

DATA REPORT

Water Quality and Stream Invertebrate Assessment
for Holland Creek, BC,
(Fall 2011)

Report prepared by:

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Table of Contents

1. Background	3
2. Introduction	3
3. Methods	4
3.1. <u>Study Site</u>	4
3.1.1. <i>Sampling Stations</i>	4
3.1.2. <i>Sampling Schedule</i>	5
3.2. <u>Water Quality</u>	5
3.2.1. <i>Field Measurements</i>	5
3.2.2. <i>Water Sampling</i>	6
3.2.3. <i>VIU Laboratory Analyses</i>	7
3.2.4. <i>ALS Laboratory Analyses</i>	7
3.2.5. <i>Quality Assurance / Quality Control</i>	7
3.2.6. <i>Data Analyses – Comparison with Applicable Guidelines</i>	7
3.3. <u>Microbiology</u>	8
3.4. <u>Stream Invertebrates</u>	9
3.4.1. <i>Sampling Stations</i>	9
3.4.2. <i>Invertebrate Sampling`</i>	9
3.4.3. <i>VIU Laboratory Analyses</i>	9
4. Results	9
4.1. <u>Water Quality</u>	10
4.1.1. <i>Field Measurements and VIU Laboratory Analyses</i>	10
4.1.2. <i>ALS Laboratory Analyses</i>	11
4.2. <u>Microbiology</u>	14
4.3. <u>Stream Invertebrates</u>	14
5. Acknowledgements	16
6. References	16
7. Appendices	17

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1. Background

This report documents a water quality and stream invertebrate assessment conducted on Holland Creek, BC, during October-November 2011.

This study was undertaken by 3rd year undergraduate students attending the Environmental Monitoring (RMOT 306) course at Vancouver Island University (VIU), offered as part of the Bachelor of Natural Resources Protection (Greg Faasse, Josiah Klassen, Nik McEwan and Stephanie Righi). Students worked under the supervision of the course instructor, Dr. Eric Demers (Vancouver Island University). This report was compiled by Dr. Eric Demers based on a student group report.

VIU students contributed approximately 125 student-hours to this project, including site visits, project proposal, field sampling, laboratory analyses, and oral and written presentations. Dr. Eric Demers contributed approximately 15 hours for project management and report compilation. Sarah Greenway provided 5 hours of laboratory support for this project.

Logistical support was provided by Fisheries and Oceans Canada (DFO). Funding for field expenses and analytical processing of water samples was provided by the Regional District of Nanaimo and Fisheries and Oceans Canada. ALS Laboratory (Burnaby, BC) provided reduced rates on its analytical services for this project.

2. Introduction

Holland Creek is located just south of the Town of Ladysmith, BC. It is approximately 12 km long from its origin on Coronation Mountain to the point where it enters Ladysmith Harbour. The watershed of Holland Creek covers an area of 28 km². Two large waterfalls are located at 2.3 and 1.2 km from the downstream end, and two Colliery dams are located at 2.4 km (Lower Colliery Dam) and 2.5 km (Upper Colliery Dam) of the downstream end.

This report documents a water quality and stream invertebrate assessment conducted on Holland Creek during October-November 2011.

Specific objectives for this study of Holland Creek included:

- establish 4 water quality sampling stations;
- obtain field measurements of water quality at the 4 sampling stations during two sampling events (31 October and 21 November 2011);
- obtain water samples from each sampling station during two sampling events (31 October and 21 November 2011) for detailed laboratory analyses; and,
- collect stream invertebrate samples at 3 sampling stations during one sampling event (31 October 2011) for analysis at Vancouver Island University.

3. Methods

3.1. Study Site

This project was conducted on Holland Creek which is located on the southern periphery of the Town of Ladysmith, BC (Figure 1). Holland Creek flows easterly from the Coronation Mountains to Ladysmith Harbour. The upstream reaches of Holland Creek flow through forestry lands, while the last 3 km flows through forested parkland. The latter section of Holland Creek was the subject of this study.



Figure 1. Approximate location of the sampling stations used for water quality and stream invertebrate assessments on Holland Creek during October-November 2011. Table 1 provides details of the specific location of each station. Table 2 details the sampling activities conducted at each station. This map was obtained from Google Earth. Map scale is approximated.

3.1.1. Sampling Stations

Four sampling stations were established on Holland Creek during October-November 2011 (Tables 1 and 2; Figure 1). Stations were numbered from upstream (Station 1) to downstream (Station 4). All stations were easily accessed via park trails or road crossings. Station 1 was located near a wooden bridge approximately 600 m upstream of the walking trail access at Mackie Road, and 2.7 km upstream of Ladysmith Harbour. Station 2 was located approximately 400 m downstream of station 1, or 200 m upstream of the walking trail access at Mackie Road. This station was located between two Colliery dams. Station 3 was located approximately 100 m upstream of the Dogwood Drive crossing. Station 4 was located approximately 100 m

downstream of the Dogwood Drive crossing. All stations consisted of shallow and gentle riffle sections.

Table 1. Description of the sampling stations used for water quality and stream invertebrate assessments on Holland Creek during October-November 2011. All northing and easting coordinates were approximated with Google Earth and are based on zone 10U.

Station	UTM Coordinates		Approximate Distance from Ladysmith Harbour (m)	General Location
	Northing	Easting		
1	5425763	439234	2,700	Wooden bridge, 600 m upstream of trail access at Mackie Road
2	5426167	439247	2,300	Between Lower and Upper Colliery Dams, 200 m upstream of trail access at Mackie Road
3	5425625	440718	450	100 m upstream of the Dogwood Drive crossing
4	5425635	440948	210	100 m downstream of the Dogwood Drive crossing

3.1.2. Sampling Schedule

Field sampling was conducted on 31 October and 21 November 2011. For this study, samples were collected for water quality analyses, microbiology and stream invertebrate assessment. Table 2 lists the specific activities conducted at each station during each sampling event. Microbiology and stream invertebrate assessments were only completed during the October event. Photographs showing site conditions and sampling activities are included in Appendix 1.

