DATA REPORT

Water Quality and Stream Invertebrate Assessment

for Richards Creek and Somenos Creek, BC,

(Fall 2009)

Report prepared by:

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1. Background

This report documents a water quality and stream invertebrate assessment conducted on Richards Creek and Somenos Creek, BC, during November 2009.

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 (MacGregor Anderson, Matthew Corbett, Brett Isbister and Krystal Reaume). 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 50 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'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. Somenos Creek flows southeasterly from Somenos Lake to the Cowichan River. 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 and Somenos Creek during November 2009.

Specific objectives for this study of Richards Creek and Somenos Creek included:

- establish 5 water quality sampling stations;
- obtain field measurements of water quality at the 5 sampling stations during two sampling events (early and late November 2009);
- obtain water samples from each sampling station during two sampling events (early and late November 2009) for detailed laboratory analyses; and,
- collect stream invertebrate samples at 3 sampling stations during one sampling event (early November 2009) for analysis at Vancouver Island University.

3. Methods

3.1. Study Site

This project was conducted on Richards Creek and Somenos Creek which are 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. Somenos Creek flows southeasterly from Somenos Lake to the Cowichan River. 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. Somenos Creek is primarily an urban stream.

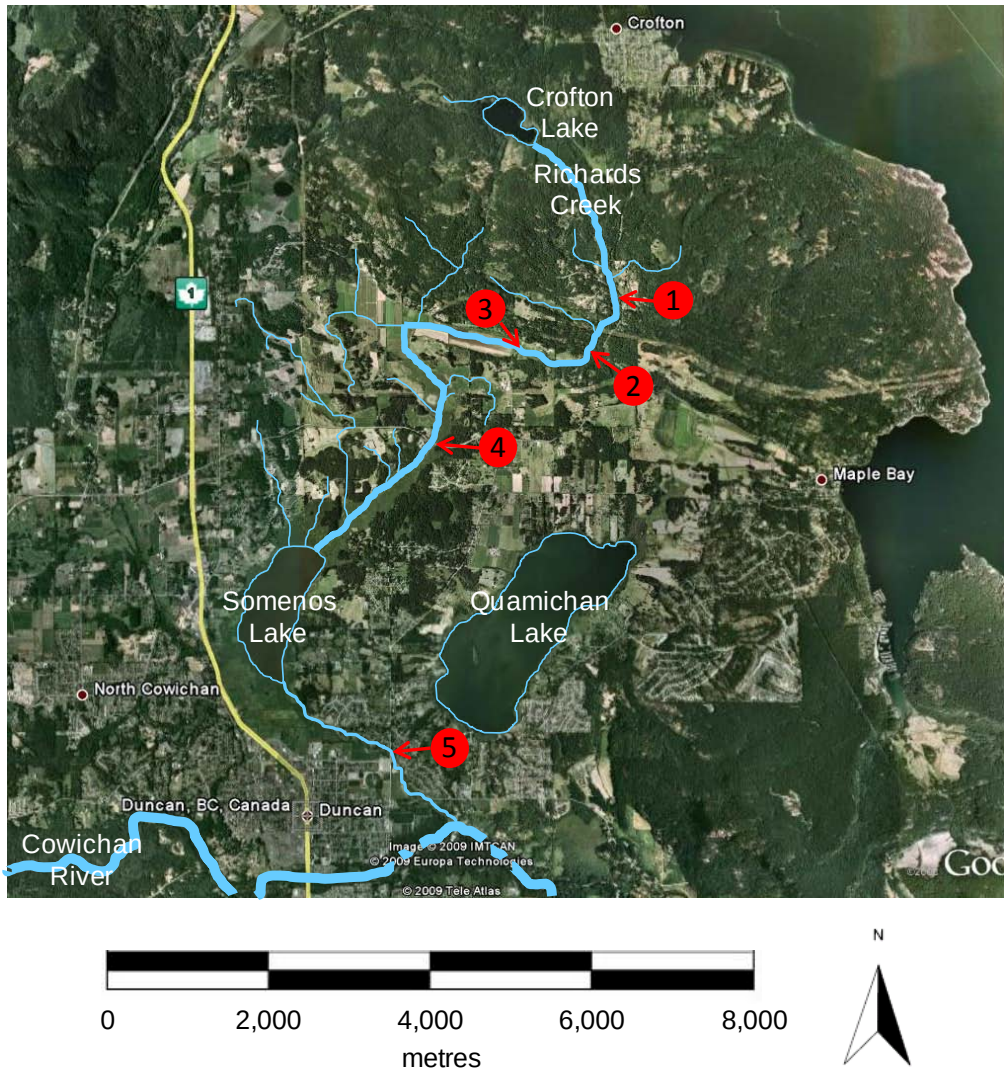

Figure 1. Approximate location of the sampling stations used for water quality and stream invertebrate assessments on Richards Creek and Somenos Creek, during November 2009. Table 1 provides details of the specific location of each station. Table 2 details the sampling activities conducted at each station. This map was obtained from Google Earth. Map scale is approximated.

3.1.1. Sampling Stations

Four sampling stations were established on Richards Creek and one station on Somenos Creek, during November 2009 (Tables 1 and 2; Figure 1). The location of each station was chosen to provide adequate coverage for the length of both creeks and to repeat sampling at stations previously used by DFO. Stations were numbered from upstream (Station 1) to downstream (Station 5). 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. Station 5 was located on Somenos Creek at a road bridge on Lakes Road, approximately 1.6 km downstream of Somenos Lake. Stations 1-3 consisted of shallow and gentle riffle sections, while stations 4-5 were deep and steep-sided.

Table 1. Description of the sampling stations used for water quality and stream invertebrate assessments on Richards Creek and Somenos Creek, during November 2009. 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
5	5403815	449700	12.8	Lakes Road crossing

3.1.2. Sampling Schedule

Field sampling was conducted on 3 and 23 November 2009. 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 3 and 23 November 2009. 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.

Table 2. Water quality and stream invertebrate sampling activities conducted at each station on Creek and Somenos Creek, during November 2009. 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, B	A, B	A	A
