.3.4 ALS Laboratory Analysis

Water samples were collected and sent to Australian Laboratory Services (ALS) in Burnaby, BC. To collect the ALS samples, we followed the same procedure as described in section 2.3.2 of this report. In addition, we added nitric acid and sulphuric acid to the bottles, respectively, which act as metal preservatives. The bottles were labeled and placed in the cooler with the VIU samples. Samples from sites two through four for both sampling events were sent to the ALS laboratory for analyses.

2.3.5 Quality Assurance / Quality Control

Quality assurance and control was one of the top priorities during this environmental project. To ensure the integrity of our samples throughout the collection, transport, storage, and analyses of our samples, several checks were built into the study. These include proper use of

PPE, cleaning and rinsing equipment, proper storage and transport of the water samples and taking replicate samples. Refer to section 2.3.2 for more details about the collection and preservation methods. In addition, the ALS laboratory and VIU laboratory analyses had overlap so comparison between results is possible. Trip blanks were not taken during this study due to human error.

2.4 Stream Invertebrate Communities

2.4.1 Invertebrate Sample Collection

Sites one through three were sampled with a Hess sampler during both events. On the October event, one sample was taken at each site and on the November event triplicate samples were taken. Each sample was collected upstream from the last. Once the samples were taken they were filled with ethanol until the ethanol represented 70% and the sample material. The collection jars were then labeled and placed in the cooler alongside the water quality measurements.

2.4.2 VIU Laboratory Analyses

Invertebrates sampled were analysed on 28-10-2020 and 18-11-2020 at the VIU laboratory within 24 hours of collection. Each sample was emptied into a tray with water and examined to remove all invertebrates and organisms present. A magnifying glass and microscope were used. The organisms were then sorted and placed under a microscope to determine the Family and Order (order not always possible) they belong to. This was recorded on a data sheet.

2.4.3 Quality Assurance / Quality Control

During the collection process, each student took a sample to ensure human error did not influence data trends. Samples were also collected in precleaned and labeled bottles with the data, location, sample number and collector. Triplicate samples were taken in November to ensure quality control. Ethanol was added to the invertebrate samples in the field to kill them and make sure there was no predatory action occurring. During the laboratory analyses, student identification was peer checked and confirmed by Mike from VIU or Owen Hargrove, the project supervisor and professor. In addition, before samples were discarded, they were also peer checked to limit invertebrates from being accidentally discarded.

2.4.4 Data Analysis

Data analysis was conducted to interpret the information we gathered and gain a better understanding of the overall steam health. Once all the invertebrates were identified and recorded on the data sheets, we were able to calculate the pollution tolerance index, stream diversity, predominant taxon ratio, predominant taxon, EPT index and overall site assessment rating. In addition, a ShannonWeiner Diversity Index was calculated for each site.

3.0 RESULTS AND DISCUSSION

3.1 General Field Conditions

3.1.1 Hydrology

During site visit one and two, discharge measurements were collected from sites one through three. Sampling event one had low water levels, while sample event two had high water levels (see table 4). This greatly increased the discharge from 0.066 m^3/s to 0.949 m^3/s in site one, 0.072m^3/s to 2.422 m^3/s at site two and 0.315 m^3/s to 2.455 m^3/s at site two (see table 4). This constitutes an average 1860% discharge increase. This extreme rise in water levels is likely due to heavy rain in the week proceeding our second sampling day. Adjustments to the dam valve to Richards Creek at Somenos Lake may have also increased water levels, although this is unknown.

Table 4: Results for Hydrology at Richards Creek, North Cowichan.

Station	Width (m)	Depth (m)	Flow (5m/s)	Discharge (m^3/s)
Sampling Event 1 – October 20, 2020				
1	2.0	0.31	47	0.066
2	3.7	0.07	18	0.072
3	4.2	0.30	20	0.315
4	7	>3m	N/A	N/A
Sampling event 2 – November 17, 2020				
1	3.1	0.60	9.8	0.949
2	5.6	0.32	3.7	2.422
3	3.0	0.63	3.85	2.455
4	10	>3m	N/A	N/A

3.2 Water Quality

3.2.1 Field Measurements

During sampling events one and two, field measurements were taken at sites one through four. These results include temperature and dissolved oxygen and are summarized below. For hydrology, which was also completed in the field, see section 3.1.1, table 4.

Table 5: Results for Temperature (°C) and Dissolved Oxygen (mg/L) at Richards Creek, North Cowichan.

Station	Water Temperature (°C)	Dissolved Oxygen (mg/L)
Sampling Event 1 – October 20, 2020		
1	11.5	11.40
2	11.3	11.75
3	11.3	11.76
4	11.6	4.90
Sampling event 2 – November 17, 2020		
1	8.7	11.34
2	8.6	11.83
3	8.6	11.48
4	6.9	6.15

3.2.1i Water Temperature

The water temperature was measured and recorded at sites one through four on both the October and November sampling events. It was observed that on sampling event one the water temperatures did not show a pattern of change and were likely influenced by microclimates at each site (see table 5). Site four recorded the highest temperature likely due to low water level which limited flushing and a pool with no canopy cover which allows the water to warm. On sampling event two we observed the temperature decreased from sites one through four. It is not clear what produced this trend or why it was absent from sampling event one.

Overall, the average temperature during sampling event one was 11.4 °C while the average temperature during sampling event two was 8.2 °C (see table 5). This is a decrease of 3.2 °C. The station with the greatest temperature change between sampling events was site four which decreased by 4.7 °C. Factors effecting temperature, such as air temperature, flushing patterns, rain fall, canopy cover, etc. are numerous, but the source remains undetermined

The 2020 results for the October and November sampling events showed that the water temperature may be increasing from past years. When compared to the summary report by Demers (2016), which compiled all data from 2008 through 2015, our temperature results demonstrated higher than average trends. The 2020 results for the October sampling had an average temperature one degrees higher than the average of 10.4 recorded in the summary report. These higher temperatures were also recorded by Danielson et al. (2019) in the November sampling event. Climate change and changes to the riparian area are potential sources to this possible trend. These higher temperatures are still within the BC Approved Water Quality Guidelines however, the implications of climate change could see increases beyond the optimum temperature ranges for salmonids and other cold-water fishes. Future years of data collection are needed to show if this trend continues.

3.2.1ii Dissolved Oxygen

Dissolved oxygen (DO) levels were consistent in sampling sites one through three in both the October and November dates (see table 5). The fluctuation was recorded to be only 0.5 mg/L between the three stations. According to the BC Approved Water Quality Guidelines these results are high enough to support healthy fish population.

Site four recorded levels considerably lower compared to sites one through three. The DO was recorded to be 4.9 mg/L in October and 6.16 mg/L in November which represents a decrease of 6.5 and 5.68 mg/L, respectively. Multiple tests were completed at site four to ensure the probe was not malfunctioning and results showed high confidence.

According to the BC Approved Water Quality Guidelines, the results for site four have the potential to cause hypoxia in fish species and is ultimately too low to support healthy fish populations This is consistent with the summary report by Demers (2016) and Danielson et al. (2019) who also identified the same trend. Demers (2019) attributes the lower DO levels at site four to increased ecosystem respiration in combination with stagnant conditions.

3.3 VIU Laboratory Analyses

3.3.1 Conductivity

Table 6: Conductivity Measurements for Richards Creek (μS/cm)

Sampling Day	Site 1	Site 2	Site 3	Site 4
Oct. 20	95	120	129	243
Nov. 17	86	92	95	122

Conductivity was measured at the laboratory after sampling had taken place and the samples had been in storage. The overall conductivity of the sites saw a dramatic decrease between sampling dates, however the pattern from site to site remained intact. Site 1, which was the furthest upstream and the least influenced by runoff, showed the lowest conductivity measurements. Sites 2 and 3 demonstrated the smallest gap between any two sites, possibly due to healthier riparian areas filtering out runoff between these two sites, and/or the distance from farms and roads this segment of the waterway. Site 4 sees a sharp rise in conductivity which is likely due to it being located next to a main road and surrounded by agricultural and residential development, receiving runoff directly into the water with minimal buffering.

Conductivity in a stream is a measurement of the ions in the water, the more ions present the higher the conductivity (Cavanagh et al. 1998). Introduced ions generally come from dissolving metals introduced through human development, in the case of Richards Creek, mostly from roads and municipal runoff.

3.3.2 pH

Table 7: PH Measurements for Richards Creek, Sites 1-4

Sampling Day	Site 1	Ste 2	Site 3	Site 4
Oct. 20	8.2	8.1	7.5	7.1
Nov.17	7.6	6.7	6.6	6.6

The PH of the sites showed a definitive difference in the averages between the two sampling dates. Both sampling days showed a visible pattern in the PH change downstream as effluents accumulate in the waters. Our most upstream site had the highest pH value of the four sites sampled on both days. The pH for both sample days decreased as the sites went downstream a full unit, which indicates an 10 times increase in acidity (Cavanagh et al. 1998). The cause of this change is likely attributed to the high concentration of farming in the area, as well as runoff from the roadways.

It is notable that the second sample set of Nov. 17 showed a lower average pH which might be attributed to a dramatic increase in rainfall, flushing more than the usual level of effluents from farms and roads into the streams. Increased effluents combined with poor riparian areas to filter these pollutants forces an increase in the acidity levels of the water. The lowest pH in the stream was at site 4 on Nov. 17 and almost reached lethal levels for aquatic life, the threshold being 6.5 PH.