3.2. Water Quality

3.2.1. Field Measurements

Water quality sampling events were conducted on 31 October and 21 November 2011. At each sampling station, field measurements of water temperature (to the nearest 0.1 °C) and dissolved oxygen (to the nearest 0.1 mg/L) were obtained with an Oxyguard Handy Polaris electronic probe. The electronic probe was placed directly in the channel water.

Basic hydrological measurements were taken at station 3 during both sampling events. Water velocity (in m/s) was measured along a 10-m stream length. A float was dropped slightly upstream of the stream length and allowed to float downstream through the stream length. A stopwatch was used to measure the travel time of the float between the upstream and downstream ends of the stream length. The average travel time from 5 passes was used to calculate average water velocity.

Stream wetted widths were measured with a metered tape to the nearest 0.1 m, and wetted depths were measured (along the same wetted widths) with a meter stick to the nearest 0.01 m. Total cross-sectional areas (in m²) were calculated as the sum of the areas of cross-section polygons. Stream discharge (in m³/s) was obtained as the product of mean water column velocity and cross sectional area.

Table 2. Water quality and stream invertebrate sampling activities conducted at each station on Holland Creek during October-November 2011. The symbols “A” or “B” indicate whether samples / measurements were taken during the October or November sampling events, respectively.

Station	Water Quality				Stream Invertebrates
	Field Measurements	VIU Analyses	ALS Lab Analyses	Microbiology	
1	A, B	A, B	A, B	A	A
2	A, B	A, B	---	A	A
3	A ¹ , B ¹	A ² , B ²	A, B	A	A
4	A, B	A, B	A, B	A	A

Note: ¹ Basic hydrological measurements were taken at station 3 during both sampling events.

² Duplicate samples were collected at station 3 for analysis at the VIU Laboratory during both sampling events.

3.2.2. Water Sampling

During each sampling event, two sets of water samples were collected for laboratory analyses: one set was transported for analysis at Vancouver Island University (VIU), and another set was shipped for analysis by ALS Laboratory, in Vancouver, BC.

Water samples for analysis at VIU were collected from all stations (Table 2). At each station, a clean pre-labelled 500-ml plastic bottle was rinsed 3 times and then used to collect a water sample (Table 3). All water samples were obtained while standing on the stream bank or within the stream channel by immersing the containers just below the water surface while facing upstream. Care was taken not to disturb the bottom sediments. All water samples were kept in a cooler and stored at approximately 4°C. Laboratory analyses were conducted at VIU within 48 hours of sampling.

Samples for analysis by ALS Laboratory were collected from stations 1, 3 and 4 during both sampling events (Table 2). At each station, water samples were collected in three clean laboratory-supplied and pre-labelled sample containers (Table 3). All samples were obtained while standing on the stream bank or within the stream channel by directly immersing the containers just below the water surface while facing upstream. Care was taken not to disturb the bottom sediments. Samples for analysis of nutrients and total metals were preserved with

laboratory-supplied sulphuric acid and nitric acid, respectively. Bottles with preservatives were inverted five times for adequate mixing. All water samples were stored in a cooler on site, and shipped with ice packs within 72 hours for laboratory analyses at ALS Laboratory.

Table 3. Sampling containers and preservatives used for water quality samples taken from Holland Creek during October-November 2011. All containers and preservatives for analysis by ALS Laboratory were provided by ALS Laboratory, Burnaby, BC.

Analytical Parameters	Container	Preservative	Analysed by
Total alkalinity, turbidity	500 ml plastic	None	VIU
Conductivity, pH, total hardness	1 L plastic	None	ALS Laboratory
Nutrients	250 ml amber glass	Sulphuric acid	ALS Laboratory
Total metals	250 ml plastic	Nitric acid	ALS Laboratory

3.2.3. VIU Laboratory Analyses

Water samples transported to Vancouver Island University were analysed for conductivity, pH, total alkalinity and turbidity. Conductivity (to the nearest 1 μ Siemens/cm) and pH (to the nearest 0.01 pH unit) were obtained with a YSI 556 MPS electronic probe. Total alkalinity (as CaCO₃) was measured to the nearest 0.1 mg/L using the HACH AL-DT digital titration method. Turbidity was measured to the nearest 0.01 NTU (Nephelometric Turbidity Units) using a HACH 2100 Potable Turbidimeter.

3.2.4. ALS Laboratory Analyses

Water samples submitted for external analyses were processed as per ALS Laboratory standard analytical procedures. The analytes were: conductivity, total hardness, pH, nutrients (ammonia, nitrite, nitrate, orthophosphate and total phosphorus), and total metals (31 metals).

3.2.5. Quality Assurance / Quality Control

Throughout this study, measures were taken to ensure that potential contamination of water samples was minimized. This included using only clean and rinsed containers, preserving samples as prescribed by the analytical laboratory, and storing collected samples in well-labelled containers. Duplicate sampling provided an estimate of the overall precision associated with the field technique and laboratory analysis.

3.2.6. Data Analyses – Comparison with Applicable Guidelines

Water quality results were compared with the applicable provincial water quality guidelines for the protection of freshwater life. The BC Water Quality Guidelines are the maximum allowable concentration (for potential acute effects) and the 30-day average concentration (for potential

chronic effects) (BCMWLAP 1998a, 1998b). These guidelines were applicable to all sampling stations.

