DATA REPORT

Water Quality and Stream Invertebrate Assessment for the

C.W. Young Channel, Englishman River, BC

(Fall 2017)

Report submitted to:

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Executive Summary

(Jaylene Harper)

Annual assessments of environmental health are imperative in watersheds that have ecological, economical, or cultural importance. The Englishman River, located on the central east coast of Vancouver Island (British Columbia), adjacent to the city of Parksville, is an important salmon-bearing stream within the region, as well as a drinking water source for a majority of Parksville's residents. Since 2008, an annual monitoring project, that analyzes current water quality and ecosystem health, has taken place in the C.W. Young Channel within the Englishman River. The channel, which runs parallel to the river's mainstem for approximately 4.1km within Englishman River Regional Park, was originally constructed in 1992 to enhance salmon habitat. It has since evolved into an important rearing area for salmon, as well as trout. Due to an array of potential environmental concerns that surround the Englishman River, as well as the need for long term data, the C.W. Young Channel monitoring project is conducted each year to provide information pertaining to overall health of the channel, as well as the Englishman River as a whole. Sampling and analysis of water quality parameters, as well as stream invertebrates, was completed by four Vancouver Island University students, under the guide and supervision of their instructor, Dr. Eric Demers. Additional water quality analysis was completed by ALS, to ensure accuracy. Samples were taken from five distinct stations, which have been utilized since 2008, to ensure uniformity. Our results verified that the C.W. Young Channel has good overall health, which is consistent with previous year's results for the area. Other than higher than usual levels of both turbidity and total phosphorus (P), likely due to a large storm cycle that had recently passed through the area, all water quality parameters were within the provincial guidelines. Traces of aluminum were detected in the channel, coinciding with past studies that found similar results. The presence of aluminum is due to the

local geology of the area and does not currently cause harm to the watershed’s health. Coliform counts were low, providing additional data that the water within the river is very clean, as well as suitable for drinking after it has gone through at least partial treatment in a water treatment plant. Stream invertebrate samples taken from three of the five stations all had pollution intolerant species present, indicating the watershed is still suitable for all aquatic life. Predominant taxon results changed from previous years’ studies, indicating that pollution intolerant species have potentially declined in the channel. This could, however, be explained by the patchiness associated with stream invertebrate sampling.

Table of Contents

List of Tables

List of Figures

1.0 Introduction

(Jaylene Harper)

1.1 Project Overview

Since 2008, an annual monitoring project, which assesses water quality and stream invertebrate health, has been conducted in the C.W. Young Channel of the Englishman River. A proposal was brought forth for the continuation of this project, to obtain information pertaining to the river's health for 2017, and therefore maintain the goal of long-term monitoring. Sampling and data analysis was conducted by four undergraduate students from Vancouver Island University, with guidance and supervision from Dr. Eric Demers. Water quality and invertebrate sampling occurred on November 1stth and November 22nd. During these events, two sets of samples were taken, with the hope and accomplishment of obtaining data at both low-flow and high-flow occurrences. There are five recognized sampling stations within the C.W. Young Channel that were strategically chosen when the project began (2008), and have continued to be utilized each year, therefore keeping data collection as consistent as possible. With the rise of global warming, as well as industrial and agricultural production, long-term environmental monitoring projects are needed more than ever. By continuing the annual sample and data collection pertaining to the health of the Englishman River, any abrupt or gradual change over time within the stream can be either detected or predicted. Such information will help make future decisions that relate to the conservation of the river, as well as grant a better understanding of long-term effects induced by current or impending changes to the stream's environment.