3.3.3 Turbidity

Table 8: Turbidity Measurements for Richards Creek Nephelometric Turbidity Units (NTU)

Sample Day	Site 1	Site 2	Site 3	Site 4
Oct. 20	2.2	1.77	3.02	5.6

Nov. 17	10.7	10.2	16.7	16.7

The turbidity of Richards creek demonstrates the effectiveness of healthy riparian areas in maintaining a sites water clarity. A healthy riparian zone is very effective at filtering sediment out water before the water flows into the stream. Maintenance of clear water in streams is paramount for aquatic life as high turbidity levels clog the gills of fish and makes any extraneous activity much harder to recover from. More sediment in a water system also blocks sunlight from reaching submerged plant life leaving them unable to photosynthesize. Across both sampling days, a pattern of increasing turbidity is seen as the sites progress downstream. This is a natural occurrence as the flow of water carries sediment downstream and collects at lower regions of a system. In the case of Richards Creek, the sediment levels found in October were within the healthy range, save for site 4 which was beginning to exceed the 5 NTU level limit that aquatic life (Cavanagh 1998). The sampling event in November, however, demonstrated the effects of insufficient riparian zones. While both sampling events showed a decrease in turbidity at site 2 (the site with the healthiest riparian zone) November saw a greater amount of rainfall which flushed sediment into the stream, With limited vegetation and root systems to filter out the excess dirt, it all flowed into the stream causing a sharp spike in turbidity across all four sites.

3.3.4 Alkalinity

Table 9: Alkalinity Measurements for Richards Creek (mg/L)

Sample Day	Site 1	Site 2	Site 3	Site 4
Oct. 20	60.4	49.6	43.2	70
Nov. 17	18	28.4	25.6	24.4

Alkalinity is a measure of a water systems ability to naturally counteract changes to the pH. Alkalinity levels are the healthiest when they are in moderation. A system whose levels are too high (>20 mg/L) are unhealthy because this usually indicates an overly high level of hardness and an unusually large concentration of sodium salts. On the other hand, systems with low alkalinity (0-10 mg/L) are not able to properly insulate the system against pH changes. The ideal concentration for alkalinity is 10-20 mg/L (Cavanagh et al 1998).

Major contributions to the demise of a site's alkalinity levels are runoff from a variety of sources. Once again, the quality of riparian zones come in to play. As the riparian zones surrounding Richards Creek are small and unhealthy, the systems ability to protect against foreign substances is limited. The samples from October indicate that Richards Creek is susceptible to local pressures. The November sampling event demonstrates much healthier alkalinity levels across the site, in part due to flushing and dilution from increased rainfall.

3.3.5 Hardness

Table 10: Hardness Measurements for Richards Creek (mg/L)

Sample Day	Site 1	Site 2	Site 3	Site 4
Oct. 20	43	60	56	260
Nov. 17	33	43	56	76

Hardness is influenced by the concentration of metallic ions in a water system. While there are multiple metallic ions that contribute to the hardness of water, calcium and magnesium at the primary influencers (Cavanagh et al. 1998). Water hardness (CaCO3) is usually a measurement for suitability of drinking water; however it also has environmental implications. Harder water reduces the toxic effects of some metals, preventing the acidic properties from bleeding out and effecting the system. Water that is too hard, anything exceeding 120mg/L, is usually considered unfit for humans. On the other hand, water systems with a hardness value under 60mg/L are generally considered to be too soft and will start to corrode metals, increasing pollution in streams. All of the sites located on Richards Creek were found to be within the allowable limit to drink (80mg/L-100mg/L), save for site 4 which exceeds the preferred limit of 200mg/L, but not the extreme undrinkable limit of 500mg/L (Cavanagh et al. 1998).

3.3.6 Nitrate

Table 11: Nitrate Measurements for Richards Creek (mg/L)

Sample Day	Site 1	Site 2	Site 3	Site 4
Oct. 20	1.10	0.27	0.38	0.02
Nov. 17	1.74	1.64	0.54	0.4

A proper nitrate level in a water system is critical for the growth and development of aquatic plants. An over abundance of nitrate, however, can prove just as problematic. An excess of nitrate causes algae blooms, disrupting the natural systems of the water bodies by consuming all the nutrients and oversaturating the system, wiping out everything else in the area and creating a monoculture. Aquatic life requires an average of 40 mg/L, as per Ministry of Environment & Climate Change Strategy (2019) guidelines. None of our sites met this, indicating very low nitrate levels.

3.3.7 Phosphate

2.4.7 Phosphate

Table 12: Phosphate Measurements for Richards Creek (mg/L)

Sample Day	Site 1	Site 2	Site 3	Site 4
Oct. 20	1.10	0.27	0.38	0.02
Nov. 17	1.74	1.64	0.54	0.4

The most growth limiting nutrient in a system is phosphate. Due to the lower natural level of this nutrients, any extra introduced into the environment can be have a large impact. The majority of introduced phosphate into a water system comes from agricultural, urban and sewage run off. Again, a water system with a healthy riparian area is far less susceptible to such effluents thus, Richards creek's poor riparian zone results in phosphate levels far beyond the BC's water quality guideline (maximum of 0.025 mg/L, British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture 2019). As can be seen from our results, both sampling days featured phosphate levels that are considered eutrophic, however most notably in November those levels were far higher than seen in October, likely a result of increased rainfall flushing effluents from nearby farms and houses into the stream.

3.3.8 Redifeld Ratio

Using the data gathered on the nitrate and phosphate levels on each site and basing our comparisons off of the 16N:1P Redfield Ratio, it can be seen that most sites have a ratio far lower than the 16N:1P guideline, indicating that the creek is nitrogen limited. Given this, there is the possibility that increased algae growth will further degrade Richards Creek. This was also found by Danielson et al. (2019).

3.4 ALS Laboratory Total Metal Analysis

Water samples that were sent to ALS Laboratories underwent testing for various metals. Most of the detected metals fell short of ALS's equipment's ability to register or fell under the provincial guideline limit for aquatic life. There were, however, three metals that were detected and exceeded the limit on both sampling events. These included aluminium, calcium and iron (see table 13 and 15). These three metals were also over the guidelines in 2019 (Danielson et al.). The source of metal contamination in Richards Creek remains unknown.

The guideline for aluminum is listed as 0.1 mg/L. As can be seen in table 13, during sampling event one, sites three and four exceeded this guideline. During sampling event two, all the sites increased and were over the guideline. Site four reached levels (1.75 mg/L) which far exceed the guideline.

The guideline for calcium is listed at 8mg/L. Each sample site on both the October and November events exceeded this guideline. Sampling event one saw levels ranging from 14.2mg/L up to 29.6mg/L. Sampling event two saw levels of calcium decrease, ranging from 11.6 to 11.8mg/L, however, calcium still exceeded the guideline for aquatic life in November.

The guideline for iron is listed as 1mg/L. The only site to exceed this level was site four. During the October event, iron reached levels of 1.02mg/L and increased to 1.24mg/L during the November sampling event.

These levels are similar to what was recorded in 2019 by Danielson et al. The concentration increased as we progressed downstream. The highest concentration for all three metals was found in site four. This is likely due to stagnant conditions which allows an accumulation of toxins. The concentration of these metals (except for calcium) increased in sampling event two. It is probable that increased runoff was the driver in these increases.

Table 13: ALS Total Metals Analysis Data for Richards Creek Oct. 20 with aluminum, calcium and iron highlighted in yellow (modified from ALS Laboratory Analyses data posted to VIU Learn)

Analytical Results

Sub-Matrix: **Water**
(Matrix: **Water**)

