Water Quality Analysis and Stream Invertebrate Assessment of Departure Creek, Nanaimo, BC 2014

Submitted by,

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Dec 12th, 2014

Executive Summary

This report has been created as part of the East Vancouver Island stream assessment report group. The following report pertains specifically to Departure Creek, located in the Departure Bay area of Nanaimo. Departure Creek is a short stream that follows a wooded ravine through the urban ecosystem of the Departure Bay neighbourhood until its conclusion in the Northwest corner of Departure Bay.

The objectives of this stream assessment in Departure Creek were to sample from four previously fixed sites on two distinct sampling events. What was collected included field measurements, water quality samples, and aquatic invertebrates. The measurements under these categories were used to determine the overall stream health of Departure Creek. The collected samples were compared to set guidelines to find any inconsistencies unique to the ecosystem. The field measurements taken were used to find changes in the streambed between the two sampling events. Stream invertebrates were sampled only during the first sampling event, using a Hess sampler and three samples were taken at each of the two predetermined sites. Water samples were taken with different parameters in mind to analyze and detect the presence of coliforms or elemental substances that could be detrimental to stream health. Samples were analyzed at a Vancouver Island University laboratory and ALS laboratories to compile raw data for interpretation and comparison to water quality guidelines. Accurate results were profoundly important in determining the overall stream health of Departure Creek.

Results concerning bacterial colonies from the first sampling event showed that Departure Creek has a high coliform count; especially at the most downstream site, and less so at the site in Woodstream Park, where habitat restoration has taken place.

According to the ALS results for metal concentrations in the creek, no metals were found to be over the BC Water Quality guideline. The moderately high amount of Calcium detected in the creek at each site indicates that the stream has a low sensitivity to acid. Field measurements showed that Departure Creek had a heightened discharge in October compared to November. Departure Creek is an isolated riparian area that runs through an urban sprawl that continually encroaches on the creek with uninhibited urban runoff and littering. The amount of habitat restoration work done by the surrounding community and city appears to have benefited the creek. Further habitat enhancement should be continued on Departure Creek in the future to sustain an overall healthy ecosystem.

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1.0 Project Introduction and Background

2.1 Project Overview

Our team undertook an environmental monitoring project on Departure Creek in Nanaimo, BC, between the dates of October 29th and November 19th, 2014. The team carrying out the project consisted of three third-year Bachelor of Natural Resource Protection (BNRP) students under the tutelage of their Environmental Monitoring instructor, Dr. Eric Demers, R.P. Bio. of Vancouver Island University (VIU). Departure Creek is a small stream located in the Departure Bay area of Nanaimo. This project focused on sampling and assessing Departure Creek, and identified potential and environmental impacts from the surrounding urban area.

Environmental monitoring projects on Departure Creek have been conducted since 2006, by groups of BNRP students at Vancouver Island University. This project is the sixth project undertaken by VIU students on Departure Creek. We monitored and assessed four sites on Departure Creek from Neyland Rd down to Departure Creek's near conclusion beside Departure Bay Rd. The data collected from this project contributes to information collected from previous years' projects by other BNRP students. Performing a project on the same aquatic area annually is beneficial and further adds to our understanding of the impacts on an urban watershed over a longer period of time. The data collected included water quality monitoring and biodiversity, and was collected from four water sampling stations along the length of the creek. The information we collected contributed to our findings concerning urban impact, effluents, adverse effects to the environment, and management recommendations.

2.2 Historical Review

Several restoration projects have been undertaken on Departure Creek since 1995, including the removal of a small dam in 2011, the removal of which allowed upstream access for ~250 pink salmon from the Georgia Strait (Harbour City River Stewards, 2013). A restoration project in 2012 included the addition of large woody debris, gravel, slope erosion stabilization, and rock-grade control riffles. This project was conducted on the section of Departure Creek in Woodstream Park (City of Nanaimo, 2012).

2.3 Potential Environmental Concerns

Departure Creek is a fairly slow moving stream that follows a steeply banked wooded ravine from north of Neyland Rd to where it empties into Departure Bay. It is in an urban setting of residential homes and fairly busy streets. Departure Creek is around 3 km in total length, and originates from two creeks, Joseph Creek and Keighley Creek. Joseph Creek is sourced from a ditch near Wellington Secondary School and Keighley Creek is sourced from the Nanaimo Golf Club (Harbour City River Stewards, 2013). Departure Creek runs through a wooded ravine amidst large neighbourhoods and busy streets, which can all create potentially toxic runoff in the rainy season. Some homes have drainage pipes from their backyards and driveways that deposit directly into the creek (Figure 1). Most environmental issues associated with the creek are rooted in the effluents from the surrounding urban area. These could include oil from the streets, cleaning products from residential homes and driveways, and any number of pollutants from the nearby gas station on Departure Bay Rd. Also noted were several storm drains that empty into the creek north of Woodstream Park. At the second site on Joseph Creek, an orange slimy substance could be distinctly seen near a drain emptying into the stream

(Figure 2). Although no garbage was found near Departure Creek in Woodstream Park, some rubbish could be seen in other sections of the creek, particularly near Newton St.

Figure 1. A drainage pipe leading from a residence into Departure Creek near Site 3.

Figure 2. A slimy orange substance directly below a pipe draining into Joseph Creek at Site 2.

2.0 Project Objectives

This project followed a pre-determined set of objectives; the purpose of this was to determine certain characteristics of Departure Creek. These characteristics included measurements of hydrology, water quality and stream invertebrates. Through the use of four sites along the study area, results were compared to the results of previous years (2007-2013) to determine if stream and riparian health had changed over time. Potential impacts both naturally and artificially caused were assessed, and the results determined the health and sustainability of the watershed. This assessment was essential to keeping Departure Creek a suitable environment for spawning salmon as well as any organisms living within the watershed. Certain parties, including Department of Fisheries and Oceans Canada, BC Conservation Foundation, Regional District of Nanaimo and the Nanaimo and Area Land Trust, are interested in the results of this analysis, and will hopefully allow an opportunity for further monitoring in the future.

