Departure Creek Environmental Monitoring 2013

Vancouver Island University

Bachelor of Natural Resource Protection

RMOT 306

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Executive Summary

This report has been generated as part the East Vancouver Island stream assessment series. The following report pertains specifically to Departure Creek located in Nanaimo, BC. The creek spans a short reach through the urban ecosystem of Departure Bay and spills into the northwest corner of Departure Bay located on the West shoreline of The Strait of Georgia.

The goals of the study carried out in the above stated area are to action two sampling events at four previously established locations to collect field measurements, water quality samples and stream invertebrates. Parameters measured under these categories were used to determine the overall status of stream health present in Departure Creek. First of all, field measurements from the creek determined how the streambed reacts to changes in discharge rates observed at the different sampling dates. Secondly, water samples were used extensively to analyze the presence of foreign, deleterious substances that could potentially compromise stream health. Microbiology analysis accompanied water quality testing to assess the presence of bacteria colonies in Departure Creek. Lastly, stream invertebrates collected during the first sampling event lead to an overall stream health outlook from a community level of organisms present at two locations on the stream. Laboratory analyses provided by both Vancouver Island University and ALS laboratories were used to compile raw data for further investigation. With the assistance of ALS labs, precise test results accompanied with various metal concentrations present in the creek were available for this report. All information gathered from analysis was critical in determining water quality of Departure Creek.

Departure Creek was found to have high fecal coliform counts and Aluminum concentrations slightly above British Columbia guidelines (November). Measurements showed that Departure Creek displayed heightened discharge in November and average to low discharge in October. Stream invertebrates present in October gave the stream a healthy rating with pollution intolerant species found at both sampling stations. The isolated green space in Nanaimo that is home to Departure Creek has been challenged over the years by uninterrupted drainage from its surrounding urban community that encroaches on the creek bed at nearly every edge. Departure Creek has seen habitat enhancement and community involvement over the past years prior to this report. It appears that creek enhancement has been beneficial to the local ecosystem and should be continued for further progression with development of the urban green space.

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1. Background

Departure Creek (Figure 1) is a short waterway, approximately 3km in length, which flows into the Strait of Georgia at Departure Bay. The creek has two sources. The first is Keighley Creek, which flows from the Nanaimo Golf Club. The other source is from Joseph Creek, which flows from a ditch near the Wellington Secondary School (Harbour City River Stewards, unknown date). Since 1995 there has been a variety of habitat restoration projects conducted on Departure Creek. A small dam that was installed to control sediment blocked the access of pink salmon to Departure Creek. This dam was removed in 2011 which allowed for the return of approximately 150 pink salmon. The most recent project was in 2012 when a restoration enhancement project was conducted in Woodstream Park that added large woody debris, spawning gravel, and an additional riffle to the creek (City of Nanaimo, 2012).

2. Introduction

Since 2006, there have been environmental monitoring projects conducted on Departure Creek in Nanaimo, BC. This report represents the fifth monitoring project that was conducted which will add to the collection of data since the last project was completed. This project was undertaken by a group of four natural resource management students at Vancouver Island University enrolled in the RMOT 306 Environmental Monitoring course. This course was taught by professor Dr. Eric Demers from the Biology department. The project took place from October 2013 to November 2013, and focused on monitoring, assessing, and identifying potential environmental impacts currently in Departure Creek.

Due to the fact that Departure Creek flows through an urban area, it is always at risk of pollution from concentrated human activity in the area. This report displays data from analyzed samples

and will discuss the status of the creek. An overall assessment of the stream habitat will be made after the analyses are completed.

In preparation for this project the following objectives were set out:

- Collect samples from four established locations on Departure Creek
- Undertake two collection events at the four locations to develop comparable results
    - At each collection event gather field measurements and water samples for further assessment
- Collect stream invertebrates from two stations on Departure Creek

The objectives ensured that appropriate measurements were collected and parameters tested for to make conclusions regarding the overall condition of Departure Creek.

3. Methods

The monitoring will provide stakeholders with an idea of the state of the creek's water quality. Parameters measured will include: water quality, toxicity, microbiology, basic hydrology and invertebrate biodiversity. These four sites have been sampled each year by Vancouver Island University students in the RMOT degree program to keep a record of the stream's water quality. All sites give an accurate representation of the overall makeup of the stream, except for Site 4, which is at the confluence with marine environment. All sites were originally visited on October 16, 2013. This site visit allowed group members to observe the sampling environment and access point

3.1 Study Area

Departure Creek is located in the neighborhood of Departure Bay in Nanaimo. The creek headwaters originate at two tributaries, firstly, Joseph Creek and secondly, Keighly Creek. Departure Creek eventually discharges into Departure Bay near the intersection of Departure Bay Road and Hammond Bay Road (Figure 1).