It is important to note that for some metal parameters, analytical detection limits were above applicable guidelines. These include aluminium, antimony, arsenic, cadmium, chromium, cobalt, copper, lead, nickel, selenium, silver, thallium and vanadium. For these metals, measured values reported to be below method detection limits cannot be assumed to be below the applicable guidelines.

3.3. Microbiology

Water samples for total and fecal coliform enumeration were collected from each sampling station on 31 October 2011 (Table 2). At each station, a sterile pre-labelled 120-ml Whirl-Pak[®] bag was used to collect a 100-ml water sample by directly immersing the bag by hand just below the water surface while facing upstream. All samples were stored in a cooler with ice packs and transported within 48 hours to Vancouver Island University for laboratory analysis.

In the laboratory, water samples were tested for total coliform and fecal coliform (*Escherichia coli* or *E. coli*) using the m-coliBlue24 membrane filtration method (Millipore Corporation). A 25-ml volume of sample water was filtered through a 47- μ m membrane filter (marked with 3-mm gridlines) using a vacuum pump. The filtration apparatus was then rinsed with approximately 5 ml of sterile water. Each membrane filter (including the blank) was then transferred to a Petri plate containing an absorbent pad saturated with m-ColiBlue24 broth. All membrane filters were incubated at 37°C for 20 hours (until bacterial colonies were clearly visible).

Upon completion of the incubation period, membrane filters were then examined for bacterial colonies under a dissection microscope (16X magnification). A red or blue colony represents a total coliform “positive” result (Table 4). A blue colony specifically represents an *E. coli* “positive” result. A clear or white colony represents a total coliform negative result.

All colonies present on a membrane filter were counted and expressed as CFU (colony forming units) per 100-ml of sample water.

Table 4. Possible outcomes of the m-coliBlue24 membrane filtration method.

Bacteria Type	Positive Result	Negative Result
Total coliform	Red or blue colony	Clear or white colony No colony
<i>E. coli</i>	Blue colony only	Non-blue colony

3.4. Stream Invertebrates

3.4.1. *Sampling Stations*

Stream invertebrate samples were collected from all stations on 31 October 2011 (Table 1; Figure 1). The sampling stations were selected based on hydrological characteristics, apparent substrate uniformity, space available for replicate samples and site access. At the time of sampling, all stations consisted of shallow riffles (water depth ~10-40 cm), with water velocity of 0.25-0.50 m/s, and primarily gravel and cobble substrate.

3.4.2. *Invertebrate Sampling*

At each station, three replicate samples (triplicates) were obtained using a Hess sampler and procedures as per the Pacific Streamkeepers procedures (Taccogna and Munro 1995). Each site was approached by walking from downstream. The cylindrical, 34-cm diameter Hess sampler was hand-pressed into the substrate to isolate a circular 0.09-m² sampling area. All stones and debris 5 cm or larger within the sampling area were held under water in front of the collecting net and rubbed gently by hand to dislodge invertebrates. Cleaned stones and debris were then placed downstream of the sampling area. The streambed was then gently agitated to a depth of 5 cm to loosen any remaining invertebrates. The content of the collecting net was then transferred in a 125-ml plastic sample jar. The net was carefully inspected to ensure all content was transferred into the sample jar. Samples were stored in a cooler and transported to Vancouver Island University, where laboratory analyses were completed within 24 hours of sampling.

3.4.3. *VIU Laboratory Analyses*

Laboratory procedures and identification also followed the Pacific Streamkeepers procedures (Taccogna and Munro 1995). The replicate samples from each station were combined into a single composite sample per station. The contents of all invertebrate sample jars from a station were poured into a shallow white tray. Invertebrates were sorted into apparent taxonomic groups. Identification to the appropriate taxonomic level (as prescribed by the Pacific Streamkeepers procedures) was confirmed using a dissecting microscope. The number of invertebrates and the number of distinguishable subgroups within each broad taxonomic group were recorded on a Pacific Streamkeeper Invertebrate Survey Field Data Sheet. From these records, various useful metrics were calculated for each station, including: total density (number per m²), total number of taxonomic groups, predominant taxonomic group, Pollution Tolerance Index, EPT (Ephemeroptera-Plecoptera-Trichoptera) Index, EPT to Total Ratio Index, Predominant Taxon Ratio Index, and overall Site Assessment Rating.

4. Results

The discharge measurements (Table 5) and field observations (see photographs in Appendix 1) for Holland Creek suggest that water level was not at bankfull during both sampling events. Discharge increased between 31 October and 21 November 2011.

Average air temperature during the 10-day period prior to each sampling event was 7.5°C and 2.7 °C for the October and November sampling events, respectively (data for Nanaimo Airport retrieved from <http://climate.weatheroffice.gc.ca>). Total rainfall during the 10-day period prior to the October and November sampling events were 27 mm and 31 mm, respectively.

Table 5. Field measurements and laboratory results (VIU Laboratory) for water samples taken from four stations on Holland Creek during 31 October and 21 November 2011.

Station	Field Measurements				VIU Laboratory		
	Discharge (m ³ /s)	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH	Total Alkalinity (mg/L CaCO ₃)	Turbidity (FAU)
31 October 2011							
1		6.2	12.0	32	6.96	7.6	0.56
2		6.6	12.0	27	6.78	8.0	0.55
3	0.32	6.7	11.8	51	6.63	9.4	0.38
4		6.7	11.8	54	6.68	11.6	0.42
21 November 2011							
1		2.4	13.4	19	6.88	5.3	0.24
2		3.1	13.2	21	7.14	7.0	0.33
3	0.63	3.6	12.9	34	6.86	8.5	0.45
4		5.4	12.6	38	6.55	9.7	0.52

4.1. Water Quality

4.1.1. *Field Measurements and VIU Laboratory Analyses*

Water temperature averaged 6.6°C and 3.6°C during the October and November sampling events, respectively (Table 5). The decrease in water temperature between events reflected a similar decrease in air temperature between sampling events. During both sampling events, dissolved oxygen levels were above the minimum guideline of 9.0 mg/L for early fish life stages (RISC 1998). Overall, dissolved oxygen concentrations were >96% saturation.