				Client sample ID	Cottle Creek-Site 3	Richards Creek- Site 2	Richards Creek- Site 3	Richards Creek- Site 4
				Client sampling date / time	27-Oct-2020 12:40	27-Oct-2020 12:00	27-Oct-2020 12:00	27-Oct-2020 12:00
Analyte	*CAS Number*	*Method*	*LOR*	*Unit*	VA20B9454-006	VA20B9454-007	VA20B9454-008	VA20B9454-009
					Result	Result	Result	Result
Physical Tests								
conductivity	----	E100	2.0	µS/cm	186	132	143	264
hardness (as CaCO3), from total Ca/Mg	----	EC100A	0.60	mg/L	63.2	46.9	49.2	98.6
pH	----	E108	0.10	pH units	7.93	7.64	7.64	7.57
Anions and Nutrients								
ammonia, total (as N)	7664-41-7	E298	0.0050	mg/L	<0.0050	<0.0050	0.0087	0.0320
nitrate (as N)	14797-55-8	E235.NO3-L	0.0050	mg/L	0.360	0.540	0.530	<0.0050
nitrite (as N)	14797-65-0	E235.NO2-L	0.0010	mg/L	0.0011	0.0016	0.0012	<0.0010
nitrogen, total	7727-37-9	E366	0.030	mg/L	0.606	0.770	0.930	2.32
phosphate, ortho-, dissolved (as P)	14265-44-2	E378-U	0.0010	mg/L	0.0016	0.0015	0.0079	0.0452
phosphorus, total	7723-14-0	E372-U	0.0020	mg/L	0.0060	0.0110	0.0242	0.414
Total Metals								
aluminum, total	7429-90-5	E420	0.0030	mg/L	0.0200	0.0334	0.133	0.312
antimony, total	7440-36-0	E420	0.00010	mg/L	<0.00010	<0.00010	<0.00010	0.00013
arsenic, total	7440-38-2	E420	0.00010	mg/L	0.00022	0.00017	0.00022	0.00111
barium, total	7440-39-3	E420	0.00010	mg/L	0.00255	0.00937	0.0101	0.0273
beryllium, total	7440-41-7	E420	0.000020	mg/L	<0.000020	<0.000020	<0.000020	<0.000020
bismuth, total	7440-69-9	E420	0.000050	mg/L	<0.000050	<0.000050	<0.000050	<0.000050
boron, total	7440-42-8	E420	0.010	mg/L	0.104	0.015	0.014	0.091
cadmium, total	7440-43-9	E420	0.0000050	mg/L	<0.0000050	0.0000137	0.0000069	0.000113
calcium, total	7440-70-2	E420	0.050	mg/L	17.4	14.2	14.4	29.6
cesium, total	7440-46-2	E420	0.000010	mg/L	<0.000010	<0.000010	<0.000010	0.000020
chromium, total	7440-47-3	E420	0.00050	mg/L	<0.00050	<0.00050	<0.00050	0.00096
cobalt, total	7440-48-4	E420	0.00010	mg/L	<0.00010	<0.00010	0.00016	0.00183
copper, total	7440-50-8	E420	0.00050	mg/L	0.00088	0.00117	0.00161	0.00894
iron, total	7439-89-6	E420	0.010	mg/L	0.204	0.150	0.267	1.02
lead, total	7439-92-1	E420	0.000050	mg/L	<0.000050	<0.000050	<0.000050	0.000441
lithium, total	7439-93-2	E420	0.0010	mg/L	<0.0010	<0.0010	<0.0010	<0.0010
magnesium, total	7439-95-4	E420	0.0050	mg/L	4.83	2.78	3.24	6.00
manganese, total	7439-96-5	E420	0.00010	mg/L	0.0126	0.0153	0.0271	0.653
molybdenum, total	7439-98-7	E420	0.000050	mg/L	<0.000050	0.000074	0.000084	0.000336
nickel, total	7440-02-0	E420	0.00050	mg/L	<0.00050	<0.00050	0.00058	0.00231

Table 14: ALS Total Metals Analysis Data for Richards Creek Nov. 17 with aluminum, calcium and iron highlighted in yellow (modified from ALS Laboratory Analyses data posted to VIU Learn)

Sub-Matrix: **Water** (Matrix: **Water**)				Client sample ID	**Richards Creek - site 3**	**Richards Creek - site 4**	**Richards Creek - site 2**
				Client sampling date / time	17-Nov-2020 15:30	17-Nov-2020 16:00	17-Nov-2020 15:00
Analyte	*CAS Number*	*Method*	*LOR*	*Unit*	**VA20C1169-011**	**VA20C1169-012**	**VA20C1169-010**
					Result	Result	Result
Physical Tests							
conductivity	----	E100	2.0	μS/cm	116	139	107
hardness (as CaCO3), from total Ca/Mg	----	EC100A	0.60	mg/L	39.4	43.0	37.0
pH	----	E108	0.10	pH units	7.17	6.69	7.29
Anions and Nutrients							
ammonia, total (as N)	7664-41-7	E298	0.0050	mg/L	0.0633	0.0264	0.0307
nitrate (as N)	14797-55-8	E235.NO3-L	0.0050	mg/L	0.974	0.691	0.769
nitrite (as N)	14797-65-0	E235.NO2-L	0.0010	mg/L	0.0060	0.0118	0.0014
nitrogen, total	7727-37-9	E366	0.030	mg/L	1.57	1.60	1.12
phosphate, ortho-, dissolved (as P)	14265-44-2	E378-U	0.0010	mg/L	0.109	0.0487	0.0143
phosphorus, total	7723-14-0	E372-U	0.0020	mg/L	0.180	0.102	0.0400
Total Metals							
aluminum, total	7429-90-5	E420	0.0030	mg/L	0.758	1.75	0.780
antimony, total	7440-36-0	E420	0.00010	mg/L	<0.00010	0.00010	<0.00010
arsenic, total	7440-38-2	E420	0.00010	mg/L	0.00036	0.00058	0.00040
barium, total	7440-39-3	E420	0.00010	mg/L	0.0170	0.0186	0.0175
beryllium, total	7440-41-7	E420	0.000020	mg/L	<0.000020	0.000025	<0.000020
bismuth, total	7440-69-9	E420	0.000050	mg/L	<0.000050	<0.000050	<0.000050
boron, total	7440-42-8	E420	0.010	mg/L	0.013	0.014	0.013
cadmium, total	7440-43-9	E420	0.0000050	mg/L	0.0000230	0.0000324	0.0000346
calcium, total	7440-70-2	E420	0.050	mg/L	11.8	11.6	11.7
cesium, total	7440-46-2	E420	0.000010	mg/L	0.000028	0.000072	0.000027
chromium, total	7440-47-3	E420	0.00050	mg/L	0.00128	0.00228	0.00133
cobalt, total	7440-48-4	E420	0.00010	mg/L	0.00041	0.00075	0.00065
copper, total	7440-50-8	E420	0.00050	mg/L	0.00450	0.00581	0.00482
iron, total	7439-89-6	E420	0.010	mg/L	0.715	1.24	0.948
lead, total	7439-92-1	E420	0.000050	mg/L	0.000203	0.000702	0.000284
lithium, total	7439-93-2	E420	0.0010	mg/L	<0.0010	0.0012	<0.0010
magnesium, total	7439-95-4	E420	0.0050	mg/L	2.39	3.40	1.86
manganese, total	7439-96-5	E420	0.00010	mg/L	0.0466	0.0752	0.0902
molybdenum, total	7439-98-7	E420	0.000050	mg/L	0.000169	0.000145	0.000142
nickel, total	7440-02-0	E420	0.00050	mg/L	0.00149	0.00231	0.00157

3.5 Stream Invertebrate Communities

3.5.1 Site Rating and Diversity

Table 15: Results for Site Rating and Diversity Index from Samples Taken at Richards Creek, Crofton, BC on October 28, 2020

Site Ratings	**Site 1**	**Site 2**	**Site 3**
Density	855	111	2355.56
Predominant Taxon	Aquatic Worm	Aquatic Worm	Aquatic Worm
Pollution Tolerance Index	13	10	12
EPT Index	3	2	1
EPT to Total Ratio Index	0.052	0.3	0.0093
Total Number of Taxa	6	5	7
Predominant Taxon Ratio Index	0.52	0.5	0.92
Overall Site Assessment Rating	2.25	2	1.25
Shannon-Weiner Diversity Index Rating	0.566	0.845	0.246

Above is the summary table of the three invertebrate samples taken from site 1-3 in Richards Creek on October 28, 2020. All sites sampled averaged poor to moderate results. Site 1 had an invertebrate density of 855/m², with the dominant taxon being the aquatic worm. Site 2 had a much lower density of only 111/m² and the aquatic worm as the dominant taxon and a moderate rating of 2. Site 3 had a poo rating of 1.25, a high invertebrate density of 2355.56 of which most of those were the pollution tolerant aquatic worm.

Table 16: Results for Site Rating and Diversity Index from Triplicate Samples from Richards Creek, Crofton, BC on November 17, 2020

Site Ratings	**Site 1**	**Site 2**	**Site 3**
Density	437.04	307	907
Predominant Taxon	Aquatic Worm	Aquatic Worm	Aquatic Worm
Pollution Tolerance Index	12	16	18
EPT Index	3	3	3
EPT to Total Ratio Index	0.22	0.19	0.37
Total Number of Taxa	6	9	9
Predominant Taxon Ratio Index	0.78	0.67	0.53
Overall Site Assessment Rating	1.75	1.75	2.5
Shannon-Weiner Diversity Index Rating	0.525	0.703	0.376

Above are the results we obtained from our November 17, 2020 sampling date where triplicate samples were used from the Hess sampler. Site 1 had a density of 437.04/m², a poor to moderate rating of 1.75 and again the dominant taxon being the aquatic worm. Site 2 followed the same trend as the October 28 sample with low density, showing only 307/m². Site 2's predominant taxon was again the aquatic worm and had a poor to moderate overall rating of 1.75. Site three had much lower density than the October sample but still had the highest of the three sites with 907/m². The dominant taxon was the aquatic worm, and it had a moderate rating of 2.5.

3.5.2 Taxon Richness and Diversity

Another calculation we did was the Shannon-Weiner diversity index rating to determine the diversity of invertebrate taxon observed in the stream. The Shannon-Weiner calculation considers the number of different taxa present in the samples and measures it against the total number of invertebrates found using logarithmic to arrive at a final diversity rating of 0-1, the closer to zero meaning less diversity and the closer to one meaning more diversity.

Below are all the calculations done in excel to get the Shannon-Weiner diversity index rating. At site one there was a moderate rating of 0.566 in October, and 0.525 in November, respectively. The invertebrate species observed at each date were relatively similar, except for many amphipods were observed in October and no amphipods were discovered in November. This could be attributed to the higher stream flow, but the cause remains undetermined. Site 2 had a much better diversity rating of 0.845 in October compared to the rating 0.703 seen in the November sampling event. Site 3 had the lowest diversity rating, with 0.246 on the October sample date and 0.376 in November. This site was particularly bad with the large number of aquatic worms found each time. Site 3 was located directly downstream of a sloped field and road culvert, so high pollution levels could be to blame for the absence of pollution intolerant invertebrates and the high incidence of pollution tolerant invertebrates.