2	A, B	A, B	A, B	A	A
3	A, B	A [1], B	A, B	A	A
4	A, B	A, B [1]	A, B	A	---
5	A, B	A, B	---	A	---

Note: [1] Duplicate samples for analysis at the VIU Laboratory were collected at stations 3 and 4 during the early and late November sampling events, respectively.

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 stations 3 and 4 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 and Somenos Creek during November 2009. 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 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 station on 3 November 2009 (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 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 3 November 2009 (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, four 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

Although no discharge measurements were collected during this study, field observations suggested that water levels in Richard Creek and Somenos Creek were not at bankfull during the early November sampling event. However, very heavy rainfall between sampling events caused both creeks to overflow during the late November sampling event (see photos in Appendix 1).

Average air temperature during the 10-day period prior to each sampling event was 7-8^{o}C (data for Victoria Airport retrieved from http://www.theweathernetwork.com). Total rainfall during the 10-day period prior to each sampling event was 33 mm for the early November sampling event and 181 mm for the late November sampling event. Heavy rain events during the week prior to the late November sampling event caused extensive flooding in the Somenos watershed.

4.1. Water Quality

4.1.1. Field Measurements and VIU Laboratory Analyses

Water temperature averaged 8.4^{o}C and 7.2^{o}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 the 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 stations 4-5 were below 9.0 mg/L during both sampling events. Dissolved oxygen levels were especially low during the early November sampling event, when they represented 21% and 50% of saturation at stations 4 and 5, respectively. The low dissolved oxygen concentrations observed at stations 4 and 5 suggest that hypoxic conditions existed at the time of sampling, possibly due to negligible water movement and elevated ecosystem respiration at these locations.

Mean conductivity decreased from 158 to 95 µS/cm between the early and late November sampling events, likely as a result of dilution due to increased discharge. During both sampling events, there was a general increase from upstream to downstream stations, except at station 5 (Somenos Creek) during late November when flooding conditions may have resulted in mixing with low-conductivity water from other sources, including the Cowichan River. Water pH was generally near or above neutral at all stations. During the early November sampling event, there was a general decrease from upstream to downstream stations. A similar trend was observed at stations 1-3 during the late November sampling event, but not at stations 4-5 where pH was higher.

Total alkalinity ranged averaged 36.2 and 22.6 mg/L during the early and late November sampling events, respectively (Table 5). Total alkalinity levels were more variable between stations during the late November sampling event, when values ranged from 10.4 to 30.4 mg/L. Overall, total alkalinity was above 10 mg/L during both sampling events, indicating “low to moderate acid sensitivity” as defined by RISC (1998).