1.2 Site Overview

Located on the central east coast of Vancouver Island, adjacent to the city of Parksville, British Columbia, the Englishman River is recognized as being a crucial salmon-bearing stream within the region (Figure 1) (Silvestri 2007). With the exception of its high elevation areas (>100 m), the river is primarily classified within the Moist Maritime Coastal Douglas Fir biogeoclimatic zone (CDFmm), and therefore is predominantly a moist, low altitude environment (Hawkes et al. 2008; Barlak et al. 2010). The river flows northeast from Mount Arrowsmith into the Georgia Strait, with a total drainage of 324 km^2 (Silvestri 2007). It provides habitat for an abundance of fish species, including all five Pacific salmon species, as well as cutthroat trout (*Oncorhynchus clarkii*) and rainbow trout (*Oncorhynchus mykiss*). The river is also an important drinking water source for the residents of Parksville (Barlak et al. 2010). Approximately 5 km of the river's mainstem falls within Englishman River Regional Park, an area owned by both the province of British Columbia, as well as The Nature Trust, Ducks Unlimited Canada, and the Nature Conservancy of Canada. The park, located 5 km upstream from the Englishman River Estuary, is utilized for fish and wildlife conservation, as well as recreational tourism (LCL 2008).

Figure 1. Location of Englishman River Watershed on Vancouver Island, as shown in green (from Silvestri 2007).

The C.W. Young Channel, our focus area, is positioned on the northern bank of the river, within the boundaries of the Englishman River Regional Park (Figure 2). The channel, originally known as the "Timberwest Channel," was constructed in 1992, with the intent of enhancing salmon rearing habitat for salmonids, particularly Coho salmon (*Oncorhynchus kisutch)* (Decker et al. 2003). In 2007, an additional length of 2 km was further added to the channel, giving it a total length of approximately 4.1km (Hawkes et al. 2008). The channel arises below the Morison Creek confluence, and ends approximately 7km upstream from the Englishman River Estuary. The channel, when created, was tactically enhanced with gravel and large woody debris, intended to increase the success of salmon reproduction, as well as smolt survival. Pools, utilized as rearing habitat, make up approximately 80% of the C.W. Young Channel, while riffles, utilized for spawning habitat, encompass the other 20% (Decker et al. 2003).

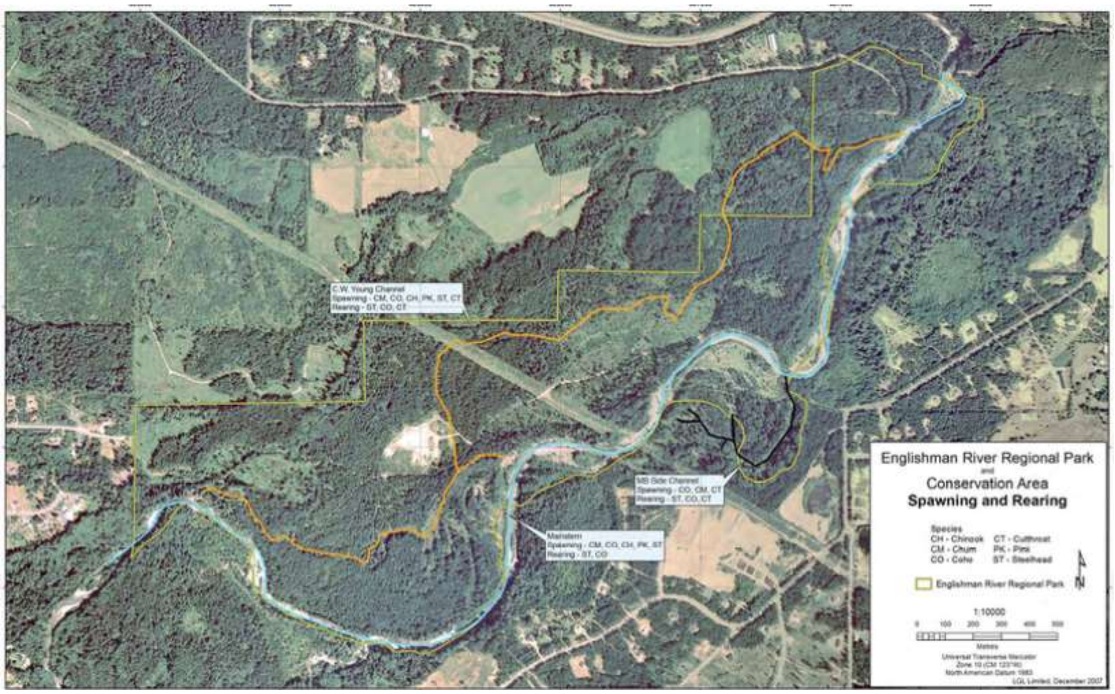

Figure 2. Location of C.W. Young Channel, as shown in orange, in respect to the Englishman River, as shown in blue. Both systems are within the Englishman River Regional Park Boundary, as shown in yellow (from Hawkes et al. 2008).