Mean conductivity decreased from 41 to 28 µS/cm between the October and November sampling events. During both sampling events, there was an increase from upstream to downstream

stations. Water pH was slightly acidic at most stations (range: 6.55-7.14), and there was a general decrease from upstream to downstream stations.

Total alkalinity averaged 9.2 and 7.6 mg/L during the October and November sampling events, respectively (Table 5). During both sampling events, there was an increase from upstream to downstream stations. Overall, total alkalinity was near or below 10 mg/L during both sampling events, indicating “high acid sensitivity” as defined by RISC (1998).

Turbidity levels averaged 0.48 and 0.39 NTU during the October and November sampling events, respectively (Table 5). There was no consistent trend among station or between sampling events.

Overall, results from duplicate samples differed by <13% during this study.

4.1.2. ALS Laboratory Analyses

Water quality results from ALS Laboratory were compared to the BC Provincial water quality guidelines for the protection of aquatic life (Table 6).

The conductivity measurements from ALS Laboratory were consistent with the field measurements obtained with the electronic probe and differed by <31%.

Total hardness followed similar trends as conductivity, namely an increase from upstream to downstream stations and a decrease between sampling events. Total hardness averaged 13.6 and 11.8 mg/L during the October and November sampling events, respectively. Overall, total hardness was below 60 mg/L during both sampling events, indicating “soft water” as defined by RISC (1998).

Field measurements of pH (range: 6.55-7.14) were lower than the ALS Laboratory results (range: 7.11-7.84). This discrepancy possibly reflects improper calibration, differences in air space content among sampling containers and/or time elapsed between sampling and laboratory analysis.

All nutrient levels were below applicable guidelines and/or below detection limits. Ammonia and nitrite were below detection limit (i.e., 0.005 and 0.001 mg/L, respectively). Nitrate concentrations averaged 0.040 and 0.053 mg/L during the October and November sampling events, respectively. Nitrate levels increased from upstream to downstream stations.

Orthophosphate were below detection limit (i.e., <0.001 mg/L). During both sampling events, total phosphorus concentrations were low at stations 1 and 3 (range: 0.0024 and 0.0033 mg/L), and higher at station 4 (range: 0.0132 and 0.0160 mg/L). Overall, total phosphorus levels indicated “oligotrophic” conditions at stations 1 and 3 (<0.010 mg/L), and “mesotrophic” conditions at station 4 (0.010-0.025 mg/L) during both sampling events (as defined by RISC (1998)).

All metals were below applicable guidelines and/or below detection limits during this study.

Table 6. Laboratory results (ALS Laboratory) for water samples taken from 3 stations on Holland Creek during 31 October and 21 November 2011. All values are expressed in mg/L unless specified otherwise. See additional notes on the next page.

Variable	BC Water Quality Guidelines ^a		31 October 2011			21 November 2011		
	BC Max mg/L	BC 30-day Mean mg/L	1	3	4	1	3	4
General/Physical								
Conductivity (µS/cm)			24.7	50.3	53.3	22.5	46.4	44.2
Hardness, Total			9.3	15.2	16.4	8.1	13.1	14.3
pH (pH units)	6.5 - 9.0		7.84	7.78	7.78	7.25	7.27	7.11
Nutrients								
Ammonia-N	7.17 ^b	1.38 ^b	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Nitrate (as N)	31.3	3	0.037	0.039	0.044	0.049	0.054	0.057
Nitrite (as N)	0.06 ^c	0.02 ^c	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Ortho Phosphate (as P)			<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Total Phosphorus			0.0024	0.0032	0.0132	0.0024	0.0033	0.0160
Total Metals								
Aluminum (Al) ^m	0.10 ^d	0.05 ^d	<0.20	<0.20	<0.20	<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	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
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	0.00001 ^e		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (Ca)			2.83	4.81	5.16	2.44	4.08	4.44
Chromium (Cr) ^m	0.001 ^f		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt (Co) ^m	0.11	0.004	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu) ^m	0.003 ^g	0.002 ^g	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron (Fe)	1.0		0.070	0.047	0.043	0.052	0.061	0.066
Lead (Pb) ^m	0.003 ^h	0.003 ^h	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium (Li)	0.87	0.096	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium (Mg)			0.53	0.78	0.85	0.50	0.70	0.77
Manganese (Mn)	0.630 ⁱ	0.641 ⁱ	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
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)			3.04	3.34	3.45	2.92	3.13	3.12
Silver (Ag) ^m	0.0001 ^k	0.00005 ^k	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium (Na)			<2.0	3.3	3.5	<2.0	2.6	2.9
Strontium (Sr)			0.014	0.035	0.037	0.013	0.028	0.031
Thallium (Tl) ^m	0.0003		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin (Sn)			<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium (Ti)	2		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
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	<0.0050	<0.0050	<0.0050	<0.0050

Table 6. (Continued)**NOTES:**

Results are expressed as mg/L except for pH and conductivity.

"<" means less than the detection limit.

