DATA REPORT

Water Quality and Stream Invertebrate Assessment

for Richards Creek, BC,

(Fall 2010)

Report prepared by:

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1. Background

This report documents a water quality and stream invertebrate assessment conducted on Richards Creek, BC, during November 2010.

This study was undertaken by 3rd year undergraduate students attending the Environmental Monitoring (RMOT 306) course at Vancouver Island University (VIU), offered as part of the Bachelor of Natural Resources Protection (Brittany Brooks, Amy Godkin and Janel McNish). Students worked under the supervision of the course instructor, Dr. Eric Demers (Vancouver Island University). This report was compiled by Dr. Eric Demers based on a student group report.

VIU students contributed approximately 125 student-hours to this project, including site visits, project proposal, field sampling, laboratory analyses, and oral and written presentations. Dr. Eric Demers contributed approximately 15 hours for project management and report compilation. Ms. Launi Davis provided 5 hours of laboratory support for this project.

Logistical support was provided by Fisheries and Oceans Canada (DFO). Funding for field expenses and analytical processing of water samples was provided by the BC Conservation Foundation's "Living Rivers - Georgia Basin / Vancouver Island" program, and Fisheries and Oceans Canada. ALS Laboratory (Vancouver, BC) provided reduced rates on their analytical services for this project.

2. Introduction

Richards Creek is located in the Somenos Basin, near the city of Duncan, B.C. It is approximately 9.2 km long and flows south-westerly from Crofton Lake to Somenos Lake. Richards Creek provides year round rearing and spawning habitat for salmonids. However, agricultural activities combined with low gradients and low summer flows in lower reaches of Richards Creek have contributed to elevated nutrient loads and hypoxic water conditions (Guimond and Sheng, 2005).

This report documents a water quality and stream invertebrate assessment conducted on Richards Creek during November 2010.

Specific objectives for this study of Richards Creek included:

- establish 4 water quality sampling stations;
- obtain field measurements of water quality at the 4 sampling stations during two sampling events (early and late November 2010);
- obtain water samples from each sampling station during two sampling events (early and late November 2010) for detailed laboratory analyses; and,
- collect stream invertebrate samples at 3 sampling stations during one sampling event (early November 2010) for analysis at Vancouver Island University.

3. Methods

3.1. Study Site

This project was conducted on Richards Creek which is located northeast of the city of Duncan, BC (Figure 1). Richards Creek flows southeasterly from Crofton Lake to Richards Trail, then southwesterly, emptying into the northeast end of Somenos Lake. The upstream half of Richards Creek flows through residential areas and riparian forest, while the downstream half flows through agricultural lands. The Cowichan Valley Regional District (CVRD) regulates flow from the Crofton Lake reservoir into Richards Creek.