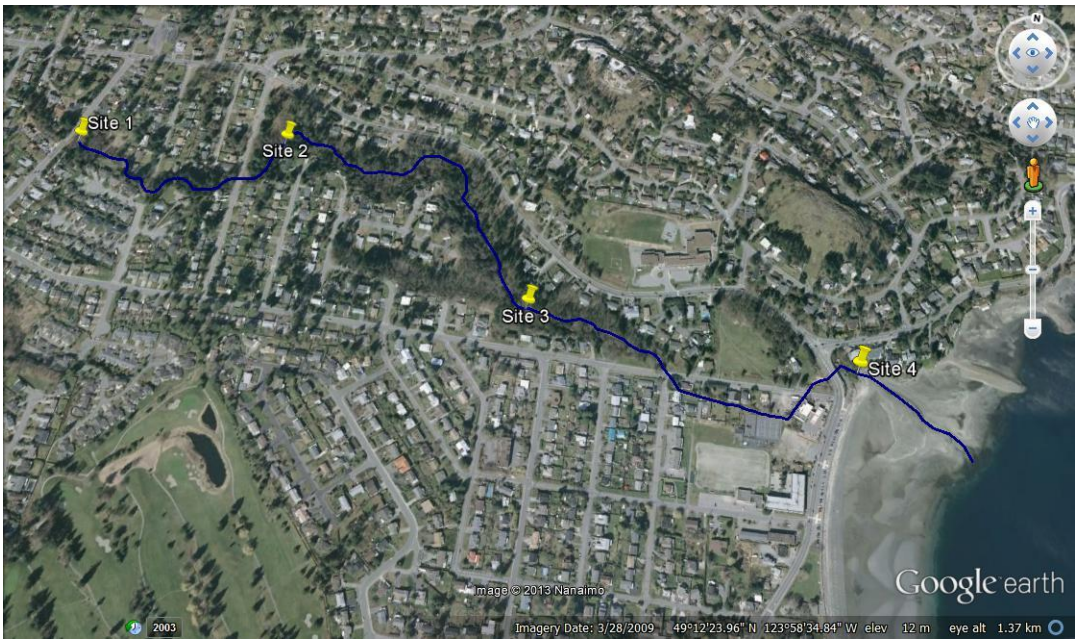

Figure 1. Study area with site locations

3.1.1 Sampling Stations

Within the study area, four sampling sites that have been used in the past for environmental monitoring have been selected on Departure Creek in Nanaimo, British Columbia (Figures 2-5). Site 1 is located 20 meters downstream of Neyland Road and the Departure Creek crossing (Figure 2). The stream width is approximately 2.5-3 meters across and has a moderate to steep slope gradient. Substrate at Site 1 consists of boulders, cobble, gravel and a small portion of

fines. Surrounding vegetation is made up of western red cedar (*Thuja plicata)* and big leaf maple (*Acer macrophyllum),* ferns, sedges and mosses making up the understory of the riparian area. Overall canopy cover is approximately 70%. Stream access is easy or moderate as the banks are steep. The creek is easily accessible from Neyland Road. Litter and residential garbage were noted at this site.

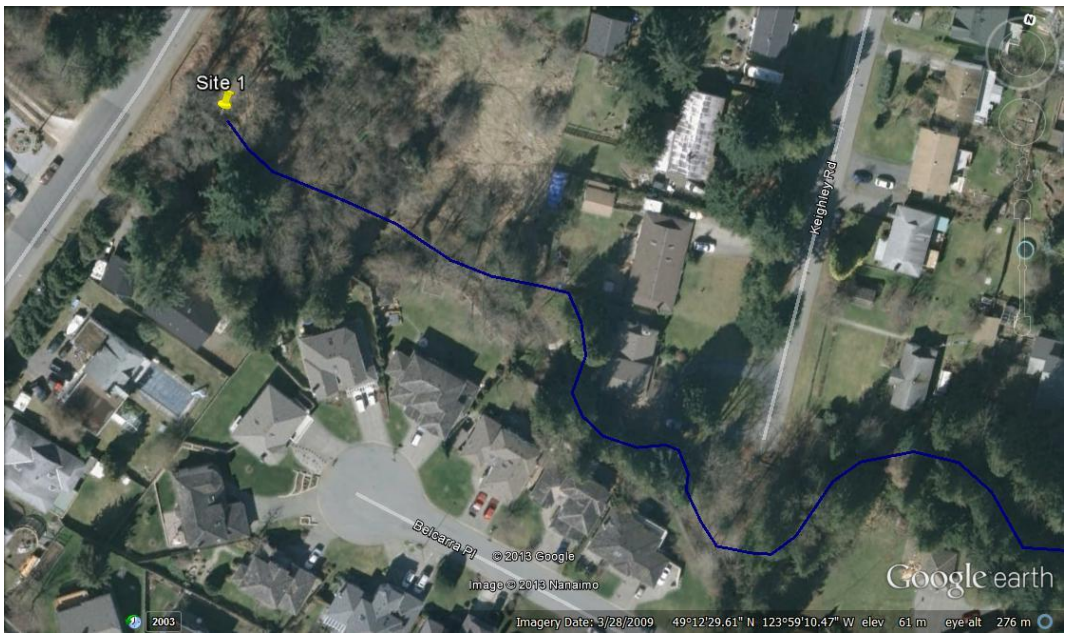

Figure 2. Aerial view of Site 1

Site 2 is located 75 meters downstream of Newton Street and the Departure Creek crossing (Figure 3). The stream is approximately 1.5-2 meters across. A gentle gradient was found at Site 2 with a balanced composition of substrates including cobble, gravel and fines. Vegetation in the riparian area includes red alder (*Alnus rubra*), western red cedar and big leaf maple, ivy, ferns, mosses and skunk cabbage making up the understory. Canopy cover is approximately 90%. Departure Creek is easily accessed and is roughly 80 metres from Newton Road.