- ^a BC Water Quality Guidelines (WQG) compiled from
http://www.env.gov.bc.ca/wat/wq/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 $0.001 * 10^{(0.86 [\log(\text{hardness})] - 3.2)}$ mg/L.
- ^f Chromium guideline is for the more toxic Chromium VI.
- ^g The maximum copper guideline is $0.001 * [0.094(\text{hardness}) + 2]$ mg/L.
 The 30-day mean copper guideline is for hardness < 50 mg/L.
- ^h The maximum lead guideline is $0.001 * e^{\{1.273 [\ln(\text{hardness})] - 1.46\}}$ mg/L.
 The 30-day mean lead guideline is $0.001 * [3.31 + e^{\{1.273 [\ln(\text{hardness})] - 4.704\}}]$ mg/L.
- ⁱ The maximum manganese guideline is $0.01102 * (\text{hardness}) + 0.54$ mg/L.
 The 30-day mean manganese guideline is $0.0044 * (\text{hardness}) + 0.605$ 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.

4.2. Microbiology

All samples collected from Holland Creek contained some coliform bacteria (Table 7). Total coliform levels were unusually high at station 2, and this result was surprising when compared to the other stations. The source of the elevated coliform levels at station 2 is unknown, but may be due to sample contamination or improper handling. With the exception of station 2, total coliform and *E. coli* levels increased with distance downstream.

Table 7. Total coliform and *E. coli* counts from water samples taken at five stations on Holland Creek during 31 October 2011. All values are expressed as CFU (colony forming units) per 100 ml. No microbiology samples were collected on 21 November 2011.

Station	Total Coliform	<i>E. coli</i>	% <i>E. coli</i>
1	24	4	16.7%
2	8,354	1,251	15.0%
3	452	12	2.7%
4	628	40	6.4%

4.3. Stream Invertebrates

A total of 333 stream invertebrates representing 8 broad taxonomic groups were counted at four stations on Holland Creek during 31 October 2011 (Table 8; Figure 2; Appendix 2). Animal density was similar among stations (226-348 animals/m²). Overall, stonefly nymphs were the most common taxonomic group at all four stations.

Site assessment ratings ranged from 3.25 to 3.75 suggesting “acceptable” to “good” invertebrate community abundance and diversity at all stations. The consistent representation of pollution-sensitive mayfly nymphs, stonefly nymphs and caddisfly larvae (EPT taxa: 78-87% of total abundance) also indicated generally “good” environmental conditions at all stations.

Table 8. Abundance and density of stream invertebrates obtained from three replicate samples taken at four stations on Holland Creek on 31 October 2011. Overall site assessment ratings are also provided for each station (out of a maximum rating of 4.00). Invertebrate Survey Field Data Sheets are included in Appendix 2. No stream invertebrate sample was collected on 21 November 2011.

Pollution Tolerance	Invertebrate Taxa	Station 1	Station 2	Station 3	Station 4
Category 1 Pollution Intolerant	Caddisfly Larva	13	7	5	10
	Mayfly Nymph	7	30	33	18
	Stonefly Nymph	33	34	37	40
Category 2 Somewhat Pollution Intolerant	Cranefly Larva	0	0	1	1
	Aquatic Beetle	3	0	0	0
Category 3 Pollution Tolerant	Aquatic Worm (oligochaete)	2	20	18	14
	Midge Larva (chironomid)	3	0	0	3
	Planarian (flatworm)	0	0	0	1
Total Abundance		61	91	94	87
Density (number / m ²)		226	337	348	322
Site Assessment Rating		3.75	3.50	3.75	3.25

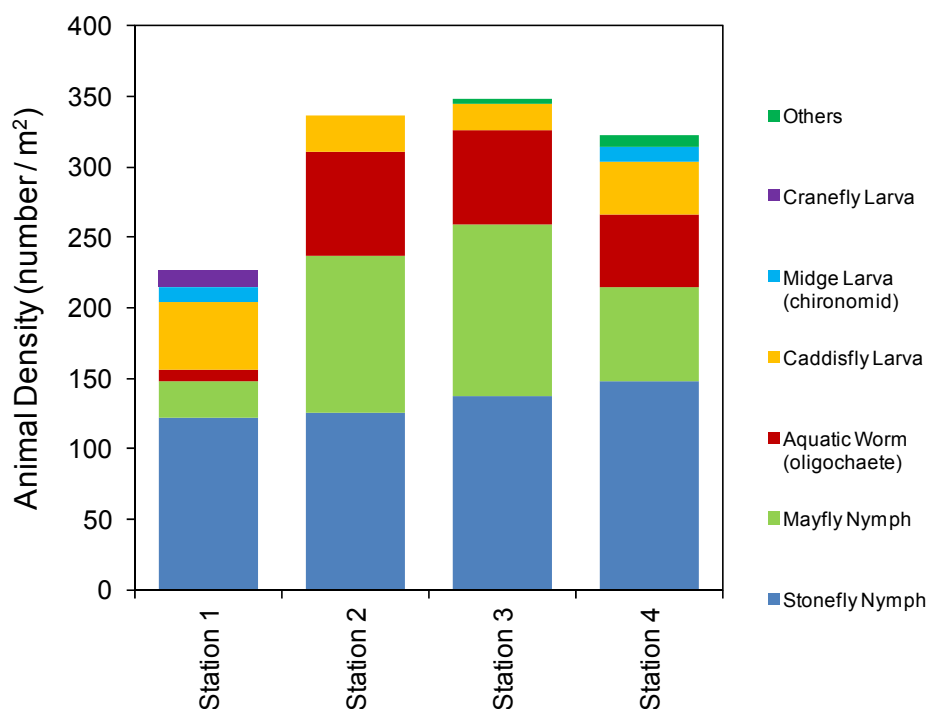


Figure 2. Density of stream invertebrates obtained from three replicate samples taken at four stations on Holland Creek during 31 October 2011. The “Other” category includes aquatic beetle and planarian (flatworm) in decreasing order of abundance. Data are summarized in Table 8 and Invertebrate Survey Field Data Sheets are included in Appendix 2.