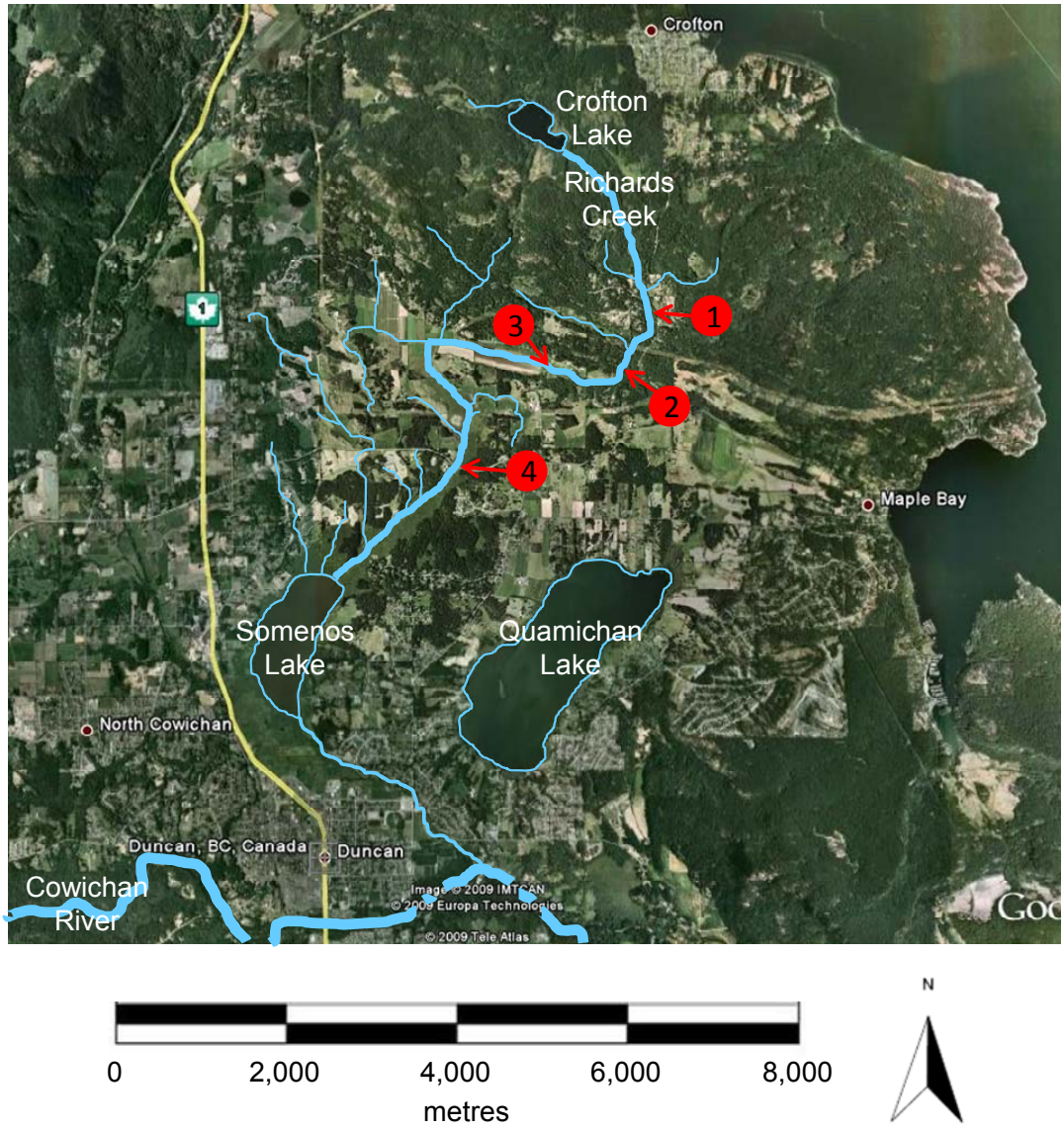

Figure 1. Approximate location of the sampling stations used for water quality and stream invertebrate assessments on Richards Creek during November 2010. Table 1 provides details of the specific location of each station. Table 2 details the sampling activities conducted at each station. This map was obtained from Google Earth. Map scale is approximated.

3.1.1. Sampling Stations

Four sampling stations were established on Richards Creek during November 2010 (Tables 1 and 2; Figure 1). The location of each station was chosen to provide adequate coverage for the length of the creek and to repeat sampling at stations previously used by DFO. Stations were numbered from upstream (Station 1) to downstream (Station 4). All stations were easily accessed via foot paths or road crossings. Station 1 was located at a culvert crossing on Escarpment Way, approximately 2.3 km downstream of Crofton Lake. Station 2 was located at the end of Rice Road on Innisvale Farm, and included a concrete weir and water depth gauge. Station 3 was located at a culvert crossing on Richards Trail, at the east corner of Pastula Farm. Station 4 was located at a road bridge on Herd Road, approximately 2.0 km upstream of Somenos Lake. Stations 1-3 consisted of shallow and gentle riffle sections, while station 4 was deep and steep-sided.

Table 1. Description of the sampling stations used for water quality and stream invertebrate assessments on Richards Creek during November 2010. All northing and easting coordinates are based on zone 10U.

Station	UTM Coordinates		Approximate Distance from Crofton Lake (km)	General Location
	Northing	Easting		
1	5409420	452560	2.3	Escarpment Way crossing
2	5408622	452083	3.5	End of Rice Road, weir and water depth gauge
3	5408795	451331	4.2	Richards Trail crossing
4	5407637	450282	7.2	Herd Road crossing

3.1.2. Sampling Schedule

Field sampling was conducted on 1 and 22 November 2010. For this study, samples were collected for water quality analyses, microbiology and stream invertebrate assessment. Table 2 lists the specific activities conducted at each station during each sampling event. Microbiology and stream invertebrate assessments were only completed during the early November event. Photographs showing site conditions and sampling activities are included in Appendix 1.

3.2. Water Quality

3.2.1. Field Measurements

Water quality sampling events were conducted on 1 and 22 November 2010. At each sampling station, field measurements of water temperature (to the nearest 0.01 ^{o}C), dissolved oxygen (to the nearest 0.01 mg/L), conductivity (to the nearest 1 µSiemens/cm) and pH (to the nearest 0.01

pH unit) were obtained with a YSI 556 MPS electronic probe. The electronic probe was placed directly in the channel water.

Basic hydrological measurements were taken at stations 1 and 3 during both sampling events. Water velocity (in m/s) was measured along a 5-m stream length. A water-filled ping-pong ball was dropped slightly upstream of the stream length and allowed to float downstream through the stream length. A stopwatch was used to measure the travel time of the ball between the upstream and downstream ends of the stream length. The average travel time from 5 passes was used to calculate average water velocity.

Stream wetted widths were measured with a metered tape to the nearest 0.1 m, and wetted depths were measured (along the same wetted widths) with a meter stick to the nearest 0.01 m. Total cross-sectional areas (in m^2) were calculated as the sum of the areas of cross-section polygons. Stream discharge (in m^3/s) was obtained as the product of mean water column velocity and cross sectional area.

Table 2. Water quality and stream invertebrate sampling activities conducted at each station on Richards Creek during November 2010. The symbols "A" or "B" indicate whether samples / measurements were taken during the early or late November sampling events, respectively.

