DATA REPORT

Water Quality and Stream Invertebrate Assessment

for Richards Creek, BC,

(Fall 2008)

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 October-November 2008.

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 (Laura Brown, Terry McDonald and Matthew Rochetta). 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 48 student-hours to this project, including site visits, project proposal, field sampling, laboratory analyses, and oral and written presentations. Dr. Eric Demers contributed approximately 10 hours for project management and report compilation. Ms. Sarah Greenway 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, BC Living Rivers Trust Fund 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, located 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).

During 2008, DFO conducted habitat restoration on Richards Creek involving summer flow augmentation. A need was identified for continued monitoring of water and habitat quality of Richards Creek. Therefore, this report documents a water quality and stream invertebrate assessment conducted on Richards Creek during October-November 2008.

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 (October, November 2008);
- obtain water samples from each sampling station during two sampling events (October, November 2008) for detailed laboratory analyses; and,
- collect stream invertebrate samples at 3 sampling stations during one sampling event (October 2008) for analysis at Vancouver Island University.

3. Methods

3.1. Study Site

This project was conducted on Richards Creek 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.

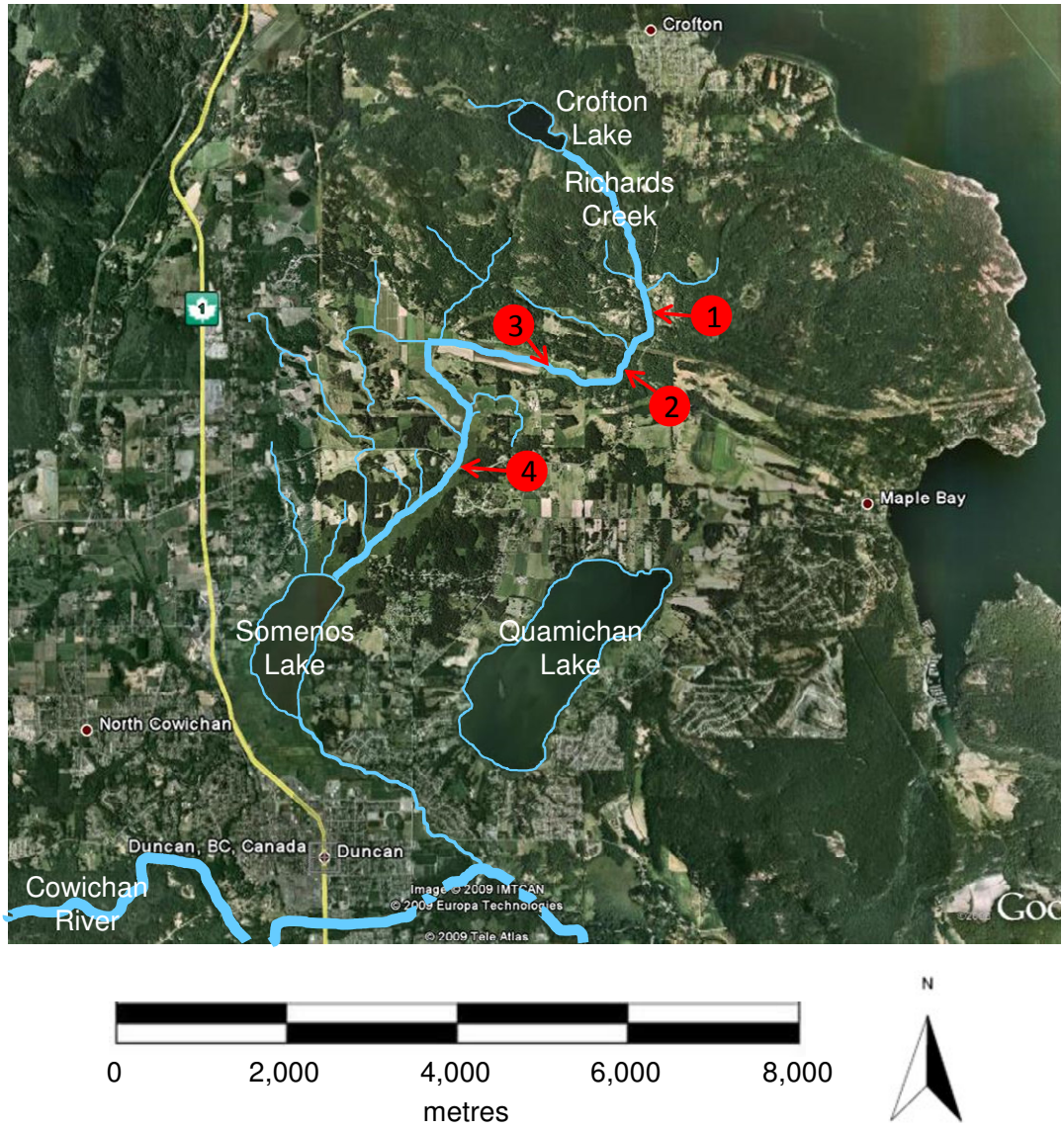

Figure 1. Approximate location of the sampling stations used for water quality and stream invertebrate assessments on Richards Creek, during October-November 2008. Table 1 provides details of the specific location of each station. Table 2 details the sampling activities conducted at each station. This map was obtained from Google Earth. Map scale is approximated.

3.1.1. Sampling Stations

Four sampling stations were established on Richards Creek, during October-November 2008 (Tables 1 and 2; Figure 1). The location of each station was chosen to provide adequate coverage for the length of Richards 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 with little water movement and a thick cover of duckweed (*Lemna minor*).

