Water Quality and Invertebrate Analysis for Richards Creek, Duncan BC, 2017

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Submitted to:
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Executive Summary

An environmental monitoring project was conducted by three students in the Natural Resource Protection Program at Vancouver Island University (VIU) on Richards Creek in the Cowichan Valley, BC. Four stations were monitored that were established by previous projects. This project is a continuation of previous assessments completed by VIU and the Department of Fisheries and Oceans (DFO).

Richards Creek is part of an extensive watershed, the Cowichan River Watershed. This watershed is essential habitat to many terrestrial and aquatic organisms, including various salmonids. Continued water quality monitoring is of interest to DFO, British Columbia Conservation Foundation (BCCF), and local groups such as the Somenos Marsh Wildlife Society.

The objective of this stream survey was to assess current stream condition in relation to suitability for aquatic life and potential pollution threats by resource uses such as farming, which occurs near the creek. To conduct this assessment, sampling was completed during low water flow and high water flow events, on October 28, 2017 and November 27, 2017, respectively. Basic hydrology, water quality parameters, microbial and stream invertebrate communities were analyzed in this project.

Water samples were analyzed at the ALS Environmental Laboratory in Vancouver, B.C and by students in the VIU Laboratory. The data was then compared to BC Water Quality Guidelines (RISC 1998). We found that Nitrate read over the readable limit at station 3 during the first sampling event and Nitrate also read over the readable limit at station 1 during the second sampling event. The pH reading at station 4 during the second sampling event was below the guidelines for freshwater aquatic life. In the microbiology samples, the high amount of fecal coliforms reflected the agriculture in the area. The invertebrate communities suggested that the stream is relatively healthy. All stations had a decent diversity of stream invertebrate taxa.

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Introduction

Historical Overview

Richards Creek is located in the Coastal Douglas Fir (CDF) biogeoclimatic zone. Richards trail provides year round rearing and spawning habitat for various salmonids, as well as other species. The northern half of Richards Creek flows through residential areas and riparian forest, and the other half of Richards Creek runs through agricultural lands (Demers E. 2016).

Potential Environmental Concerns

Monitoring conducted on specific sites of Richards Creek have focus on the environmental changes the creek has developed as it flows towards Somenos Lake. Possible environmental issues would include the inflow of water from Crofton Lake storage that annually augments low summer flows, potential reverse flow due to the withdrawal of water for agricultural farming, anoxia in the lower reaches of the creek (Preikshot, Willmott, and Lange 2015), As well as, nutrient enrichment from adjacent agricultural lands (non-point sources) and storm-water effluents (point sources).

Project Objectives

The primary objective was to investigate potential environmental impacts augmented water flow from Crofton Lake storage has on Richards Creek in the month of October. The investigation was conducted well after the influx and mixing of lake water, and during the fall rain season. Specific attention was focused on the levels of oxygen in

Richards Creek, as levels have been reported to be low in past years. This is especially important for the Coho Salmon (*Oncorhynchus kisutch*), that swim up the creek in comparatively large numbers to spawn in the late fall and early winter (Preikshot, Willmott, and Lange 2015). Four locations were predetermined and selected for the team to sample.

The secondary objective was to test the condition of Richards Creek in the fall of 2017, and examine its environment to develop a better understanding of the healthiness of the creek. The study of the creek included water quality, water microbiology, and macroinvertebrates sampling. Water samples were analyzed at the VIU facilities as well as Australian Laboratory Services (ALS) in Vancouver, BC. Outcomes were analyzed and compared to previous years to help mitigate the potential for water use conflict to ensure the creek's health for fish and fish habitat.

Methods

Locations and Habitat Characteristics

This study is reflective of the previous studies conducted on Richards Creek by third year graduate students from Vancouver Island University since 2008. As in the previous studies, the same four sampling stations were used. These stations were selected because of habitat, accessibility, safety and the nearby environment. Each station was surrounded by residential areas or agricultural lands.

Station 1 was located on Escarpment Way. The site was overgrown with trees and thick brush of various species. The stream substrate consisted of cobble, with few larger rocks. The sampling site was shallow and had slow moving water. There was residential housing near the creek and one agricultural field.

Station 2 was located at the end of Rice Road. The substrate of the creek consisted of cobble with some larger rocks. This station had a relatively large riparian buffer.

Station 3 was located at the bridge crossing of Richards Trail. The substrate of the creek consisted of large cobble but also had cement slabs near the culvert/bridge from road work. This area was mainly surrounded by agricultural area.

Station 4 was located at the bridge crossing on Herd Road. The station was located on the east side under the bridge. The water was deep with a low gradient. The substrate consisted of small cobbles. This site area was at the end of agriculture fields, and duckweed was present during the first sampling event.

Sampling Frequency

Sampling occurred twice within a one month span with sampling events on October 28th and November 27th. To give the most representative results, the first sampling event was during a low flow and the second sampling event was during high flow.

Triplicate samples of invertebrates were collected during the first sampling event at stations 1 and 2. Four samples of invertebrates were taken during the first sampling event at station 3. Microbiology water samples were also collected during the first sampling event and were taken from all four stations. Hydrology measurements, VIU and ALS Laboratory water samples were collected during both sampling events and at all sites. At station 1, VIU and ALS samples were collected, at station 2 VIU and ALS samples were collected as well as a replicate sample to be analyzed by VIU, at station 3 VIU and ALS samples were collected, and at station 4 VIU samples were collected.

Basic Hydrology

Many water quality parameters are dependent on the stream discharge for proper interpretation. Stream discharge was calculated at all stations and was determined by the float method. The float method is done by calculating the cross-sectional area (m^2) of the stream at a specific point, measuring the mean water velocity (m/s) and completing a simple calculation to determine discharge (m^3/s).

Water Quality

All water quality parameters were measured during both sampling events. This was done in order to compare the parameters between high and low flow events. The water quality parameters measured include water temperature, dissolved oxygen, conductivity, pH, turbidity, total alkalinity, hardness, nitrate, and phosphate. Water samples were also collected to determine fecal counts.

Field Measurements

Temperature and dissolved oxygen were measured on site using an electronic dissolved oxygen meter.

Water Sample Collection

Samples collected for analysis at VIU were conducted using a clean, pre-labelled 500ml plastic bottle. This bottle was rinsed in Richards Creek three times prior collecting the sample. Samples were obtained by either standing on the adjacent bank or within the stream channel itself. Samples were collected while facing upstream. Samples were taken in a manner to avoid collecting excess sediment within them.