Table 17: Results for the Shannon-Weiner diversity index at sites 1, 2, and 3 for Richards Creek

RICHARDS CREEK SITE 1 OCTOBER 28, 2020

Column A	Column B	Column C	Column D
Pollution tolerance	Common Name	Number Counted	Number of Taxa
intolerant	Caddisfly Larva	1	1
	Mayfly Nymph	2	1
	Stonefly Nymph	1	1
	subtotal	**4**	**3**
somewhat	Amphipod	33	1
	subtotal	**33**	**1**
tolerant	Aquatic Worm	40	2
	subtotal	**40**	**2**
	TOTAL	**77**	**6**

Common Name	Column C	$p_i(C/T)$	$\ln(p_i)$	$p_i*\ln(p_i)$
Caddisfly Larva	1	0.012987013	-4.34	-0.056
Mayfly Nymph	2	0.025974026	-3.65	-0.095
Stonefly Nymph	1	0.012987013	-4.34	-0.056
Aquatic Worm	40	0.519480519	-0.65	-0.340
Amphipod	33	0.428571429	-0.85	-0.363
			TOTAL	*-0.911*
			SWDI	**0.566**

RICHARDS CREEK SITE 1 NOVEMBER 17, 2020

Column A	Column B	Column C	Column D
Pollution tolerance	Common Name	Number Counted	Number of Taxa
intolerant	Caddisfly Larva	13	1
	Mayfly Nymph	11	1
	Stonefly Nymph	2	1
	subtotal	**26**	**3**
somewhat			
	subtotal	**0**	**0**
tolerant	Aquatic Worm	92	3
	subtotal	**92**	**3**
	TOTAL	**118**	**6**

Common Name	Column C	$p_i(C/T)$	$\ln(p_i)$	$p_i*\ln(p_i)$
Caddisfly Larva	13	0.110169492	-2.21	-0.243
Mayfly Nymph	11	0.093220339	-2.37	-0.221
Stonefly Nymph	2	0.016949153	-4.08	-0.069
Aquatic Worm	92	0.779661017	-0.25	-0.194
			TOTAL	*-0.727*
			SWDI	**0.525**

RICHARDS CREEK SITE 2 OCTOBER 28, 2020

Column A	Column B	Column C	Column D
Pollution tolerance	Common Name	Number Counted	Number of Taxa
intolerant	Mayfly Nymph	1	1
	Stonefly Nymph	2	1
	subtotal	**3**	**2**
somewhat	Amphipod	1	1
	subtotal	**1**	**1**
tolerant	Aquatic Worm	5	1
	Water Mite	1	1
	subtotal	**6**	**2**
	TOTAL	**10**	**5**

Common Name	Column C	$p_i(C/T)$	$\ln(p_i)$	$p_i*\ln(p_i)$
Mayfly Nymph	1	0.1	-2.30	-0.230
Stonefly Nymph	2	0.2	-1.61	-0.322
Amphipod	1	0.1	-2.30	-0.230
Aquatic Worm	5	0.5	-0.69	-0.347
Water Mite	1	0.1	-2.30	-0.230
			TOTAL	*-1.359*
			SWDI	**0.845**

RICHARDS CREEK SITE 2 NOVEMBER 17, 2020

Column A	Column B	Column C	Column D
Pollution tolerance	Common Name	Number Counted	Number of Taxa
intolerant	Caddisfly Larva	6	1
	Mayfly Nymph	6	1
	Stonefly Nymph	4	1
	subtotal	**16**	**3**
somewhat	Amphipod	3	1
	subtotal	**3**	**1**
tolerant	Aquatic Worm	40	3
	Blackfly Larva	6	1
	Midge Larva	2	1
	subtotal	**48**	**5**
	TOTAL	**67**	**9**

Common Name	Column C	$p_i(C/T)$	$\ln(p_i)$	$p_i*\ln(p_i)$
Caddisfly Larva	6	0.089552239	-2.41	-0.216
Mayfly Nymph	6	0.089552239	-2.41	-0.216
Stonefly Nymph	4	0.059701493	-2.82	-0.168
Aquatic Worm	40	0.597014925	-0.52	-0.308
Amphipod	3	0.044776119	-3.11	-0.139
Blackfly Larva	6	0.089552239	-2.41	-0.216
Midge Larva	2	0.029850746	-3.51	-0.105
			TOTAL	*-1.368*
			SWDI	**0.703**

RICHARDS CREEK SITE 3 OCTOBER 28, 2020

Column A	Column B	Column C	Column D
Pollution tolerance	Common Name	Number Counted	Number of Taxa
intolerant	Mayfly Nymph	2	1
	subtotal	**2**	**1**
somewhat	Amphipod	6	2
	Clam	8	1
	subtotal	**14**	**3**
tolerant	Aquatic Worm	196	3
	subtotal	**196**	**3**
	TOTAL	**212**	**7**

Common Name	Column C	$p_i(C/T)$	$\ln(p_i)$	$p_i*\ln(p_i)$
Mayfly Nymph	2	0.009433962	-4.66	-0.044
Amphipod	6	0.028301887	-3.56	-0.101
Clam	8	0.037735849	-3.28	-0.124
Aquatic Worm	196	0.924528302	-0.08	-0.073
			TOTAL	*-0.341*
			SWDI	**0.246**

RICHARDS CREEK SITE 3 NOVEMBER 17, 2020

Column A	Column B	Column C	Column D
Pollution tolerance	Common Name	Number Counted	Number of Taxa
intolerant	Caddisfly Larva	13	1
	Mayfly Nymph	46	1
	Stonefly Nymph	31	1
	Gilled Snail	1	1
	subtotal	**91**	**4**
somewhat	Aquatic Beetle	1	1
	Amphipod	16	2
	subtotal	**17**	**3**
tolerant	Aquatic Worm	131	2
	Leeches	3	1
	subtotal	**134**	**3**
	TOTAL	**242**	**10**

Common Name	Column C	$p_i(C/T)$	$\ln(p_i)$	$p_i*\ln(p_i)$
Caddisfly Larva	13	0.053719008	-2.92	-0.157
Mayfly Nymph	46	0.190082645	-1.66	-0.316
Stonefly Nymph	31	0.128099174	-2.05	-0.263
Gilled Snail	1	0.004132231	-5.49	-0.023
Aquatic Beetle	1	0.004132231	-5.49	-0.023
Amphipod	16	0.066115702	-2.72	-0.180
Aquatic Worm	131	0.541322314	-0.61	-0.332
Leeches	3	0.012396694	-4.39	-0.054
			TOTAL	*-0.781*
			SWDI	**0.376**

4.0 CONCLUSIONS AND RECOMMENDATIONS

Results from this 2020 environmental monitoring program suggest that water quality at Richards Creek is 'acceptable'. However, there was a decline in water quality as we progressed downstream, especially at site 4 (the Herd Rd. crossing). An area of high concern was that this site had hypoxic conditions for fish and excessive nutrient loading of phosphorus. The high nutrient loading at site four is likely the cause of reduced environmental quality. Both the VIU and ALS data analysis determined other values also exceeding the BC Fresh Water Guidelines. Some metals such as aluminum, calcium and iron were over these guidelines and show contamination from an unknown source. In addition, the results for invertebrate communities in Richards Creek continue to show an overall decline in environmental health.

Several environmental concerns were identified which warrant future monitoring of Richards Creek. These include rising temperatures, hypoxic conditions in site 4, excessive nutrient loading, decrease in macroinvertebrates, high abundance of pollution tolerant invertebrates, and contamination from metals. Trends from past studies show that the quality of the creek is in continued decline.

Continued monitoring at the same time of year and location and use of methodologies will be helpful to provide long term data to detect current and future changes in Richards Creek. It is also recommended that restoration efforts, such as riparian area restoration, be undertaken if ecosystem quality is to be improved. Public outreach may also help as it is unclear if farmers have been contacted in recent years and if they will continue to apply fertilizers in the fields bordering the stream. It is suggested that conversing with homeowners about how nutrient loading, metal contamination and riparian area degradation effects environmental and physical health and the subsequent consequences of such degradation. It is possible that future projects for students could address some of these recommendations.

The results from the 2020 environmental monitoring project for Richards Creek indicate that the water quality in the creek is not sufficient to support healthy populations of aquatic life. Migrating salmonids and other resident species will continue to decline in productivity if efforts are not made to correct the degradation humans have caused.

5.0 ACKNOWLEDGEMENTS

Stacey J, Evans T, and Penner C would like to acknowledge and thank Owen Hargrove for facilitating the 2020 study and taking extra time to organize and provide us with equipment to conduct our field work. Hargrove spent several days in the lab from 0930 till after 1700 and spent extra time sanitizing equipment to ensure students safety. We would also like to acknowledge Eric Demers for his many past years on the project. In addition, we would like to recognize Mike from Vancouver Island University for his help in data analysis and organizing equipment. Recognition also goes to the Department of Fisheries and Oceans Canada for continued interest and support of the long-term monitoring project.