4.0 Methods

4.1 Sampling Stations

Departure Creek is located in the Departure Bay area of Nanaimo. Originally, this creek flows from two tributaries: Joseph Creek, a small tributary running along Departure Bay road, and Keighley Creek, a small urban creek. Departure Creek runs for a distance of approximately 3 km before emptying into Departure Bay. The area of Departure Creek used for this study includes four individual sites where testing and observations occurred.

4.1.1 Locations

Four sites along the length of the creek were selected for specific sampling procedure (Figure 3). These sites are spaced along the whole length of the creek, allowing the diverse properties of the watershed to be observed. Site 1 is located where Departure Creek crosses under Neyland Road, immediately on the upstream side of the stream crossing. Site 2 is located on Joseph Creek, one of the tributaries that flow into Departure Creek. The site is located immediately upstream of the Newton Street stream crossing. Site 3 is located approximately 100 metres upstream from the Bay Street Woodstream Park parking lot following a park trail. Site 4 is located upstream of the Departure Bay road crossing, approximately at the intersection of Departure Bay Road and Bay Street and approximately 50 metres from the ocean.

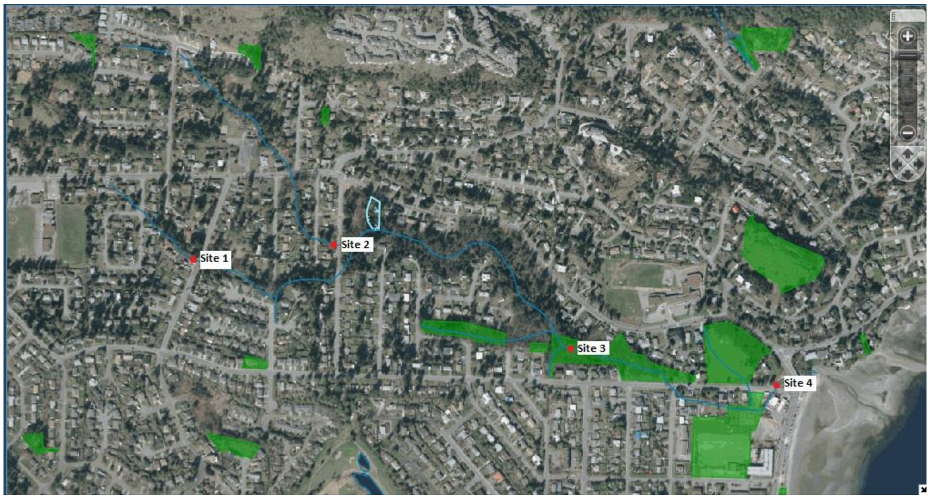

Figure 3. A map of Departure Creek, Nanaimo, BC showing the 4 Sample Sites (adapted from Nanaimo Maps, 2014).

4.1.2 Habitat Characteristics

At Site 1, the stream width is approximately 1.5 metres across and on a moderate grade. The stream is primarily a riffle at this location, with a gravel and cobble streambed (Figure 4). Surrounding vegetation includes Western Red Cedar (*Thuja plicata*), ferns, Skunk Cabbage (*Lysichiton americanus*) and grasses. An approximate canopy cover of 70% is present, and there is an instream cover of approximately 30%. Access to the creek is easy from the road, and the slope of the banks is not steep.

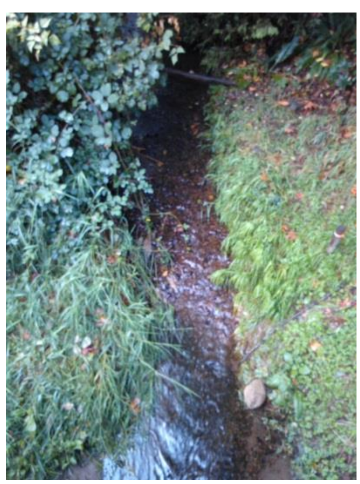

Figure 4. Sampling Site 1 of Departure Creek.

At Site 2 the stream is approximately 1.5 metres across on a moderate to steep grade. The stream is a riffle here, with small waterfalls falling in several levels. The streambed is composed of boulders and gravel (Figure 5). Vegetation surrounding the stream is made up of ferns, skunk cabbage, Douglas Fir (*Pseudotsuga menziesii*) and Red Alder (*Alnus rubra*). Some introduced bamboo has also taken root. The canopy cover is approximately 90%, and there is no instream cover to be observed. Access to the creek is via the road and is fairly easy.

Figure 5. Sampling Site 2 on Joseph Creek, a Departure Creek tributary.

At Site 3 the stream is approximately 4.5 metres wide in this section, on a moderate grade, and is composed mainly of cobble and fines (Figure 6). The water is a riffle and turns into a glide further downstream. Vegetation in the area is varied, including Red Alder, ferns, salmonberry (*Rubus spectabilis*), Western Red Cedar and Big Leaf Maple (*Acer macrophyllum*). Canopy cover is approximately 30-40%, while instream cover is approximately 10%. Access to the creek is easy, with a trail going from the parking lot on Bay St to the creek side; however, one side of the creek bank is eroded and slightly hazardous.

Figure 6. Sampling Site 3 of Departure Creek in Woodstream Park.

The stream at Site 4 is approximately 2 metres wide and on a slight gradient. It is mainly a glide, and the streambed mainly consists of fines and boulders, with some cobble (Figure 7). Vegetation in the area is mainly Himalayan Blackberry (*Rubus armeniacus*) with some salmonberry. There is next to no canopy cover, while in stream cover is about 50%. Access to the creek is easy, as it is located right next to Bay Street, as well as Departure Bay Road. However, it is also hazardous due to the proximity to the road, and extra caution must be taken at this site.