Station	Water Quality				Stream Invertebrates
	Field Measurements	VIU Analyses	ALS Lab Analyses	Microbiology	
1	A, B	A [1], B [1]	A, B	A	A
2	A, B	A, B	A, B	A	A
3	A, B	A, B	A, B	A	A
4	A, B	A, B	A, B	A [2]	---

Note: [1] Duplicate samples for analysis at the VIU Laboratory were collected at station 1 during the early and late November sampling events, respectively.
[2] Duplicate samples for microbiology were collected at station 4 during the early November sampling event.

3.2.2. Water Sampling

During each sampling event, two sets of water samples were collected for laboratory analyses: one set was transported for analysis at Vancouver Island University (VIU), and another set was shipped for analysis by ALS Laboratory, in Vancouver, BC.

Water samples for analysis at VIU were collected from all stations (Table 2). At each station, a clean pre-labelled 500-ml plastic bottle was rinsed 3 times and then used to collect a water sample (Table 3). Duplicate samples were collected at station 1 for analysis at the VIU Laboratory during the early and late November sampling events, respectively. All water samples

were obtained while standing on the stream bank or within the stream channel by immersing the containers just below the water surface while facing upstream. Care was taken not to disturb the bottom sediments. All water samples were kept in a cooler and stored at approximately 4^{o}C. Laboratory analyses were conducted at VIU within 48 hours of sampling.

Samples for analysis by ALS Laboratory were collected from all stations during both sampling events (Table 2). At each station, water samples were collected in three clean laboratory-supplied and pre-labelled sample containers (Table 3). All samples were obtained while standing on the stream bank or within the stream channel by directly immersing the containers just below the water surface while facing upstream. Care was taken not to disturb the bottom sediments. Samples for analysis of nutrients and total metals were preserved with laboratory-supplied sulphuric acid and nitric acid, respectively. Bottles with preservatives were inversed five times for adequate mixing. All water samples were stored in a cooler on site, and shipped with ice packs within 72 hours for laboratory analyses at ALS Laboratory.

Quality control samples (one trip blank) were also included during both sampling events for analysis at the VIU Laboratory. The trip blank was prepared at the VIU Laboratory and consisted of distilled water placed in a 500-ml plastic bottle. The trip blank bottle was transported to the sampling stations, but remained unopened.

Table 3. Sampling containers and preservatives used for water quality samples taken from Richards Creek during November 2010. All containers and preservatives for analysis by ALS Laboratory were provided by ALS Laboratory, Vancouver, BC.

Analytical Parameters	Container	Preservative	Analysed by
Total alkalinity, turbidity	500 ml plastic	None	VIU
Conductivity, pH, total hardness	1 L plastic	None	ALS Laboratory
Nutrients	250 ml amber glass	Sulphuric acid	ALS Laboratory
Total metals	250 ml plastic	Nitric acid	ALS Laboratory

3.2.3. VIU Laboratory Analyses

Water samples transported to Vancouver Island University were analysed for total alkalinity and turbidity. Total alkalinity (as $CaCO_3$) was measured to the nearest 0.1 mg/L using the HACH AL-DT digital titration method. Turbidity was measured to the nearest 1 FAU (Formazin attenuation units) using a HACH DR2000 Spectrophotometer (Method 8006).

3.2.4. ALS Laboratory Analyses

Water samples submitted for external analyses were processed as per ALS Laboratory standard analytical procedures. The analytes were: conductivity, total hardness, pH, nutrients (ammonia, nitrite, nitrate, orthophosphate and total phosphorus), and total metals (31 metals).

3.2.5. Quality Assurance / Quality Control

Throughout this study, measures were taken to ensure that potential contamination of water samples was minimized. This included using only clean and rinsed containers, preserving samples as prescribed by the analytical laboratory, and storing collected samples in well-labelled containers. Duplicate sampling provided an estimate of the overall precision associated with the field technique and laboratory analysis. The inclusion of trip blanks provided means of detecting any widespread contamination resulting from the container (including caps) or field procedures.

3.2.6. Data Analyses – Comparison with Applicable Guidelines

Water quality results were compared with the applicable provincial water quality guidelines for the protection of freshwater life. The BC Water Quality Guidelines are the maximum allowable concentration (for potential acute effects) and the 30-day average concentration (for potential chronic effects) (BCMWLAP 1998a, 1998b). These guidelines were applicable to all sampling stations.

It is important to note that for some metal parameters, analytical detection limits were above applicable guidelines. These include aluminium, antimony, arsenic, cadmium, chromium, cobalt, copper, lead, nickel, selenium, silver, thallium and vanadium. For these metals, measured values reported to be below method detection limits cannot be assumed to be below the applicable guidelines.

3.3. Microbiology

Water samples for total and fecal coliform enumeration were collected from each sampling station on 1 November 2010 (Table 2). At each station, a sterile pre-labelled 120-ml Whirl-Pak® bag was used to collect a 100-ml water sample by directly immersing the bag by hand just below the water surface while facing upstream. Duplicate samples were collected at station 4. All samples were stored in a cooler with ice packs and transported within 48 hours to Vancouver Island University for laboratory analysis.