Table 1. Description of the sampling stations used for water quality and stream invertebrate assessments on Richards Creek, during October-November 2008. 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 27 October and 17 November 2008. 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 October 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 27 October and 17 November 2008. 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. Unfortunately, a malfunction of the electronic probe occurred during the October sampling event; therefore, the only field measurements reported for that sampling event are estimates of water temperature.

Table 2. Water quality and stream invertebrate sampling activities conducted at each station on Richards Creek, during October-November 2008. The symbols "O" or "N" indicate whether samples / measurements were taken during the October or November sampling events, respectively.

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

Note: [1] A malfunction of the electronic probe occurred during the October sampling event. Only estimates of water temperature are reported for that sampling event.

[2] Duplicate samples were collected at station 1 for analysis at the VIU Laboratory.

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. 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 and one field 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. The field blank was prepared by transferring 500 ml of distilled water into a plastic bottle while in the field.

Table 3. Sampling containers and preservatives used for water quality samples taken from Richards Creek during October-November 2008. All containers and preservatives for analysis by ALS Laboratory were provided by ALS Laboratory, Vancouver, BC.

Analytical Parameters	Container	Preservative	Analysed by
Total hardness, total alkalinity, total suspended solids, reactive phosphorus, nitrate	500 ml plastic	None	VIU
Conductivity, pH, total hardness, total suspended solids	1 L plastic	None	ALS Laboratory
Anions, 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 hardness, total alkalinity, total suspended solids, reactive phosphorus and nitrate. Total hardness (as $CaCO_3$) was measured to the nearest 1 mg/L using a HACH HA-71A test kit. Total alkalinity (as $CaCO_3$) was measured to the nearest 0.1 mg/L using the HACH AL-DT digital titration method. Total suspended solids (TSS) were measured to the nearest 1 mg/L using a HACH DR2800 Spectrophotometer (Method 8006). Reactive phosphorus (orthophosphate) was measured to the nearest 0.01 mg/L using a HACH DR2800 Spectrophotometer (Method 8048). Nitrate was measured to the nearest 0.01 mg/L using a HACH DR2800 Spectrophotometer (Method 8192).

