Fall 2014 Water Quality and Stream Invertebrate Assessment of Richards Creek, Crofton, British Columbia

Submitted to:

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Executive Summary

Since water quality monitoring began in 2008, Richards Creek has shown to have phosphate levels that exceed British Columbia's Water Quality guidelines in the downstream portion that empties into Somenos Lake. This lower portion of Richards Creek runs directly through agricultural lowland where water flow is reduced due to gradient of 0%. During the summer months when precipitation is low and air temperature increases, water flow is further reduced and insufficient "flushing" increases algae-blooms, increasing biological oxygen demand and decreasing the amount of dissolved oxygen. Combined with other contributing factors such as excessive nutrient loading from agricultural land run-off and sparse riparian vegetation buffer areas, the water quality is considered eutrophic, which limits aquatic life such as salmonid populations due to its hypoxic state. Being that Richards Creek is the largest tributary of Somenos Lake, and found to support large coho salmon spawning populations, as well as cutthroat and rainbow trout (Burns 1999). Continued water quality monitoring is of interest to Department of Fisheries and Oceans Canada (DFO), British Columbia Conservation Foundation (BCCF), and local interest groups like the Somenos Marsh Wildlife Society.

The main objective of the study is to provide a baseline overview of the water quality and stream invertebrate analysis from samples collected at four sampling station locations of Richards Creek that represent the overall habitat characteristics of the stream. Two sampling events were conducted on October 27th, 2014, and November 17th to capture water samples that represented low water flow in October and high flow in November. Hydrology measurements taken at sampling stations 1 and 2, showed discharge rates to be higher at sampling station 1 during both sampling events. The grade of slope was determined not to be a factor contributing to the higher discharge rate due to both stations having a 4% gradient. It was instead speculated water uptake from Richards Creek to residential properties and agricultural use may be the reason for reduced discharge rate at sampling station two.

Water quality parameters tested for included dissolved oxygen, pH, alkalinity, conductivity, turbidity, hardness, and nitrate and phosphate levels. Water quality samples were taken during both sampling events and analysed at Vancouver Island University lab in Nanaimo, BC and independently by ALS Laboratories in Burnaby, BC. ALS laboratories included total metals, anions, and nutrients in their analysis.

Microbiology samples were taken during sampling event one on October 27th, 2014. Samples were analyzed at Vancouver Island University and all samples were found to contain fecal coliform. Sampling station four received the highest number of fecal coliform colonies. These results were expected due to Richards Creek proximity to agricultural land.

A Hess Sampler was used to collect stream invertebrates during sampling event one in stations 1, 2, and 3. Sampling station 4 was not conducive to invertebrate sampling due to the deep depth this section of the stream. The Shannon-Weiner Index found stations 1, 2, and 3 to all have an EPT rating of marginal, indicating a relatively healthy population of pollution intolerant invertebrates.

A brief summary of results include the following:

- Phosphate levels increased downstream, receiving the highest value at station four during both sampling events. All phosphate values exceeded BC Water Quality guidelines. Water quality has reached eutrophic levels in this portion of Richards Creek
- Aluminum in stations 3 and 4 exceeded BC Water Quality guidelines during the first sampling event
- Fecal coliform colonies increased downstream where station 4 received the highest value
- Dissolved oxygen level decrease downstream and were found not to support salmonid populations in station four during sampling event one
- Conductivity and turbidity decreased during sampling event two due to increased water flow
- Stream invertebrate taxonomy was the highest at sampling station three
- Riparian vegetation decreases downstream where it has been cleared for agricultural land

Methods employed for laboratory analysis are discussed in detail, and are standard test used in the analysis of water quality monitoring.

Disclaimer

Results in this report are based from data collected during field surveys and water sample collections from a single year (2014). It is understood that ecosystems respond differently in both time and space to variable environmental conditions, even inter-annually. This data's accuracy is based on the results from students learning to conduct water quality monitoring at Vancouver Island University.

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1.0 Introduction

1.1 Project Overview

On October 27th, 2014 and November 17th, 2014, Bachelor of Natural Resource Protection students enrolled in Environmental Monitoring at Vancouver Island University (VIU), conducted a water quality assessment of Richards Creek, BC. This study was completed for Professor Eric Demers and contributing funders of the project (Department of Fisheries and Ocean (DFO) and British Columbia Conservation Foundation (BCCF)).

The water quality data collected for in this report is used to identify the environmental impacts Richards Creek is currently experiencing. A main focus of this study is to contribute to long-term data being compiled by DFO in an effort to determine non-point sources of effluent causing excess levels of nutrients in the lower portions of Richards Creek.

1.2 Historical Review

Richards Creek is a relatively small stream, which originates from the southern end of Crofton Lake on the east coast of Vancouver Island. The stream flows south for 9.6 km before draining into Somenos Lake. Richards Creek is the largest tributary of Somenos Lake, which eventually drains into the Cowichan River (HCTF 2009). The majority of the Richards Creek travels through agricultural land, while only the upper most portions flows through forested areas. The lower portion of Richards Creek is low gradient, and highly channelized (Figure 1). Numerous stream crossing occur over Richards Creek, which serve as potential point sources of storm water and road runoff, and non-point sources such as agricultural run-off (Figure 1).