Samples collected for analysis at ALS Laboratory were conducted using three, pre-labelled, clean, laboratory-supplied sample containers. Samples were obtained by either standing on the adjacent bank or within the stream channel itself. Samples were collected while facing upstream. Samples were taken in a manner to avoid collecting excess sediment within them

Samples taken to test for total and fecal coliforms were collected in a sterile 100-mL Whirlpak bag. The water samples were kept in a refrigerator for a maximum of 92 hours until they were analyzed in the lab.

VIU Laboratory Analysis

Turbidity, alkalinity, and hardness were all tested for at VIU using their HACH kits. Measuring for nitrate and phosphate was done with a DR 2800 HACH Spectrophotometer.

ALS Laboratory Analysis

Samples were submitted to ALS Laboratories in Vancouver, BC. This lab provided general water quality parameters, nutrient analysis (ammonia, nitrate, orthophosphate, and total phosphorus) and a total metal (31 metals) scan. ALS water quality was conducted at stations 1, 2 and 3.

Quality Assurance/ Quality Control

To ensure that all data collected was accurate, both Quality Assurance and Quality Control precautions were taken. The Ambient Freshwater and Effluent Sampling Manuel produced by the Government of British Columbia (2003) was followed. VIU sample bottles were rinsed three times, samples were taken facing upstream, samples were stored properly, and blank and replicate samples were taken, etc.

Data Analysis and Results

All data collected during this project was compared to the Guidelines for Interpreting Water Quality Data prepared by the RISC (1998).

Microbiology

Samples were obtained at each station during the first sampling event using a sterile, pre-labelled, 120ml Whirl-Pak ® bag. Each sample was obtained by placing the bag just below the surface of the water while facing upstream. The samples were stored in a cooler with ice packs and transported to VIU within 72 hours for laboratory analysis.

Stream Invertebrate Communities

Invertebrate Sample Collection

Samples were obtained using a Hess Sampler during the first sampling event, October 28th 2017. Sampling stations have historically been at stations 1, 2 and 3. This study replicated those locations as they had been chosen according to their hydrological characteristics, substrate uniformity, ease of access, and safety. In order to maintain consistency with previous studies, three replicates were obtained at each station (1, 2, and 3).

As per Demers (2016) the following procedures were implemented when collecting invertebrates:

- The Hess sampler was pressed into the substrate to isolate a circular 0.09m² sampling area.
- Stones and debris 5 cm or larger within the sampling area were rubbed by hand in front of the collecting net to gently dislodge invertebrates.
- Cleaned stones were placed downstream of the sampling area.

- The contents of the net was transferred to a 125 ml plastic jar and stored in a cooler.
- The cooler and the samples within were transported to the VIU lab for analysis within 72 hours of sampling.

Data Analysis

Analysis of the invertebrates obtained was conducted at the Vancouver Island University laboratory. The triplicate samples from each station were combined into a single composite sample per station.

Each composite sample was sorted and identified to the appropriate taxonomic level utilizing the Pacific Streamkeepers procedures (Taccogna and Munro 1995).

Using a dissecting microscope, an invertebrate identification was confirmed by using the invertebrate identification sheets, and numbers of invertebrates were tallied and recorded on a Pacific Streamkeepers Invertebrate Survey Field Data Sheet.

These sheets provided the following information:

- Total density of invertebrates (per m^2)
- Total number of taxonomic groups
- Predominant taxonomic group
- Pollution Tolerance Index
- Ephemeroptera-Plecoptera-Trichoptera (EPT) Index
- EPT to Total Ratio Index

- Predominant Taxon Ratio Index
- Overall Site Assessment Rating

Results and Discussion

Water Quality

VIU and ALS Laboratory Analysis

Table 1 and Table 2 provide a full listing of parameters analyzed for the sampling events on October 20, 2017 and November 18, 2017.

Table 1. VIU Water Quality Analysis from October 20, 2017 Sampling Event.

Parameter	Units	Station 1 Results	Station 2 Results	Replicate Results	Station 3 Results	Station 4 Results	BC Water Quality Guidelines
Acidity (pH)	No units	7.7	7.6	7.5	7.4	6.4	**6.5-9.0**
Conductivity	µS/cm	161	202	203	211	333	No specific unit
Turbidity	NTU	4.91	3.51	24.10	2.07	3.20	**Aquatic life** 5 NTU increase when background = 50 NTU 10% increase when background > 50 NTU

Alkalinity	mg/L as CaCO3	37.2	46.0	46.0	51.2	36.0	**Aquatic life:** 0-10 mg/L high sensitivity 10-20 mg/L moderate sensitivity >20 mg/L low sensitivity
Hardness	mg/L as CaCO3	83	80	84	96	124	N/A.
Nitrate*	mg/L as NO_3^-	0.03	0.13	0.19	0.57 (Over Range)	0.17	**Aquatic life** maximum of 200 mg/L and average of 40 mg/L
Phosphate*	mg/L as PO43-	0.09	0.53	0.22	0.26	0.30	None.

*Nitrate and Phosphate levels were sampled within the trip blank. The results were as follows:

Nitrate: 0.01 mg/L

Phosphate: 0.05 mg/L

Table 2. VIU Water Quality Analysis from November 18, 2017 Sampling Event.

Parameter	**Units**	**Station 1 Results**	**Station 2 Results**	**Replicate Results**	**Station 3 Results**	**Station 4 Results**	**BC Water Quality Guidelines**
Acidity (pH)	No units	8.1	8.1	7.9	7.4	7.2	**6.5-9.0**
Conductivity	µS/cm	127	130	130	142	155	No specific unit

Turbidity	NTU	3.0	1.6	1.4	2.3	5.0	**Aquatic life** 5 NTU increase when background = 50 NTU 10% increase when background > 50 NTU
Alkalinity	mg/L as CaCO3	19.6	23.2	22.0	22.8	19.2	**Aquatic life:** 0-10 mg/L high sensitivity 10-20 mg/L moderate sensitivity >20 mg/L low sensitivity
Hardness	mg/L as CaCO3	48	47	46	49	64	N/A.
Nitrate*	mg/L as NO_3^-	2.26 (Over Range)	0.72	1.40	1.77	1.96	**Aquatic life** maximum of 200 mg/L and average of 40 mg/L
Phosphate*	mg/L as PO43-	1.4	1.6	0.6	0.9	1.4	None.