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, total suspended solids (TSS), six anions and nutrients, 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 and field 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 and federal 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). The guidelines from the Canadian Council of Ministers of the Environment were also used for water quality comparisons (CCME 2003). Both sets of 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 stations on 27 October 2008 (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. 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 10-ml volume of sample water was extracted from each sample bag with a sterile pipette and 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 100-mm 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 27 October 2008 (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 (triplicates) 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 triplicate samples from each station were combined into a single composite sample per station. The contents of the 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

Discharge measurements for Richards Creek suggested that water levels were not at bankfull at the time of sampling. Stream discharge was measured during both sampling events using the concrete weir and water level gauge at Station 2. Water levels were 0.150 and 0.165 m during the October and November sampling events, respectively. Calculations using mathematical formulae provided by DFO (M. Wright, unpublished data) resulted in stream discharge measurements of 0.025 and 0.034 m^3/s on 27 October and 17 November, 2008, respectively.

During this sampling program, weather conditions were sunny with clouds, no precipitation and air temperature of 7-9^{o}C. Average air temperature during the 10-day period prior to each sampling event were 8.1^{o}C for the October event and 9.6^{o}C for the November event (data for Victoria Airport retrieved from http://www.theweathernetwork.com).

4.1. Water Quality

4.1.1. Field Measurements and VIU Laboratory Analyses

Water temperature averaged 6.8^{o}C and 8.6^{o}C during the October and November sampling events, respectively (Table 5). The increase in water temperature between events reflected the warmer air temperature during the 10-day period prior to the November event. During the November sampling event, all dissolved oxygen levels were above the minimum guideline of 9.0 mg/L for early fish life stages (RISC 1998), except for station 4 where dissolved oxygen was 1.88 mg/L. Dissolved oxygen concentrations were at 78-91% saturation at stations 1-3, and 16% saturation at station 4. 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.

During the November sampling event, conductivity ranged from 149 to 204 µS/cm and increased as expected from upstream to downstream (i.e., from station 1 to 4) (Table 5). Water pH was near neutral at all stations. The pH at stations 1-3 ranged from 7.41 to 7.55, whereas pH was 6.20 at station 4. The lower pH at station 4 suggests higher carbon dioxide concentrations, which would result from elevated ecosystem respiration.

During both sampling events, total hardness and total alkalinity increased from upstream to downstream stations (Table 6). In addition, total hardness and total alkalinity were consistently higher on 17 November than on 27 October. Overall, total alkalinity was above 20 mg/L during

both sampling events, indicating "low acid sensitivity" as defined by RISC (1998). Total hardness was generally below 60 mg/L during both sampling events, indicating "soft water" as defined by RISC (1998).

Table 5. Field measurements taken from four stations on Richards Creek during 27 October and 17 November 2008. A malfunction of the electronic probe occurred during the October sampling event; only estimates of water temperature are reported for that sampling event. "N/A" = data unavailable.

Station	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH
		27 October 2008		
1	6	N/A	N/A	N/A
2	7	N/A	N/A	N/A
3	7	N/A	N/A	N/A
4	7	N/A	N/A	N/A
		17 November 2008		
1	8.52	9.83	149	7.48
2	8.46	10.61	167	7.41
3	8.49	9.16	181	7.55
4	8.83	1.88	204	6.20

Levels of total suspended solids (TSS) were relatively low during both sampling events, with values ranging from below detection limits to 6 mg/L (Table 6). During both sampling events, the highest TSS levels were observed at station 4.

During both sampling events, reactive phosphorus levels generally increased from upstream to downstream (Table 6). In addition, reactive phosphorus concentrations were consistently higher on 17 November than on 27 October. The highest reactive phosphorus concentrations were observed at station 4, with levels of 0.30 and 1.00 mg/L during the October and November sampling events, respectively. These levels of reactive phosphorus are indicative of nutrient-enriched conditions typical of "eutrophic" waters.