In the laboratory, water samples were tested for total coliform and fecal coliform (*Escherichia coli* or *E. coli*) using the m-coliBlue24 membrane filtration method (Millipore Corporation). A 100-ml volume of sample water was filtered through a 47-µm membrane filter (marked with 3-mm gridlines) using a vacuum pump. The filtration apparatus was then rinsed with approximately 5 ml of sterile water. A filtration blank was also completed with 10 ml of sterile water using the same filtration procedures. Each membrane filter (including the blank) was then transferred to a Petri plate containing an absorbent pad saturated with m-ColiBlue24 broth. All membrane filters were incubated at 37°C for 20 hours (until bacterial colonies were clearly visible).

Upon completion of the incubation period, membrane filters were then examined for bacterial colonies under a dissection microscope (16X magnification). A red or blue colony represents a total coliform "positive" result (Table 4). A blue colony specifically represents an *E. coli* "positive" result. A clear or white colony represents a total coliform negative result.

All colonies present on a membrane filter were counted and expressed as CFU (colony forming units) per 100-ml of sample water.

Table 4. Possible outcomes of the m-coliBlue24 membrane filtration method.

Bacteria Type	Positive Result	Negative Result
Total coliform	Red or blue colony	Clear or white colony No colony
E. coli	Blue colony only	Non-blue colony

3.4. Stream Invertebrates

3.4.1. Sampling Stations

Stream invertebrate samples were collected from stations 1, 2 and 3 on 1 November 2010 (Table 1; Figure 1). The sampling stations were selected based on hydrological characteristics, apparent substrate uniformity, space available for replicate samples and site access. At the time of sampling, all stations consisted of shallow riffles (water depth ~10-25 cm), with water velocity of <0.5 m/s, and primarily sand and gravel substrate.

3.4.2. Invertebrate Sampling

At each station, three replicate samples were obtained using a Hess sampler as per the Pacific Streamkeepers procedures (Taccogna and Munro 1995). Each site was approached by walking from downstream. The cylindrical, 34-cm diameter Hess sampler was hand-pressed into the substrate to isolate a circular 0.09-m^2 sampling area. All stones and debris 5 cm or larger within the sampling area were held under water in front of the collecting net and rubbed gently by hand to dislodge invertebrates. Cleaned stones and debris were then placed downstream of the sampling area. The streambed was then gently agitated to a depth of 5 cm to loosen any remaining invertebrates. The content of the collecting net was then transferred into a 125-ml plastic sample jar. The net was carefully inspected to ensure all contents were transferred into the sample jar. Samples were stored in a cooler and transported to Vancouver Island University, where laboratory analyses were completed within 48 hours of sampling.

3.4.3. VIU Laboratory Analyses

Laboratory procedures and identification also followed the Pacific Streamkeepers procedures (Taccogna and Munro 1995). The replicate samples from each station were combined into a single composite sample per station. The contents of all invertebrate sample jars from a station were poured into a shallow white tray. Invertebrates were sorted into apparent taxonomic groups. Identification to the appropriate taxonomic level (as prescribed by the Pacific Streamkeepers procedures) was confirmed using a dissecting microscope. The number of invertebrates and the number of distinguishable subgroups within each broad taxonomic group were recorded on a Pacific Streamkeeper Invertebrate Survey Field Data Sheet. From these

records, various useful metrics were calculated for each station, including: total density (number per m^2), total number of taxonomic groups, predominant taxonomic group, Pollution Tolerance Index, EPT (Ephemeroptera-Plecoptera-Trichoptera) Index, EPT to Total Ratio Index, Predominant Taxon Ratio Index, and overall Site Assessment Rating.

4. Results

The discharge measurements (Table 5) and field observations (see photographs in Appendix 1) for Richards Creek suggest that water level was near bankfull during both sampling events.

Average air temperature during the 10-day period prior to each sampling event was 9.4°C and 0.4 °C for the early and late November sampling events, respectively (data for Nanaimo Airport retrieved from http://climate.weatheroffice.gc.ca). Total rainfall during the 10-day period prior to the early November sampling event was 39 mm. Total precipitation during the 10-day period prior to the late November sampling event included 24 mm of rain and 32 cm of snow, with 24 cm of snow on 19 November 2010.

4.1. Water Quality

4.1.1. Field Measurements and VIU Laboratory Analyses

Water temperature averaged 10.4°C and 2.2°C during the early and late November sampling events, respectively (Table 5). The decrease in water temperature between events reflected a similar decrease in air temperature between sampling events. During both sampling events, dissolved oxygen levels at stations 1-3 were above the minimum guideline of 9.0 mg/L for early fish life stages (RISC 1998). Dissolved oxygen levels at station 4 was below 9.0 mg/L during both sampling events. Dissolved oxygen level was especially low during the early November sampling event, when it represented 22% of saturation. The low dissolved oxygen concentration observed at station 4 suggests that hypoxic conditions existed at the time of sampling, possibly due to negligible water movement and elevated ecosystem respiration at this location. Similar results were found in previous students conducted in 2008 (VIU, 2009) and 2009 (VIU, 2010).