*Nitrate and Phosphate levels were sampled within the trip blank. The results were as follows:

Nitrate: 0.04 mg/L

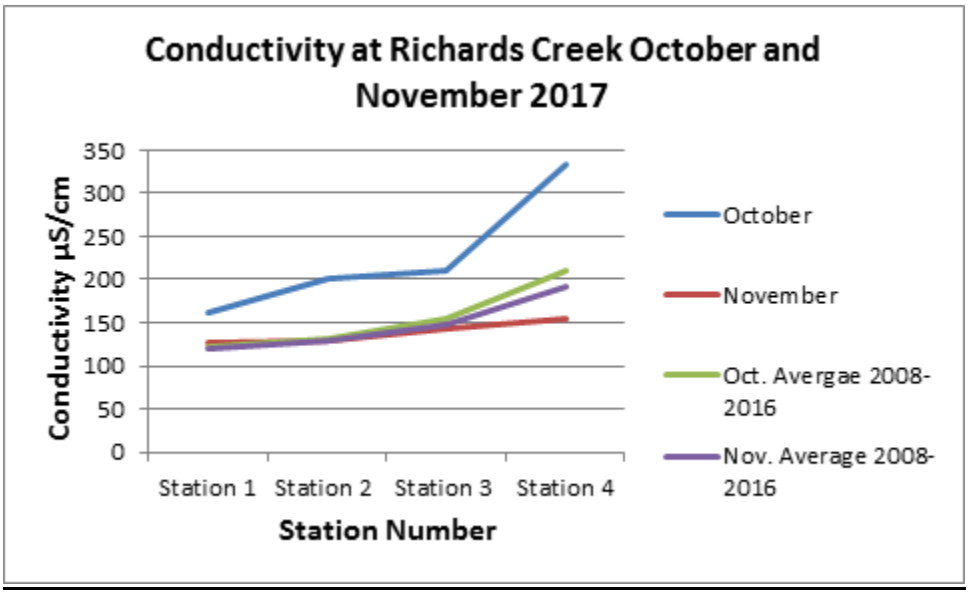
Phosphate: 0.8 mg/L

Conductivity

Conductivity results in Figure 1 show a general increase in parameters from Station 1 downstream through stations 2, 3 and 4. Figure 1 also includes a comparison chart of average levels from previous study years (2008-2016). These averages were obtained from Demers (2016) and George et al. (2016). Conductivity levels from Stations 1, 2 and 3 were also analyzed by ALS. The results from ALS showed approximately a 5%

variation in concentration. See Appendix 1 and 2. While the conductivity appeared to be significantly higher than the average during the October 2017 sampling event, it should be noted that similar high numbers were observed in the 2013 study as noted in Demers 2016. The lower ratings from October to November are due to increased precipitation and dilution. The trends identified are consistent with the results from previous years.

Figure 1. Comparison of Conductivity at Richards Creek between 2017 and previous sampling years (2008-2016).

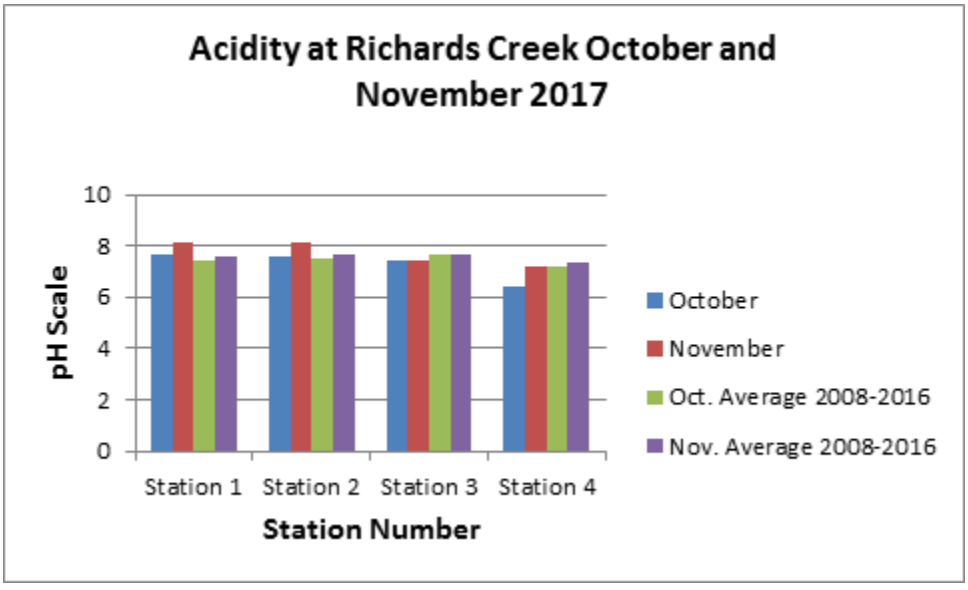


Acidity

Acidity results in Figure 2 show a general increase in acidity from Station 1 downstream through stations 2, 3 and 4. Figure 2 also includes a comparison chart of average levels from previous study years (2008-2016). These averages were obtained from Demers (2016) and George et al. (2016). Acidity levels from Stations 1, 2 and 3 were also

analyzed by ALS. The results from ALS showed approximately a 5-10% variation in pH. See Appendix 1 and 2. Note that the pH rating for Station 4 was below the BC Water Quality Guidelines for Aquatic Life on the October sampling event. This was also the lowest pH reading recorded at Station 4 when compared to previous results, the previous lowest recording was 6.8 at Station 4 in 2015 (Demers 2016). Due to the depth and steep embankments at Station 4, sampling was taken close to shore which may have resulted in a lower pH being detected. The higher ratings from October to November are due to increased precipitation and dilution. Aside from the October 2017 Station 4 results, the trends identified are consistent with the results from previous years.

Figure 2. Comparison of Acidity at Richards Creek between 2017 and previous sampling years (2008-2016).