Nitrate concentrations displayed different trends between the two sampling events (Table 6). During the October sampling event, nitrate levels increased from upstream to downstream with the highest level of 0.73 mg/L observed at station 4. During the November sampling event, nitrate levels did not display an upstream to downstream trend, and ranged from 0.65 to 1.05 mg/L.

A comparison of the water quality results from the duplicate samples indicates that most values were within ±13% of each other (Table 6). The only exceptions were the reactive phosphorus concentrations for the November sampling event, which differed by 46%. Results for trip blank and field blank samples were generally low or near minimum detection limits compared with the water samples collected from Richards Creek. These results indicate that results obtained at the VIU laboratory were reproducible, and that sampling and analytical techniques did not result in gross contamination.

Table 6. Laboratory results for water samples taken from four stations on Richards Creek during 27 October and 17 November 2008. Duplicate samples (Samples 1A and 1B) were obtained from Station 1. Trip blank and field blank samples were not analysed for total hardness, total alkalinity and total suspended solids (shown as "N/A").

Station	Total Hardness (mg/L $CaCO_3$)	Total Alkalinity (mg/L $CaCO_3$)	Total Suspended Solids (mg/L)	Reactive Phosphorus (mg/L)	Nitrate (mg/L)
27 October 2008					
1 (Sample 1A)	29	19.2	1	0.07	0.10
1 (Sample 1B)	30	21.2	<1	0.08	0.09
2	33	26.4	3	0.02	0.21
3	39	33.2	5	0.08	0.20
4	53	40.0	6	0.30	0.73
Trip Blank	N/A	N/A	N/A	0.03	0.10
Field Blank	N/A	N/A	N/A	0.04	0.06
17 November 2008					
1 (Sample A)	42	30.8	3	0.05	0.86
1 (Sample B)	43	32.0	2	0.08	0.85
2	49	37.6	2	0.12	0.65
3	53	34.8	2	0.15	1.05
4	62	41.6	4	1.00	0.59
Trip Blank	N/A	N/A	N/A	0.03	0.04
Field Blank	N/A	N/A	N/A	0.03	0.05

4.1.2. ALS Laboratory Analyses

Water quality results were compared to the BC Provincial water quality guidelines and the federal CCME guidelines for the protection of aquatic life (Table 7).

The conductivity measurements from ALS Laboratories were consistent with the field measurements obtained with the electronic probe during the November sampling event and differed by <3%. During both sampling events, conductivity increased from upstream to downstream stations. In addition, conductivity was higher during the November sampling event by an average of 70 µS/cm.

Similarly, trends in total hardness measurements from ALS Laboratories were consistent with the VIU laboratory results, although ALS Laboratories results for the November sampling events were on average 23% higher than VIU laboratory results.

All total suspended solids (TSS) results were below detection limits (<3.0 mg/L) during both sampling events, except for station 4 during the November sampling event where TSS was 3.9 mg/L.

The pH measurements from ALS Laboratories were less variable (6.95-7.86) than field measurements obtained with the electronic probe during the November sampling event. Field measurements of pH were generally lower than the ALS Laboratories results. This discrepancy possibly reflects improper probe calibration, differences in air space content among sampling containers and/or time elapsed between sampling and laboratory analysis. During both sampling event, pH was consistently lower at station 4 than stations 1-3.

All anion levels were well below applicable guidelines. Nitrate levels from ALS Laboratories were generally lower than the VIU laboratory results, although in both cases overall levels were consistent and below applicable guidelines.

All total metal concentrations at stations 1-3 were below the applicable water quality guidelines during both sampling events. At station 4, iron concentration exceeded the applicable water quality guidelines during both sampling events, and aluminum and zinc also exceeded the applicable water quality guidelines during the November sampling event. There was no evidence to indicate that the exceedances for station 4 occurred as a result of sample contamination.

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%.

The combination of field measurements, and results from the VIU and ALS Laboratories indicate reduced water quality at station 4 compared to upstream stations 1-3. This is evident based on consistent results of lower pH, lower dissolved oxygen, higher conductivity, higher reactive phosphorus and total metal exceedances at this station.