Figure 7. Sampling Site 4 of Departure Creek, at the intersection of Departure Bay Rd and Bay St.

4.1.3 Sampling Frequency

Sampling of the creek took place during two different sampling events. These events took place on the dates of October 29th, 2014, and November 19th, 2014. The two events were used in an attempt to effectively determine sampling properties at periods of both low and high flow. Hydrology and water quality were tested during both sampling events, while microbiology and invertebrate diversity were sampled only during the first event.

4.2 Basic Hydrology

Basic hydrological measurements were collected during both sampling sessions. The first sampling was done when the water was at a relatively higher flow and the second sampling while the water was at a low flow. Velocity was measured using the 'float method'. A glide of 5 metres of uninterrupted water was selected from the site. A round plastic model fishing bobber was dropped into the water at the upstream section of the glide and timed with a stopwatch to determine how long it took to reach the end of the glide. This test was completed 5 times and the times were averaged for accuracy. The wetted width of the stream was also measured (m) and the stream depth (cm) was measured in 7 places across the stream. These measurements were then used to calculate the stream's discharge. Stream discharge (m^3/s) is important to determine because it can affect the results seen in water quality testing.

4.3 Water Quality

4.3.1 Field Measurements

Water quality measurements that were taken in the field were: water temperature and dissolved oxygen. These measurements were all taken with an electronic YSI meter borrowed from VIU. These measurements were taken starting at the furthest downstream site, working upstream to ensure that there was no disturbance due to testing upstream sites first that may have accidentally skewed the results. The electronic probe was placed into the middle of the stream, a few cm below the surface level if possible and held until results were obtained. It was necessary to wade into the stream to reach the middle, so the sampling site was always approached from downstream to avoid contaminating the samples. It was also necessary to calibrate the YSI meter before sampling at a new site to ensure that the results were accurate representations of each site.

4.3.2 Water Sample Collection

Water samples were collected from all four sampling sites on both sampling events for analysis in the VIU laboratory. Samples for ALS Laboratory analysis were only collected at sites 2 and 3 during both sampling events. The samples for the VIU lab were collected in pre-labeled water bottles. The bottles were always rinsed three times each in the creek before being filled and capped. The samples were taken from the middle of the creek, midstream. The sampling location was always approached by the student from downstream. The bottle was plunged downward and turned upstream to fill with water to avoid collecting bottom or surface film.

The samples for ALS Lab were collected in three different bottles at each of the two sites: a 1L plastic bottle for general parameters, a 250mL white plastic bottle for total metals, and a 250mL amber glass bottle for nutrients. These bottles were not rinsed 3 times in the creek because they were already pre-rinsed. A vial of nitric acid was then added to the plastic bottle used to test total metals and a vial of sulphuric acid added to the metal bottle used to test the nutrient content in order to properly preserve the samples.

In addition to the water samples collected in bottles, at each site a 100mL whirlpak bag was filled during the first sampling event only. There was also no rinsing required for these bags. These were used to test for coliforms in the water in the VIU lab.

4.3.3 VIU Laboratory Analyses

In the VIU Laboratory, the collected water samples were tested for the following parameters; conductivity, pH, turbidity, alkalinity, hardness, nitrate and phosphate. All samples were stored in a cooler immediately after collection and kept cool until analysis later that same day. All containers and equipment used in the lab were rinsed 3 times with distilled water before coming in contact with the sample water.

4.3.4 ALS Laboratory Analyses

Water samples from sites 2 and 3 were sent to the ALS Laboratory. These samples were stored in a cooler immediately after collection and then transferred to a refrigerator until shipment to ALS Laboratory. The sample was tested at ALS labs for general parameters (pH, conductivity, hardness), as well as the nutrients present and the total metals contained in the sample.

4.3.5 Quality Assurance/ Quality Control

A number of steps were undertaken to ensure quality assurance throughout the field sampling and laboratory analysis. For quality assurance in the field, only clean and specific containers were used for water collection. All hands were clean while handling all of the equipment. The water samples were properly stored in a refrigerator after collection until they are analyzed in the VIU lab or couriered to ALS Lab.

For quality control, a ratio of 10% of the total samples was used for duplicate samples and blank samples. Therefore, one replicate sample and one trip blank were included in each sampling session.

4.3.6 Data Analyses, Comparison to Guidelines

The data collected in the VIU lab and ALS lab from each site and sampling date were compared to each other. The data set was compared to data from previous years to determine if any trends are present regarding stream health. The results were also compared to the BC Water Quality Guidelines (Guidelines for Interpreting Water Quality Data, 1998), to determine if the parameters are acceptable for aquatic life.

4.4 Stream Invertebrate Communities

Macroinvertebrate presence in Departure Creek was sampled and analyzed. The results of this sampling were then used to help determine the health of the Departure Creek. It helped to categorize the stream based on the varying types of invertebrates found.

4.4.1 Invertebrate Sample Collection

Sampling for macroinvertebrates was done at two sites along Departure Creek only during the first sampling event, and was sampled using a Hess sampler. The samples were taken from portions of stream with a riffle and a substrate consisting of gravel and cobble. When using the Hess sampler, the “operator” used hands and, if safe, feet to stir up any rocks or gravel in the sample area, ensuring safe operation of the sampler and avoiding unnecessary damage to the stream bed. Captured invertebrates were immediately stored in a container of stream water and kept at a low temperature in a cooler to preserve the sample until it could be analyzed in a secure and sterile lab environment on VIU campus later that day.

4.4.2 VIU Laboratory Analyses

Invertebrates from each sample were identified, and counted in the VIU lab. Each station's results were recorded on separate invertebrate survey field data sheets. Calculations were then made for abundance, density, diversity, most abundant taxon, and overall site ratings.