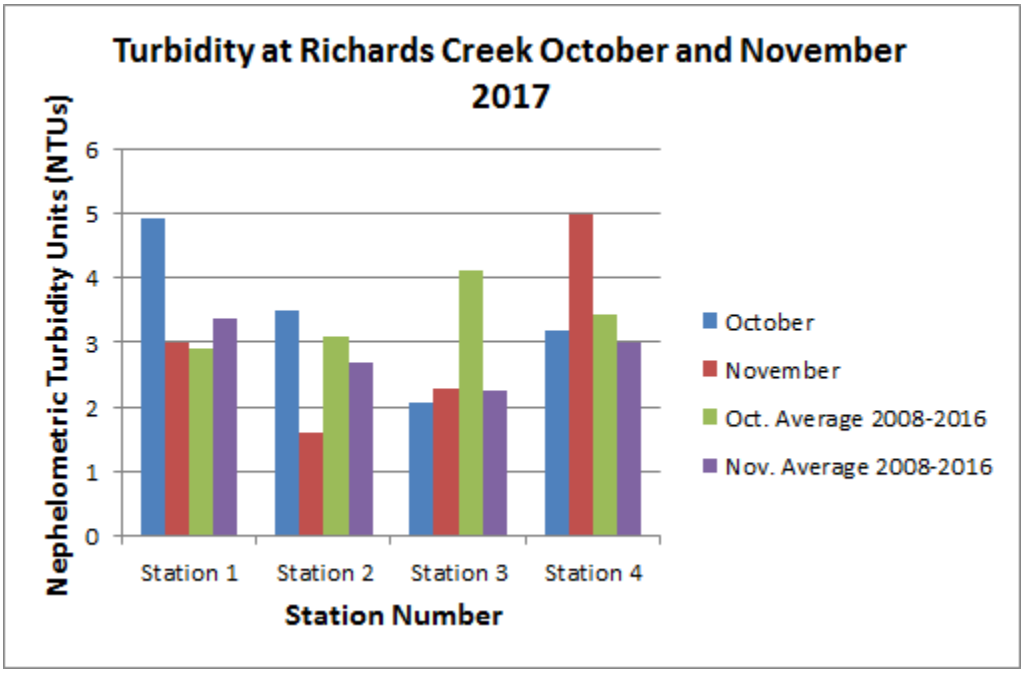


Turbidity

Turbidity results are included in Figure 3 along comparison chart of average levels from previous study years (2008-2016). These averages were obtained from Demers (2016) and George et al. (2016). Note that the turbidity rating for the Station 2 replicate on the October 2017 sampling was not considered as the spike in NTUs is likely a result of sampling within a sediment plume and should be attributed to a sampling error. The results appeared to be within the BC Water Quality Guidelines for Aquatic Life. Results for the turbidity analysis were varied when compared to previous years. This is due to a potential variety of factors such as weather, erodible banks within the vicinity of the sampling location, and errors of sampling in situ. The Station 1 October and Station 4 November sampling event results were likely skewed due to sediment plumes during the sampling.

Average results varied dependent upon the location due to precipitation, soil exposure and stability. Stations 1 and 2 have high amounts of vegetative cover while 3 and 4 are more exposed. Station 4 is located underneath a bridge with erodible, exposed slopes.

Figure 3. Comparison of Turbidity at Richards Creek between 2017 and previous sampling years (2008-2016).

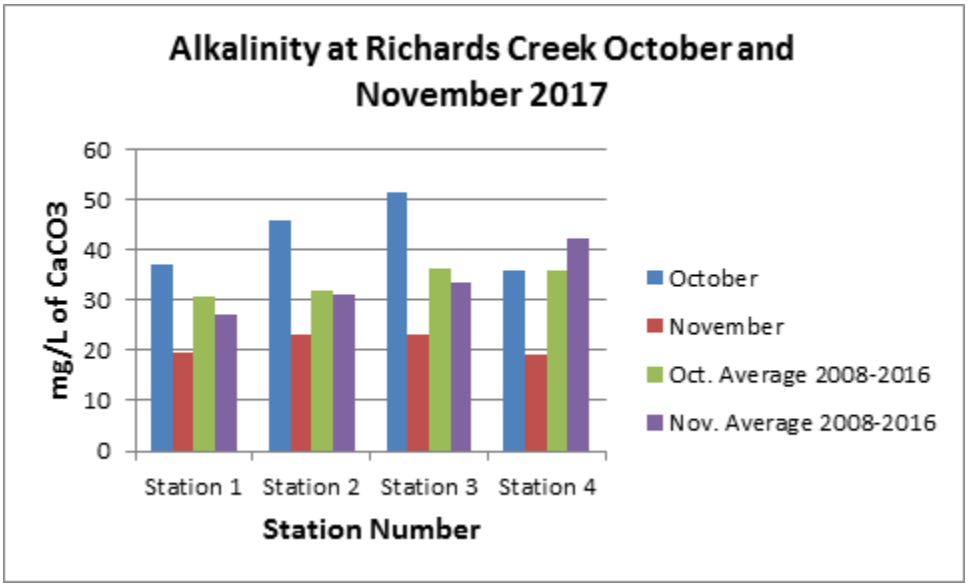


Alkalinity

Alkalinity results are included in Figure 4 along comparison chart of average levels from previous study years (2008-2016). These averages were obtained from Demers (2016) and George et al. (2016). The results appeared range from moderate (November 2017) to low (October 2017) sensitivity as per the BC Water Quality Guidelines for Aquatic Life. Results for the alkalinity analysis showed an increasing trend from Stations 1 to 3 and then decrease at Station 4. These results appear consistent with the increased acidity at Station 4. Alkalinity had a general decrease due to dilution from increased precipitation between the October and November sampling events. The trends identified show some variation with the results from previous years. As noted above for conductivity, the average results were compiled for the 2008-2016 sampling events; October 2010 had similar results to the October 2017. The Alkalinity being lower at

Station 4 for the November 2017 sampling event was an anomaly that was tested multiple times within the VIU laboratory. The results were accurate with the testing methods and equipment utilized at VIU. The sampling was obtained close to the shore of Station 4 due to the steep embankments and deep water which may have resulted in skewed data.

Figure 4. Comparison of Alkalinity at Richards Creek between 2017 and previous sampling years (2008-2016).



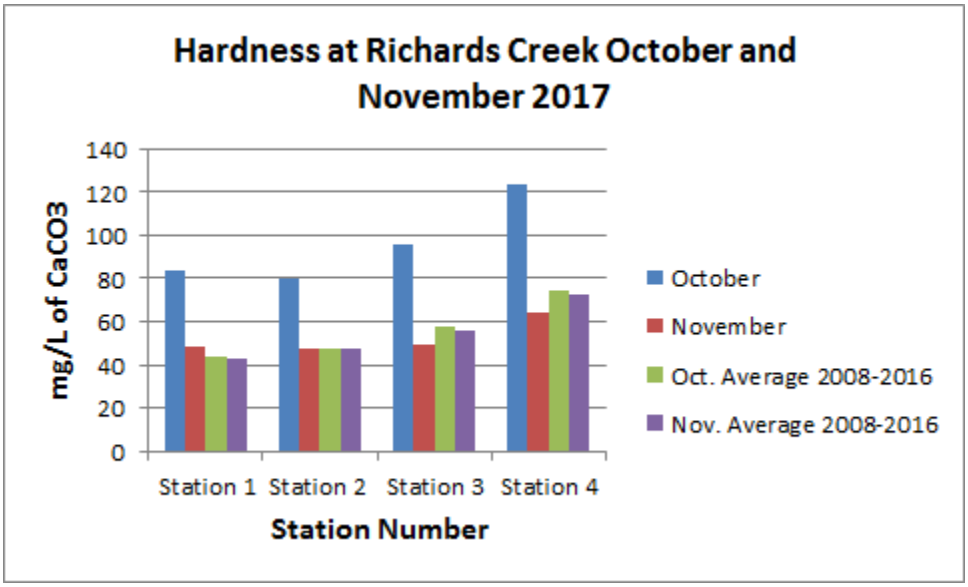
Hardness

Hardness results are included in Figure 5 along comparison chart of average levels from previous study years (2008-2016). These averages were obtained from Demers (2016) and George et al. (2016). The results provide a general trend of increasing water hardness from Station 1 to Station 4. This is consistent with the results from previous years. Hardness had a general decrease due to dilution from increased precipitation between the October and November sampling events. Hardness levels from Stations 1,