Prior to 2008, Richards Creek suffered from extremely low summer flow, and Crofton Lake was identified as a potential source of water to augment Richards Creek throughout summer months. Crofton Lake was at one point used as the primary water supply for the town of Crofton by the District of North Cowichan (DNC) (HCTF 2009). The original dam was built at the lake in 1956 in order to increase water storage. Initial engineering was not suitable for significant releases into Richards Creek, so infrastructure modifications were necessary (HCTF 2009). In June of 2008, the Richards Creek flow augmentation project was completed allowing 2/3 of Crofton Lake to be made available for Richards Creek with the additional 1/3 being maintained as back up for city supply (HCTF. 2009). Benefits of the flow augmentation are most significant in the higher gradient, upper portions of the stream. The high biological oxygen demand in the lower portion of Richards Creek still remains an issue due to large quantities of macrophytes and the shallow depth of Somenos Lake (Guimond and Sheng, 2005).

1.3 Project Objectives

The objectives for the Richards Creek environmental monitoring project are to examine the current environmental conditions, and ecosystem health within Richards Creek. By continuing to contribute to long-term monitoring efforts on the environmental conditions of the creek and surrounding ecosystems, we are able to compare the results from previous year's data (2009-2013) and build a long-term analysis of the overall stream and ecosystem health.

By determining point source and non-point source pollutants we will then be able to evaluate potential impacts on the watershed. Vancouver Island University (VIU), The District of North Cowichan, the British Columbia Conservation Foundation, and the Department of Fisheries and Oceans Canada may all take interest in our results and findings.

1.4 Potential Environmental Concerns

Urban development and pastures rich in phosphates and nitrates may be causing excessive nutrient loading into the lower portions of Richards Creek. The nutrient runoff from the surrounding agricultural land is likely the primary non-point source of nutrients leading to eutrophication. Previous water quality monitoring data collected by the DFO in 2008-2009 and VIU students have shown a trend of nutrient rich water in the downstream reaches of Richards Creek. Measurements of low dissolved oxygen have also been consistently found, indicating a high level of biological oxygen damage (BOD) (VIU 2013).

Low amounts of native riparian species are present in the lower reaches, especially in areas where the ground has been disturbed by storm drain excavation. Plant uptake aiding in the filtration of excessive nutrients have been greatly reduced. Invasive disturbance species such as Himalayan Blackberry and English Ivy have cultivated in these disturbed areas and out-competed the native riparian species.

2.0 Methods

2.1 Study Site

This project was conducted on Richards Creek, located northeast of the city of Duncan, BC. Richards Creek flows southeasterly from Crofton Lake to Richards Trail, and then travels in a southwesterly direction, emptying into the northeast end of Somenos Lake. Somenos Lake drains southeasterly through Somenos Creek to the Cowichan River. The upstream portions of Richards Creek flow through residential areas and riparian forest while the lower portion of the creek flows primarily through agricultural lands. District of North Cowichan augments flow to Richards Creek in the summer months through releases from the dam on Crofton Lake (HCTF, 2009).