Mean conductivity increased from 143 to 156 µS/cm between the early and late November sampling events. During both sampling events, there was a general increase from upstream to downstream stations. Water pH was slightly acidic to neutral at most stations (range: 6.64-7.24), with the exception of station 1 during the late November sampling event when pH was 5.38.

Total alkalinity averaged 53 and 49 mg/L during the early and late November sampling events, respectively (Table 5). During both sampling events, there was a general increase from upstream to downstream stations. Overall, total alkalinity was above 20 mg/L during both sampling events, indicating "low acid sensitivity" as defined by RISC (1998).

Turbidity levels averaged 11 and 4 FAU during the early and late November sampling events, respectively (Table 5). The higher turbidity level during early November may have resulted from the watershed flushing effect of the rainfall that preceded the sampling event.

A comparison of the water quality results from the duplicate samples taken at station 1 indicates that most values were within ±30% of each other.

Table 5. Field measurements and laboratory results (VIU Laboratory) for water samples taken from four stations on Richards Creek during 1 and 22 November 2010. Results for total alkalinity and turbidity at station 1 during both sampling events represent the average of duplicate samples.

	Field Measurements					VIU Laboratory	
Station	Discharge (m^3/s)	Temperature (^oC)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH	Total Alkalinity (mg/L $CaCO_3$)	Turbidity (FAU)
			1 November 2010				
1	0.19	10.85	9.47	120	7.02	45	10
2		10.26	10.80	141	6.55	54	11
3	0.20	10.41	10.70	161	6.76	59	17
4		9.92	2.50	150	6.37	55	6
			22 November 2010				
1	0.15	2.63	13.12	135	5.38	41	4
2		2.44	13.73	146	7.24	46	2
3	0.39	2.17	13.61	162	6.64	52	5
4		1.71	8.81	182	6.67	58	5

4.1.2. ALS Laboratory Analyses

Water quality results from ALS Laboratory were compared to the BC Provincial water quality guidelines for the protection of aquatic life (Table 6).

The conductivity measurements from ALS Laboratory were consistent with the field measurements obtained with the electronic probe and differed by ≤2%.

Total hardness followed similar trends as conductivity, namely a general increase from upstream to downstream stations and a slight increase between sampling events. Total hardness averaged 53.2 and 57.8 mg/L during the early and late November sampling events, respectively. Overall, total hardness was below or near 60 mg/L during both sampling events, indicating "soft water" as defined by RISC (1998).

Field measurements of pH (range: 5.38-7.24) were generally more variable than the ALS Laboratory results (range: 6.98-7.75). This discrepancy possibly reflects improper calibration, differences in air space content among sampling containers and/or time elapsed between sampling and laboratory analysis.

All nutrient levels were below applicable guidelines and/or below detection limits. During both sampling events, the highest ammonia concentrations were found at the downstream stations (0.075 mg/L at station 3 during early November and 0.064 mg/L at station 4 during late November). Nitrate concentrations ranged from 0.434 to 0.776 mg/L during this study, with the exception of station 4 during the early November sampling event where nitrate level was 0.008 mg/L. Nitrite levels were near or below detection limits (i.e., <0.002 mg/L) at all stations during both sampling events, except at station 3 during early November where nitrite level was 0.011 mg/L.

Orthophosphate were below detection limit (i.e., ≤0.001 mg/L) at stations 1-2 during both sampling events, but not at stations 3 and 4. The highest orthophosphate levels occurred during early November and reached 0.226 mg/L at station 3. Total phosphorus followed a similar pattern as orthophosphate, with the highest levels (0.299 mg/L) observed at station 3 during early November. Overall, total phosphorus levels indicated "oligotrophic" conditions at stations 1 and 2, and "eutrophic" conditions (≥0.025 mg/L) at stations 3 and 4 during both sampling events (as defined by RISC (1998)).

With the exception of aluminium and iron, all metals were below applicable guidelines. Total aluminium exceeded the applicable guidelines at station 1-3 during the early November sampling event and at stations 3 and 4 during the late November sampling event. Total iron exceeded the applicable guidelines at station 3 during the early November sampling event.

It should be noted that total metal analyses measure the combined amount of metals dissolved in water and bound to particles. In general, dissolved metals are more bio-available (hence toxicologically available) than metals that are bound to particles. The dissolved fraction of total metals in water is often lower than 100%.

Table 6. Laboratory results (ALS Laboratory) for water samples taken from 4 stations on Richards Creek during 1 and 22 November 2010. All values are expressed in mg/L unless specified otherwise. The values enclosed in boxes exceeded at least one of the applicable water quality guidelines. See additional notes on the next page.