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7.0 APPENDIX INDEX

A) Field Notes and Sketches
B) Map Reference
C) Photographs
D) Data Sheets/ results

A)

Field notes and sketches

Field Notes / Sketches
Site visit
North Cowichan, BC

1549 - Group met at Drinkwater Rd Tim Hortons to discuss plan for site visit. Decided to locate sites 4, 3, 2, 1 for Richards creek. Check in w/ owen.

1621 - Arrived at Site 4 - Herd Rd Bridge

Site access - Easy public access from Herd Rd. Grassy uneven terrien leads to bridge, then deconds to steeper bank.

Conditions - moderate slope to sample site. Grassy banks, not much riparian cover. Stream was stagnant, covered in duckweed. water unknown depth. Tested depth w/ stick. A least 5 ft deep right off bank.

Hazards - Garbage under bridge. Possible homeless activity? Heavy traffic (>50 km/hr). No foot access on bridge. Deep water, drowning hazard. Sample location not far from road for all

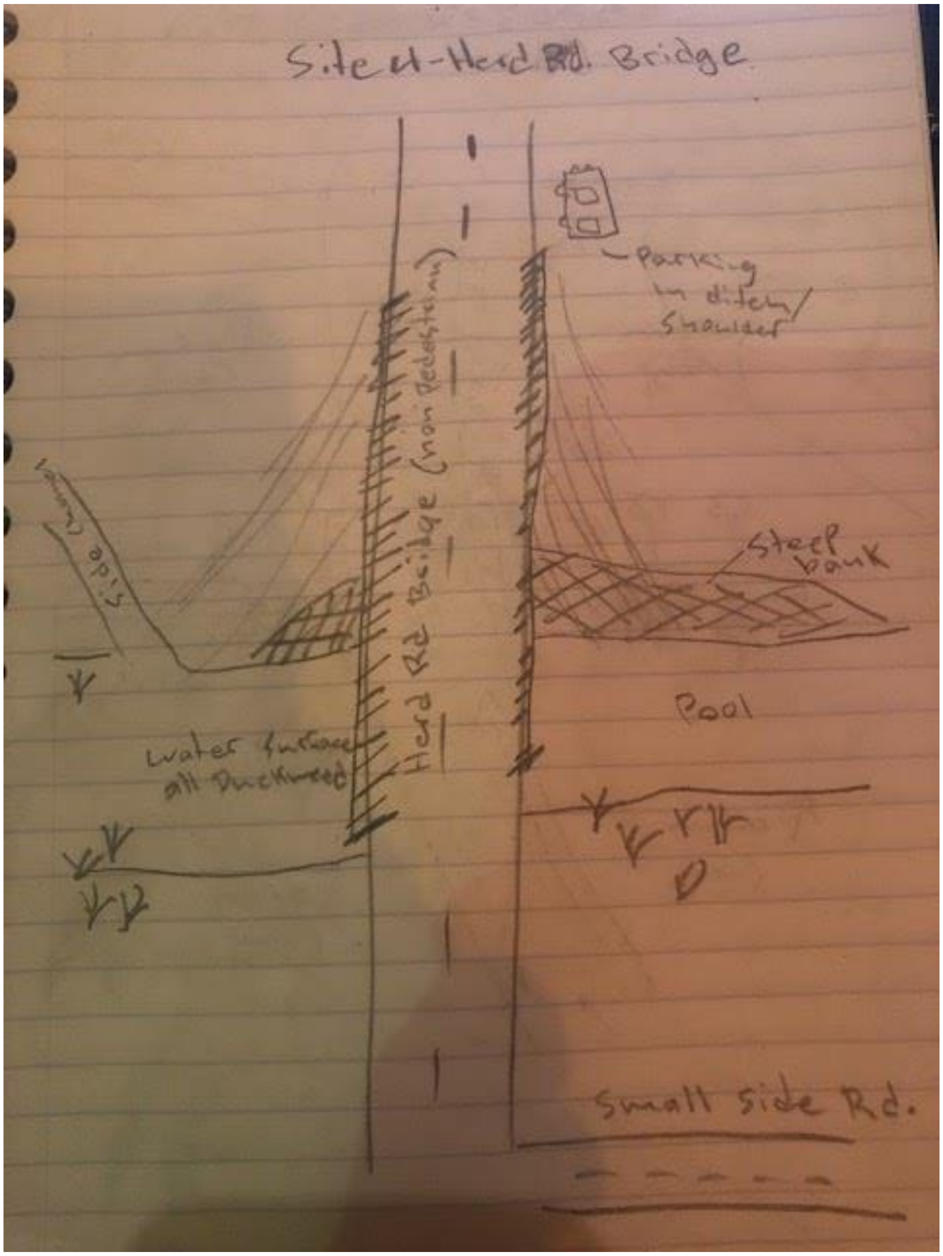
1652 - Arrived at Site 3 - Richards trail crossing

Site access - Easy public access off quit road.

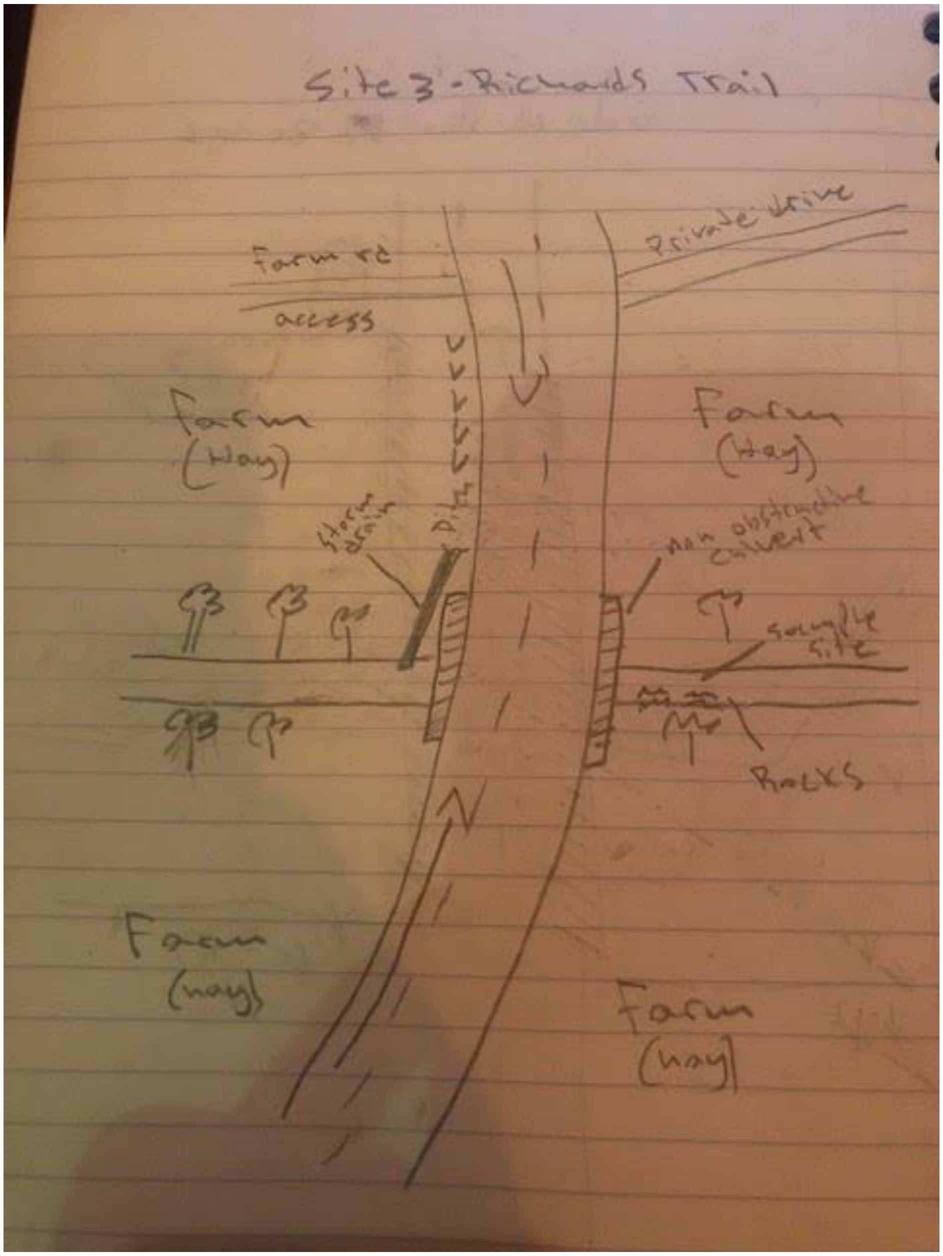
Conditions - Flowing riffles <1ft deep. Ideal sample location right off rd 3m down stream of culvert. Hay fields around creek (agriculture run-off) Ditch flood pipe observed. Drains water from surrounding roads. 25-50% canopy cover w/ small riparian zone.