5. Acknowledgements

The authors would like to acknowledge Margaret Wright (Fisheries and Oceans Canada) and Joan Michel (Regional District of Nanaimo) for their continued support in facilitating this and other monitoring projects. Additional support was provided by students attending the Environmental Monitoring (RMOT 306) course at Vancouver Island University (VIU) – Nicole Boss, Melissa Dorey, Sarah Gordon, Greg Haider, Alina Koch, Braeden Lattanzi, Hayley McCabe, Heather McCubbin, Dan McNeill, Jackie Morris, Clayton Smith, Olivia van Jarrett and Chris White. The Resource Management Officer Technology (RMOT) and Biology Departments at VIU provided some laboratory supplies, equipment, vehicle and covered fuel expenses. The Regional District of Nanaimo and Fisheries and Oceans Canada provided funding for analytical processing of water samples. ALS Laboratory provided reduced rates on some of its analytical services for this project and other projects conducted as part of the Environmental Monitoring course.

6. References

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- BCMWLAP. 1998b. A Compendium of Working Water Quality Guidelines for British Columbia: 1998 edition updated August 23, 2001. British Columbia Ministry of Water, Land and Air Protection. Victoria, BC.
- RISC. 1998. Guidelines for Interpreting Water Quality Data. Resources Information Standards Committee, Victoria, BC.
- Taccogna, G., and K. Munro (eds). 1995. The Streamkeepers Handbook: a Practical Guide to Stream and Wetland Care. Salmonid Enhancement Program, Dept. Fisheries and Oceans, Vancouver, BC.

7. Appendices

APPENDIX 1. Photographs showing site conditions on the Holland Creek taken on 31 October 2011. All photographs taken by Stephanie Righi.



Photo 1. Upstream view of Holland Creek at station 1, with wooden bridge visible in background.

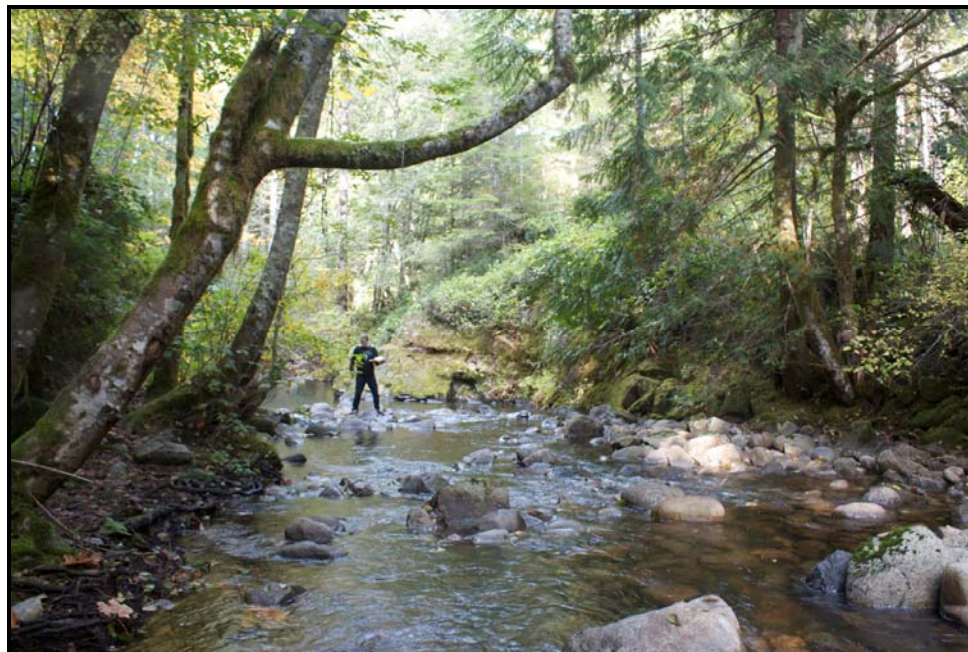


Photo 2. Downstream view of Holland Creek at station 2.

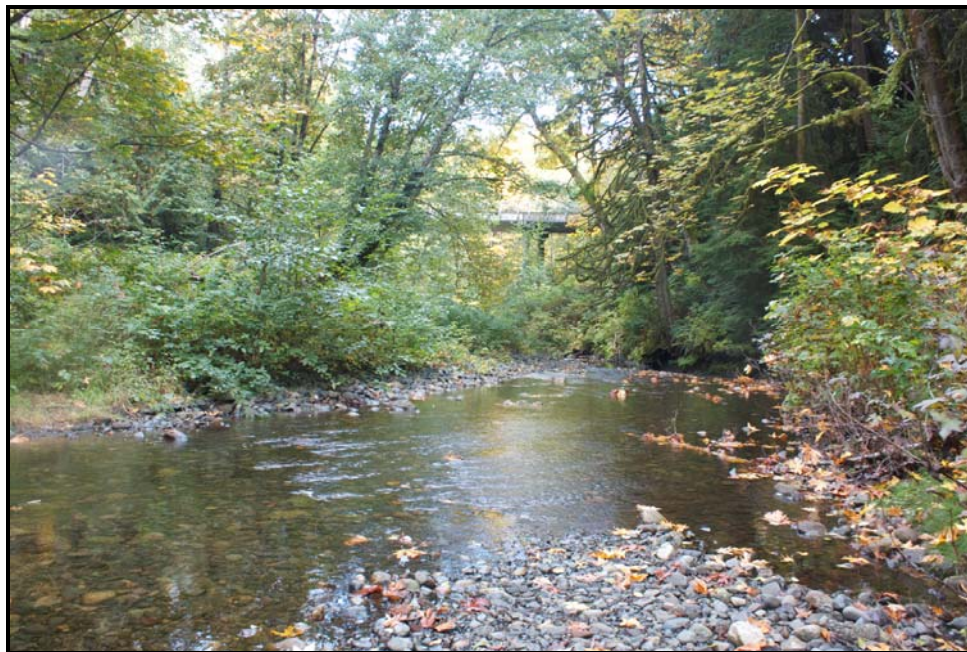
APPENDIX 1. (Continued)

Photo 3. Downstream view of Holland Creek station 3, with Dogwood Drive overpass visible in background.