	BC Water Quality Guidelines [a]		1 November 2010				22 November 2010			
	BC Max	BC 30-day Mean								
Variable	mg/L	mg/L	1	2	3	4	1	2	3	4
General/Physical										
Conductivity (µS/cm)			118	138	158	148	135	146	160	182
Hardness, Total			43.2	51.6	59.4	58.4	48.1	53.9	60.2	68.9
pH (pH units)	6.5 - 9.0		7.25	7.48	7.48	6.98	7.54	7.75	7.53	7.38
Nutrients										
Ammonia-N	8.88 [b]	1.71 [b]	0.0065	<0.0050	0.0748	0.0374	0.0068	0.0054	0.0088	0.0638
Nitrate (as N)	31.3	3	0.756	0.634	0.776	0.008	0.447	0.434	0.621	0.767
Nitrite (as N)	0.06 [c]	0.02 [c]	0.0011	<0.0010	0.0112	0.0017	<0.0010	<0.0010	0.0015	0.0093
Ortho Phosphate (as P)			<0.0010	<0.0010	0.2260	0.1170	<0.0010	<0.0010	0.0527	0.0674
Total Phosphorus			0.030	0.030	0.299	0.191	0.007	0.008	0.071	0.107
Total Metals										
Aluminum (Al) [m]	0.10 [d]	0.05 [d]	0.62	0.60	0.89	<0.20	<0.20	<0.20	0.24	0.27
Antimony (Sb) [m]	0.02		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic (As) [m]	0.005		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium (Ba)	5	1	0.016	0.016	0.019	0.013	0.011	0.012	0.012	0.014
Berylium (Be)	0.0053		<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth (Bi)			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron (B)	1.2		<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium (Cd) [m]	0.00002 [e]		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (Ca)			13.3	15.9	17.1	16.3	15.2	17.0	18.1	20.7
Chromium (Cr) [m]	0.001 [f]		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt (Co) [m]	0.11	0.004	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu) [m]	0.006 [g]	0.002 [g]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron (Fe)	1.0		0.803	0.775	1.030	0.545	0.233	0.225	0.316	0.472
Lead (Pb) [m]	0.028 [h]	0.004 [h]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium (Li)	0.87	0.096	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium (Mg)			2.42	2.92	4.05	4.26	2.49	2.80	3.65	4.21
Manganese (Mn)	1.02 [i]	0.80 [i]	0.108	0.068	0.058	0.157	0.056	0.033	0.034	0.020
Molybdenum (Mo)	2	1	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel (Ni) [m]	0.025 [j]		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus (P)			<0.30	<0.30	0.31	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)	373		<2.0	<2.0	2.3	<2.0	<2.0	<2.0	<2.0	<2.0
Selenium (Se) [m]		0.002	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon (Si)			4.98	5.65	6.27	2.50	5.29	5.61	5.92	5.12
Silver (Ag) [m]	0.0001 [k]	0.00005 [k]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium (Na)			6.7	7.0	7.8	8.9	7.4	6.9	7.5	7.9
Strontium (Sr)			0.045	0.054	0.073	0.090	0.046	0.051	0.069	0.094
Thallium (Tl) [m]	0.0003		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin (Sn)			<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium (Ti)	2		0.032	0.029	0.039	<0.010	<0.010	<0.010	0.013	0.013
Vanadium (V) [m]	0.006		<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc (Zn)	0.033 [l]	0.0075 [l]	<0.0050	0.0056	0.0057	0.0064	<0.0050	<0.0050	<0.0050	<0.0050

Table 6. (Continued)

NOTES:

Results are expressed as mg/L except for pH and conductivity.
"<" means less than the detection limit.

[a] BC Water Quality Guidelines (WQG) compiled from
http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html
http://www.env.gov.bc.ca/wat/wq/BCguidelines/working.html

[b] Total ammonia guideline is dependent on water temperature and pH of tested water.

[c] Nitrite guideline is for chloride concentration < 2 mg/L.

[d] Aluminum guidelines for pH ≥ 6.5.

[e] The maximum cadmium guideline is $0.001 * 10^{\{0.86 [\log(\text{hardness})] - 3.2\}}$ mg/L.

[f] Chromium guideline is for the more toxic Chromium VI.

[g] The maximum copper guideline is 0.001 * [0.094(hardness) + 2] mg/L.
The 30-day mean copper guideline is for hardness < 50 mg/L.

[h] The maximum lead guideline is $0.001 * e^{\{1.273 [\ln(\text{hardness})] - 1.46\}}$ mg/L.
The 30-day mean lead guideline is $0.001 * [3.31 + e^{\{1.273 [\ln(\text{hardness})] - 4.704\}}]$ mg/L.

[i] The maximum manganese guideline is 0.01102 * (hardness) + 0.54 mg/L.
The 30-day mean manganese guideline is 0.0044 * (hardness) + 0.605 mg/L.

[j] Nickel guideline is for hardness < 60 mg/L.

[k] Silver guidelines are for hardness < 100 mg/L.

[l] Zinc guidelines are for hardness < 90 mg/L.

[m] Analytical detection limits were above applicable guidelines for these metals.