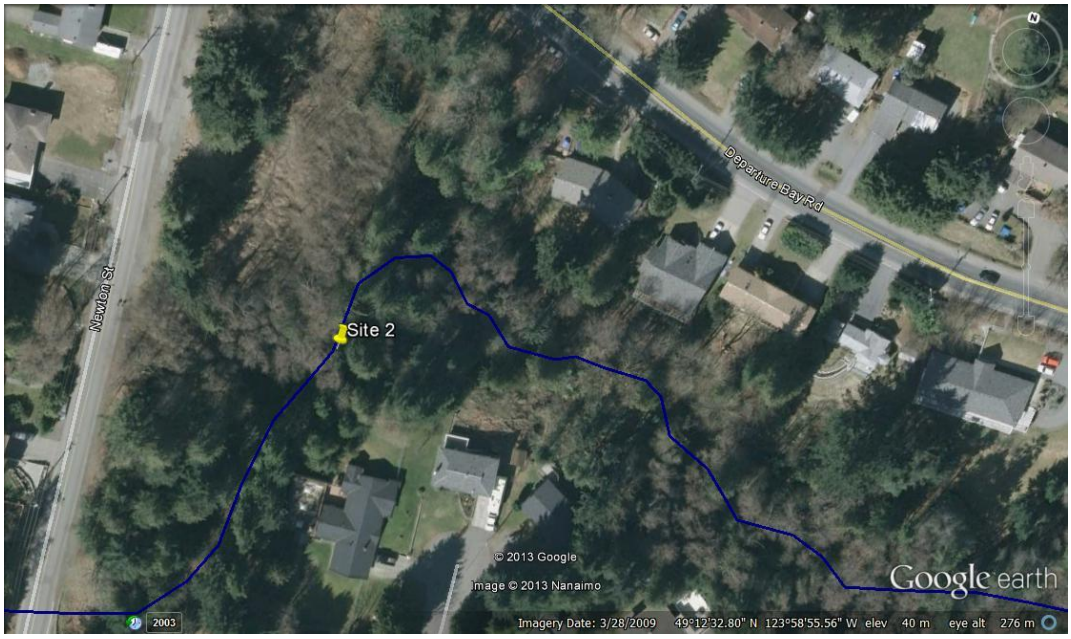

Figure 3. Aerial view of Site 2

Site 3 is located in Woodstream Park. It is approximately 200 meters upstream of the parking lot on Bay Street (Figure 4). The stream is approximately 4 meters across. Minimal gradient allows the creek to spill over its banks at this location with fluctuating water levels. Substrate consists of cobble, gravel and fines. Surrounding vegetation includes big leaf maple accompanied with blackberry shrubs, ferns, sedges and mosses. Canopy cover is approximately 50%. Stream access is easy. This area has less vegetation due to the fact that the creek has cut channels, removing new growth vegetation in the valley bottom of Woodstream Park. A public trail used regularly by local residents runs adjacent to Site 3.

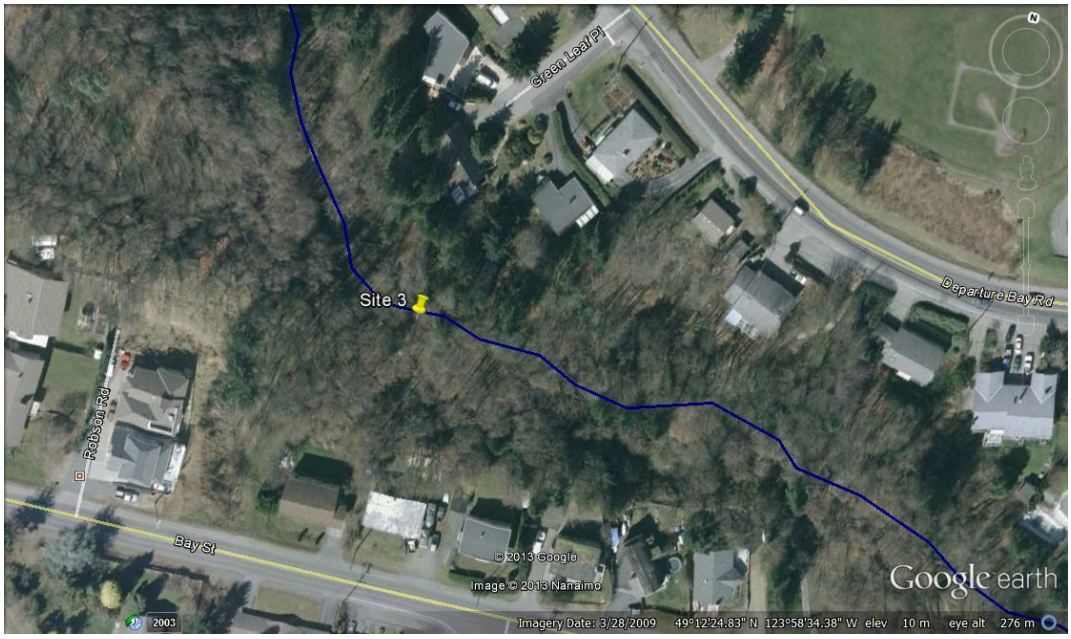

Figure 4. Aerial view of Site 3

Site 4 is located 10 metres downstream of Departure Bay Road and the Departure Creek crossing (Figure 5). The stream is approximately 3 metres across and has a modest gradient. Substrate consists of boulders, cobble, gravel and fines. Surrounding vegetation is sparse with only a collection of arbutus trees (*Arbutus menziesii*). The riparian area next to the site is void of any substantial vegetation matter because it is next to a beach ecosystem. Stream access is easy due to the close proximity of the beach.

Figure 5. Aerial view of Site 4

Each sampling station was positioned at permanent location which was recorded with GPS waypoints. Waypoints allowed each site to be reassessed for further sampling at a later date. Way points remained consistent with previous years of study on Departure Creek (Table 1). Appendix 1 and 2 contain images displaying sampling conditions during sampling events at Departure Creek.

Table 1. Description of the sampling stations used for water quality and stream invertebrate assessment on Departure Creek, during sampling in 2013

Station	Northing	Easting	Distance from Departure Bay (m)	General Location
1	5451086	428081	1,700	Directly downstream of Neyland Rd.
2	5451159	428412	1,300	Downstream of Newton Rd. near Josephs Creek
3	5450929	428842	600	Woodstream Park
4	5450857	429394	5	Departure Bay waterfront

3.2 Sampling Frequency

Sampling occurred during two separate dates. Initial samples were collected on October 28, 2013 and a second collection was made on November 18, 2013. These two dates were selected to attempt a low and high flow representation of the stream. During each sampling event different samples were collect for analysis as outlined in Table 2. The various samples were stored appropriately, refrigerated at <4°C until pre-determined analysis could be completed.

3.3 Water Quality

Water sampling was conducted at each site during both sampling events. With four sites to be assessed, a total of eight water quality samples were collected throughout the study. The first sampling event occurred October 28, 2013 and the second on November 18, 2013. Samples were collected for both VIU and ALS laboratory (Table 2).

3.3.1 Field Measurements

Measurements to determine discharge were taken at two sites on both sampling events. These measurements included width, depth and flow of Departure Creek at each respective site. The sites selected are listed below in Table 2.

Table 2. Water quality and stream invertebrate sampling activities conducted on Departure Creek, during assessment in 2013. "A" represents October 28, 2013 sampling event. "B" represents November 18, 2013 sampling event.