1.3 Historical Review and Land Use

Around 90% of the forests surrounding the Englishman River have been previously logged, therefore almost all forests are second growth (Decker et al. 2003). Logging roads are present within the watershed, although use of most of these roads is restrained by locked gates, allowing vehicle access to only those permitted. Roughly 10% of the watershed is surrounded by rural and urban development, with residential areas residing near the river in several locations. Agricultural development is also significant in some rural areas near the river, and such activities have been documented by Hawkes et al. (2008) to cause sediment loading into the watershed. Two highway crossings have also been built over the Englishman River, both of which experience substantial traffic daily.

1.4 Potential Environmental Concerns

As indicated above, a range of anthropological developments encase the Englishman River Watershed. These developments pose potential impacts to the river's health. Residential areas near the river can pollute the watershed through septic tank use, or use of lawn fertilizers. Agriculture development can impact the river through sediment loading, as well as fecal contamination from livestock. Gas from vehicles leaking into the river, also referred to as road runoff, poses a potentially large threat to the river's health, as vehicle driven roads in reach of the river are utilized for logging, residential areas, as well as highway crossings (Hawkes et al. 2008). The construction of roads, as well as the loss of forest cover through logging, has also caused repercussions along the river such as "slope instability, landslides, altered run-off patterns, and sediment loading" (Decker et al. 2003). These factors, along with major snow accumulation on the river's upper headwaters (especially during La Nina events), has caused significant winter flooding (Decker et al. 2003; Fleming et al. 2014). Studies done by Weston et al. (2003) have furthermore projected that climate change may likely affect the flood regime in the Englishman River, increasing peak annual flows by 8% by 2020, 14% by 2050, and 17% by 2080.

2.0 Project Objectives

(Jaylene Harper)

The principal objective of this monitoring project was to obtain samples from the C.W. Young Channel that can provide data pertaining to the present overall health of the channel, as well as the Englishman River as a whole. Our results can then be compared and added to the data that has accumulated over the last 9 years for this monitoring project, thus revealing any changes occurring in the watershed, and continuing long-term data collection. To reach our principal objective, water quality measurements were taken from five sampling stations on two separate occasions. These samples were then analyzed and documented in a laboratory setting. Furthermore, stream invertebrate sampling took place at three sampling stations (on one occasion), and were also analyzed and documented in a laboratory setting.

3.0 Environmental Sampling and Analytical Procedures

3.1 Sampling Program

(Teagan Wardrop)

In 2007 the C.W. Young Channel was extended by 2 km, drawing it out to 4.3 km in total (Hawkes et al., 2008). As part of a long-term management plan to monitor the success of the channel, five sites were established, at intervals of less than 1.7 km apart, where samples have been collected from and analyzed on an annual basis since 2008 (Demers, 2016). To fulfill the objectives of this project, an initial site assessment was piloted on October 18th and followed by a repeat environmental sampling program conducted in the C.W. Young Channel of the

Englishman River during the month of November, 2017. November is known to have the highest average rainfall in millimeters per month around the City of Nanaimo, which results in high discharge rates along the Englishman River during this time (Barlak et al., 2010). To maintain the consistency of the program, samples were collected from the established sites during the same time frame as previous years, analyzed in accordance with outlined procedures, and compared to preceding data in order to assess any changes in hydrology, water quality, microbiology, or invertebrate population health within the channel. Once the results of the sample analysis had been gathered, a report was written to outline the findings.