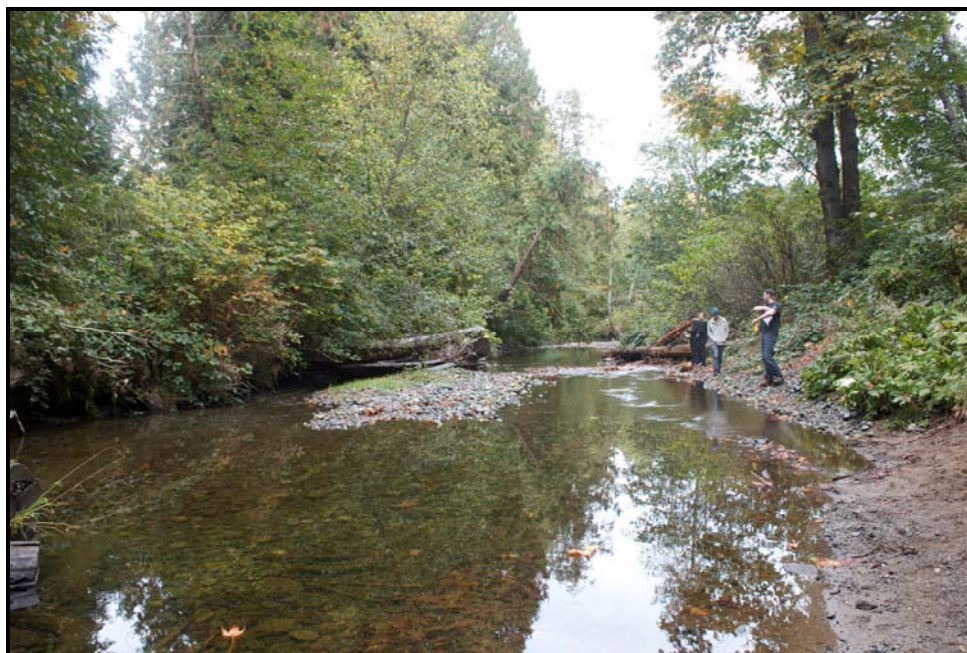


Photo 4. Downstream view of Holland Creek at station 4.

APPENDIX 2. Invertebrate Survey Field Data Sheet completed for triplicate stream invertebrate samples collected at stations 1-4 on Holland Creek on 31 October 2011.

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Holland Creek		Date: 31 October 2011
Station Name: Station 1		Flow status: Moderate
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m ²) x no. replicates 0.09 x 3 = 0.27 m ²

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	13	3
	Mayfly Nymph (EPT)	7	2
	Stonefly Nymph (EPT)	33	5
Pollution Intolerant	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		53	10
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Crane fly Larva	3	1
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)		
	Watersnipe Larva		
Sub-Total		3	1
Category 3	Aquatic Worm (oligochaete)	2	2
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	3	2
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		5	4
TOTAL		61	15

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell CT: 61

DENSITY: Invertebrate density per square metre:

$$\frac{61}{0.27} = 226$$

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

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

$$3 \times D1 + 2 \times D2 + D3$$

$$3 \times \underline{10} + 2 \times \underline{1} + \underline{4} = 36$$
36

EPT INDEX: Total number of EPT taxa.

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

$$EPT4 + EPT5 + EPT6$$

$$\underline{3} + \underline{2} + \underline{5} = 10$$
10

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

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

$$(EPT1 + EPT2 + EPT3) / CT$$

$$(\underline{13} + \underline{7} + \underline{33}) / \underline{61} = 0.87$$
0.87

SECTION 3 - DIVERSITY

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

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

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

$$Col. C for S3 / CT$$

$$\underline{33} / \underline{61} = 0.54$$
0.54

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S4, S5, S6, S8), then calculate the average.

Assessment Rating		Assessment	Rating	Average Rating
Good	4	Pollution Tolerance Index	4	3.75
Accpetable	3	EPT Index	4	
Marginal	2	EPT To Total Ratio	4	
Poor	1	Predominant Taxon Ratio	3	

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Holland Creek	Date:	31 October 2011
Station Name:	Station 2	Flow status:	Moderate
Sampler Used:	Number of replicates	Total area sampled (Hess, Surber = 0.09 m ²) x no. replicates	
Hess	3	0.09 x 3 = 0.27 m ²	

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	7	1
	Mayfly Nymph (EPT)	30	2
	Stonefly Nymph (EPT)	34	2
Pollution Intolerant	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		71	5
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)		
	Watersnipe Larva		
Sub-Total		0	0
Category 3	Aquatic Worm (oligochaete)	20	2
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		20	2
TOTAL		91	7

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell CT: 91

DENSITY: Invertebrate density per square metre:

$$\frac{91}{0.27} = 337$$

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

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

$$3 \times D1 + 2 \times D2 + D3$$

$$3 \times \underline{5} + 2 \times \underline{0} + \underline{2} = 17$$

EPT INDEX: Total number of EPT taxa.

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

$$EPT4 + EPT5 + EPT6$$

$$\underline{1} + \underline{2} + \underline{2} = 5$$

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

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

$$(EPT1 + EPT2 + EPT3) / CT$$

$$(\underline{7} + \underline{30} + \underline{34}) / \underline{91} = 0.78$$

SECTION 3 - DIVERSITY

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

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

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

$$Col. C for S3 / CT$$

$$\underline{34} / \underline{91} = 0.37$$

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.