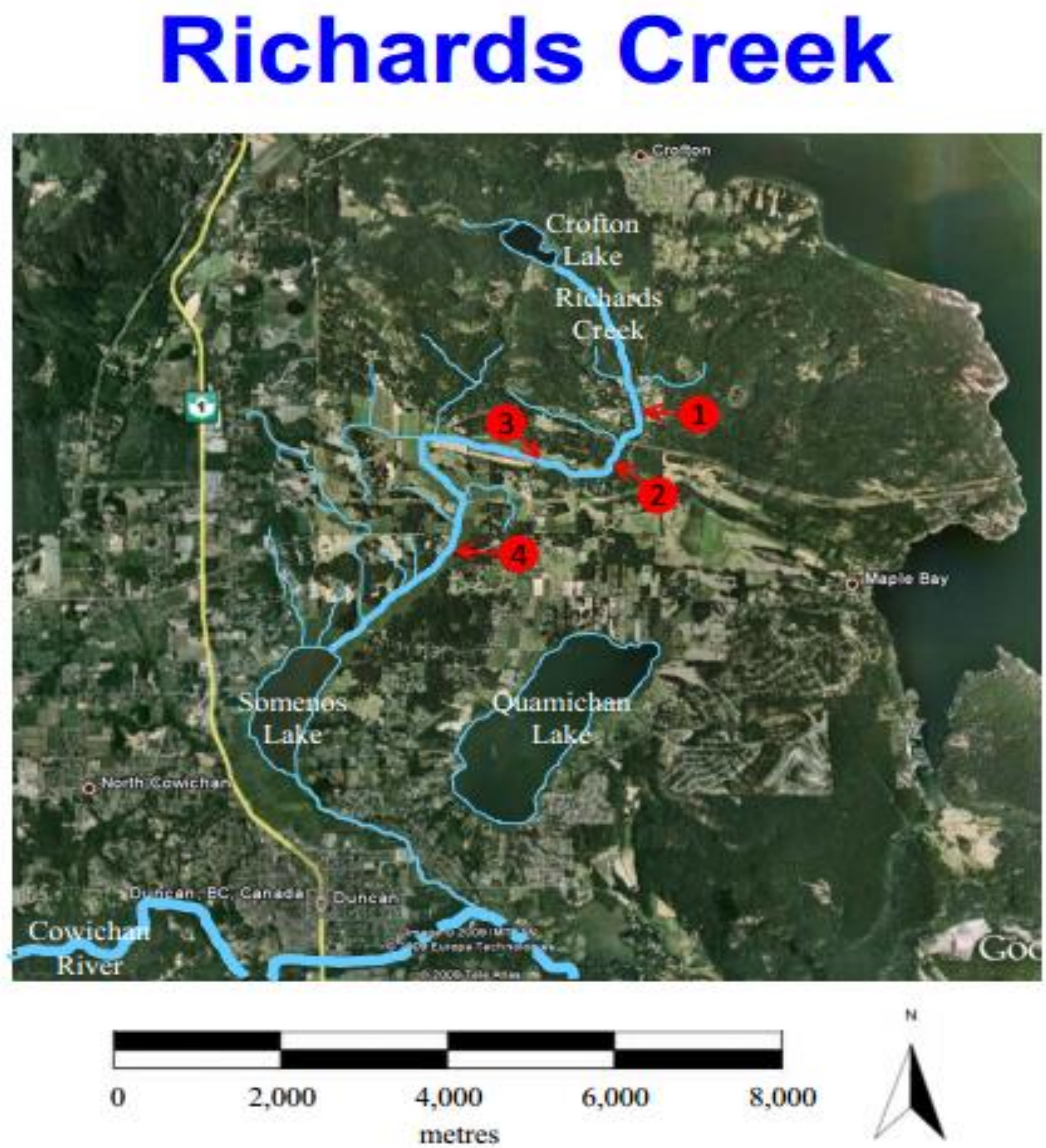

Figure 1. Approximate location of the sampling stations used for water quality and stream invertebrate assessments on Richards Creek during the fall of 2014.

2.1.1 Stations and Habitat Characteristics

Sample station choice was based on locations used in previous years of monitoring (Guimond and Sheng. 2005). Stations were numbered from upstream (sampling station 1) to downstream (sampling station 4). All stations were easily accessed via footpaths or road crossings. Sampling station 1 is located on Escarpment Way off Osborne Bay Road (Table 1). Surrounding the area is private residence and a five-acre agricultural field. The headwater of Richards Creek is approximately 2.12 km upstream at Crofton Lake. Three similar sections of stream riffles with 70% gravel and 30% sand bottom substrate with a gradient of 2% were chosen to be the locations where stream invertebrates, water quality, and microbiology would be sampled. Predominate riparian vegetation consists of Pacific Ninebark (*Physocarpus capitatus*), Red Alder (*Alnus rubus)*, Hardhack (*Spiraea douglasii*), and Western Red Cedar (*Tsuga plicata*) (Appendix 1 Photo 1).

Table 1. Description of the sampling stations used for water quality and stream invertebrate assessments on Richards Creek fall 2014 sampling. 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 N	452560 E	2.3	Escarpment way crossing
2	5408622 N	452083 E	3.5	Rice road crossing, Innisvale Farm
3	5408795 N	451331 E	4.2	Richards Trail crossing
4	5409420 N	452560 E	7.2	Herd Road crossing

Sampling station 2 is located on the private residence of Innisvale Farm, at the end of Rice Road. Sampling took place on the east bank of Richards Creek. Access to the sampling location is down a steep sloped trail that opens to a wide rifled section of the stream. The bottom substrate consisted of 30% bedrock, 20% cobble, 40% gravel and 10% sand with a gradient of 4%. Dense riparian vegetation consisted of Salmonberry (*Rubus spectabilis)*, Sitka Sedge (*Carex* aquatilis), Maidenhair Fern (*Adiantum pedatum*), Lady Fern (*Athyrium filix-femina)* and Skunk Cabbage (*Lysichiton americanum*). Invasive species included English Ivy (*Hedra helix*) and Periwinkle (*Littorina littorea*), which comprised approximately 40% of the left and right banks vegetation. Surrounding the sampling site is agricultural land currently in use. There is an intake pipe for residential water in close proximity (25 meters) to the sampling site. The site is easily accessible via Rice Road. Landowner granted permission to conduct water quality samples on their property.

Station 3 is located off of Richards Trail Road, on the east corner of Pastula farm. Access is directly down an excavated embankment, next to an active agricultural field. A fence paralleling the west bank along the agricultural field blocks access to the stream. There is a storm drain that empties into a pool at the mouth of the culvert where microbiology and water quality samples were taken. Stream invertebrate samples were taken upstream in riffles with substrate composed of bedrock (60%) mixed with 20% gravel and 20% sand. This section of Richards Creek has low gradient of 4% and travels through agricultural land. There is a low amount of riparian vegetation consisting predominantly of Nootka Rose (*Rosa nootkana*) and Red Alder (*Alnus rubus*).