2 and 3 were also analyzed by ALS. The results from ALS showed approximately a 10% variation in CaCO3 concentration. ALS tended to have slightly lower results for the October sampling event, and slightly higher for the November sampling event. See Appendix 1 and 2.

The trends identified show the October 2017 sampling event as slightly higher than average when compared to the October sampling in previous years. The November 2017 results were consistent with the results from previous years.

Figure 5. Comparison of Hardness at Richards Creek between 2017 and previous sampling years (2008-2016).

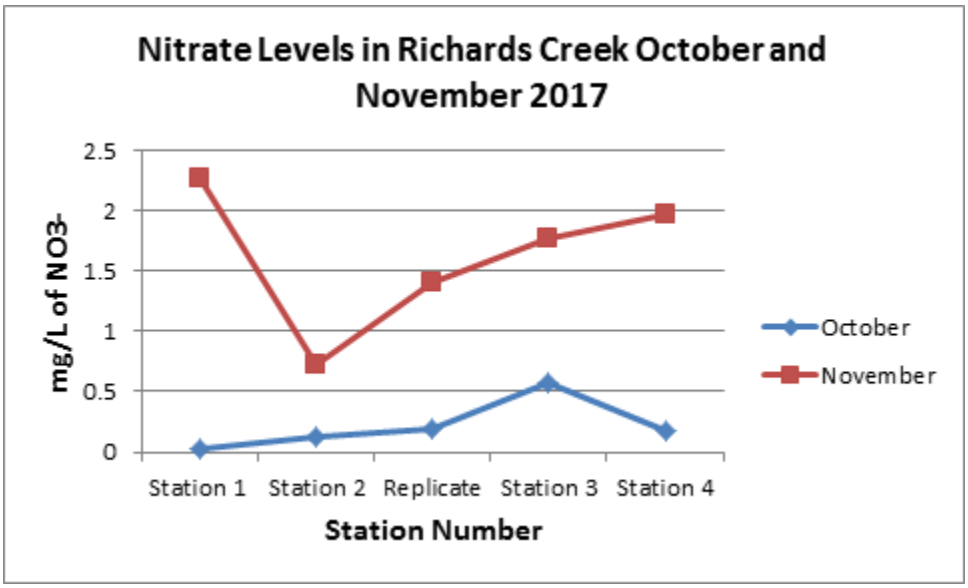


Nitrate

Nitrate results are included in Figure 6 for the October and November sampling events. According to Demers (2016), nitrate levels ranged from 0.08 to 2.15 mg/L for the October results in 2008-2015 and 0.29 to 0.81 mg/L for the November results in 2008-

2015. Nitrate results for October 2017 were within the ranges from previous years and tended to be on the lower end of the spectrum provided by Demers (2016). The November 2017 results contained a higher variation and significantly higher results than those found in 2008-2015. The results provide a general trend of increasing nitrate concentration from Station 1 to Station 4. Station 1 during the November sampling event was found to be very high in comparison to previous results. The replicate sample from Station 2 was included in the figure below to show that there is some variation in the results. This is potentially due to sampling or analysis errors. As each station is located close to agricultural land, the elevated levels could also be attributed to recently fertilized fields followed by heavy precipitation.

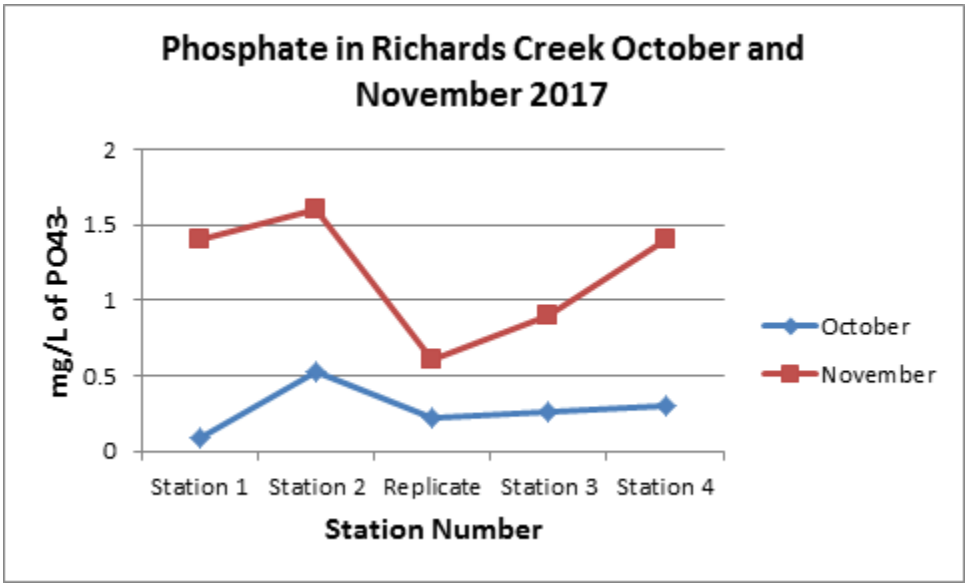
Figure 6. Comparison of Nitrate at Richards Creek between October and November 2017.



Phosphate

Phosphate results are included in Figure 7 for the October and November sampling events. Phosphate results indicate an increase in levels from Station 1 to Station 4. The trip blank included a high result of 0.8 mg/L for the November sample analysis indicating possible equipment contamination that likely skewed the results. The replicate sample from Station 2 was included in the figure below to show that there is some variation in the results. This is potentially due to sampling or analysis errors. As each station is located close to agricultural land, the elevated levels could also be attributed to recently fertilized fields followed by heavy precipitation.

Figure 7. Comparison of Phosphate at Richards Creek between October and November 2017.