Turbidity levels were variable throughout this study and ranged from below detection limit to 6 FAU (Table 5).

A comparison of the water quality results from the duplicate samples taken at station 3 and 4 indicates that most values were within ±10% of each other.

Table 5. Field measurements and laboratory results (VIU Laboratory) for water samples taken from four stations on Richards Creek and one station on Somenos Creek during 3 and 23 November 2009. Results for total alkalinity and turbidity at stations 3 and 4 during the early November and late November, respectively, represent the average of duplicate samples.

Station	Temperature (^oC)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH	Total Alkalinity (mg/L $CaCO_3$)	Turbidity (FAU)
			3 November 2009			
1	8.16	10.23	135	8.38	43.6	4
2	7.95	11.29	175	8.26	34.8	4
3	7.79	11.12	184	8.00	39.2	2
4	7.30	2.54	212	7.65	29.6	5
5	10.80	5.58	85	7.57	33.6	4
			23 November 2009			
1	7.13	11.20	78	7.50	10.4	2
2	7.36	11.40	86	7.15	27.6	6
3	7.36	11.40	91	6.89	15.6	0
4	6.67	8.75	110	8.75	28.8	1
5	7.26	7.95	108	7.95	30.4	5

4.1.2. ALS Laboratory Analyses

Water quality results from ALS Laboratory were compared to the BC Provincial water quality guidelines and the federal CCME 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 ≤4%.

Total hardness followed similar trends as conductivity, namely a general increase from upstream to downstream stations and a decrease between sampling events. Total hardness averaged 62.1 and 32.0 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: 6.89-8.75) were generally more variable than the ALS Laboratory results (range: 7.03-7.61). 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. Total ammonia was below detection limit (i.e., <0.02 mg/L) at stations 1-3 during the early November sampling event, but not at the station 4. During the late November sampling event, total ammonia generally increased from upstream to downstream stations. Nitrate concentrations decreased between the early (average: 0.976 mg/L) and late November sampling events (average: 0.418 mg/L). Nitrate levels decreased from upstream to downstream stations during the early November sampling event, while the opposite trend was observed during the late November sampling event. The highest nitrate concentrations were observed at stations 1 and 2 during the early November sampling event (1.07 and 1.01 mg/L, respectively). Nitrite levels were below detection limits (i.e., <0.001 mg/L) at stations 1-3 during both sampling events, but not at the station 4.

Orthophosphate was 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 at stations 4 during both sampling events. Total phosphorus generally increased from upstream to downstream stations and increased between sampling events. The highest total phosphorus levels occurred at stations 4 during both sampling events (0.097 and 0.113 mg/L during the early and late November sampling events, respectively). Overall, total phosphorus levels indicated "eutrophic" conditions (≥0.025 mg/L) at all stations during both sampling events (as defined by RISC (1998)), except at stations 1 and 2 during the early November sampling events when "mesotrophic" conditions (<0.010 mg/L) occurred.

With the exception of aluminium, iron and zinc, all metals were below applicable guidelines. Total aluminium and iron concentrations exceeded the applicable guidelines at station 4 during the early November sampling event and at all stations during the late November sampling event. There was also an excedance for zinc at station 4 during the late November sampling event. For most elements, there was a general increase from upstream to downstream stations and a decrease between sampling events.

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 the results from the VIU and ALS Laboratory indicate progressively reduced water quality in Richards Creek with distance downstream, especially at station 4. This is evident based on consistent results of lower dissolved oxygen, and higher conductivity, nutrient and metal concentration at this station.