4.4.3 Quality Assurance/ Quality Control

Sampling at each of the two sites used all proper methods and techniques to ensure quality. All measures were taken to ensure data was not compromised and that no contamination of the samples occurred. Containers used to store captured invertebrates were clean and rinsed in the creek water before sampling took place. While using the Hess sampler, areas of gravel and cobble under riffle conditions were chosen to ensure proper water flow through the sampler. All group members stood downstream of the sampling to avoid contaminating the water flow entering the collection container. Triplicate samples were also taken at each site to ensure reliable data. These samples were taken at the furthest downstream location and moved upstream with each sample to avoid contamination.

4.4.4 Data Analyses

Analysis of the samples took place at Vancouver Island University in a lab with sufficient access to analytical tools and materials, and individual specimens were categorized based on order and family and were categorized following Pacific Streamkeeper's procedures (PSKF, 2013). The Shannon-Weiner Index was used to calculate diversity of organisms in the samples. The results allowed the stream to be assessed for overall health dependent on which species were the most abundant.

5.0 Results and Discussion

5.1 General Field Conditions

Discharge was much higher during sampling event 1 than sampling event 2. Sampling event 1 showed a discharge of 0.303 m^3/s while sampling event 2 showed a discharge of only 0.049 m^3/s (Table 1). There was a large storm 3 days prior to the first sampling event, which explains why the discharge was higher during the first event. There had been very little rainfall preceding the second sampling event. Departure Creek is a very flashy creek and responds very quickly to rainfall or lack of rain.

Table 1. Stream Hydrology in Departure Creek taken at Site 3 on 29-OCT-14 and 19-NOV-14.

Sampling Event	Stream Width	Stream Area (m^2)	Velocity (m/s)	Discharge (m^3/s)
Event 1: 29-OCT-14	4.50m	0.688	0.44	0.303
Event 2: 19-NOV-14	4.21m	0.180	0.27	0.049

5.2 Water Quality

5.2.1 Field Measurements

Water quality measurements taken in the field included water temperature and dissolved oxygen. Water temperature decreased by about 4 degrees from a range of 12.6-13.3 degrees Celsius during the first sampling event to a range of 8.0-10.7 degrees Celsius during the second sampling event (Figure 8). Inversely, the dissolved oxygen levels increased from 9.84-10.62 mg/L during the first event to 10.53-11.37 mg/L during the second event. This is expected because water at a lower temperature is able to hold more dissolved oxygen. Dissolved oxygen levels are high enough at all sites to support aquatic life, including fish embryo and alevin stages.

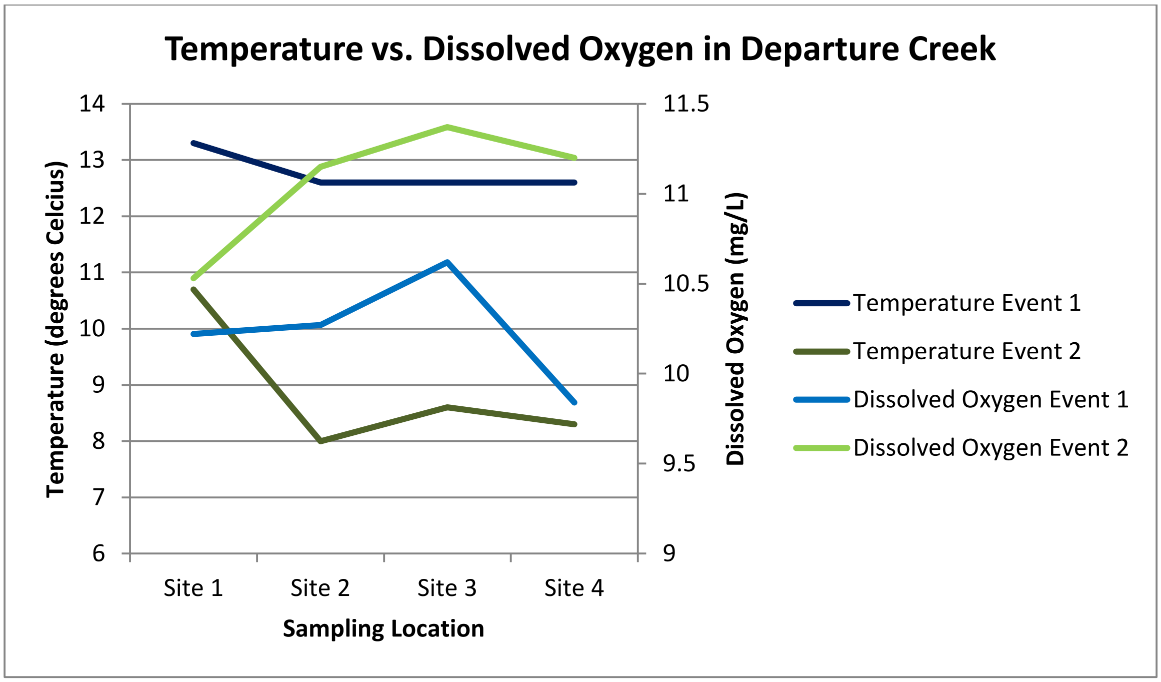

Figure 8. Water Temperature in degrees Celsius vs. Dissolved Oxygen in mg/L in Departure Creek taken at all sampling sites on 29-OCT-14 and 19-NOV-14. The graph shows an inverse trend between water temperature and dissolved oxygen.

5.2.2 VIU Laboratory Analyses

The general water quality parameters from all sites were measured in the VIU laboratory. The pH levels stayed relatively stable across all sites throughout both sampling events ranging between 7.7-7.9, with the exception of a slight spike to a pH of 8.2 at site 3 during sampling event 1 (Table 2).

Table 2. VIU Laboratory Results for General Water Quality Parameters from all 4 stations taken on 29-OCT-14 and 19-NOV-14.