Total metals

With the exception of aluminum and iron, most metals were below the applicable water quality guidelines or below the minimum detection limits. The ALS results provide a

detailed breakdown of metals analyzed for Stations 1 to 3 and can be found in appendix 1 and 2 for the October 2017 and November 2017 sampling events respectively.

Stations 1 and 2 in the October 2017 sampling event were found to have a concentration of aluminum at 0.37 mg/L and 0.21 mg/L respectively. Station 3 was found to have a concentration of aluminum of 0.28 mg/L during the November sampling event. These are above the BC water quality guidelines for aquatic life that allow for a maximum of 0.1 mg/L of aluminum. The other stations not noted above were found to be below the BC water quality guidelines for aquatic life.

Station 1 in the October 2017 sampling event was found to have a concentration of iron at 1.07 mg/L. This is above the BC water quality guideline for aquatic life at a maximum concentration of 1.0 mg/L of iron. Station 1 was found to have an iron concentration below the BC Water Quality Guidelines during the November sampling event. The other stations not noted above were found to be below the BC water quality guidelines for aquatic life.

Microbiology

All of the samples collected from Richards Creek contained both fecal and non-fecal coliforms (Table 8). The total coliform numbers were low. The coliform numbers were expected to raise the further downstream but this was not the case. The numbers decreased as you went further downstream.

Table 3. Fecal and non-fecal coliform counts from Richards Creek October 28, 2017.

Colony Units CFUs/100mL	Station 1	Station 2	Station 3	Station 4
Fecal Coliform (Blue)	6	1	11	5
Non-Fecal Coliform (Red)	242	131	131	90
Total	248	132	142	95

Quality Assurance/ Quality Control

ALS instructions were obtained, reviewed and implemented during each sampling event for the samples to be sent to ALS Laboratory. Chain of custody documents were utilized for transportation of samples from VIU to ALS Laboratory.

The samples obtained for the ALS Laboratory analysis were taken from Stations 1, 2 and 3.

All samples were stored within a cooler with ice packs following each sample event. In addition, a trip blank was also included during each sampling event.

Within 96 hours of each sampling event, the samples were analyzed at the VIU lab and transported to ALS Laboratory.

Stream Invertebrate Communities

Taxon Richness and Diversity

Stream invertebrate densities showed a steady trend between the sites. This trend was mainly due to the stable densities of pollution-sensitive (category 1) and low pollution tolerant (category 3) taxa. Overall, the proportion of stream invertebrates made up of pollution sensitive taxa (category 1) ranged from 40 to 84%. Pollution-sensitive taxa only include mayflies, which they are indicators of good water quality, however, with only the one group a poor water quality. Stream invertebrate densities were highest at station 3 (55 animals / m^2) compared to stations 1 and 2 (37-42 animals / m^2). Reasons for the low numbers are unknown, however, may be due to the sampling technique. It is important to note that measurements of stream invertebrate densities can be highly variable, and subject to fluctuations in environmental variables, substrate types, flow regime and sampling efficiency. Average site assessment ratings ranged from 2 to 2.5 (out of 4.0), with an overall average of 2.3 (Tables 4,5,6). This average rating suggests a “marginal” condition that exists for the stream invertebrates during this the fall of 2017. The highest average site assessment rating (2.5) was recorded at station 1 and 3 (Table 4,5). All Invertebrate Survey Field Data Sheets are included in Appendix A.

Conclusions and Recommendations

Results from the fall 2017 environmental monitoring program suggest that water quality of Richards Creek is marginal at best. The general decline in water quality was expected the further downstream samples were taken, especially under the bridge at station 4 (Herd Road crossing). Consistently low dissolved oxygen concentrations in this area were especially of concern, suggesting that hypoxic conditions and poor habitat quality prevailed. However, there was a steady rise in nitrates, phosphates and conductivity. The high nutrient concentrations at station 4 suggest that nutrient enrichment was likely the cause of the reduced environmental quality, as per past years.

The stream invertebrate population and taxa numbers were low, with a marginal rating. Recommendations for Richards Creek are to continue the monitoring of low dissolved oxygen levels, rising trend in nitrate levels and phosphorus concentrations. Continued monitoring at the same time of year and location, and using the same quality control and quality assurance methods will help monitor the water quality and detect changes in environmental quality.

Acknowledgements

We would like to thank Fisheries and Oceans Canada and the Cowichan Valley Regional District for their support with this project. We would also like to thank Dr. Eric Demers and Ms. Kim Ives for their assistance during the sample collection and water analysis in the laboratory, as well as the ALS Environmental Laboratory for their services for water parameter testing. A special thank you to the VIU Biology and Natural Resource Protection department for the use of their equipment and past Natural Resource students for their data for us to build on.

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Appendices

Appendix 1. ALS Laboratory Results for October Sampling Event.

Results Summary L2017715					
Job Reference	ENVIRONMENTAL MONITORING COURSE				
Report To	Eric Demers, Vancouver Island University				
Date Received	3-Nov-2017 8:30				
Report Date	10-Nov-2017 18:04				
Report Version	1				
Client Sample ID			RICHARDS CREEK - STATION 1	RICHARDS CREEK - STATION 2	RICHARDS CREEK - STATION 3
Date Sampled			28-Oct-2017	28-Oct-2017	28-Oct-2017
Time Sampled			9:30	9:30	9:30
ALS Sample ID			L2017715-1	L2017715-2	L2017715-3
Parameter	Lowest Detection Limit	Units	Water	Water	Water

Physical Tests (Water)					
Conductivity	2.0	uS/cm	177	206	218
Hardness (as CaCO3)	0.50	mg/L	68.6	78.5	86.1
pH	0.10	pH	7.58	7.77	7.77
Anions and Nutrients (Water)					
Ammonia, Total (as N)	0.0050	mg/L	0.0209	0.0055	0.0074
Nitrate (as N)	0.0050	mg/L	0.130	0.606	0.591
Nitrite (as N)	0.0010	mg/L	<0.0010	<0.0010	0.0010
Total Nitrogen	0.030	mg/L	0.526	0.695	0.854
Orthophosphate-Dissolved (as P)	0.0010	mg/L	0.0015	0.0040	0.0236
Phosphorus (P)-Total	0.0020	mg/L	0.0321	0.0097	0.0309
N:P	N/A	N/A	16.4	71.6	27.6

Total Metals (Water)					
Aluminum (Al)-Total	0.20	mg/L	0.37	0.21	<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	0.018	0.016	0.014
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	21.0	22.9	23.9
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	1.07	0.427	0.203
Lead (Pb)-	0.050	mg/L	<0.050	<0.050	<0.050

Total					
Lithium (Li)-Total	0.010	mg/L	<0.010	<0.010	<0.010
Magnesium (Mg)-Total	0.10	mg/L	3.93	5.14	6.4034
Manganese (Mn)-Total	0.0050	mg/L	0.283	0.0840	0.0358
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	8.83	9.44
Silver (Ag)-Total	0.010	mg/L	<0.010	<0.010	<0.010
Sodium (Na)-Total	2.0	mg/L	9.5	11.0	11.2
Strontium (Sr)-Total	0.0050	mg/L	0.0756	0.0858	0.0999
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	0.022	0.011	<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
Qualifier Legend					
HTC	Hardness was calculated from Total Ca and/or Mg concentrations and may be biased high (dissolved Ca/Mg results unavailable).				