Table 6. Laboratory results (ALS Laboratory) for water samples taken from 4 stations on Richards Creek during 3 and 23 November 2009. 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]			3 November 2009				23 November 2009			
	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)				138	177	185	212	75.4	83.5	88	112
Hardness, Total				47.6	61.1	65.9	73.6	26.4	30.3	31.7	39.5
pH (pH units)	6.5 - 9.0		6.5 - 9.0	7.39	7.56	7.61	7.03	7.28	7.31	7.34	7.22
Nutrients											
Ammonia-N	1.02 [c]	0.197 [c]	0.715 [c]	<0.020	<0.020	<0.020	0.049	0.023	0.06	0.071	0.115
Nitrate (as N)	200	40	13	1.07	1.0100	0.958	0.867	0.268	0.259	0.397	0.749
Nitrite (as N)	0.06 [d]	0.02 [d]	0.06	<0.0010	<0.0010	<0.0010	0.0111	<0.0010	<0.0010	<0.0010	0.0051
Ortho Phosphate (as P)				<0.0010	<0.0010	0.0195	0.06	<0.0010	<0.0010	0.0153	0.0714
Total Phosphorus				0.0057	0.0072	0.0363	0.097	0.0161	0.017	0.034	0.113
Total Metals											
Aluminum (Al) [n]	0.10 [e]	0.05 [e]	0.10 [e]	<0.20	<0.20	<0.60	0.28	0.33	0.32	0.46	0.49
Antimony (Sb) [n]	0.02			<0.20	<0.20	<0.60	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic (As) [n]	0.005			<0.20	<0.20	<0.60	<0.20	<0.20	<0.20	<0.20	<0.20
Barium (Ba)	5	1		0.011	0.012	<0.030	0.018	0.012	0.012	0.013	0.014
Berylium (Be)	0.0053			<0.0050	<0.0050	<0.015	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth (Bi)				<0.20	<0.20	<0.60	<0.20	<0.20	<0.20	<0.20	<0.20
Boron (B)	1.2			<0.10	<0.10	<0.30	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium (Cd) [n]	0.00001 [f]		0.00001 [f]	<0.010	<0.010	<0.030	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (Ca)				14.6	18.5	19.2	21.3	8.3	9.7	9.9	11.8
Chromium (Cr) [n]	0.001 [g]		0.001 [g]	<0.010	<0.010	<0.030	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt (Co) [n]	0.11	0.004		<0.010	<0.010	<0.030	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu) [n]	0.003 [h]	0.002 [h]	0.002 [h]	<0.010	<0.010	<0.030	<0.010	<0.010	<0.010	<0.010	<0.010
Iron (Fe)	0.3		0.3	0.177	0.140	0.276	0.391	0.378	0.370	0.440	0.451
Lead (Pb) [n]	0.006 [i]	0.004 [i]	0.001 [i]	<0.050	<0.050	<0.15	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium (Li)	0.87	0.096		<0.010	<0.010	<0.030	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium (Mg)				2.7	3.6	4.4	4.9	1.4	1.5	1.7	2.4
Manganese (Mn)	0.68 [j]	0.66 [j]		0.033	0.017	0.019	0.031	0.042	0.032	0.031	0.019
Molybdenum (Mo)	2	1	0.073	<0.030	<0.030	<0.090	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel (Ni) [n]	0.025 [k]		0.025 [k]	<0.050	<0.050	<0.15	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus (P)				<0.30	<0.30	<0.90	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)	373			<2.0	<2.0	<6.0	<2.0	<2.0	<2.0	<2.0	<2.0
Selenium (Se) [n]		0.002	0.001	<0.20	<0.20	<0.60	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon (Si)				4.02	5.23	5.78	5.24	3.80	4.23	4.47	4.50
Silver (Ag) [n]	0.0001 [l]	0.00005 [l]	0.0001	<0.010	<0.010	<0.030	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium (Na)				7.3	8.7	9.8	11.1	4.3	4.6	4.8	5.9
Strontium (Sr)				0.049	0.064	0.077	0.114	0.027	0.029	0.034	0.057
Thallium (Tl)	0.0003	0.0008		<0.20	<0.20	<0.60	<0.20	<0.20	<0.20	<0.20	<0.20
Tin (Sn)				<0.030	<0.030	<0.090	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium (Ti)	2			<0.010	<0.010	<0.030	0.014	0.017	0.016	0.021	0.023
Vanadium (V) [n]	0.02	0.006		<0.030	<0.030	<0.090	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc (Zn)	0.033 [m]	0.0075 [m]		<0.0050	<0.0050	<0.015	<0.0050	<0.0050	<0.0050	<0.0050	0.012

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/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] Total ammonia guideline is dependent on water temperature and pH. Guideline shown is based water temperature of 7-11^{o}C and pH of 6.8-8.8 for the tested water.

[d] Nitrite guideline is dependent on chloride concentration. Guideline range shown is based on chloride concentration < 2 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 15-28 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 15-28 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 15-28 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 15-28 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 and Somenos Creek contained some coliform bacteria (Table 7). Total coliform levels increased with distance downstream, and ranged from 8 CFU / 100 ml at station 1 to 917 CFU / 100 ml at station 5. The proportion of total coliform made up of *E. coli* bacteria was moderate at stations 1-3 and 5, but greatly exceeded 50% at station 4. The higher *E. coli* results at station 4, along with reduced water quality at this station, suggest poor conditions for aquatic life (especially salmonids).