Sampling station 4 is located directly under the Herd Road Bridge, which can be accessed via a footpath on the north side of Herd Road. This site is roughly two kilometers upstream of Somenos Lake. Flat, agricultural land surrounds this section of the creek. Water movement in this location is severely reduced due to the low gradient of 0%. Historically, European settlers drained this area known as the "Somenos flats" for its fertile lowland (Somenos Marsh 2014). Substrate composition could not be determined at this site due to the deep-water depth. There is a low amount of riparian vegetation; Nootka Rose (*Rosa nootkana*), Hardhack (*Spiraea douglasii*), and Scouler's Willow (*Salix scouleriana*) accounted for 30% of the surrounding vegetation. A species of duckweed (*Lemnoideae sp*) was present in high densities on the first sampling day, indicating nutrient-rich water.

2.1.2 Sampling Frequency

A preliminary site visit took place on October 15/2014 and field sampling was conducted on October 27 and November 17/2014. For this study, samples were collected for water quality analyses, microbiology and stream invertebrate assessment (Table 2). Measurements of dissolved oxygen, temperature and flow rate were taken in the field. Hydrology data was collected at stations 1 and 2 and water samples from all stations were collected on both sampling days.

Table 2. Water quality and stream invertebrate sampling activities conducted at each station on Richards Creek, Fall 2014.

	Samples collected for:	Date collected
Station 1 - Escarpment Way Crossing Culvert	Water Quality (VIU and ALS)	October 27/2014 November 17/2014
	Microbiology	October 27/2014
	Stream Invertebrates	October 27/2014
Station 2 - Innisvale Farm	Water Quality (VIU only)	October 27/2014 November 17/2014
	Microbiology	October 27/2014
	Stream Invertebrates	October 27/2014
Station 3 - Richards Trial Crossing Culvert	Water Quality (VIU and ALS)	October 27/2014 November 17/2014
	Microbiology	October 27/2014
	Stream Invertebrates	October 27/2014
Station 4 Herd Road Bridge	Water Quality (VIU and ALS)	October 27/2014 November 17/2014
	Microbiology	October 27/2014
	Stream Invertebrates	N/A

2.2 Hydrology

We measured the stream profile and water velocity to evaluate the flow rates of Richards Creek on each given day. During both sampling events, stations 1 and 2 were sampled.

Equipment included:

- a float
- measuring tape
- measuring stick
- stop watch

We determined the wetted width, and took the average of three water depths along a transect. Velocity was determined by floating a float 3 times over a measure distance and taking the average of the three runs. Discharge (m^3/s) was then calculated as the product of the cross-sectional area and average velocity.

2.3 Water Quality

2.3.1 Field Measurements

Field measurements for temperature and dissolved oxygen were taken on site with an OxyGuard dissolved oxygen metre by placing the probe directly into the stream channel. Temperature was taken to the nearest 0.01°C and to the dissolved oxygen 0.01 mg/L at each site.

2.3.2 Water Sample Collection

Water samples were taken by submersing a bottle in the water with the opening facing upstream. We approached the sample sites from downstream carefully so bottom sediments were not disturbed. We began sampling at station 1 and proceeded downstream until we reached station 4. A trip blank accompanied us on the sampling days and a replicate was taken at station 1 on each sampling event. At all sample stations we collected one sample (1L) for VIU laboratory analysis; at stations 1, 3 and 4 we collected 3 different samples for ALS laboratory analysis. A replicate sample was collected from station 1 on each day. All samples were kept in a fridge until the analysis was conducted.

2.3.3 VIU Laboratory Analysis

At the VIU lab we conducted tests for various water quality parameters using a variety of equipment under the guidance of Dr. Eric Demers and Sarah Greenway. Water quality parameters tested for included:

- pH using an electronic pH meter
- Conductivity to the nearest µS/cm
- Hardness to the nearest mg/L as $CaCO_3$ using a HACH HA-71A test kit
- Total alkalinity to the nearest mg/L as $CaCO_3$ using a HACH AL-DT test kit
- Phosphate to the nearest mg/L HACH DR2800 spectrometer (Method 8192)
- Nitrate nearest mg/L using a HACH DR2800 spectrometer (Method 8048)
- Turbidity to the nearest 0.01 NTU (Nephelometric Turbidity Units) using a portable turbidity meter.

2.3.4 ALS Laboratory Analysis

Professor Eric Demers submitted labeled samples with the appropriate chain of custody via courier to ALS Laboratory in Burnaby BC via a cooler shipment. Tests for conductivity, pH, hardness, alkalinity and nutrients such as ammonia, nitrate, phosphate, and total metals were completed.

2.4 Microbiology

Water samples for microbiology were gathered during the first sampling event in sterile 120mLWhirl-Pac sampling bags from stations 1, 2, 3, and 4. These were kept on ice until analysis could begin at the VIU laboratory. A sample of 25 mL of water was filtered through a membrane filter with a vacuum pump. Nutrients and the membrane filter were added to a growth medium in a petri dish. Samples were then incubated, so a total and fecal coliform count could be performed. A filtration blank was used to ensure quality assurance.