Station	Water Quality				Invertebrate Analysis
	Field Measurement	VIU Analysis	ALS Analysis	Microbiology	
1	A,B	A,B	-	A	-
2	A,B	A,B	-	A	-
3	A[1],B[1]	A,B	A,B	A	A
4	A[1],B[1]	A,B	A,B	A	A

Note: [1] Hydrology measurements were taken from Sites 3 and 4 at both sampling events

3.3.2 VIU Analysis

Water was tested for several different parameters including: dissolved oxygen (mg/L), temperature (degrees Celsius), conductivity (us/cm), pH levels, turbidity (NTU), alkalinity (mg/L), hardness (mg/L), nitrate (mg/L) and phosphate (mg/L). The dissolved oxygen and temperature was tested at the sites using a dissolved oxygen meter. Collected water was stored appropriately between field sampling and laboratory analysis. The above noted tests, other than temperature and dissolved oxygen, were carried out at Vancouver Island University by the members of this group.

3.3.3 ALS Analysis

In addition to VIU, professional testing was completed by ALS labs in Vancouver. Specific conditions pertaining to ALS samples were followed in all cases and shipping was handled by Dr. Demers. Samples analyzed by ALS were tested for 31 metals as well as nutrients, anions and physical characteristics found in the water samples submitted.

3.3.4 Quality Control and Quality Assurance

All water samples that were collected and analyzed adhered to the ambient freshwater and effluent sampling manual provided by the Government of British Columbia, (BC Ministry of Environment) to ensure quality assurance and quality control is maintained during sampling. These measures included:

- keeping clean sample bottles,
- sampling while standing downstream of the sample site,
- only opening the containers immediately before the collection occurred,
- keeping the inside of the rim of the bottles free of contact,
- rinsing all the instruments a minimum of three times with distilled water
- using gloves at all times in the lab.

To ensure quality control during the entirety of the project two trip blanks and two replicates were taken. One trip blank and replicate was used per sampling date. Each replicate sample was collected at a site chosen at random.

3.4 Microbiology

Microbiology testing was completed at Vancouver Island University laboratory on October 30, 2013. Testing was completed by a vacuum pump for water filtration system that would be

separated by a 0.45µm filter membrane. M-ColiBlue24 solution was used to cover the filtration pad. A 25 mL sample of water collected with a whirl-pack was filtered through the vacuum pump. Finally the filter membrane was placed in a petri dish and incubated for 24-hours at 37°C before colonies of bacteria could be counted.

Samples were then analyzed for coliform colony counts. The m-ColiBlue24 solution caused the coliforms colonies to either turn red or blue (Table 3). One filtration blank was used for quality control in this portion of analysis. All other quality control and assurance measures listed in section *3.3.4* were followed.

Table 3. Possible filtration results when using the m-coliBlue24 membrane filtration method.

Microbiology Potential Results		
Bacteria Type	**Positive Result**	**Negative Result**
Total Coliform	Red or Blue Colony	Clear or White Colony or no colony
Fecal Coliform (*e.coli)*	Blue Colony	Non-blue Colony

3.5 Stream Invertebrates

Invertebrate sampling occurred during the first sampling event of the study. As a safety consideration plans to sample invertebrates during the second sampling event were not made due to high flow in the creek leading to increased risk of falls. The samples were collected at two sites. Firstly Site 3 and secondly, Site 4. A Hess sampler was used at both sites to collect eight samples (four replicates per site). The samples were kept live over a ~48 hour storage period and were identified in the Vancouver Island University laboratory.

Surveys were done to determine abundance, diversity, predominant taxa, water quality indicators and finally to develop an overall site assessment rating (Appendix 3). Shannon-Weiner diversity indexes were calculated to determine the overall distribution of invertebrate species at each site sampled in the creek. Field data sheets from invertebrate sampling are attached in Appendix 3. Invertebrate samples were treated with care and quality control and assurance and control measures were taken to maintain consistent and accurate reporting. To properly identify invertebrates, individuals from each sample were identified by using an invertebrates guide provided by Vancouver Island University and a microscope. Samples were also double checked by two group members to ensure accuracy in identification.

4. Results

4.1 Field Measurements

Measurements taken from Departure Creek during both sampling events suggest that the creek was flowing at an average level at the end of October. Increased discharge was observed during the second sampling event as displayed in Table 4. It should be noted that measurements were taken from Sites 3 and 4 on the lower end of the creek. Site 4 saw daily tidal influence as it was located adjacent to the beach on Departure Bay. Future assessments of Departure Creek should take hydrological measurements from stations other than Site 4 because the area is influenced by tidal waters, which can be unreliable even at low tide. Tidal influence is the reason data in Table 4 is not representative of higher flow at Site 4 in November than October (1.11 m^3/s - October vs. 0.52 m^3/s – November).

Table 4. Field measurements taken from four stations on Departure Creek on October 28 and November 13, 2013. Discharge measurements were collected at stations 3 and 4 during both sampling events.

28-Oct-13					
Station	**Discharge (m^3/s)**	**Temperature (C°)**	**Dissolved Oxygen (mg/L)**	**Conductivity (µs/cm)**	**pH**
1		12.1	10.71	238	8.13
2		11.2	10.75	262	8.29
3	0.29	10.3	11.3	258	8.33
4	1.11	10.4	11.1	302	8.2
Replicate (4)		10.4	11.1	288	8.15
18-Nov-13					
1		9.2	9.64	50	7.56
2		9.6	9.63	92	7.86
3	2.51	9.7	9.63	202	8.02
4	0.52	10.1	9.37	230	7.81
Replicate (3)		10.1	9.37	230	7.82

Field observations from each site included temperature ratings collected from the Nanaimo weather station located at the Nanaimo airport (Environment Canada). During the period 10 days prior to the first sampling event from October 18 to October 28 the following information was collected. Firstly, average temperature which was 9.05℃ and secondly precipitation which was 1.2mm. Prior to the second sampling event weather records reported an average of 7.32℃ and a total of 22.9mm of precipitation. The majority of rain fall prior to the November sampling event accumulated in the watershed 24 hours prior to sampling. Departure Creek is a short stream system with minimal drainage from the local urban community. Given its urban isolation and lack of natural barriers for water to pass through, Departure Creek water discharge is easily impacted by local precipitation events.