Appendix 2. ALS Laboratory results for November Sampling Event.

Results Summary L2026212					
Job Reference	ENVIRONMENTAL MONITORING COURSE				
Report To	Eric Demers, Vancouver Island University				
Date Received	23-Nov-2017 8:35				
Report Date	30-Nov-2017 15:30				
Report Version	1				
Client Sample ID			RICHARDS CREEK - STATION 1	RICHARDS CREEK - STATION 2	RICHARDS CREEK - STATION 3
Date Sampled			18-Nov-2017	18-Nov-2017	18-Nov-2017
Time Sampled			9:30	9:30	9:30
ALS Sample ID			L2026212-1	L2026212-2	L2026212-3
Parameter	Lowest Detection Limit	Units	Water	Water	Water
Physical Tests					

(Water)					
Conductivity	2.0	uS/cm	126	137	149
Hardness (as CaCO3)	0.50	mg/L	44.5	50.9	57.5
pH	0.10	pH	7.27	7.48	7.52
Anions and Nutrients (Water)					
Ammonia, Total (as N)	0.0050	mg/L	0.0097	0.0053	0.0081
Nitrate (as N)	0.0050	mg/L	1.06	1.13	1.71
Nitrite (as N)	0.0010	mg/L	0.0010	0.0010	0.0027
Total Nitrogen	0.030	mg/L	1.23	1.33	1.96
Orthophosphate-Dissolved (as P)	0.0010	mg/L	<0.0010	0.0013	0.0415
Phosphorus (P)-Total	0.0020	mg/L	0.0066	0.0060	0.0497
N:P	N/A	N/A	186.4	221.7	39.4

Total Metals (Water)					
Aluminum (Al)-Total	0.20	mg/L	<0.20	<0.20	0.28
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	0.013	0.015	0.016
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	14.1	16.3	17.7
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	0.221	0.148	0.277
Lead (Pb)-	0.050	mg/L	<0.050	<0.050	<0.050

Total					
Lithium (Li)-Total	0.010	mg/L	<0.010	<0.010	<0.010
Magnesium (Mg)-Total	0.10	mg/L	2.26	2.45	3.26
Manganese (Mn)-Total	0.0050	mg/L	0.0423	0.0185	0.0249
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	5.21	5.22	5.87
Silver (Ag)-Total	0.010	mg/L	<0.010	<0.010	<0.010
Sodium (Na)-Total	2.0	mg/L	7.7	7.0	7.5
Strontium (Sr)-Total	0.0050	mg/L	0.0458	0.0511	0.0672
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	0.014
Vanadium (V)-Total	0.030	mg/L	<0.030	<0.030	<0.030
Zinc (Zn)-Total	0.0050	mg/L	<0.0050	<0.0050	0.0091
Qualifier Legend					
HTC	Hardness was calculated from Total Ca and/or Mg concentrations and may be biased high (dissolved Ca/Mg results unavailable).				

Appendix 3

INVERTEBRATE SURVEY FIELD DATA SHEET

Stream Name:	Richards Creek	Date:	28-Oct-17
Station Name:	Paul Farruiga	Flow status: 0.089m/s	Low

Sampler Used:	Number of replicates	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates
Hess	3	3 x 0.09 m² = 0.27 m²

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1 **Pollution Intolerant**	Caddisfly Larva (EPT)		
	Mayfly Nymph (EPT)	19	1
	Stonefly Nymph (EPT)		
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		19	1
Category 2 **Somewhat Pollution Tolerant**	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	10	1
	Watersnipe Larva	4	1
Sub-Total		14	2
Category 3 **Pollution Tolerant**	Aquatic Worm (oligochaete)	5	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)	1	1
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	3	1
Sub-Total		9	3
TOTAL		42	6

Figure 8

INVERTEBRATE SURVEY INTERPRETATION SHEET

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell CT: **32**

DENSITY: Invertebrate density per total area sampled:

From page 1

32	÷	0.09	m^2 =	355.56 / m^2

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (in): **Mayfly Nymph**

SECTION 2 - WATER QUALITY ASSESSMENTS

POLLUTION TOLERANCE INDEX: Sub-total number of taxa found in each tolerance category.

Good	Acceptable	Marginal	Poor
>22	22-17	16-11	<11

3 x D1 + 2 x D2 + D3

3 x 1 + 2 x 2 + 3 = **10**

EPT INDEX: Total number of EPT taxa.

Good	Acceptable	Marginal	Poor
>8	5-8	2-4	0-1

EPT4 + EPT5 + EPT6

0 + 1 + 0 = **1**

EPT TO TOTAL RATIO INDEX: Total number of EPT organisms divided by the total number of organisms.

Good	Acceptable	Marginal	Poor
0.75-1.0	0.50-0.74	0.25-0.49	<0.25

(EPT1 + EPT2 + EPT3) / CT

(0 + 19 + 0) / 32= **0.59**

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell DT: **6**

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the predominant taxon (S1) divided by CT.

Good	Acceptable	Marginal	Poor
<0.40	0.40-0.59	0.60-0.79	0.80-1.0

Col. C for S1 / CT

19 / 32 = **0.59**

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2, S3, S4, S5), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance In	1
EPT Index	1
EPT To Total Ratio	3
Predominant Taxon Ra	4

Average Rating
Average of R1, R2, R3, R4
2.25

Figure 9

INVERTEBRATE SURVEY FIELD DATA SHEET

Stream Name:	Richards Creek	Date:	28-Oct-17
Station Name:	Site: 2	Flow status: 0.208m/s	Low

Sampler Used:	Number of replicates	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates
Hess	3	3 x 0.09 m^2 = 0.27 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1 **Pollution Intolerant**	Caddisfly Larva (EPT)		
	Mayfly Nymph (EPT)	31	1
	Stonefly Nymph (EPT)		
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		31	1
Category 2 **Somewhat Pollution Tolerant**	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	2	1
	Watersnipe Larva	2	1
Sub-Total		4	2
Category 3 **Pollution Tolerant**	Aquatic Worm (oligochaete)	1	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	1	1
Sub-Total		2	2
TOTAL		37	5

Figure 10

INVERTEBRATE SURVEY INTERPRETATION SHEET

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell CT: **37**

DENSITY: Invertebrate density per total area sampled:

From page 1

37	÷	0.09	m^2 =	411.11	/ m^2

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (in): **Mayfly Nymph**

SECTION 2 - WATER QUALITY ASSESSMENTS

POLLUTION TOLERANCE INDEX: Sub-total number of taxa found in each tolerance category.