2.5 Stream Invertebrates

We collected stream invertebrates at stations 1, 2, and 3 using a Hess Sampler. At each station we collected three replicates, thus providing us with a better representation of the invertebrate community at each station. At each location, samples were collected in areas with similar substrate. We approached sites from downstream, and sampled from riffles. The samples were held in separate clean, pre-labelled containers, and were kept cold in order to preserve them until they were analyzed at VIU. Our findings were documented on three separate invertebrate field data sheets (Appendix 2).

2.6 Quality Assurance/ Quality Control

Various measures were used to ensure the events and analysis maintained quality assurance and quality control. A trip blank was used for each sampling day. Filtration blanks were used when conducting VIU laboratory analysis of coliforms. A replicate water sample from station 1 was included during each sample event and analyzed at the VIU lab. All bottles that arrived from the ALS laboratory were clean and were not rinsed before samples were taken as they were pre-sterilized. While in transit all samples were stored in a cooler with ice packs, until a fridge was available in order to hinder any biological activity. We ensured that our samples were held for the least amount of time (under five days), as holding times would affect results.

3.0 Results and Discussion

The discharge measurements from October for Richards Creek show that there was actually a lower discharge of water at station 2, downstream from station 1 (Table 3). This may have been the result of water usage by farms or residences along the creek. The discharge in Richard Creek increased by the November 17/2014 sampling day following a period of high rainfall.

3.1 Water Quality

3.1.1 VIU Analysis

Table 3. Field measurements and VIU lab analysis of water samples collected from four samples sites on Richards Creek on October 27/2014 and November 17/2014.

		Field Measurements				VIU Lab Analysis			
Station	Discharge (m^3/s)	Temperature (°C)	Dissolved Oxygen (mg/L)	% Saturation	Conductivity (µS/cm)	pH	Alkalinity (mg/L as $CaCO_3$)	Hardness (mg/L as $CaCO_3$)	Turbidity (NTU)
October 27/2014									
1	0.067	9.4	9.1	98	148	7.4	39	61	1.57
1	-	-	-	-	148	7.4	29	86	1.50
2	0.046	9.4	10	99	180	7.6	32	86	1.76
3	-	9.5	9.8	97	180	7.7	40	86	3.21
4	-	10.3	1.9	12	220	6.9	32	86	3.33
November 17/2014									
1	0.13	4.5	12.9	97	80	8.0	62	36	0.84
1	-	-	-	-	83	7.7	60	37	0.77
2	0.16	4.2	13.1	98	101	7.7	72	45	0.73
3	-	3.6	13.3	99	104	7.7	80	49	1.14
4	-	3.0	5.6	39	153	7.2	121	82	2.96

The temperature at all stations on both events was safe for juvenile or adult salmonids (RISC 1998). Dissolved oxygen levels were safe for all aquatic stream life at stations 1, 2 and 3 (Table 3). Station 4 was in hypoxic conditions in October but increased water levels caused by a relatively major flush of water based on recent flood signs observed at the station and decreased temperature, increased the dissolved oxygen level by the November sampling day. Although the dissolved oxygen level at station 4 on November 17/2014 was in accordance with the BC Guideline for everything except juvenile or embryo salmonids, percent saturation remained low (39%).

Conductivity levels increased downstream on both days and an overall decrease was observed on the second day (Table 3). The levels of pH decreased downstream (Table 3). An increase in pH was observed on the second sampling day. Turbidity increased downstream due to accumulation of suspended particulates in the water column (Table 3). The overall decrease observed on the second day is likely due to dilution.

Alkalinity values observed were all greater than 20mg/L (Table 3). This means that Richards Creek has low acid sensitivity and the stream has strong capacity to buffer acidic inputs. Values observed for hardness ranged from 61 to 86 mg/L on the October 27 sampling day and decreased to a range of 36 to 82 mg/L on November 17 (Table 3). On October 27 Richards Creek had a higher hardness level than on November 17 when all sites except 4 were be considered soft by the BC Water Quality Guideline.

3.1.1 ALS Analysis

The values measured by ALS laboratory for hardness and pH are comparable to those measured at the VIU lab. Our measurements of conductivity were consistently lower than those measured by ALS. This discrepancy may be a result of improper calibration of the conductivity probe (Table 4).

Nitrate values were well below the BC guideline on both sampling days (Table 4). A decrease was observed on the November 17 sampling day likely due to the dilution observed as a result of a recent rain event. During each sampling event phosphate levels were found to change from upstream to downstream. On October 27 we found that phosphate levels increased downstream. Station 1 was oligotrophic based on BC Water Quality Guideline but stations 3 and 4 were eutrophic. On November 17 station 1 and 4 were found to be eutrophic, while station 3 was mesotrophic (Table 4). At sampling station 1 the agriculture field directly adjacent to the stream had recently been fertilized with manure based observation made in the field.

Aluminum was the only heavy metal detected above BC Water Quality Guidelines and this was only at stations 3 and 4 on October 27. Aluminum wasn't detected on November 17 due to dilution (Table 4). More precise testing would be needed to determine if other metal exceed the guideline because some of the guidelines are below the detection limits of ALS laboratory testing.

Table 4. ALS Laboratory results for water samples taken from stations 1, 3 and 4 on Richards Creek on October 27th and November 17th, 2014. Highlighted values exceed at least one outlined BC water quality guideline.