Table 7. Laboratory results (ALS Laboratory) for water samples taken from 4 stations on Richards Creek during 27 October and 17 November 2008. 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]			27 October 2008				17 November 2008			
	BC Max	BC 30-day Mean	CCME [b]								
Variable	mg/L	mg/L	mg/L	1	2	3	4	1	2	3	4
General/Physical											
Conductivity (µS/cm)				76.9	90	107	145	150	170	177	201
Hardness, Total				28.0	33.1	39.6	53.7	52.9	62.6	68.9	76.2
pH (pH units)	6.5 - 9.0		6.5 - 9.0	7.24	7.30	7.39	6.95	7.76	7.84	7.86	7.43
Total Suspended Solids				<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	3.90
Nutrients											
Bromide (Br)				<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride (Cl)	600	150		5.12	6.32	7.63	12.7	14.5	14.1	14.5	14.5
Fluoride (F)	0.2 [c]			0.023	0.026	0.03	0.047	0.021	0.024	0.028	0.041
Nitrate (as N)	200	40	13	0.01	0.05	0.06	0.33	0.57	0.62	0.62	0.61
Nitrite (as N)	0.18 [d]	0.06 [d]	0.06	<0.0010	<0.0010	<0.0010	0.0052	<0.0010	0.001	0.0011	0.0235
Sulfate (SO_4)	100			7.81	8.41	9.03	10.8	13.4	19.7	18.7	25.4
Total Metals											
Aluminum (Al) [n]	0.10 [e]	0.05 [e]	0.10 [e]	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.21
Antimony (Sb) [n]	0.02			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic (As) [n]	0.005			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium (Ba)	5	1		<0.010	<0.010	<0.010	<0.010	0.012	0.013	0.013	0.018
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) [n]	0.00001 [f]		0.00001 [f]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (Ca)				8.7	10.0	11.5	16.0	16.4	19.6	20.7	22.0
Chromium (Cr) [n]	0.001 [g]		0.001 [g]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt (Co) [n]	0.11	0.004		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu) [n]	0.005 [h]	0.002 [h]	0.002 [h]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron (Fe)	0.3		0.3	0.152	0.133	0.179	0.339	0.176	0.197	0.203	0.328
Lead (Pb) [n]	0.015 [i]	0.004 [i]	0.001 [i]	<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)				1.5	2.0	2.7	3.3	2.9	3.4	4.2	5.2
Manganese (Mn)	0.84 [j]	0.72 [j]		0.023	0.015	0.012	0.029	0.056	0.030	0.013	0.117
Molybdenum (Mo)	2	1	0.073	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel (Ni) [n]	0.025 [k]		0.025 [k]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus (P)				<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	0.4
Potassium (K)	373			<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	3.1
Selenium (Se) [n]		0.002	0.001	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon (Si)				1.97	2.86	3.64	4.25	5.01	5.84	6.44	5.63
Silver (Ag) [n]	0.0001 [l]	0.00005 [l]	0.0001	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium (Na)				3.5	4.1	4.8	6.4	7.6	7.9	8.7	8.6
Strontium (Sr)				0.026	0.032	0.040	0.062	0.054	0.063	0.079	0.105
Thallium (Tl)	0.0003	0.0008		<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			<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.012
Vanadium (V) [n]	0.006	0.02		<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc (Zn)	0.033 [m]	0.0075 [m]		<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.009

Table 7. (Continued)

NOTES:

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

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

[b] Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines (WQGs) compiled from CCME (2003).

[c] Fluoride guideline is 0.2 mg/L for hardness < 50 mg/L.

[d] Nitrite guideline is dependent on chloride concentration. Guideline range shown is based on chloride concentration ≥ 4 mg/L.

[e] Aluminum guidelines for pH ≥ 6.5.