Good	Acceptable	Marginal	Poor
>22	22-17	16-11	<11

3 x D1 + 2 x D2 + D3

3 x 1 + 2 x 2 + 2 = **9**

EPT INDEX: Total number of EPT taxa.

Good	Acceptable	Marginal	Poor
>8	5-8	2-4	0-1

EPT4 + EPT5 + EPT6

0 + 1 + 0 = **1**

EPT TO TOTAL RATIO INDEX: Total number of EPT organisms divided by the total number of organisms.

Good	Acceptable	Marginal	Poor
0.75-1.0	0.50-0.74	0.25-0.49	<0.25

(EPT1 + EPT2 + EPT3) / CT

(0 + 1 +0) / 37= **0.027**

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell DT: **5**

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the predominant taxon (S1) divided by CT.

Good	Acceptable	Marginal	Poor
<0.40	0.40-0.59	0.60-0.79	0.80-1.0

Col. C for S1 / CT

31 / 37 = **0.838**

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2,S3,S4,S5), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1
Figure 11	

Assessment	Rating
Pollution Tolerance In	1
EPT Index	1
EPT To Total Ratio	2
Predominant Taxon Ra	4

Average Rating
Average of R1, R2, R3, R4
2

INVERTEBRATE SURVEY FIELD DATA SHEET

Stream Name:	Richards Creek	Date:	28-Oct-17
Station Name:	Site: 3	Flow status: 0.112m/s	Low

Sampler Used:	Number of replicates	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates
Hess	4	4 x 0.09 m^2 = 0.36 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1 Pollution Intolerant	Caddisfly Larva (EPT)		
	Mayfly Nymph (EPT)	22	1
	Stonefly Nymph (EPT)		
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		22	1
Category 2 Somewhat Pollution Tolerant	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	9	1
	Watersnipe Larva	6	1
Sub-Total		15	2
Category 3 Pollution Tolerant	Aquatic Worm (oligochaete)	17	1
	Blackfly Larva		
	Leech	1	1
	Midge Larva (chironomid)		
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		18	2
TOTAL		55	5

Figure 12

INVERTEBRATE SURVEY INTERPRETATION SHEET

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell CT: **55**

DENSITY: Invertebrate density per total area sampled:

From page 1

55	÷	0.09	m^2 =	611.11	/ m^2

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (in: **Mayfly Nymph**

SECTION 2 - WATER QUALITY ASSESSMENTS

POLLUTION TOLERANCE INDEX: Sub-total number of taxa found in each tolerance category.

Good	Acceptable	Marginal	Poor
>22	22-17	16-11	<11

3 x D1 + 2 x D2 + D3

3 x 1 + 2 x 2 + 2 = **9**

EPT INDEX: Total number of EPT taxa.

Good	Acceptable	Marginal	Poor
>8	5-8	2-4	0-1

EPT4 + EPT5 + EPT6

0 + 1 + 0 = **1**

EPT TO TOTAL RATIO INDEX: Total number of EPT organisms divided by the total number of organisms.

Good	Acceptable	Marginal	Poor
0.75-1.0	0.50-0.74	0.25-0.49	<0.25

(EPT1 + EPT2 + EPT3) / CT

(0 + 22 +0) / 32= **0.6875**

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell DT: **5**

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the predominant taxon (S1) divided by CT.

Good	Acceptable	Marginal	Poor
<0.40	0.40-0.59	0.60-0.79	0.80-1.0

Col. C for S1 / CT

22 / 32 = **0.6875**

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2,S3 S4,S5), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance In	1
EPT Index	1
EPT To Total Ratio	3
Predominant Taxon R	4

Average Rating
Average of R1, R2, R3, R4
2.25

Figure 13

Shannon Wiener Diversity Index

H_{max}=ln(N)=ln(#) = #.##

Table 4. Macroinvertebrates obtained from *triplicate* samples taken with a Hess sampler at Richards Creek.

Common Name	Column C	Pi(C/T)	In(pi)	Pi*In(pi)
Mayfly Nymph	19	0.45	-0.80	-0.36
Water snipe Lava	4	0.10	-2.3	-0.23
Scud (amphipod)	10	0.24	-1.43	-0.343
Aquatic Worm (oligochaete)	5	0.12	-2.12	-0.254
Flatworm	1	0.02	-3.91	-0.078
Water mite	3	0.07	-2.66	-0.186
TOTAL S=04	42	1	----------	-1.451

H value for Richards Creek: H= -(-1.451) / ln (6) = 0.8098

H = 0.81

Table 5. Macroinvertebrates obtained from *triplicate* samples taken with a Hess sampler at Richards Creek.

Common Name	Column C	Pi(C/T)	In(pi)	Pi*In(pi)
Mayfly Nymph	31	0.83	-0.186	-0.154
Water snipe Lava	2	0.054	-2.92	-0.158
Scud (amphipod)	2	0.054	-2.92	-0.158
Aquatic Worm (oligochaete)	1	0.027	-3.612	-0.098
Water mite	1	0.027	-3.612	-0.098
TOTAL S=12	37	1	---------	-0.666

H value for Richards Creek: H= -(-0.666) / ln (5) = 0.4138

H = 0.414

Table 6. Macroinvertebrates obtained from *quad* samples taken with a Hess sampler at Richards Creek.

Common Name	Column C	Pi(C/T)	In(pi)	Pi*In(pi)
Mayfly Nymph	22	0.4	-0.916	-0.366
Water snipe Lava	6	0.11	-2.207	-0.243
Scud (amphipod)	9	0.163	-1.814	-0.296
Aquatic Worm (oligochaete)	17	0.309	-1.174	-0.363
Leach	1	0.018	-4.017	-0.072
TOTAL S=09	55	1	----------	-1.34

H value for Richards Creek: H= -(-1.34) / ln (5) = 0.8325

H = 0.833