Station	pH	Conductivity (*u*s/cm)	Hardness (mg/L $CaCO_3$)	Alkalinity (mg/L $CaCO_3$)	Turbidity (NTU)	Nitrate (mg/L NO_{3-})	Phosphate (mg/L PO_4^{3-})
Event 1: 29-OCT-14							
Trip Blank	n/a	n/a	n/a	n/a	n/a	0.03	0.02
Site 1	7.8	168	65	43.0	1.1	0.81	0.11
Site 2	7.8	160	61	44.4	1.6	0.50	0.07
Site 3	8.2	236	77	74.0	1.5	0.33	0.07
Site 4	7.8	236	77	72.0	5.2	0.47	0.07
Site 4 Rep	7.7	238	80	72.4	2.17	2.05	0.06
Event 2: 19-NOV-14							
Trip Blank	n/a	n/a	n/a	n/a	n/a	BDP	0.33
Site 1	7.8	193	95	62.4	.64	0.08	0.15
Site 2	7.8	146	64	50.8	.68	0.08	0.14
Site 3	7.9	229	100	81.2	.79	0.55	0.07
Site 4	7.9	233	99	82.4	.96	0.78	0.19
Site 4 Rep	7.9	233	100	82.4	1.0	0.63	0.41

The conductivity of the creek shows an increasing pattern as the water moves downstream. Site 2 in both sampling event 1 and sampling event 2 shows the lowest conductivity reading of 168 *u*s/cm and 193 *u*s/cm respectively. This does not disrupt the overall pattern as Site 2 is a tributary creek and is not downstream of Site 1. The conductivity increases further downstream because the water has had more opportunity to pick up ions from metals and rocks it passes over. Site 4 showed the highest conductivity readings during both sampling event 1 and sampling event 2 with 236 *u*s/cm and 233 *u*s/cm. The replicate water sample taken at site 4 showed consistency with the site 4 sample with results of 238 *u*s/cm and 233 *u*s/cm during sampling events 1 and 2.

The stream's hardness increased during the second sampling event ranging from 61 - 80 mg/l $CaCO_3$ during the first event to 64-100 mg/L $CaCO_3$ during the second event. These results are considered between soft and hard water. Hardness shows the same trend as conductivity; increasing as the move downstream with the tributary creek at Site 2 showing the lowest results.

The alkalinity of the water tells us that Departure creek has a low acid sensitivity. During sampling event 1, results of site 1 and 2 were very comparable with results of 43.0 and 44.4 mg/L CaCO3. Similarly, results in site 3 and 4 were very close with 74.0mg/L CaCO3 in site 3 and 72.0 mg/L CaCO3 in site 4. Sampling event 2 showed an increase in alkalinity ranging from 50.8 to 82.4 mg/L CaCO3. This is important for the creek's health because it means the creek will keep a stable pH even with the potential for residential pollution.

The creek shows decreased turbidity readings during the second sampling event. During the first sampling event, results ranged from 1.1 to 5.2. Station 4 with the result of 5.2 was inconsistent with the rest of the data set, as well as with the replicate with had a result of 2.17. This sample was possibly contaminated through human error despite the measures undertaken to avoid it. Sampling event 2 had consistently lower turbidity results ranging from .64 to 1.0 NTU. This is expected because of the lower discharge during the second sampling event. With less discharge, there is less force to stir up sediment from the streambed.

Departure Creek showed very low levels of Nitrate at both sampling events with a range from below detectable parameters to 2.05 mg/L NO_{3-} .

There were very low levels of phosphate recorded, with the highest level of both sampling events at 0.33 mg/L PO_4^{3-} belonging to the trip blank (Table 2).

Coliform colonies were present in water samples from all four sampling sites. Site 2 had the least fecal coliform with a count of only 120 fecal coliform colonies per 100ml of water and making up only 5% of total coliforms (table 3). Site 4 had the highest fecal coliform count with 688 fecal coliform colonies per 100 ml of water making up 30% of the total coliforms. None of these sites meet the water quality criteria for drinking water and only sites 2 and 3 meet the criteria for livestock general usage and recreation. With such a large difference in fecal coliform levels, there may be sewage draining into Departure Creek somewhere between sites 3 and 4.

Table 3. Microbiology analysis showing total and fecal coliform colonies per 100mL from all four sampling stations on Departure Creek taken on 29-OCT-14.

Station	Total Coliforms	Fecal Coliforms	% Fecal
1	1696	484	29
2	2420	120	5
3	848	200	24
4	2380	688	30

5.2.3 ALS Laboratory Analyses

Samples from both site 2 and site 3 were sent to ALS Laboratories in Burnaby, British Columbia for analysis to determine general parameters (pH, conductivity, total metals). The samples were received by ALS on October 31st, 2014, and November 21st, 2014. Analysis was performed on both samples and the results sent back to VIU. Results from the sampling events were analyzed and compared to BC Water Quality guidelines (BC Ministry of Environment, 2014) to see if Departure Creek's water quality is acceptable for aquatic life. Results showed that all properties and content of Departure Creek's water met minimum requirements for aquatic life during both sampling events. The pH data showed optimal level for aquatic life, and hardness indicated an effective balance between hard and soft water. All metals in the water during both sampling events one and two showed acceptable levels and concentrations, and no metals exceeded the BC Water Quality Guidelines for the survival of aquatic life, and few metals were detected in any significant levels at all (Table 4). It must be noted that many of the water quality guidelines are lower than the detection limit and therefore we cannot determine if the guidelines are met. The level of Calcium was greater than 8 mg/L at both sites two and three for both sampling events, indicating a low sensitivity to acid. The ALS results helped to determine a more accurate depiction of the stream's health and guidelines for aquatic life.

Table 4: ALS Laboratory results for general parameters, nutrients and total metals in Departure Creek from Sites 2 and 3 taken on 29-OCT-14 and 19-NOV-14. All units are in mg/L unless otherwise specified.