[f] The BC maximum cadmium guideline is $0.001 * 10^{\{0.86 [\log(\text{hardness})] - 3.2\}}$ mg/L. Guideline shown is based on hardness of 27-76 mg/L.

[g] Chromium guideline is for the more toxic Chromium VI. The guideline for Chromium VI is 0.0089 mg/L.

[h] The BC maximum copper guideline is 0.001 * [0.094(hardness) + 2] mg/L. The BC 30-day mean copper guideline is 0.002 µg/L for hardness < 50 mg/L. The CCME guideline for copper is 0.002 mg/L at hardness of 1-120 mg/L. Guidelines shown are based on hardness of 27-76 mg/L.

[i] The BC maximum lead guideline is $0.001 * e^{\{1.273 [\ln(\text{hardness})] - 1.46\}}$ mg/L. The BC 30-day mean lead guideline is $0.001 * [3.31 + e^{\{1.273 [\ln(\text{hardness})] - 4.704\}}]$ mg/L. The CCME guideline for lead is 0.001 mg/L for hardness of 0-60 mg/L. Guidelines shown are based on hardness of 27-76 mg/L.

[j] The BC maximum manganese guideline is 0.01102 * (hardness) + 0.54 mg/L. The BC 30-day mean manganese guideline is 0.0044 * (hardness) + 0.605 mg/L. Guidelines shown are based on hardness of 27-76 mg/L.

[k] Nickel guideline is 0.025 mg/L for hardness of 0-60 mg/L.

[l] The BC maximum silver guideline is 0.0001 mg/L for hardness ≤100 mg/L. The BC 30-day mean silver guidelines is 0.00005 mg/L for hardness ≤100 mg/L.

[m] The BC maximum zinc guideline is 0.033 mg/L for hardness ≤90 mg/L. The BC 30-day mean zinc guidelines is 0.0075 mg/L for hardness ≤90 mg/L.

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

4.2. Microbiology

All samples collected from Richards Creek contained some coliform bacteria (Table 8). Total coliform levels ranged from 410 CFU / 100 ml at station 2 to 1,490 CFU / 100 ml at station 4. The proportion of total coliform made up of *E. coli* bacteria was low at stations 2-4, but exceeded 50% at station 1. The higher total coliform and *E. coli* results at station 1 were unexpected as bacterial load typically increases from upstream to downstream.

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

Table 8. Total coliform and *E. coli* counts from water samples taken at four stations on Richards Creek during 27 October 2008. All values are expressed as CFU (colony forming units) per 100 ml. No microbiology samples were collected on 17 November 2008.

Station	Total Coliform	*E. coli*	% *E. coli*
1	960	560	58.3
2	410	10	2.4
3	1170	40	3.4
4	1490	10	0.7
Filtration blank	0	0	---

4.3. Stream Invertebrates

A total of 574 stream invertebrates representing 9 broad taxonomic groups were counted at three stations on Richards Creek during 27 October 2008 (Table 9; Figure 2; Appendix 2). Animal density increased from upstream to downstream stations, with a range of 315-1,207 animals/m^2. Overall, caddisfly larvae was the most common taxonomic group, although aquatic worms (oligochaetes) and stonefly nymphs were the dominant taxa at stations 1 and 2, respectively.

Site assessment ratings ranged from 2.5 to 3.75 suggesting “acceptable” (station 1) to “good” (stations 2-3) invertebrate community abundance and diversity. The consistent representation of pollution-sensitive mayfly nymphs, stonefly nymphs and caddisfly larvae (EPT taxa: 27-79% of total abundance) indicated generally “favourable” environmental conditions, although invertebrate diversity was lowest at station 1.

Table 9. Abundance and density of stream invertebrates obtained from triplicate samples taken at three stations on Richards Creek during 27 October 2008. 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 17 November 2008.