4.2. Microbiology

All samples collected from Richards Creek contained some coliform bacteria (Table 7). Total coliform levels generally increased with distance downstream, and ranged from 508 CFU / 100 ml at station 1 to 2341 CFU / 100 ml at station 3. The proportion of total coliform made up of *E. coli* bacteria was moderate at stations 1 and 4, but greatly exceeded 50% at stations 2 and 3.

The filtration blank completed with sterile water did not produce any bacterial colonies.

Table 7. Total coliform and *E. coli* counts from water samples taken at five stations on Richards Creek during 1 November 2010. All values are expressed as CFU (colony forming units) per 100 ml. No microbiology samples were collected on 22 November 2010.

Station	Total Coliform	*E. coli*	% *E. coli*
1	508	216	42.5%
2	1156	824	71.3%
3	2341	1695	72.4%
4	1292	525	40.7%
Filtration blank	0	0	---

4.3. Stream Invertebrates

A total of 467 stream invertebrates representing 11 broad taxonomic groups were counted at three stations on Richards Creek during 1 November 2010 (Table 8; Figure 2; Appendix 2). Animal density was relatively consistent among stations, with a range of 533-637 animals/m^2. Overall, aquatic worms (oligochaetes) was the most common taxonomic group, although mayfly nymphs, stonefly nymphs and caddisfly larvae were also abundant. Taxonomic diversity was relatively similar among stations.

Site assessment ratings ranged from 3.00 to 3.25 suggesting "acceptable" invertebrate community abundance and diversity at all stations. The consistent representation of pollution-sensitive mayfly nymphs, stonefly nymphs and caddisfly larvae (EPT taxa: 37-42% of total abundance) indicated generally "moderately favourable" environmental conditions at all stations.

Table 8. Abundance and density of stream invertebrates obtained from four replicate samples taken at three stations on Richards Creek on 1 November 2010. Overall site assessment ratings are also provided for each station (out of a maximum rating of 4.00). Invertebrate Survey Field Data Sheets are included in Appendix 2. No stream invertebrate samples were collected on 22 November 2010.

Pollution Tolerance	Invertebrate Taxa	Station 1	Station 2	Station 3
Category 1 Pollution Intolerant	Caddisfly Larva	13	19	24
	Mayfly Nymph	27	28	11
	Stonefly Nymph	21	16	29
	Dobsonfly (hellgrammite)	0	1	0
Category 2 Somewhat Pollution Intolerant	Clam, Mussel	5	0	6
	Cranefly Larva	10	19	19
	Scud (Amphipod)	16	0	1
	Watersnipe Larva	0	2	0
Category 3 Pollution Tolerant	Aquatic Worm (oligochaete)	49	63	71
	Midge Larva (chironomid)	0	0	6
	Water Mite	3	3	5
	Total Abundance	144	151	172
	Density (number / m^2)	533	559	637
	Site Assessment Rating	3.00	3.00	3.25

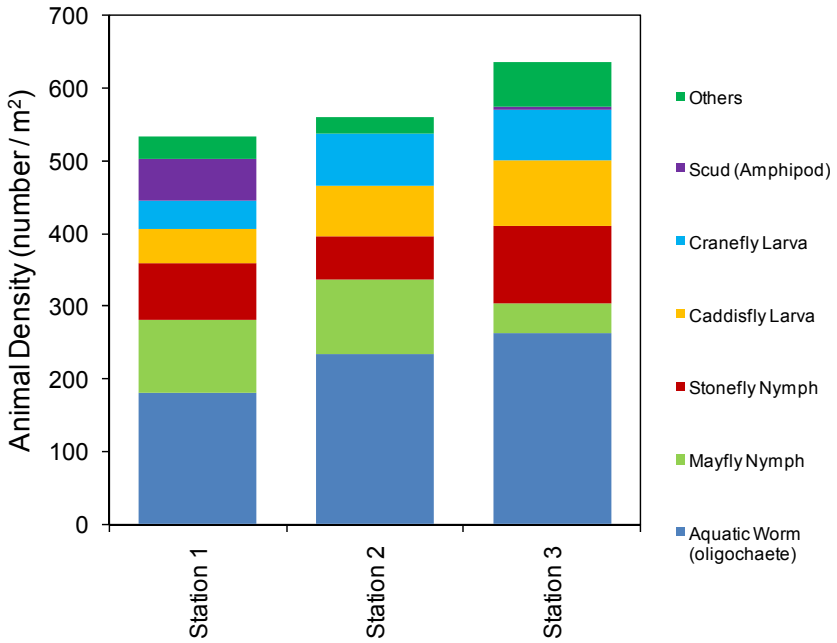

Figure 2. Density of stream invertebrates obtained from three replicate samples taken at three stations on Richards Creek during 1 November 2010. The "Other" category includes scud (amphipod), watersnipe larva, aquatic worm (oligochaete), midge larva (chironomid) and water mite in decreasing order of abundance. Data are summarized in Table 8 and Invertebrate Survey Field Data Sheets are included in Appendix 2.

5. Acknowledgements

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7. Appendices

APPENDIX 1. Photographs showing site conditions and sampling activities conducted on the Richards Creek. Note the significant change in water velocity and discharge between sampling events.