4.2 Water Quality

4.2.1 VIU Analysis

Water temperature averaged 11℃ on October 28th and 9.7℃ on November 18th. On the first sampling series temperature readings steadily decreased while moving downstream toward Departure Bay. On November 18th readings were scattered with no apparent correlation. Water and air temperature decreased at a similar rate of a few degrees between the two sampling events (Table 4).

Departure Creek was found to contain enough dissolved oxygen to support fish growth (RISC 1998). During both sampling events dissolved oxygen readings were >9mg/L (Table 4).

Conductivity and pH measured at levels that would be expected given the environment surrounding Departure Creek. Lacking natural drainage, Departure Creek is the collection point for urban runoff from the urban community. These local factors lead to more ions in the creek which, in-turn, raised conductivity. During sampling in November, heightened discharge observed in the creek assisted with dispersion of ions and, therefore, conductivity decreased. The stream had consistent pH readings throughout the reach that was assessed. Site 3 had the highest pH during both sampling events at 8.33 and 8.02 respectively (Table 4).

Turbidity was measured in NTU's during laboratory analysis at Vancouver Island University. At low flow stage in October, all samples were clear of noticeable suspended particles. During sampling in November, water samples from the top end of Departure Creek were more turbid than the lower stations. This is unusual because particles suspended in water are often higher at lower portions of streams before they enter a lake or a marine environment. The riparian area surrounding Departure Creek houses many big leaf maple trees (*Acer macrophylum).* The maple

trees nearby contributed to leaf litter in the creek which assisted in removing particles from moving water, therefore producing less turbid samples at the lower sampling sites (Table 5). Nutrient levels measured at VIU labs determined that both nitrogen and phosphorous were present in Departure Creek. The lab results also determined that nitrogen and phosphorous levels were different at both sampling events. In October, the creek had higher phosphorous concentrations making nitrogen the limiting nutrient in the Redfield ratio. In November, nitrogen was more available in the creek making phosphorous the limiting nutrient (Table 5).

Departure creek was found to have a low sensitivity to acids with alkalinity ratings > 20mg/L $CaCO_3$. Alkalinity ranged from 95.6 mg/L $CaCO_3$ to 20.6 mg/L $CaCO_3$. In comparison, alkalinity and hardness were also high. Only two stations sampled (1 and 2 in November) were found to have soft water (Table 5). A trend between conductivity (Table 4), alkalinity and hardness can be seen in the creek (Table 5).

Table 5. Laboratory results (VIU Laboratory) of water samples collected at four stations on Departure Creek on October 28 and November 13, 2013.

28-Oct-13					
Station	Alkalinity (mg/L as $CaCO_3$)	Turbidity (NTU)	Nitrate (mg/L)	Phosphate (mg/L)	Hardness (mg/L as $CaCO_3$)
1	94	0.7	0.7	0.26	222.3
2	92.4	0.6	0.37	0.15	205.2
3	91.2	0.31	0.82	0.17	171
4	82.8	0.41	1.22	0.92	153.9
Replicate (4)	95.6	0.55	1.12	0.25	239.4
18-Nov-13					
1	20.6	7.67	0.48	0.11	24
2	39.6	8.59	0.56	0.07	42
3	77.6	2.23	2.22	0.09	77
4	80	3.6	1.43	0.1	79
Replicate (3)	78.4	3.3	1.46	0.1	78

4.2.2 ALS Laboratory Analysis

Physical tests from ALS lab were compared with VIU lab results. In October, hardness measures taken from Site 3 had a 29% difference between VIU and ALS results (Tables 5 and 6). At Site 4, a 34% difference in hardness was calculated between ALS and VIU. Conductivity was also compared between labs. Site 3 had a 9% difference and Site 4 had a 6% difference in October. In November, Site 3 had a 13% difference and Site 4 was <1%. pH results were within 5% of each other when comparing between ALS and VIU (table 5 and 6). The difference in laboratory results displayed in tables 5 and 6 are a caused by of instrument and operator accuracy. At VIU students operated instruments in a classroom lab whereas ALS utilizes specially trained individuals to test samples for various organizations.

Nutrient levels in the stream determined by ALS laboratory as shown in Table 6 display concentrations of nitrogen, phosphorous and ammonia. Nutrients were present in the creek, but none exceeded BC water quality guidelines. Phosphorous was found to be the limiting nutrient at all stations except Site 3 in the first sampling event. All other nitrate and phosphorous samples were at expected levels close to the Redfield ratio of 16:1.

Table 6. Laboratory Results I (ALS Laboratory) for water samples taken from two stations on Departure Creek on October 28 and November 18, 2013. All values expressed in mg/L unless otherwise specified. See notation below table.

Physical Tests	BC Water Quality Guideline	28-Oct-13		18-Nov-13		Detection Limit
		Site 3	Site 4	Site 3	Site 4	
Conductivity		282	320	232	232	2
Hardness (as CaCO3)		121	119	82.6	90.6	0.5
pH	6.5-9.0	8.18	8.12	8.04	7.89	0.1
Anions/Nutrients						
Ammonia, Total (as N)	5.91[a]	<0.0050	0.0123	0.018	0.018	0.005
Nitrate (as N)	31.1	0.521	0.543	0.825	0.825	0.005
Nitrite (as N)	0.06[b]	<0.0010	0.0012	0.0036	0.0036	0.001
Total Nitrogen		0.69	0.587	1.15	1.15	0.05
Orthophosphate-Dissolved (as P)		0.0081	0.0081	0.0063	0.0063	0.001
Phosphorus (P)-Total		0.0132	0.0131	0.0719	0.0719	0.002

Notes:
-"<" means less than the detection limit.
-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
http://www.ilmb.gov.bc.ca/risc/pubs/aquatic/interp/index.htm

[a] Ammonia guideline is dependent on water temperature and pH of tested water
[b] Nitrite guideline is for chloride concentration less than 2mg/L
- Analytical detection limits were above applicable guidelines for certain tests

All metal concentrations were compared to the BC Water Quality Guidelines. The metal concentrations tested from the October 28, 2013 sampling event met all BC water quality guidelines. The only metal found to be over the BC guideline was aluminum, which was 0.20 and 0.41 at Sites 3 and 4 respectively. The source of aluminum present in Departure Creek was not apparent, although presence of abandoned waste in the area was apparent. Shopping carts and other urban waste products in the watershed could have contributed to aluminum concentration in the creek, which was noticeable in November with increased water levels in the creek. The

margin of detection was minimal with many of the metals tested due to minimum detection limits of testing at ALS. Certain elements such as cadmium, iron, copper and zinc were dependent on the overall hardness of sample water. Water quality guidelines for bismuth, magnesium, potassium, silicon, strontium and tin were not available (Table 7).