Pollution Tolerance	Invertebrate Taxa	Station 1	Station 2	Station 3
Category 1 Pollution Intolerant	Caddisfly larva	4	2	117
	Mayfly nymph	7	33	54
	Stonefly nymph	12	93	67
Category 2 Somewhat Pollution Intolerant	Alderfly larva		1	3
	Cranefly larva	6	7	5
	Scud (Amphipod)			7
Category 3 Pollution Tolerant	Aquatic Worm (Oligochaete)	46	23	68
	Midge larva (Chironomid)	2	2	5
	Water mite	8	2	
	Total Abundance	85	163	326
	Density (number / m^2)	315	604	1,207
	Site Assessment Rating	2.50	3.75	3.75

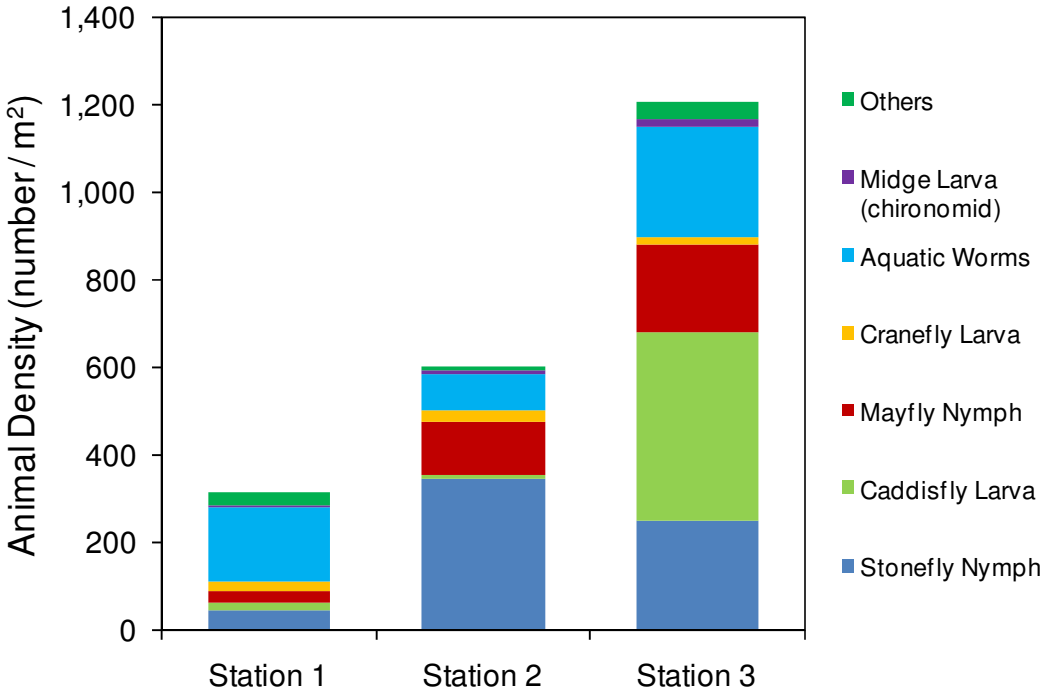

Figure 2. Density of stream invertebrates obtained from triplicate samples taken at three stations on Richards Creek during 27 October 2008. The "Other" category includes water mite, scud (amphipod) and alderfly larvae. Data are summarized in Table 9 and Invertebrate Survey Field Data Sheets are included 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 during October 2008 (courtesy of Matthew Rochetta).

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

Photo 2. Richards Creek at the Innisvale Farm located at the end of Rice Road (station 2). The concrete weir and water depth gauge (red ruler) are visible on this photograph.

APPENDIX 1. (Continued)

Photo 3. Richards Creek at Richards Trail located at the east end of Pastula Farm (station 3).

Photo 4. Richards Creek at the Herd Road Bridge (station 4).

APPENDIX 1. (Continued)

Photo 5. Matthew Rochetta obtaining a stream invertebrate sample with a Hess sampler at Station 2.