Photo 1. Richards Creek at the Escarpment Way crossing (station 1) on 1 November 2010.

Photo 2. Richards Creek at the end of Rice Road (station 2) on 1 November 2010.

APPENDIX 1. (Continued)

Photo 3. Richards Creek at Richards Trail (station 3) on 1 November 2010.

Photo 4. Richards Creek at the Herd Road Bridge (station 4) on 1 November 2010.

APPENDIX 2. Invertebrate Survey Field Data Sheet completed for replicate stream invertebrate samples collected at Stations 1, 2 and 3 on Richards Creek on 1 November 2010.

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Richards Creek		Date: 1 November 2010
Station Name: **Station 1**		Flow status: Moderate
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.09 x 3 = 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)	13	2
	Mayfly Nymph (EPT)	27	1
	Stonefly Nymph (EPT)	21	1
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		61	4
Category 2 / Somewhat Pollution Tolerant	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel	5	1
	Cranefly Larva	10	2
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	16	1
	Watersnipe Larva		
Sub-Total		31	4
Category 3 / Pollution Tolerant	Aquatic Worm (oligochaete)	49	2
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	3	1
Sub-Total		52	3
TOTAL		144	11

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 144

DENSITY: Invertebrate density per square metre:

144 ÷ 0.27 = 533

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (Col. C): Aquatic Worm (oligochaete)

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 4 + 2 x 4 + 3 = 23

EPT INDEX: Total number of EPT taxa.

Good	Accpetable	Marginal	Poor
>8	5-8	2-5	0-1

EPT4 + EPT5 + EPT6

2 + 1 + 1 = 4

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

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

(EPT1 + EPT2 + EPT3) / CT

(13 + 27 + 21) / 144 = 0.42

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 11

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S3) divided by CT.

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

Col. C for S3 / CT

49 / 144 = 0.34

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S4, S5, S6, S8), then calculate the average.

Assessment Rating	
Good	4
Accpetable	3
Marginal	2
Poor	1

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

Average Rating
3.00

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Richards Creek		Date:	1 November 2010
Station Name:	**Station 2**		Flow status:	Moderate
Sampler Used:	Number of replicates	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates		
Hess	3	0.09 x 3 = 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)	19	2
	Mayfly Nymph (EPT)	28	3
	Stonefly Nymph (EPT)	16	2
	Dobsonfly (hellgrammite)	1	1
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		64	8
Category 2 **Somewhat Pollution Tolerant**	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	19	1
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)		
	Watersnipe Larva	2	1
Sub-Total		21	2
Category 3 **Pollution Tolerant**	Aquatic Worm (oligochaete)	63	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	3	1
Sub-Total		66	2
TOTAL		151	12

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 151

DENSITY: Invertebrate density per square metre:

151 ÷ 0.27 = 559

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (Col. C): Aquatic Worm (oligochaete)

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 8 + 2 x 2 + 2 = 30

EPT INDEX: Total number of EPT taxa.

Good	Accpetable	Marginal	Poor
>8	5-8	2-5	0-1

EPT4 + EPT5 + EPT6

2 + 3 + 2 = 7

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

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

(EPT1 + EPT2 + EPT3) / CT

(19 + 28 + 16) / 151 = 0.42

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 12

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S3) divided by CT.

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

Col. C for S3 / CT

63 / 151 = 0.42

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S4, S5, S6, S8), then calculate the average.

Assessment Rating	
Good	4
Accpetable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	4
EPT Index	3
EPT To Total Ratio	2
Predominant Taxon Ratio	3

Average Rating
3.00

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Richards Creek		Date: 1 November 2010
Station Name: **Station 3**		Flow status: Moderate
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.09 x 3 = 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)	24	5
	Mayfly Nymph (EPT)	11	2
	Stonefly Nymph (EPT)	29	2
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		64	9
Category 2 Somewhat Pollution Tolerant	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel	6	1
	Cranefly Larva	19	2
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	1	1
	Watersnipe Larva		
Sub-Total		26	4
Category 3 Pollution Tolerant	Aquatic Worm (oligochaete)	71	2
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	6	1
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	5	1
Sub-Total		82	4
TOTAL		172	17

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 172

DENSITY: Invertebrate density per square metre:

172 ÷ 0.27 = 637

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (Col. C): Aquatic Worm (oligochaete)

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 9 + 2 x 4 + 4 = 39

EPT INDEX: Total number of EPT taxa.

Good	Accpetable	Marginal	Poor
>8	5-8	2-5	0-1

EPT4 + EPT5 + EPT6

5 + 2 + 2 = 9

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

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

(EPT1 + EPT2 + EPT3) / CT

(24 + 11 + 29) / 172 = 0.37

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 17

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S3) divided by CT.

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

Col. C for S3 / CT

71 / 172 = 0.41

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S4, S5, S6, S8), then calculate the average.

Assessment Rating	
Good	4
Accpetable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	4
EPT Index	4
EPT To Total Ratio	2
Predominant Taxon Ratio	3

Average Rating
3.25