<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th colspan="2" style="padding: 2px;">Assessment Rating</th> </tr> <tr> <td style="padding: 2px;">Good</td> <td style="padding: 2px;">4</td> </tr> <tr> <td style="padding: 2px;">Accpetable</td> <td style="padding: 2px;">3</td> </tr> <tr> <td style="padding: 2px;">Marginal</td> <td style="padding: 2px;">2</td> </tr> <tr> <td style="padding: 2px;">Poor</td> <td style="padding: 2px;">1</td> </tr> </table>	Assessment Rating		Good	4	Accpetable	3	Marginal	2	Poor	1	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="padding: 2px;">Assessment</th> <th style="padding: 2px;">Rating</th> </tr> <tr> <td style="padding: 2px;">Pollution Tolerance Index</td> <td style="padding: 2px;">3</td> </tr> <tr> <td style="padding: 2px;">EPT Index</td> <td style="padding: 2px;">3</td> </tr> <tr> <td style="padding: 2px;">EPT To Total Ratio</td> <td style="padding: 2px;">4</td> </tr> <tr> <td style="padding: 2px;">Predominant Taxon Ratio</td> <td style="padding: 2px;">4</td> </tr> </table>	Assessment	Rating	Pollution Tolerance Index	3	EPT Index	3	EPT To Total Ratio	4	Predominant Taxon Ratio	4	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="padding: 2px;">Average Rating</th> </tr> <tr> <td style="padding: 2px; text-align: center;">3.50</td> </tr> </table>	Average Rating	3.50
Assessment Rating																								
Good	4																							
Accpetable	3																							
Marginal	2																							
Poor	1																							
Assessment	Rating																							
Pollution Tolerance Index	3																							
EPT Index	3																							
EPT To Total Ratio	4																							
Predominant Taxon Ratio	4																							
Average Rating																								
3.50																								

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Holland Creek	Date:	31 October 2011
Station Name:	Station 3	Flow status:	Moderate
Sampler Used:	Number of replicates	Total area sampled (Hess, Surber = 0.09 m ²) x no. replicates	
Hess	3	0.09 x 3 = 0.27 m ²	

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1 Pollution Intolerant	Caddisfly Larva (EPT)	5	2
	Mayfly Nymph (EPT)	33	2
	Stonefly Nymph (EPT)	37	2
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		75	6
Category 2 Somewhat Pollution Tolerant	Alderfly Larva		
	Aquatic Beetle	1	1
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)		
	Watersnipe Larva		
Sub-Total		1	1
Category 3 Pollution Tolerant	Aquatic Worm (oligochaete)	18	3
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		18	3
TOTAL		94	10

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell CT: 94

DENSITY: Invertebrate density per square metre:

$$\frac{94}{0.27} = 348$$

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

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

$$3 \times D1 + 2 \times D2 + D3$$

$$3 \times \underline{6} + 2 \times \underline{1} + \underline{3} = 23$$
23

EPT INDEX: Total number of EPT taxa.

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

$$EPT4 + EPT5 + EPT6$$

$$\underline{2} + \underline{2} + \underline{2} = 6$$
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	0.50-0.74	0.25-0.49	<0.25

$$(EPT1 + EPT2 + EPT3) / CT$$

$$(\underline{5} + \underline{33} + \underline{37}) / \underline{94} = 0.80$$
0.80

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell DT: 10

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

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

$$Col. C for S3 / CT$$

$$\underline{37} / \underline{94} = 0.39$$
0.39

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S4, S5, S6, S8), then calculate the average.

Assessment Rating	
Good	4
Accpetable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	4
EPT Index	3
EPT To Total Ratio	4
Predominant Taxon Ratio	4

Average Rating
3.75

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Holland Creek	Date:	31 October 2011
Station Name:	Station 4	Flow status:	Moderate
Sampler Used:	Number of replicates	Total area sampled (Hess, Surber = 0.09 m ²) x no. replicates	
Hess	3	0.09 x 3 = 0.27 m ²	

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1 Pollution Intolerant	Caddisfly Larva (EPT)	10	1
	Mayfly Nymph (EPT)	18	2
	Stonefly Nymph (EPT)	40	2
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		68	5
Category 2 Somewhat Pollution Tolerant	Alderfly Larva		
	Aquatic Beetle	1	1
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)		
	Watersnipe Larva		
Sub-Total		1	1
Category 3 Pollution Tolerant	Aquatic Worm (oligochaete)	14	2
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	3	1
	Planarian (flatworm)	1	1
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		18	4
TOTAL		87	10

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell CT: 87

DENSITY: Invertebrate density per square metre:

$$\frac{87}{0.27} = 322$$

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

SECTION 2 - WATER QUALITY ASSESSMENTS

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

$$3 \times D1 + 2 \times D2 + D3$$

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

$$3 \times \underline{5} + 2 \times \underline{1} + \underline{4} = 21$$
21

EPT INDEX: Total number of EPT taxa.

$$EPT4 + EPT5 + EPT6$$

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

$$\underline{1} + \underline{2} + \underline{2} = 5$$
5

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

$$(EPT1 + EPT2 + EPT3) / CT$$

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

$$(\underline{10} + \underline{18} + \underline{40}) / \underline{87} = 0.78$$
0.78

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell DT: 10

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

$$\text{Col. C for S3} / CT$$

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

$$\underline{40} / \underline{87} = 0.46$$
0.46

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		Assessment	Rating	Average Rating
Good	4	Pollution Tolerance Index	3	3.25
Accpetable	3	EPT Index	3	
Marginal	2	EPT To Total Ratio	4	
Poor	1	Predominant Taxon Ratio	3	