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 and Somenos Creek during 3 November 2009. All values are expressed as CFU (colony forming units) per 100 ml. No microbiology samples were collected on 23 November 2009.

Station	Total Coliform	*E. coli*	% *E. coli*
1	8	4	50%
2	10	4	40%
3	19	6	32%
4	90	81	90%
5	917	248	27%
Filtration blank	0	0	---

4.3. Stream Invertebrates

A total of 334 stream invertebrates representing 14 broad taxonomic groups were counted at three stations on Richards Creek during 3 November 2009 (Table 8; Figure 2; Appendix 2). Animal density was relatively consistent among stations, with a range of 272-331 animals/m^2. Overall, aquatic worms (oligochaetes) was the most common taxonomic group, although mayfly larvae, scuds (amphipods) and stonefly nymphs were also abundant. Taxonomic diversity was lower at station 1 than at stations 2 and 3.

Site assessment ratings ranged from 2.00 to 3.75 suggesting "marginal" (station 1) to "acceptable or good" (stations 2-3) invertebrate community abundance and diversity. The strong representation of pollution-sensitive mayfly nymphs, stonefly nymphs and caddisfly larvae (EPT taxa: 42-59% of total abundance) indicated generally "favourable" environmental conditions at stations 2 and 3, but not at station 1. These results are consistent with a similar assessment conducted during Fall 2008 (VIU, 2009).

Table 8. Abundance and density of stream invertebrates obtained from four replicate samples taken at three stations on Richards Creek on 3 November 2009. 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 23 November 2009.

Pollution Tolerance	Invertebrate Taxa	Station 1	Station 2	Station 3
Category 1 Pollution Intolerant	Caddisfly Larva	1	1	18
	Mayfly Nymph	3	32	22
	Stonefly Nymph		25	10
	Riffle Beetle			1
Category 2 Somewhat Pollution Intolerant	Aquatic Beetle			1
	Clam, Mussel			8
	Cranefly Larva		6	
	Dragonfly Larva		4	
	Scud (amphipod)	38	3	11
	Watersnipe Larva		1	
Category 3 Pollution Tolerant	Aquatic Worm (oligochaete)	75	22	46
	Leech		1	
	Midge Larva (chironomid)		2	2
	Water Mite		1	
	Total Abundance	117	98	119
	Density (number / m^2)	325	272	331
	Site Assessment Rating	2.00	3.75	3.25

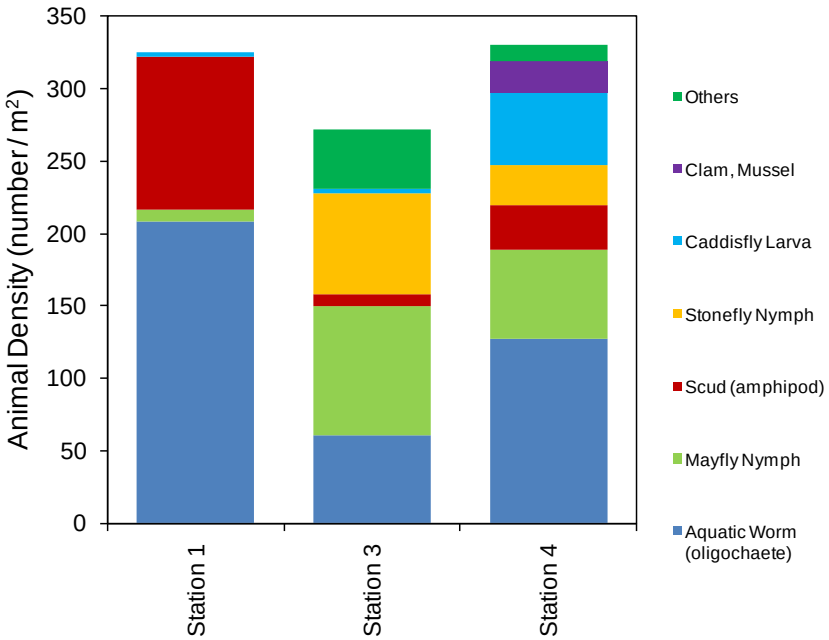

Figure 2. Density of stream invertebrates obtained from four replicate samples taken at three stations on Richards Creek during 3 November 2009. The "Other" category includes cranefly larva, dragonfly larva, midge larva (chironomid), riffle beetle, aquatic beetle, watersnipe larva, leech and water mite 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 and Somenos 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 3 November 2009.