Physical Tests	**BC Water Quality Guideline**	**29-OCT-14**		**19-NOV-14**		**Detection Limit**
		Site 2	**Site 3**	**Site 2**	**Site 3**	
Conductivity (us/cm)		180	262	173	263	2
Hardness (as CaCO3)		59.3	80.6	62.6	106	0.5
pH	6.5-9.0	7.77	8.08	7.79	8.08	0.1
Anions and Nutrients						
Ammonia, Total (as N)		0.0067	0.0069	<0.0050	<0.0050	0.0050
Nitrate (as N)	200	1.40	2.34	0.406	0.966	0.0050
Nitrite (as N)	0.06	0.0021	0.0052	<0.0010	<0.0010	0.0010
Total Nitrogen		1.54	2.42	0.526	1.02	0.05
Orthophosphate-Dissolved (as P)		0.0021	0.0049	0.0015	0.0089	0.001
Phosphorus (P)-Total		0.0092	0.0107	0.0038	0.0085	0.002
TN:TP		167	226	138.4	120.0	
Total Metals						
Aluminum (Al)-Total	0.1	<0.20	<0.20	<0.20	<0.20	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	0.018	<0.010	0.011	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	Variable**	<0.010	<0.010	<0.010	<0.010	0.10
Calcium (Ca)-Total		16.2	22.1	17.0	28.0	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	Variable**	<0.010	<0.010	<0.010	<0.010	0.010
Iron (Fe)-Total	1.0	0.348	0.166	0.141	0.053	0.030
Lead (Pb)-Total	Variable**	<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		4.57	6.17	4.92	8.66	0.10
Manganese (Mn)-Total	Variable**	0.0347	0.0133	0.0145	0.0050	0.0050
Molybdenum (Mo)-Total	2.0	<0.030	<0.030	<0.030	<0.030	0.030
Nickel (Ni)-Total		<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		7.38	6.42	8.22	8.76	0.050
Silver (Ag)-Total		<0.010	<0.010	<0.010	<0.010	0.010
Sodium (Na)-Total		11.9	24.2	11.5	14.9	2.0
Strontium (Sr)-Total		0.0618	0.0965	0.0671	0.105	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		<0.010	0.010	<0.010	<0.010	0.010
Vanadium (V)-Total		<0.030	<0.030	<0.030	<0.030	0.030
Zinc (Zn)-Total	0.033	0.0071	<0.0050	0.0054	<0.0050	0.0050

** Guideline is calculated based on water hardness and varies for each event and site

5.2.4 Quality Assurance/Quality Control

For quality control, we used replicate samples at Site 4 during both sampling events. Event 1 had some dissimilarities between the sample and the replicate in regards to nitrate and turbidity. The nitrate for the sample was 0.47 mg/L NO_{3-} and the replicate was 2.05 mg/LNO_{3-}. The turbidity for the sample was 5.2 NTU, while the replicate was only 2.17 NTU. This could be explained as human disturbance as we did have to wade into the stream. If we stirred up bottom sediment it would have been most prominent while the sample was taken and would have started to settle while the replicate was taken. During sampling event 2 all parameters were very similar to each other.

5.3 Stream Invertebrate Communities

5.3.1 Total Density

Stream invertebrates were sampled at Site 2 and Site 3 to provide contrast between habitats. Site 2 had very low water flow and had had no restoration efforts done in the past, while Site 3 had the exact opposite characteristics. Three samples were taken from each site, using the Hess Sampler. After analysis at VIU laboratory, it was found that there were 67 invertebrates collected from Site 2, and 147 invertebrates collected from Site 3, each from an area of $0.27m^2$. The invertebrate density per total area sampled for Site 2 was $248.15/m^2$, and for Site 3 was $544.44/m^2$ (Appendix 1). Of those 67 invertebrates in Site 2, 24% were pollution intolerant species, namely the stonefly nymph (Plecoptera), 17% were somewhat pollution tolerant, and 59%, were pollution tolerant. Of those pollution tolerant species, there were 38 oligochaetes (Figure 9), which were the majority of the Site 2 samples at 56.7%. Of the 147 invertebrates sampled from Site 3, 74% were pollution intolerant species, 6% were somewhat pollution tolerant, and 20% were pollution tolerant (Figure 10). Of the pollution intolerant species, there were 98 stonefly nymphs, which were the majority of the Site 3 samples at 66.7%.

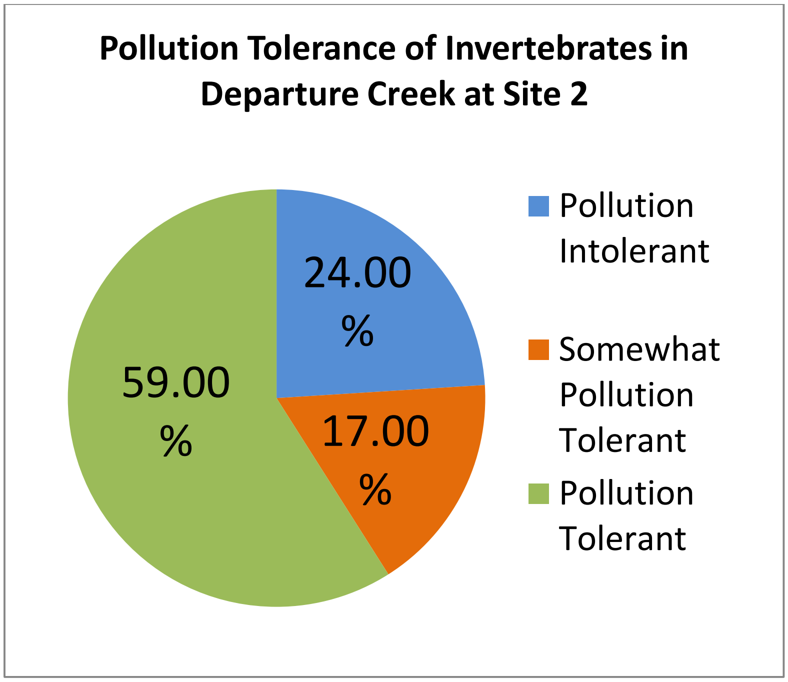

Figure 9. Percentage of Pollution Tolerant, Somewhat Pollution Tolerant and Pollution Intolerant species at Site 2 of Departure Creek taken on 29-OCT-14.