Photo 6. Laura Brown obtaining a stream invertebrate sample with a Hess sampler at Station 3.

APPENDIX 2. Invertebrate Survey Field Data Sheet completed for triplicate stream invertebrate samples collected at Stations 1, 2 and 3 on Richards Creek during 27 October 2008.

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Richards Creek		Date:	27 October 2008
Station Name:	**Station 1**		Flow status:	Low
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)	4	1
	Mayfly Nymph (EPT)	7	1
	Stonefly Nymph (EPT)	12	2
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		23	4
Category 2 **Somewhat Pollution Tolerant**	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	6	2
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)		
	Watersnipe Larva		
Sub-Total		6	2
Category 3 **Pollution Tolerant**	Aquatic Worm (oligochaete)	46	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	2	1
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	8	1
Sub-Total		56	3
TOTAL		85	9

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 85

DENSITY: Invertebrate density per square metre:

85 ÷ 0.27 = 315

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 2 + 3 = 19

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

1 + 1 + 2 = 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	0.50-0.75	0.25-0.50	0-0.25

(EPT1 + EPT2 + EPT3) / CT

(4 + 7 + 12) / 85 = 0.27

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 9

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

Good	Accpetable	Marginal	Poor
0-0.40	0.40-0.60	0.60-0.80	0.80-1.0

Col. C for S3 / CT

46 / 85 = 0.54

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	3
EPT Index	2
EPT To Total Ratio	2
Predominant Taxon Ratio	3

Average Rating
2.50

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Richards Creek		Date:	27 October 2008
Station Name:	**Station 2**		Flow status:	Low
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)	2	1
	Mayfly Nymph (EPT)	33	5
	Stonefly Nymph (EPT)	93	3
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		128	9
Category 2 Somewhat Pollution Tolerant	Alderfly Larva	1	1
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	7	2
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)		
	Watersnipe Larva		
Sub-Total		8	3
Category 3 Pollution Tolerant	Aquatic Worm (oligochaete)	23	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	2	1
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	2	1
Sub-Total		27	3
TOTAL		163	15

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 163

DENSITY: Invertebrate density per square metre:

163 ÷ 0.27 = 604

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (Col. C): Stonefly Nymph (EPT)

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 3 + 3 = 36

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

1 + 5 + 3 = 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	0.50-0.75	0.25-0.50	0-0.25

(EPT1 + EPT2 + EPT3) / CT

(2 + 33 + 93) / 163 = 0.79

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 15

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

Good	Accpetable	Marginal	Poor
0-0.40	0.40-0.60	0.60-0.80	0.80-1.0

Col. C for S3 / CT

93 / 163 = 0.57

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	4
Predominant Taxon Ratio	3

Average Rating
3.75

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Richards Creek		Date:	27 October 2008
Station Name:	**Station 3**		Flow status:	Low
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)	117	4
	Mayfly Nymph (EPT)	54	4
	Stonefly Nymph (EPT)	67	5
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		238	13
Category 2 Somewhat Pollution Tolerant	Alderfly Larva	3	1
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	5	1
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	7	1
	Watersnipe Larva		
Sub-Total		15	3
Category 3 Pollution Tolerant	Aquatic Worm (oligochaete)	68	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	5	2
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		73	3
TOTAL		326	19

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 326

DENSITY: Invertebrate density per square metre:

326 ÷ 0.27 = 1207

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (Col. C): Caddisfly Larva (EPT)

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 13 + 2 x 3 + 3 = 48

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

4 + 4 + 5 = 13

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	0.50-0.75	0.25-0.50	0-0.25

(EPT1 + EPT2 + EPT3) / CT

(117 + 54 + 67) / 326 = 0.73

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 19

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

Good	Accpetable	Marginal	Poor
0-0.40	0.40-0.60	0.60-0.80	0.80-1.0

Col. C for S3 / CT

117 / 326 = 0.36

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	3
Predominant Taxon Ratio	4

Average Rating
3.75