	BC Water Quality Guidelines							
	BC Max	BC 30-day mean		October 27/2014			November 17/2014	
Variable								
Physical Tests	mg/L	mg/L	1	3	4	1	3	4
Conductivity			164	204	241	102	129	191
Hardness (as CaCO3)			57.2	77.2	84.1	37.4	50.2	77.1
pH	6.5-9.0		7.51	7.73	7.10	7.55	7.67	7.20
Anions and Nutrients								
Ammonia, Total (as N)	8.88[b]	1.71[b]	0.0120	0.0096	0.106	0.0184	<0.0050	0.162
Nitrate (as N)	31.3	3	1.65	1.58	1.40	0.216	0.327	0.334
Nitrite (as N)	0.06[c]	0.02[c]	0.0035	0.0034	0.0551	<0.0010	<0.0010	0.0112
Total Nitrogen			1.83	2.06	2.40	0.685	0.542	1.52
Orthophosphate-Dissolved (as P)			<0.0010	0.0526	0.109	<0.0010	0.0047	0.166
Phosphorus (P)-Total			0.0062	0.0828	0.197	0.0661	0.0102	0.214
TN:TP			295	25	12	10.4	53.1	7.1
Total Metals								
Aluminum (Al)[m]	0.10[d]	0.05[d]	<0.20	0.25	0.38	<0.20	<0.20	<0.20
Antimony (Sb)[m]	0.02		<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
Barium (Ba)	5	1	0.014	0.016	0.020	<0.010	0.011	0.018
Beryllium (Be)	0.0053		<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
Boron (B)	1.2		<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium (Cd)[m]	0.00002		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (Ca)			17.6	22.5	24.8	11.8	15.5	23.7
Chromium (Cr)[m]	0.001[f]		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt (Co)[m]	0.11	0.04	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu)[m]	0.008[g]	0.002[g]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron (Fe)[m]	1.0		0.260	0.339	0.568	0.148	0.176	0.490
Lead (Pb)[m]	0.031[h]	0.0038[h]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium (Li)	0.087	0.098	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium (Mg)			3.19	5.08	5.41	1.92	2.78	4.37

Manganese (Mn)	0.71[i]	0.28[i]	0.0653	0.0198	0.0612	0.0359	0.0158	0.213
Molybdenum (Mo)	2	1	<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
Phosphorus (P)			<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)	373		<2.0	<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
Silicon (Si)			5.66	7.33	6.71	3.74	4.93	5.23
Silver (Ag)[m]	0.0001[k]	0.00005[k]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium (Na)			8.6	10.6	12.7	5.0	6.1	8.7
Strontium (Sr)			0.0605	0.0991	0.132	0.0354	0.0508	0.0951
Thallium (Tl)[m]	0.0003		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin (Sn)-Total			<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium (Ti)	2		<0.010	0.015	0.020	<0.010	<0.010	0.012
Vanadium (V)[m]	0.006		<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc (Zn)	0.033[l]	0.0075[l]	<0.0050	<0.0050	0.0063	<0.0050	<0.0050	0.0075

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(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(hardness)] - 1.46} mg/L.
The 30-day mean lead guideline is 0.001 * [3.31 + e {1.273 [ln(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.

3.2 Microbiology

All water samples collected from Richards Creek contained fecal coliform (*E. coli*) (Table 5). Total coliform counts and fecal coliform counts increased downstream but the percent fecal remained relatively consistent. A filtration blank cultured with sterile water did not produce any coliform forming units.

Table 5. Total coliform and fecal coliform counts from water samples taken from each of the four sites on Richards Creek on October 27/2014. Values are expressed in coliform forming units (CFU) per 100mL.

Sample	Total Coliform	Fecal Coliform (*E. coli*)	% Fecal Coliform
1	372	48	13
1	336	28	8
2	532	80	15
3	724	92	13
4	1328	160	12
Filtration Blank	0	0	0

3.3 Stream Invertebrates

Collectively 104 individuals were collected in the three replicates resulting in a density of 385/m^2 at station 1 (Figure 2). The predominant taxon was mayfly nymphs. Two groups of EPT taxa (stonefly and mayfly nymphs) were present at station 1. This site had acceptable EPT to total and predominant taxon ratios (Table 6).

The predominant taxon observed at station 2 was stonefly nymphs. 30 invertebrates were collect giving an invertebrate density of 111/m^2 (Figure 2). Two crayfish were collected in this sample, which may have resulted in decreased overall counts due to the predatory nature of crayfish and the time between collection and processing. Station 2 had an overall site assessment rating of marginal based on *The Stream Keepers Handbook* (Table 6).

Amphipods were the predominant taxon at station 3 followed closely by stonefly nymphs. 122 invertebrates were collected at station 3 resulting in a density of 452/m^2 (Figure 2). The highest diversity and most individuals counted was at station 3 followed by station 1 (Table 6). The best overall rating was observed at station 3 with a good pollution tolerance index (Table 6).