Table 7. Laboratory Results II (ALS Laboratory) for water samples taken from two stations on Departure Creek on October 28 and November 18, 2013. Values exceeding BC water quality guidelines are enclosed in boxes. All values expressed in mg/L unless otherwise specified. See notation below table.

		28-Oct-13		18-Nov-13		
Total Metals	**BC Water Quality Guideline**	**Site 3**	**Site 4**	**Site 3**	**Site 4**	**Detection Limit**
Aluminum (Al)-Total	0.1[a]	<0.20	<0.20	0.20	0.41	0.20
Antimony (Sb)-Total	0.02	<0.20	<0.20	<0.20	<0.20	0.20
Arsenic (As)-Total	0.005	<0.20	<0.20	<0.20	<0.20	0.20
Barium (Ba)-Total	5	<0.010	<0.010	<0.010	0.012	0.010
Beryllium (Be)-Total	0.0053	<0.0050	<0.0050	<0.0050	<0.0050	0.0050
Bismuth (Bi)-Total		<0.20	<0.20	<0.20	<0.20	0.20
Boron (B)-Total	1.2	<0.10	<0.10	<0.10	<0.10	0.10
Cadmium (Cd)-Total	0.08(site 3)[b] 0.073(site 4)[b]	<0.010	<0.010	<0.010	<0.010	0.010
Calcium (Ca)-Total	>8[c]	30.7	29.6	20.8	23.6	0.050
Chromium (Cr)-Total	0.001	<0.010	<0.010	<0.010	<0.010	0.010
Cobalt (Co)-Total	0.11	<0.010	<0.010	<0.010	<0.010	0.010
Copper (Cu)-Total	0.018(site 3)[d] 0.016(site 4)[d]	<0.010	<0.010	<0.010	<0.010	0.010
Iron (Fe)-Total	1.000	0.052	0.120	0.360	0.740	0.030
Lead (Pb)-Total	0.162(site 3)[e] 0.142(site 4)[e]	<0.050	<0.050	<0.050	<0.050	0.050

Lithium (Li)-Total	0.87	<0.010	<0.010	<0.010	<0.010	0.010
Magnesium (Mg)-Total		10.6	10.9	7.43	7.72	0.10
Manganese (Mn)-Total	2.424(site 3)[f] 2.236(site 4)[f]	<0.0050	0.0109	0.0221	0.0599	0.0050
Molybdenum (Mo)-Total	2	<0.030	<0.030	<0.030	<0.030	0.030
Nickel (Ni)-Total	0.11[g]	<0.050	<0.050	<0.050	<0.050	0.050
Phosphorus (P)-Total	0.01	<0.30	<0.30	<0.30	<0.30	0.30
Potassium (K)-Total		<2.0	<2.0	<2.0	<2.0	2.0
Selenium (Se)-Total	0.002	<0.20	<0.20	<0.20	<0.20	0.20
Silicon (Si)-Total		10.4	10.5	7.50	8.16	0.050
Silver (Ag)-Total	0.003[h]	<0.010	<0.010	<0.010	<0.010	0.010
Sodium (Na)-Total		12.9	22.9	20.9	12.4	2.0
Strontium (Sr)-Total		0.106	0.111	0.0878	0.0909	0.0050
Thallium (Tl)-Total	0.002	<0.20	<0.20	<0.20	<0.20	0.20
Tin (Sn)-Total		<0.030	<0.030	<0.030	<0.030	0.030
Titanium (Ti)-Total	4.6[i]	0.012	0.011	0.015	0.033	0.010
Vanadium (V)-Total	0.1[j]	<0.030	<0.030	<0.030	<0.030	0.030
Zinc (Zn)-Total	0.094(site 3)[k] 0.081(site 4)[k]	<0.0050	<0.0050	0.0133	0.0110	0.0050

Notes:

-Results are expressed as mg/L

"<" means less than the detection limit.

-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

http://www.ilmb.gov.bc.ca/risc/pubs/aquatic/interp/index.htm

a - Aluminum guidelines for pH $\geq$ 6.5.

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

c - Calcium low sensitivity

d - The maximum copper guideline is 0.001 * [0.094(hardness) + 2] mg/L.

e - The maximum lead guideline is $0.001 * e^{\{1.273\ [\ln(\text{hardness})] - 1.46\}}$ mg/L.
f - The maximum manganese guideline is 0.01102 * (hardness) + 0.54 mg/L.
g - Nickel guideline is for hardness < 60 mg/L.
h - Silver guidelines are for hardness < 100 mg/L.
i - Titanium with Daphnia survival
j - Vanadium with Livestock
k - Zinc guidelines are for hardness < 90 mg/L.

*water quality guidelines derived from British Columbia Ministry of Environment (http://www.ilmb.gov.bc.ca/risc/pubs/aquatic/interp/index.htm)

4.3 Microbiology

Coliform colonies were observed in all samples taken from Departure Creek on October 28, 2013. High counts of blue coliforms suggest that something in the stream was introducing potentially harmful bacteria to the ecosystem. Although blue (*e.coli)* colonies were seen in all samples (68-98%), an especially high ratio of 98% was observed at Site 4 directly below an outflow from the City of Nanaimo building. At the time of sampling the smell of bacteria was evident from Site 4 (Table 8).

The filtration blank used during sampling returned sterile results free of bacteria colonies.

Table 8. Microbiology analysis table with total and fecal coliforms colony counts from four stations on Departure Creek collected on October 28, 2013. All values expressed as colonies per 100mL of sample water.