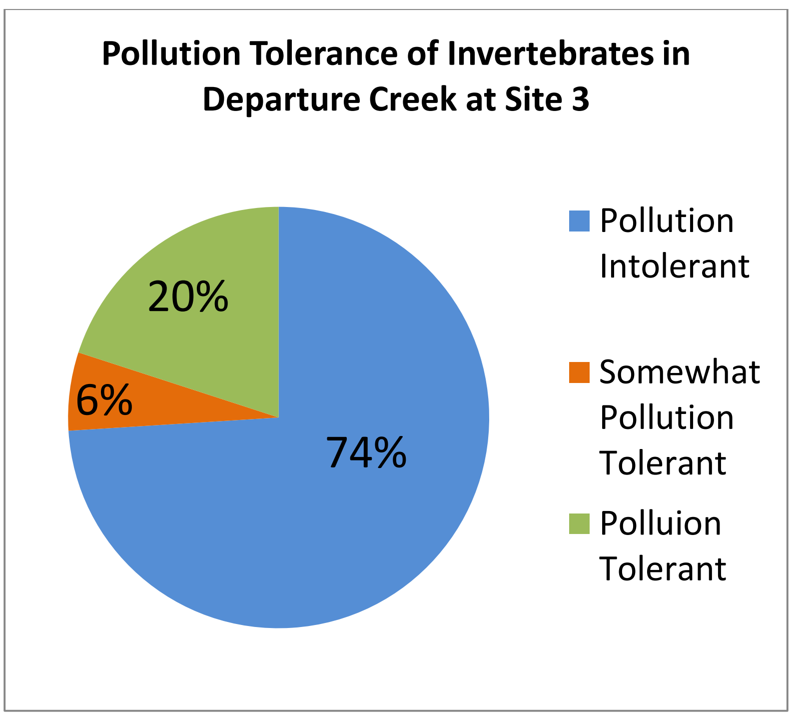

Figure 10. Percentage of Pollution Tolerant, Somewhat Pollution Tolerant and Pollution Intolerant species at Site 3 of Departure Creek taken on 29-OCT-14.

Very few taxa belonging to the somewhat pollution tolerant category were found at Site 3 (6%), while a higher percentage were found at Site 2 (24%). The somewhat pollution tolerant and pollution tolerant genera were more prevalent at Site 2 compared to Site 3, which illustrates the difference in habitat quality for each site. The presence of abundant leaf litter and a higher percentage of canopy cover at Site 2 may account for the higher biodiversity of invertebrates found there.

5.3.2 Taxon Richness and Diversity

Site 2 was given an overall site rating of 2.5, and Site 3 was given an overall site rating of 3, giving Departure Creek an average rating of 2.75 out of a possible 4 (Table 5). It computes that Site 2 would have a lower average rating than Site 3, as it has not had any habitat restoration done to it, and is located on a trickle of a stream that joins Departure Creek. Calculations for the Shannon Weiner Diversity Index were also done for each site. Site 2 was given 0.632 out of a possible 1, and Site 3 was given 0.504 out of 1. This suggests that although there were more pollution tolerant species at Site 3, it actually had a lower biodiversity of invertebrates than Site 2. This would be due to the high number of stonefly nymphs at Site 3. Although the prevalence of Plecopterans reduces the biodiversity of Site 3, their presence implies that Woodstream Park lacks high pollution levels. The results of these calculations indicate that Departure Creek is a healthy ecosystem overall, especially considering its location and proximity to urban development.

Table 5. Stream invertebrates obtained from a sample and two replicates from each Site 2 and Site 3 in Departure Creek on 29-OCT-14.

Pollution Tolerance	Invertebrate Taxa	Site 2	Site 3
Category 1 Pollution Intolerant	Caddisfly Nymph	1	6
	Mayfly Nymph	1	3
	Stonefly Nymph	12	98
	Dobsonfly	2	1
Category 2 Somewhat Pollution Tolerant	Alderfly Larva	N/A	5
	Cranefly Larva	2	3
	Amphipod	8	1
	Clam (Mussel)	1	N/A
Category 3 Pollution Tolerant	Oligochaete	38	26
	Planarian	N/A	3
	Water Mite	2	1
Total		67	147
Density (number/m^2)		372	817
Site Assessment Rating		2.5	3
Shannon Weiner Diversity Index		0.632	0.504

Note: Invertebrate sampling sheets can be found in Appendix 1.

6.0 Conclusion and Recommendations

The analysis of Departure Creek and the studies that were conducted for this report help to develop and understanding of the health of this watershed and its ability to support aquatic life. These tests give an idea of each individual station's health, but also serve as an indicator of the overall health of the entire stream. Departure Creek shows a high content of nutrients and essential ingredients to support aquatic life, and shows no concerning levels of toxic chemicals or metals. The physical properties of the creek suit life for small fish, and aquatic insects with good velocity, depth, and width to support a variety of habitats. The creek also possesses a respectable amount of aquatic invertebrates and shows impressive variety for a stream of its size. Even due to the flashy and urban nature of this creek, in its stable condition the water provides any nutrients needed for aquatic life, and is a diverse ecosystem with varying types of habitat and riparian zones. The overall health of Departure Creek in regards to aquatic life is thus good, and it was determined that the suitability for aquatic insects and other life is high.