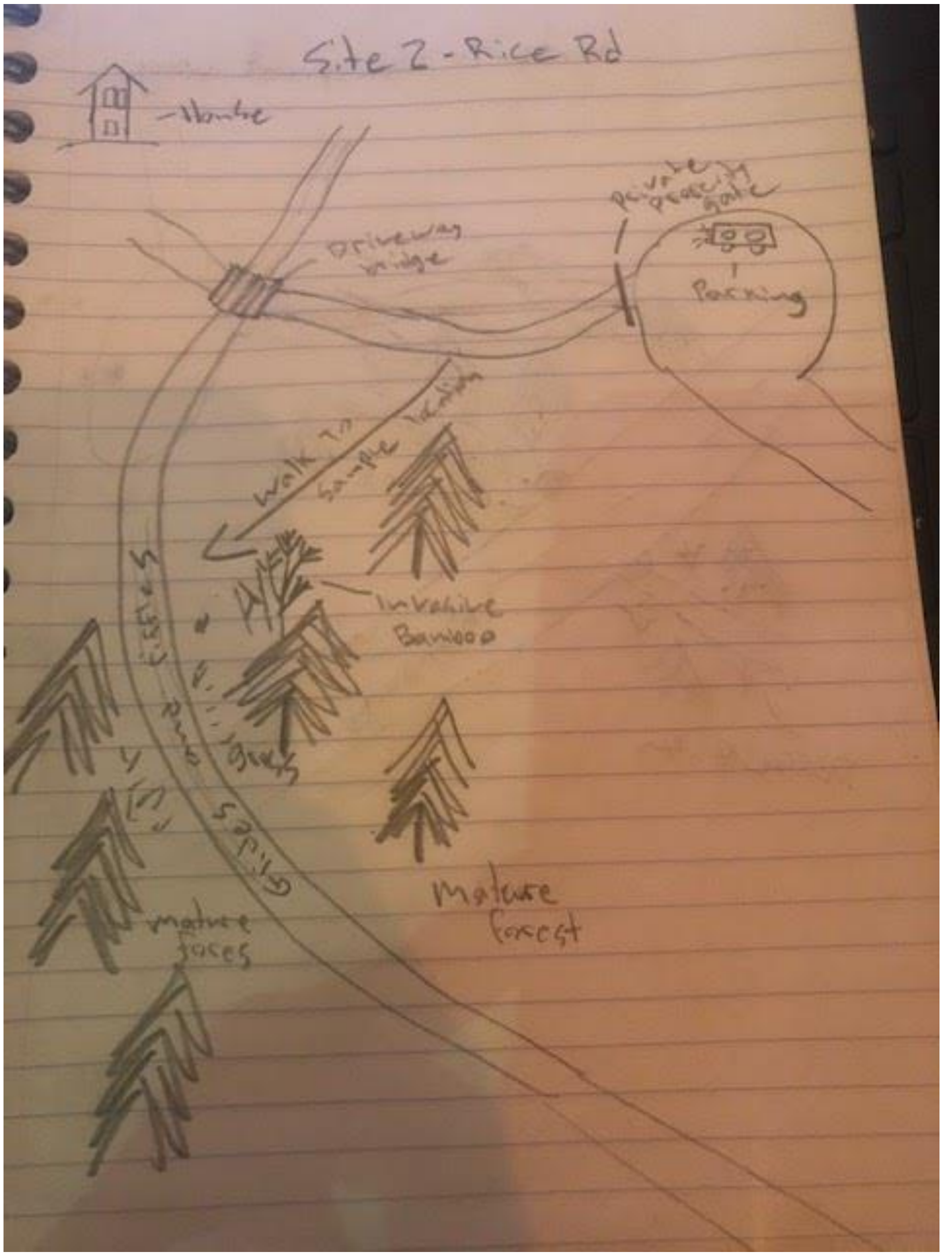
Hazards - Observed 1 dog. Apeard to be friendly. Stream is low flow. Narrow rd. but safe place to park and slow moving light traffic (<50 km/hr).

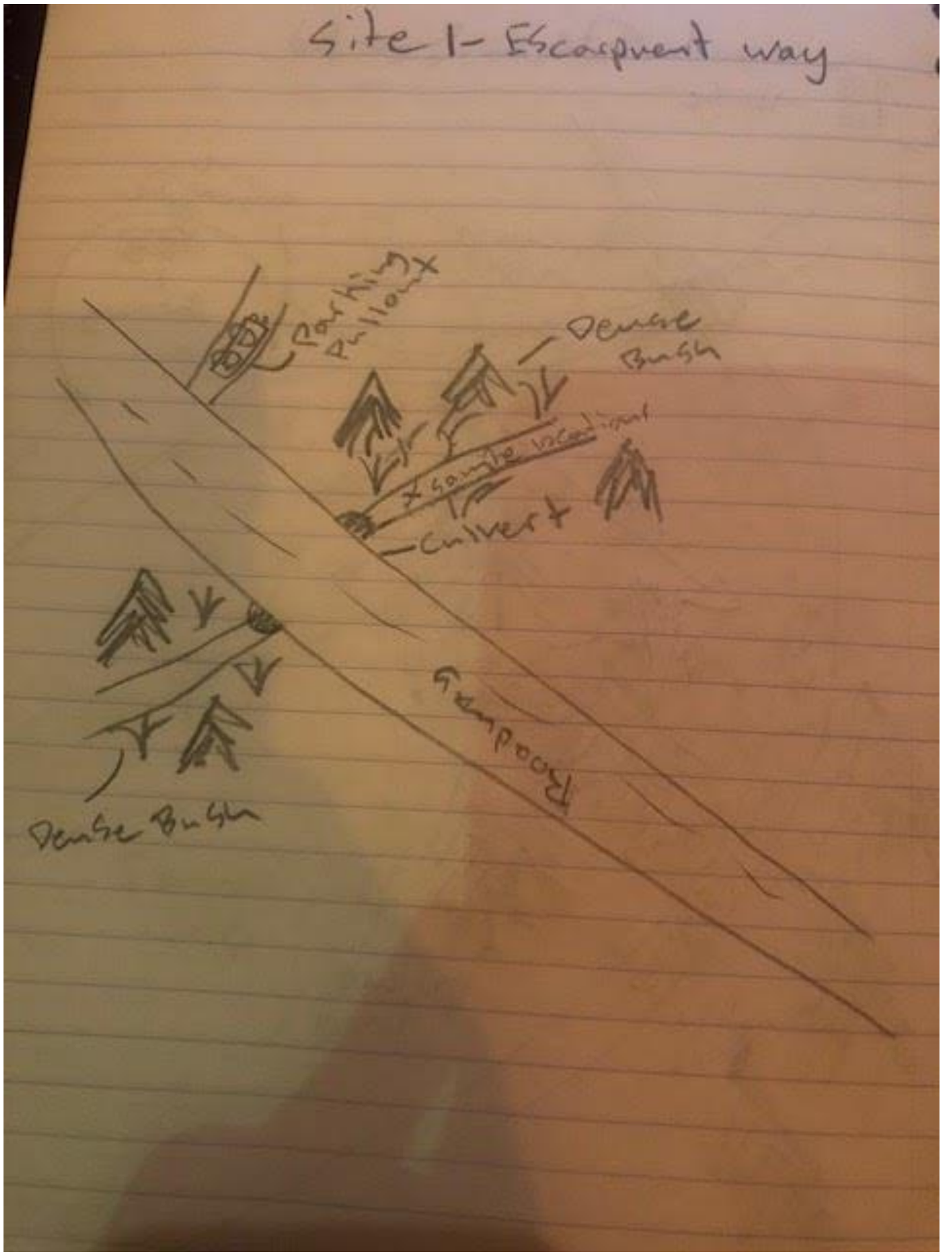
1711- Arrived at site 2 - Rice Rd. Private property
1714- Gate w/ private property sign and phone #
Called number on gate (250)-746-7143) Spoke w/
unknow individual (home owner) who granted access
to property.
1717- Site access - site located at end of Rd. with large
parking area. Very little traffic. Gradual uneven slope
leads to sample site on forest floor terrain —
Choose sample site 20m down private drive and
20m off Rd. to creek.
Conditions - Riffles and glides, low flow, not too
deep. 75-90% canopy cover, riparian zone large.
Invasive bamboo, holly.
Hazards - Site is greatest distance from Rd. Will
advise home owner when we arrive/leave. Potential
trips/falls.
1728- Advised homeowner we left property
1735- Arrived at site #1 - Escarpment way Crossing —
Site access - Easy public access from Rd. Sample
sites either side of Rd.? We may need to bush
wack slightly for ideal sample sites
Conditions - riffles and glides, shallow. level terries,
grass, shrubs, trees, in stream cover 50-75%.
No garbage / infrastructure. Area seems undisturbed.
Hazards - light traffic 50 km/hr. Good parking
spot, small grassy shoulder on Rd. Good sight
lines for oncoming traffic. Easy access, cell
coverage (also cell coverage at all sites)
1745- Back at Tim Hortons. Signed out w/ Owen



Site H-Herd Rd. Bridge
Parking in ditch/ Shoulder
Herd Rd Bridge (non pedestrian)
Side Channel
Steep bank
Pool
Water surface all Duckweed
Small side Rd.