Photo 2. Richards Creek at the end of Rice Road (station 2) on 3 November 2009.

APPENDIX 1. (Continued)

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

Photo 4. Richards Creek at the Herd Road Bridge (station 4) on 3 November 2010.

APPENDIX 1. (Continued)

Photo 5. Somenos Creek at the Lakes Road Bridge (station 5) on 3 November 2010.

Photo 6. Richards Creek at the Escarpment Way crossing (station 1) on 23 November 2009.

APPENDIX 1. (Continued)

Photo 7. Richards Creek at the end of Rice Road (station 2) on 23 November 2009.

Photo 8. Richards Creek at Richards Trail (station 3) on 23 November 2010.

APPENDIX 1. (Continued)

Photo 9. Richards Creek at the Herd Road Bridge (station 4) on 23 November 2010.

Photo 10. Somenos Creek at the Lakes Road Bridge (station 5) on 23 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 3 November 2009.

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Richards Creek		Date:	3 November 2009
Station Name:	**Station 1**		Flow status:	Moderate
Sampler Used:	Number of replicates	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates		
Hess	4	0.09 x 4 =	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)	1	1
	Mayfly Nymph (EPT)	3	2
	Stonefly Nymph (EPT)		
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		4	3
Category 2 **Somewhat Pollution Tolerant**	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	38	2
	Watersnipe Larva		
Sub-Total		38	2
Category 3 **Pollution Tolerant**	Aquatic Worm (oligochaete)	75	6
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		75	6
TOTAL		117	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**: 117

DENSITY: Invertebrate density per square metre:

117 ÷ 0.36 = 325

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (Col. C): 75

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 3 + 2 x 2 + 6 = 19

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

1 + 2 + 0 = 3

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

(1 + 3 + 0) / 117 = 0.03

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

75 / 117 = 0.64

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	1
Predominant Taxon Ratio	2

Average Rating
2.00

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Richards Creek		Date: 3 November 2009
Station Name: **Station 2**		Flow status: Moderate
Sampler Used: Hess	Number of replicates 4	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.09 x 4 = 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)	1	1
	Mayfly Nymph (EPT)	32	8
	Stonefly Nymph (EPT)	25	6
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		58	15
Category 2 **Somewhat Pollution Tolerant**	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	6	3
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva	4	2
	Fishfly Larva		
	Scud (amphipod)	3	1
	Watersnipe Larva	1	1
Sub-Total		14	7
Category 3 **Pollution Tolerant**	Aquatic Worm (oligochaete)	22	4
	Blackfly Larva		
	Leech	1	1
	Midge Larva (chironomid)	2	1
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	1	1
Sub-Total		26	7
TOTAL		98	29

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 98

DENSITY: Invertebrate density per square metre:

98 ÷ 0.36 = 272

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (Col. C): 32

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 15 + 2 x 7 + 7 = 66

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

1 + 8 + 6 = 15

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

(1 + 32 + 25) / 98 = 0.59

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 29

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

32 / 98 = 0.33

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

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Richards Creek		Date: 3 November 2009
Station Name:	**Station 3**		Flow status: Moderate
Sampler Used: Hess	Number of replicates 4	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.09 x 4 = 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)	18	3
	Mayfly Nymph (EPT)	22	3
	Stonefly Nymph (EPT)	10	2
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle	1	1
	Water Penny		
Sub-Total		51	9
Category 2 **Somewhat Pollution Tolerant**	Alderfly Larva		
	Aquatic Beetle	1	1
	Aquatic Sowbug		
	Clam, Mussel	8	2
	Cranefly Larva		
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	11	2
	Watersnipe Larva		
Sub-Total		20	5
Category 3 **Pollution Tolerant**	Aquatic Worm (oligochaete)	46	3
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	2	1
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		48	4
TOTAL		119	18

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 119

DENSITY: Invertebrate density per square metre:

119 ÷ 0.36 = 331

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (Col. C): 46

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 5 + 4 = 41

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

3 + 3 + 2 = 8

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

(18 + 22 + 10) / 119 = 0.42

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 18

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

46 / 119 = 0.39

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	4

Average Rating
3.25