Station	Total Coliforms	Fecal Coliforms	% Fecal
1	484	1009	68
2	120	576	83
3	323	4436	93
4	92	10936	98
Trip Blank	0	0	N/A

4.4 Stream Invertebrates

Invertebrates were sampled at two sites on Departure Creek. After analysis at VIU laboratory, 284 invertebrates were found from eight different sampling containers (four replicates/site).

Overall, Site 4 had a higher density of invertebrates at 567 individuals per metre^2. Although Site 4 had a higher density of invertebrates, Site 3 had a more even distribution as measured with a Shanon-Weiner diversity index (Table 9).

Pollution tolerant invertebrates were found at both sites. At Site 3, over 50% of invertebrates were pollution intolerant stonefly nymphs and caddisfly larvae (Figure 6). Site 4 had a dominant population of amphipods which made up nearly 75% of the collected samples (Figure 7). Overall the stream rated at an acceptable three out of four when averaging the invertebrate data survey sheets completed at both invertebrate sampling locations (Appendix 3).

Table 9. Stream invertebrates obtained from four replicate samples taken at Site 3 and 4 from Departure Creek on October 28, 2013.

Pollution Tolerance	Invertebrate Taxa	Site 3	Site 4
Category 1 Pollution Intolerant	Caddisfly Larva	21	13
	Mayfly Nymph	N/A	2
	Stonefly Nymph	32	4
Category 2 Somewhat Pollution Intolerant	Damselfly Larva	3	N/A
	Aquatic Sowbug	N/A	36
	Amphipod (scud)	8	145
Category 3 Pollution Tolerant	Oligochaete Worm	7	4
	Chronomid Larva	6	N/A
	Planarian (flatworm)	1	N/A
	Water Mite	2	N/A
Total		**80**	**204**
	Density (number/m^2)	222	567
	Site Assessment Rating	3.5	2.5
	Shannon Weiner Diversity Index	0.78	0.52

Note: Invertebrate sampling sheets are included in appendix 3

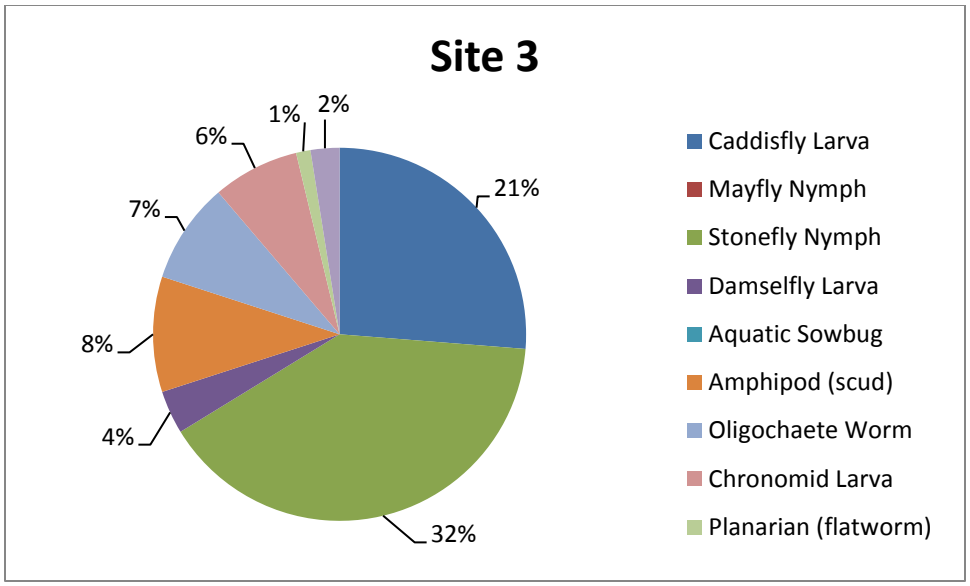

Figure 6. Stream invertebrates observed during laboratory analysis of four replicates from Site 3.

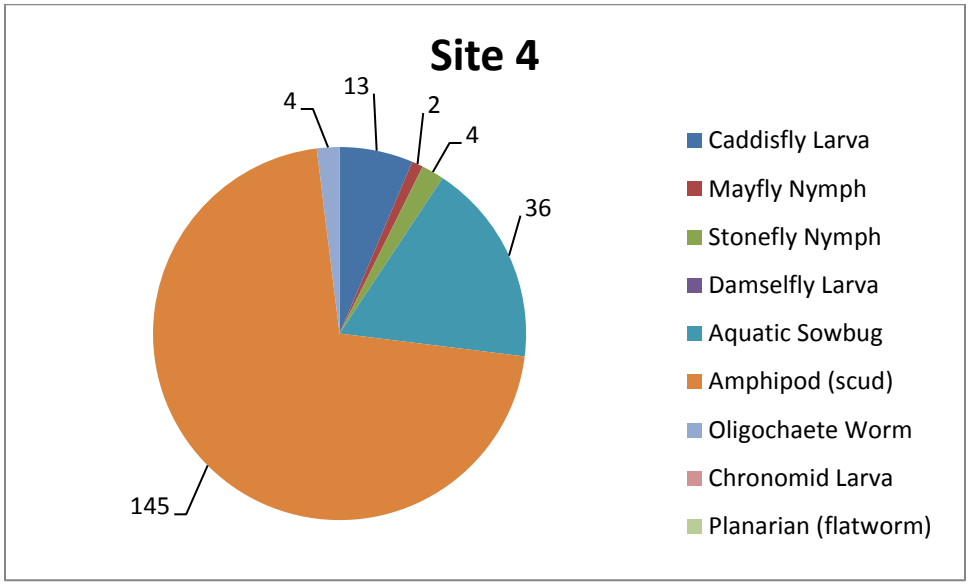

Figure 7. Stream invertebrates observed during laboratory analysis of four replicates from Site 4.