Site 3 - Richards Trail
Private drive
Farm rd
access
Farm
(Hay)
Farm
(Hay)
storm drain
non obstructive culvert
sample site
Rocks
Farm
(hay)
Farm
(hay)

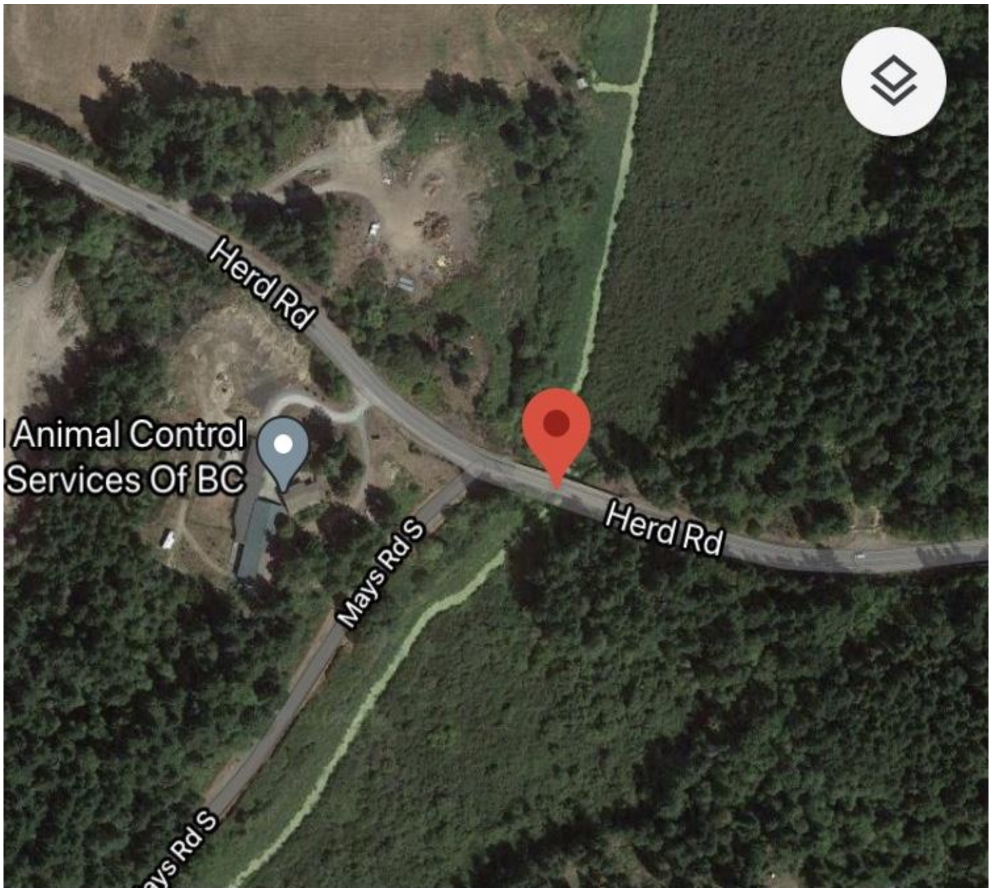

Site 2 - Rice Rd
Driveway bridge
Parking
Walk to sample location
Invasive Bamboo
Mature forest


Site 1- Escarpment way
Parking Pullout
Dense Bush
X sample location
Culvert
Roadway
Dense Bush

B)

Map References

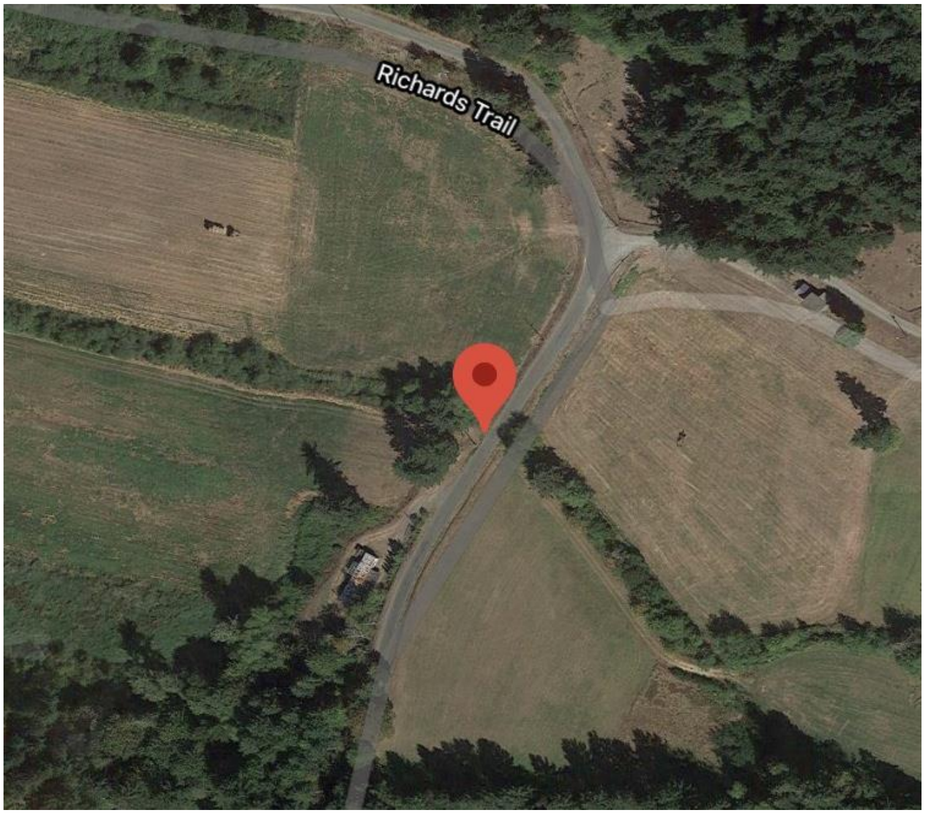
SITE 4



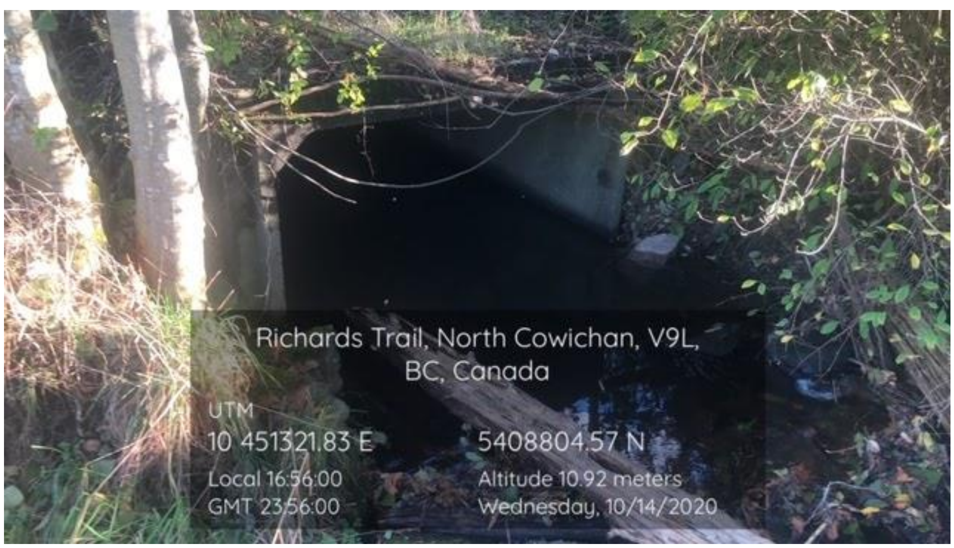
(Map modified from Google)

(Location stamped photo)

Site 3

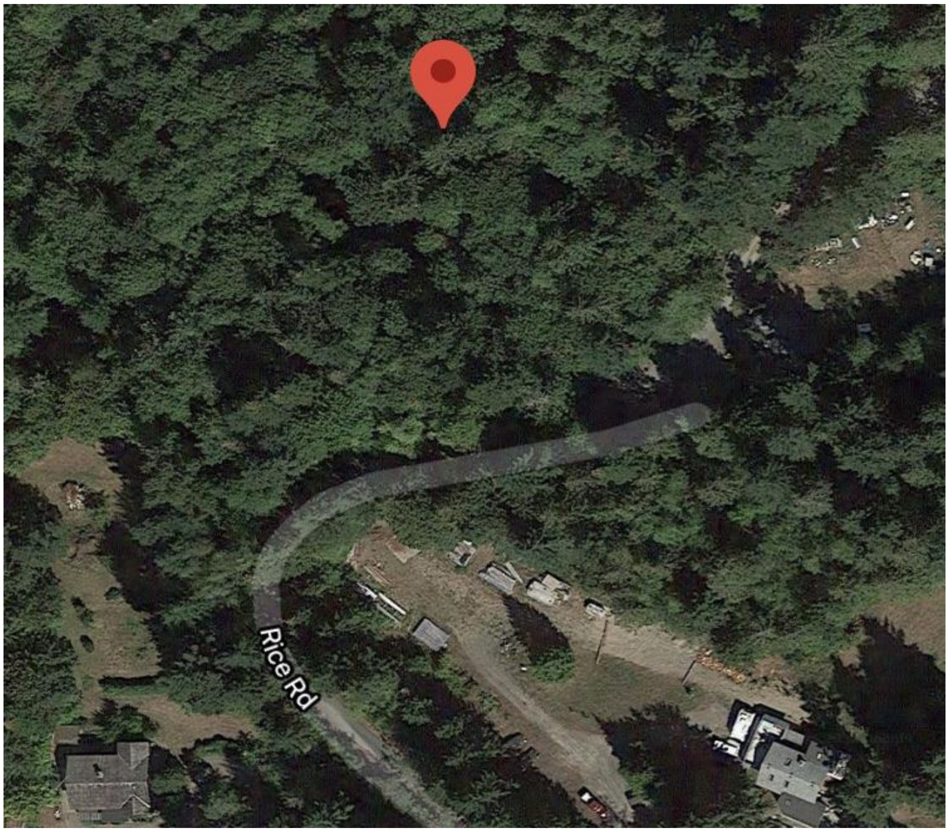


(Map modified from Google)