A change in the predominant taxa was observed from the most upstream site to the most downstream site. Mayfly nymphs and stonefly were the predominant taxa at station 1 and 2 but a shift to amphipods and other somewhat and pollution tolerant species begins to occur at station 3 (Figure 2). We were unable to sample at station 4 but presumably invertebrate populations would reflect lentic species opposed to lotic and have high pollution tolerance.

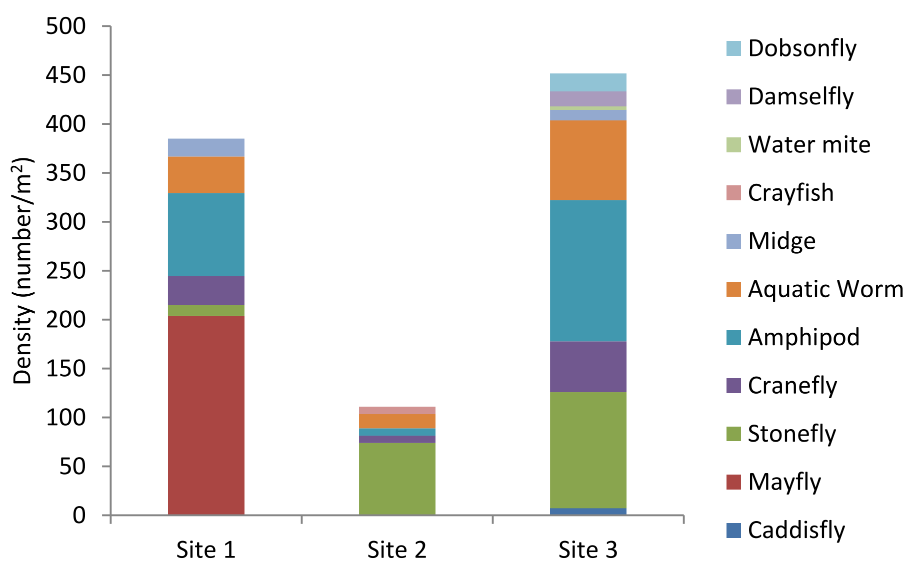

Figure 2. Density per metre squared for each taxonomic group of stream invertebrates counted at each of the three sites on Richards Creek on October 27/2014.

Table 6. Overall site assessment rating based on The Stream Keepers Handbook and Shannon-Weiner diversity index for invertebrate samples collected on Richards Creek on October 27/2014 using a 0.09m^2 Hess sampler.

Site	1	2	3
Assessment	Rating	Rating	Rating
Pollution Tolerance Index	Marginal	Marginal	Good
EPT Index	Marginal	Marginal	Marginal
EPT to total ratio	Acceptable	Acceptable	Marginal
Predominant taxa ratio	Acceptable	Marginal	Acceptable
Shannon-Weiner Index	0.749	0.671	0.780

4.0 Conclusion

A common trend observed amongst most variables was an increase downstream due to accumulation of particles in the water from the various point and non-point sources over the course of the stream. Decreases in most values between the first and second day are likely due to the increased volume of water in the stream, which caused a dilution effect to occur. An increase in dissolved oxygen was observed, which correlates with the observed temperature drop. Hypoxic conditions at station 4 are likely caused by high biological oxygen demands resulting from eutrophication due to agricultural run-off. ALS laboratory results show that Richards Creek is oligotrophic in its upper portions but becomes eutrophic as it moves downstream through residential and agricultural areas. Fecal coliform presence may be the result of fertilizers or a failing septic field along the banks of the creek, which would also indicate a non-point source of nutrients into the stream leading the eutrophication. Stream invertebrates observed in Richards Creek indicate that the overall site assessment based on *The Stream Keepers Handbook* is marginal to acceptable. This could be improved greatly with better water quality.

5.0 Recommendations

Based on our results and the results of the past water quality studies on Richards Creek, continued monitoring by Vancouver Island University is recommended in order to establish long-term data sets.

Establishing long-term trends will indicate whether phosphate levels are increasing or decreasing and whether they continue to exceed the maximum acceptable levels set out in the BC Water Quality Guideline. This will also give insight whether eutrophication of the lower portion of the stream continues to occur. The data may also show an increasing or decreasing trend in the amount of other nutrients or heavy metals entering Richards Creek.

Native riparian plant restoration along the excavated bank at sampling station 3 through to sampling station 4 where a low density of riparian plants currently exist, would provide a natural buffering system that would parallel the agricultural land. The riparian plant species will provide a natural filtration system that would decrease eutrophication and help to increase the amount of dissolved oxygen available to the aquatic community. Salmonid populations of the Somenos basin would also benefit from increased riparian areas for these areas give shade, cool the temperature of stream, provide shelter and food from fallen insects and leaf litter. Being the largest tributary of the Somenos basin, Richards Creek has the potential to increase salmonid spawning and rearing numbers if restoration successfully mitigates excessive nutrient levels.

Educational programs based on preserving the water quality of the Somenos basin by non-for-profit organizations like the Somenos Marsh Wildlife Society and government programs like The Pacific Stream Keepers can encourage communication and cooperation in watershed management. Agricultural landowners along Richards Creek could further learn how they could be contributing negatively to Richards Creek and what they can do to change their husbandry practices to reduce effects on the creek.