A recommendation for future groups working sampling Departure Creek is that a site be set up at the convergence of Departure Creek's main stem, and it's tributary Joseph Creek. A site at this location could potentially give information on how the addition of water from Joseph Creek is affecting the Departure Creek water compared to a sample taken upstream of the convergence. It could also be recommended that a study be conducted into the source of high levels of fecal coliforms in the water located between site 3 and site 4. Levels of coliforms spiked from 200 fecal coliform colonies per 100mL of water at site 3 to 688 in site 4. This could be a variety of factors, and a more in depth look might provide the source and an opportunity to clean up or resolve the problem.

Overall this project was organized and conducted successfully, and the results collected are a good sign that both the natural health of Departure creek is good, and that the restoration work being done to parts of the creek shows promising results, which hopefully continue to stay at this level or increase as reports continue. With higher water levels this stream might see an increase of salmon travelling from Departure Bay and spawning in the stream. With invertebrates and water quality both showing healthy levels, the Departure Creek watershed is on the right path to staying one of Nanaimo's many healthy and successful aquatic ecosystems.

7.0 Acknowledgements

We would like to thank Dr. Eric Demers for the valuable knowledge, expertise and lab materials we have received and used through the RMOT 306 course, and will continue to use in our prospective careers. We would like to thank Sara Greenway for her assistance in getting lab equipment set up and ready to use, and for organizing equipment afterwards. We would also like to thank Dr. John Morgan for the introductory environmental monitoring and habitat management skills we learned in the RMOT 206 course in the autumn of 2013. The combination of field experience and scientific knowledge we as a team have collectively acquired from these two courses made this project possible. Thank you to all of our other professors and Vancouver Island University for the use of the lab in Building 370, and the use of the lab equipment.

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9.0 Appendix

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Departure Creek		Date: Oct 29, 2014
Station Name: Site 2		Flow status: Medium
Sampler Used: Hess	Number of replicates: 3	Total area sampled (Hess, Surber = 0.09 m²) x no. replicates: ~~[illegible]~~ 0.27m² m²

Column A Pollution Tolerance	Column B Common Name		Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	1	EPT1 𝍷	EPT4 1
	Mayfly Nymph (EPT)	1	EPT2 𝍷	EPT5 1
	Stonefly Nymph (EPT)	12	EPT3 𝍸𝍸𝍷𝍷	EPT6 2
	Dobsonfly (hellgrammite)	2	𝍷𝍷	1
Pollution Intolerant	Gilled Snail			
	Riffle Beetle			
	Water Penny			
Sub-Total			C1 16	D1 5
Category 2	Alderfly Larva			
	Aquatic Beetle			
	Aquatic Sowbug			
	Clam, Mussel	1	𝍷	1
	Cranefly Larva	2	𝍷𝍷	2
	Crayfish			
Somewhat Pollution Tolerant	Damselfly Larva			
	Dragonfly Larva			
	Fishfly Larva			
	Amphipod (freshwater shrimp)	8	𝍸𝍷𝍷𝍷	1
	Watersnipe Larva			
Sub-Total			C2 12	D2 4
Category 3	Aquatic Worm (oligochaete)	38	𝍸𝍸𝍸 [illegible] 12 #6	2
	Blackfly Larva			
	Leech			
	Midge Larva (chironomid)			
Pollution Tolerant	Planarian (flatworm)			
	Pouch and Pond Snails			
	True Bug Adult			
	Water Mite	2	𝍷𝍷	1
Sub-Total			C3 40	D3 3
TOTAL			CT 67	DT 12

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: S1 67

DENSITY: Invertebrate density per total area sampled:
S1 67 ÷ 0.27 m^2 = S2 248.15 / m^2

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (Col. C) S3 38 (Oligochaetes)

SECTION 2 - WATER QUALITY ASSESSMENTS

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

4

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

3 x D1 + 2 x D2 + D3
3 x 5 + 2 x 4 + 3 = S4 26

EPT INDEX: Total number of EPT taxa.

2

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

EPT4 + EPT5 + EPT6
1 + 1 + 2 = S5 4

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

1

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

(EPT1 + EPT2 + EPT3) / CT
(1 + 1 + 12) / 67 = S6 0.209

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.

3

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

Col. C for S3 / CT
38 / 67 = S8 0.567

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 1
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: Departure Creek		Date: Oct 29, 2014
Station Name: Site 3		Flow status: Medium/Low
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m²) x no. replicates 0.27 m²

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT) 6	EPT1 𝍸 |	EPT4 /
	Mayfly Nymph (EPT) 3	EPT2 ///	EPT5 2
	Stonefly Nymph (EPT) 98	EPT3 25+13+30+30	EPT6 3
	Dobsonfly (hellgrammite) 1	/	/
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 108	D1 7
Category 2	Alderfly Larva 5	𝍸	1
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva 3	///	2
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp) 1	/	/
	Watersnipe Larva		
Sub-Total		C2 9	D2 4
Category 3	Aquatic Worm (oligochaete) 26	11+3+12	2
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
Pollution Tolerant	Planarian (flatworm) 3	///	/
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite 1	/	/
Sub-Total		C3 30	D3 4
TOTAL		CT 147	DT 15

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell CT: S1 147

DENSITY: Invertebrate density per total area sampled:

S1 147 ÷ 0.27 m² = S2 544.44 /m²

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (Col. C) S3 98 (Stonefly)

SECTION 2 - WATER QUALITY ASSESSMENTS

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

4

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

3 x D1 + 2 x D2 + D3

3 x 7 + 2 x 4 + 4 = S4 33

EPT INDEX: Total number of EPT taxa.

3

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

EPT4 + EPT5 + EPT6

1 + 2 + 3 = S5 6

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

3

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

(EPT1 + EPT2 + EPT3) / CT

(6 + 3 + 98) / 147 = S6 0.728

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell DT: S7 15

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

2

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

Col. C for S3 / CT

98 / 147 = S8 0.667

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 3
EPT To Total Ratio	R3 3
Predominant Taxon Ratio	R4 2

Average Rating
Average of R4, R5, R6, R8
3