(Location stamped photo)

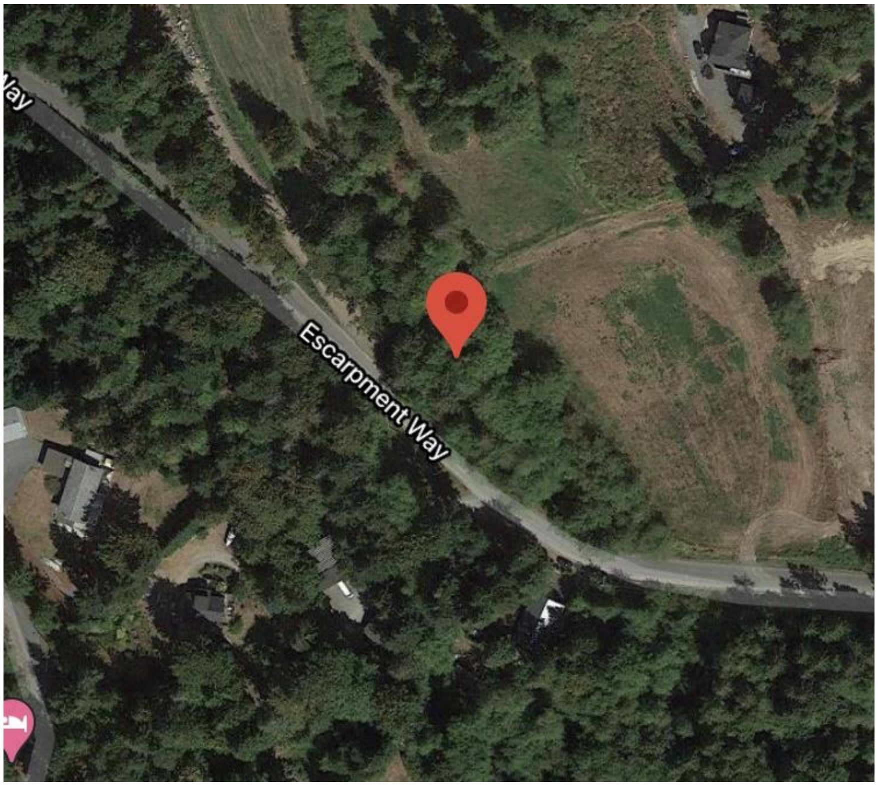
Site 2



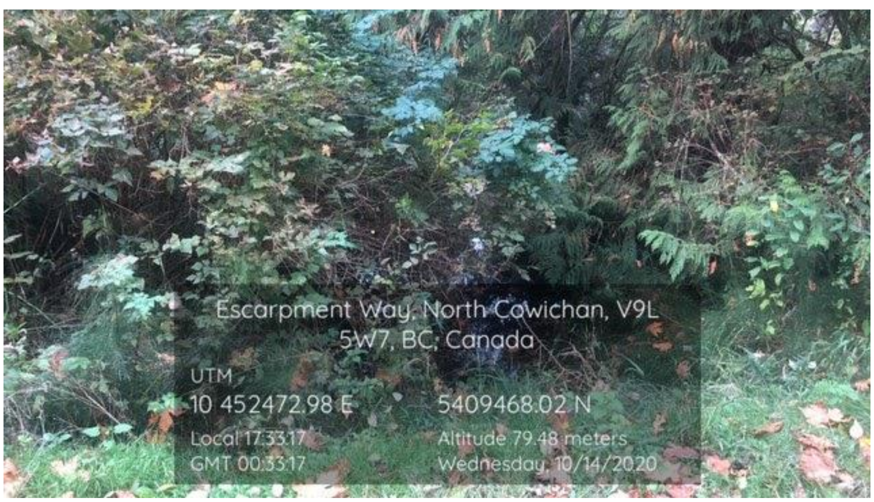
(Map modified from Google)

(Location stamped photo)

Site 1



(Map modified from Google)

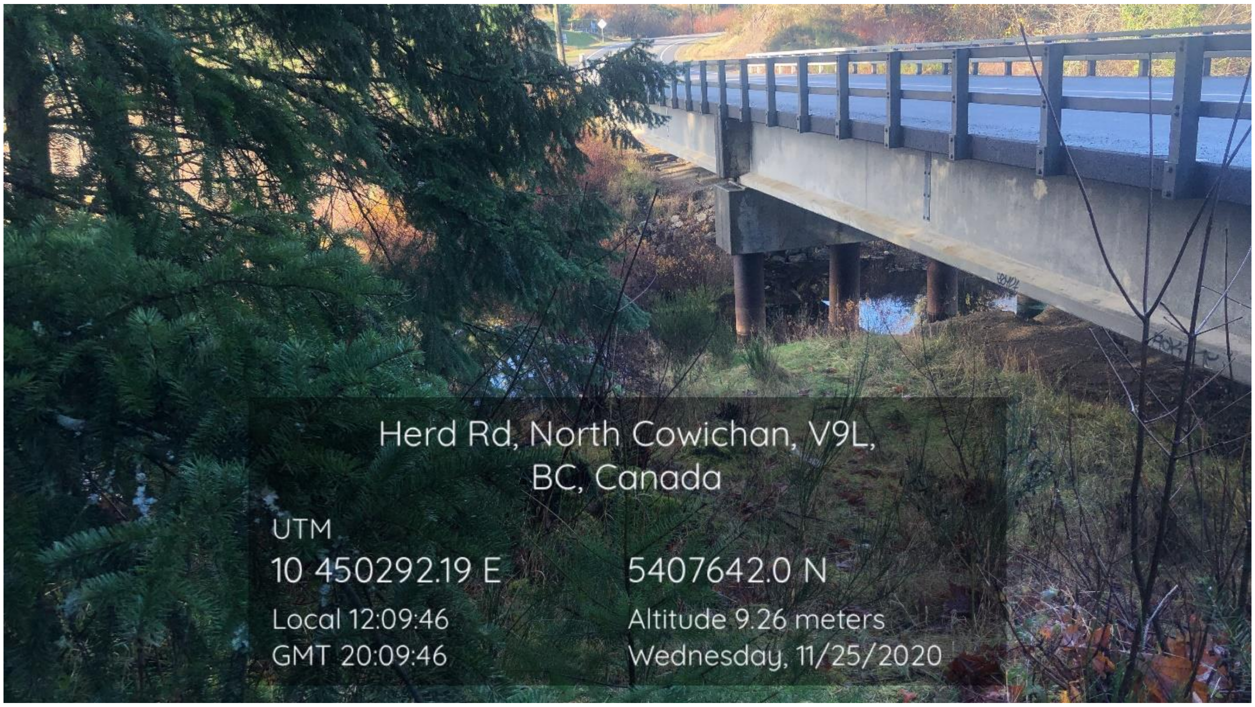


(Location stamped photo)

C)

Photographs

Photo 1



Site #	Date	Description
4	25-11-2020	Approach to sampling site via grassy slope

Photo 2

Site #	Date	Description
4	14-10-2020	Under the bridge at Herd Rd. crossing. Heavy duckweed on waters surface.

Photo 3

Site #	Date	Description
4	14-10-2020	Upstream view showing zero canopy cover

Photo 4

Site #	Date	Description
4	27-10-2020	Downstream view showing zero canopy cover. A flock of mallards can be seen in the background.

Photo 5

Site #	Date	Description
3	14-10-2020	Water flowing under unobstructed culvert crossing

Photo 6

Site #	Date	Description
3	14-10-2020	Storm runoff ditch drain on upstream side of crossing. Not ideal for sampling due to large boulders

Photo 7

Site #	Date	Description
3	14-10-2020	Ideal sampling location on upstream side of crossing

Photo 8

Site #	Date	Description
3	17-11-2020	High water levels flowing under road and making Hess sampling a challenge

Photo 9

Site #	Date	Description
2	14-10-2020	End of Rice Rd. private property sign at start of driveway

Photo 10

Site #	Date	Description
2	14-10-2020	Sign with phone number for access to private property

Photo 11

Site #	Date	Description
2	14-10-2020	Access to ideal sampling site via gradual slope on uneven forest terrain

Photo 12

Site #	Date	Description
2	14-10-2020	Invasive holly tree in the riparian area near sampling site

Photo 13

Site #	Date	Description
2	14-10-2020	Riffle and glide in ideal Hess sampling location sounded by dense riparian area

Photo 14

Site #	Date	Description
2	25-11-2020	Looking upstream to sampling site with riffles and glides and dead salmon

Photo 15

Site #	Date	Description
2	25-11-2020	Dead salmon with eyes and brain consumed

Photo 16

Site #	Date	Description
1	14-10-2020	Access to sampling site via grassy flat terrain. Stream located to the left and farm fields to the right showing limited riparian area

Photo 17

Site #	Date	Description
1	14-10-2020	Sampling location with glide and ~50% in stream cover

Photo 18

Site #	Date	Description
1	14-10-2020	Concrete barrier near road provides reference for sampling location ~10m upstream from culvert