6.0 Acknowledgements

We would like to thank Dr. Eric Demers and Sara Greenway for their guidance and expertise during the analysis of water quality parameters tested for at the Vancouver Island University laboratory. We would also like to thank BC Conservation Foundation’s “Living Rivers - Georgia Basin / Vancouver Island” program and Fisheries and Oceans Canada for supplying funding for analytical processing of water quality. Special thanks to the owners of Innisvale Farm for granting permission to access the stream on their property. Also VIU Biology and Natural Resource Protection program for supplying lab and field equipment. ALS Environmental Testing Lab provided their services at a reduced rate for this project. Past RMOT 306 environmental monitoring groups whose past data on Richards Creek gave us founding data we hope will continue to be built upon.

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8.0 Appendix

Appendix 1. Photos from sampling days on Richards Creek

Photo 1. Habitat characteristics of sampling station 1

Photo 2. Habitat characteristics of sampling station 2

Photo 3. Habitat characteristics of sampling station 3

Photo 4. Site 4 looking upstream on October 27/2017

Appendix 2.

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Richards Creek		Date: 27/10/2014
Station Name: Site 1		Flow status:
Sampler Used: Hess	Number of replicates: 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates: 0.27 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	EPT1	EPT4
	Mayfly Nymph (EPT)	EPT2 55	EPT5 1
	Stonefly Nymph (EPT)	EPT3 3	EPT6 1
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 58	D1 2
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	8	3
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	23	
	Watersnipe Larva		
Sub-Total		C2 31	D2 3
Category 3	Aquatic Worm (oligochaete)	10	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	5	1
	Planarian (flatworm)		
Pollution Tolerant	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 15	D3 2
TOTAL		CT 104	DT 7

Site 1

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: S1 104

DENSITY: Invertebrate density per total area sampled:

S1 104 ÷ 0.27 m^2 = S2 385 / m^2

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (Col. C) S3 Mayfly (55)

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 2 + 2 x 3 + 2 = S4 14

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

0 + 1 + 1 = S5 2

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

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

(EPT1 + EPT2 + EPT3) / CT

(0 + 55 + 3) / ____ = S6 0.56

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: S7 7

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

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

Col. C for S3 / CT

58 / 104 = S8 0.56

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
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	R1 2
EPT Index	R2 2
EPT To Total Ratio	R3 3
Predominant Taxon Ratio	R4 3

Average Rating
Average of R4, R5, R6, R8
2.5

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Richards Creek			Date: 27/10/2014
Station Name: Site 2			Flow status:
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.27 m^2	

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	EPT1	EPT4
	Mayfly Nymph (EPT)	EPT2	EPT5
	Stonefly Nymph (EPT)	EPT3 20	EPT6 2
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 20	D1 2
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	2	1
	Crayfish	2	1
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	2	1
	Watersnipe Larva		
Sub-Total		C2 6	D2 3
Category 3	Aquatic Worm (oligochaete)	4	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)		
Pollution Tolerant	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 4	D3 1
TOTAL		CT 30	DT 6

Site 2

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: S1 30

DENSITY: Invertebrate density per total area sampled:

S1 30 ÷ 0.27 m^2 = S2 111 / m^2

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (Col. C) S3 Stonefly (20)

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 2 + 2 x 3 + 1 = S4 13

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

0 + 0 + 2 = S5 2

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

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

(EPT1 + EPT2 + EPT3) / CT

(0 + 0 + 20) / 30 = S6 0.66

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: S7 6

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

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

Col. C for S3 / CT

20 / 30 = S8 0.66

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
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	R1 2
EPT Index	R2 2
EPT To Total Ratio	R3 3
Predominant Taxon Ratio	R4 2

Average Rating
Average of R4, R5, R6, R8
2.25

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Richards Creek		Date: 27/10/2014
Station Name: Site 3		Flow status:
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.27 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	EPT1 2	EPT4 1
	Mayfly Nymph (EPT)	EPT2	EPT5
	Stonefly Nymph (EPT)	EPT3 32	EPT6 2
	Dobsonfly (hellgrammite)	5	1
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 39	D1 4
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	14	3
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva	4	1
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	39	2
	Watersnipe Larva		
Sub-Total		C2 57	D2 6
Category 3	Aquatic Worm (oligochaete)	22	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	3	1
	Planarian (flatworm)		
Pollution Tolerant	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	1	1
Sub-Total		C3 26	D3 3
TOTAL		CT 122	DT 13

Site

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: S1: 122

DENSITY: Invertebrate density per total area sampled:

S1 122 ÷ 0.27 m^2 = S2: 452 /m^2

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (Col. C) S3: Amphipod 39

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 4 + 2 x 6 + 3 = S4: 27

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

1 + 0 + 2 = S5: 3

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

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

(EPT1 + EPT2 + EPT3) / CT

(2 + 0 + 32) / 122 = S6: 0.28

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: S7: 13

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

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

Col. C for S3 / CT

57 / 122 = S8: 0.47

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
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	R1 4
EPT Index	R2 2
EPT To Total Ratio	R3 2
Predominant Taxon Ratio	R4 3

Average Rating
Average of R4, R5, R6, R8
2.75