5. Conclusion and Recommendations

In conclusion, we believe that, despite Departure Creek's urban location, it is generally a healthy stream. Water quality data that was collected (dissolved oxygen, conductivity, pH, turbidity, nitrate/phosphate, alkalinity and hardness) showed levels that were all within a healthy limit for sustaining aquatic life. As far as the ALS total metals analysis, almost all metals found in

Departure Creek were below the minimum detection limits, as shown in Table 7. One area of the monitoring project that does standout is the coliform count. Throughout the sampling stations there were high fecal coliform counts. We believed this is due to the urban location of the creek. Departure Creek is lacking natural drainage; therefore, fecal material is more likely to drain straight into the stream before getting filtered out. Also, we believe that the sewage pump house located at Site 4, where we found the highest fecal coliform counts, is possibly contributing to the abnormally high levels. Despite the very high fecal coliform counts, the stream appears to support a healthy invertebrate population. The majority of the invertebrates found in the samples taken from Sites 3 and 4 were either category 1 (pollutant intolerant) or category 2 (somewhat pollution intolerant). The invertebrates collected help to represent that the creek is healthy and is not impacted by pollutants.

We recommend that the annual VIU student monitoring projects continue at Departure Creek so data on the creek is kept up-to-date on overall health. Additionally, continued monitoring allows for recent data to be compared with previous reports. These comparisons are used to develop overall trends seen in the creek over the years. This information may also be used with similar comparisons with other coastal BC streams. Future hydrology measurements should not be taken at Site 4, as mentioned previously, to avoid any tidal influence. Also, in the areas of Sites 2 and 3 there were pipes that appeared to originate from private properties and discharge onto the banks of the creek. We recommend that further water samples be taken of the discharge pipes leading from private property to get a more confident idea of waste materials entering Departure Creek. The various habitat enhancement projects, both ongoing and completed on Departure Creek, have been beneficial to the reintroduction of fish, particularly pink salmon (*onchorynchus*

gorbuscha). Therefore, community education and involvement with the creek should be continued to ensure Departure Creeks continued health for the future.

6. Acknowledgements

The authors would like to commend the Pacific Salmon Foundation, the City of Nanaimo, and the Harbor City River Stewards for their efforts to enhance Departure Creek's salmon bearing potential. Their efforts greatly enhanced fish habitat and allowed populations to return. Also, the habitat restoration provided the background for this environmental monitoring project. A special thanks to Dr. Eric Demers for coordinating this project and providing the necessary training to undergo effective analysis. The Science and Technology department at VIU is also acknowledged for providing the field equipment, laboratory supplies, and funding for ALS lab tests. A special thanks to ALS laboratory for providing reduced rates on their laboratory services to this and other project from VIU over the years. Lastly, other groups of RMOT 306 students can be thanked for carrying out monitoring projects on other Vancouver Island streams in order to assess water quality and stream health in the region.

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APPENDIX 1. Photographs from October 28th representing conditions during sampling events at Departure Creek

Photo 1. Looking upstream towards site one located in a small pool below the culvert passing beneath Neyland Road.

Photo 2. Looking downstream from Site 2.

Photo 3. Looking upstream towards Site 3 in Woodstream Park

Photo 4. Cross stream view of Site 4 at the lowest point in Departure Creek, directly before a short riffle leading into Departure Bay

Photo 5. Drainage pipe originating from property on the north bank of Departure Creek near Site 3 in Woodstream Park.

APPENDIX 2. Photograph from November 18th representing conditions during sampling event on Departure Creek.

Note wet and rainy condition restricted camera usage at the sampling event. Overall the group observed more leaf litter and increased along with discharge throughout the creek.

APPENDIX 3. Invertebrate Field Survey Field Data Sheets representing samples collected at Departure Creek sites 3 and 4 on October 28, 2013.

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Departure Creek		Date: 28/10/2013.
Station Name: Site #~~4~~ 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	Caddisfly Larva (EPT)	EPT1 21	EPT4 ~~8~~ 3
	Mayfly Nymph (EPT)	EPT2	EPT5 1
	Stonefly Nymph (EPT)	EPT3 32	EPT6 5
Pollution Intolerant	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 53	D1 9
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva	~~4~~ 3	
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	8	~~1~~
	Watersnipe Larva		
Sub-Total		C2 11	D2 ~~1~~ 0
Category 3	Aquatic Worm (oligochaete)	7	2
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	6	
Pollution Tolerant	Planarian (flatworm)	1	
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	2	
Sub-Total		C3 16	D3 2
TOTAL		CT 80	DT 11

Appendix 3 (continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: S1 = 80

DENSITY: Invertebrate density per total area sampled:

S1 80 ÷ 0.36 m^2 = S2 222 $/m^2$

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (Col. C): S3 = Stonefly nymph

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 9 + 2 x 0 + 2 = S4 29

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

3 + 1 + 5 = S5 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	X	0.50-0.75	0.25-0.50	0-0.25

(EPT1 + EPT2 + EPT3) / CT

(21 + 0 + 32) / 80 = S6 0.66

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: S7 = 11

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

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

Col. C for S3 / CT

32 / 80 = S8 0.4

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	R1 4
EPT Index	R2 4
EPT To Total Ratio	R3 3
Predominant Taxon Ratio	R4 3

Average Rating
Average of R4, R5, R6, R8
3.5

Appendix 3 (continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Departure Creek		Date: 28/10/2013
Station Name: Site #4		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	Caddisfly Larva (EPT)	EPT1 13	EPT4 3
	Mayfly Nymph (EPT)	EPT2 2	EPT5 1
	Stonefly Nymph (EPT)	EPT3 4	EPT6 2
Pollution Intolerant	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 19	D1 6
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug	36	1
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	145	x4
	Watersnipe Larva		
Sub-Total		C2 181	D2 5
Category 3	Aquatic Worm (oligochaete)	4	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
Pollution Tolerant	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 4	D3 1
TOTAL		CT 204	DT 12

Appendix 3 (continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: S1 = 204

DENSITY: Invertebrate density per total area sampled:

S1 204 ÷ 0.36 m^2 = S2 566 / m^2

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (Col. C) S3 = Scud Amphipod

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 6 + 2 x 5 + 1 = S4 = 29

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6: 3 + 1 + 2 = S5 = 6

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: (13 + 2 + 4) / 204 = S6 = 0.09

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: S7 = 12

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: 145 / 204 = S8 = 0.711

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	R1 4
EPT Index	R2 3
EPT To Total Ratio	R3 1
Predominant Taxon Ratio	R4 2

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