3.1.1 Locations

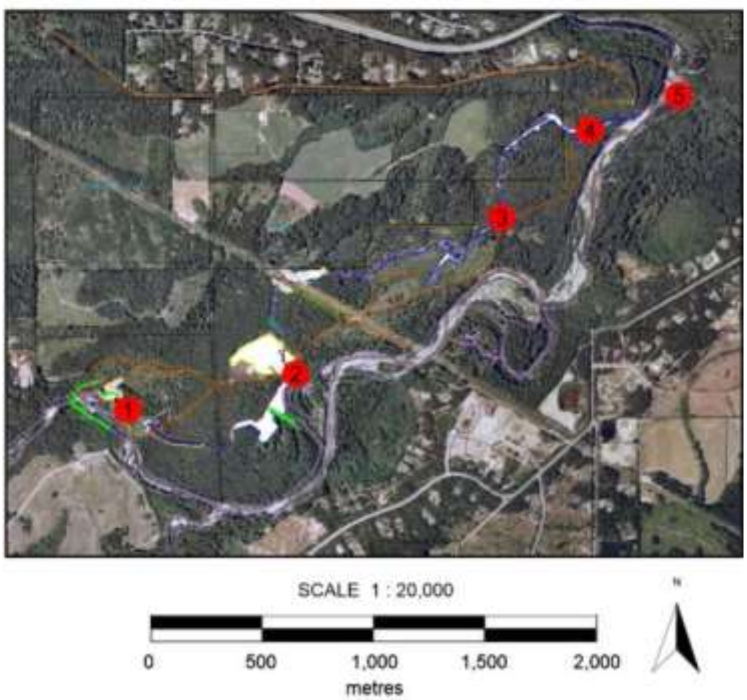

Figure 3. A map of the C.W. Young Channel shown in blue, with the five established sampling sites monitored from 2008 – 2016 in red (from Demers, 2016).

The sampling locations (Figure 4), as established in 2008 due to their accessibility and accurate representation of the overall channel, have been monitored annually for the past nine years and are described as follows (Demers, 2016).

Site #1 is located at the upstream entrance to the C.W. Young Channel, at the western end of Allsbrook Trail (UTM 10U 0405267mE 5459846mN) (Demers, 2016).

Site #2 is located 1,250 m east of site #1 (UTM 10U 0406143mE 5459962mN) (Demers, 2016). Here the channel flows underneath Allsbrook Trail through a culvert. The sampling site is on the downstream side of the culvert, and is a 1.5 m downhill, muddy slope from the trail to the water. The stream appears to be even here at a gradient of <1°.

Site #3 is tucked behind a dense "mesic second-growth coniferous forest" adjacent to Allsbrook Trail, and 2,900 m from site #1 (UTM 10U 0407089mE 5460663mN) (Hawkes et al., 2008; Demers 2016). The entrance to site #3 is located at a curve in the trail, where a small opening in between two large root wads on the left (if facing east) opens up to a narrow, northerly walking trail. After approximately 30 m, the trail leads to a clearing next to a riparian thicket where the channel can be accessed. Here, the channel displays a low gradient.

Site #4 is located beneath a metal walking bridge 3,800 m downstream from site #1 (UTM 10U 0407495mE 5461056mN) (Demers, 2016). If facing east, the bridge is a 10 m walk down a small trail on the right side, but visible from the main Allsbrook Trail. The sampling site is in the middle of a steep gradient where the channel converts from a pool to a riffle.

Crossing the bridge at site #4 and continuing along the divergent trail for roughly 200 m would lead to site #5 at the downstream end of the C.W. Young Channel, where it reconnects to the main stream of the Englishman River (UTM 10U 0407805mE 5461177mN) (Demers, 2016; E Demers, pers. comm., Oct 18, 2017). Unfortunately, due to weather conditions, site #5 could not be accessed during the initial site assessment, but was accessed during the first and second sampling sessions.

3.1.2 Habitat Characteristics

Site #1 is a pool habitat which receives outflow from the Englishman River through a metal effluent release pipe connected to a blue, metal valve. Beneath about 2 m of water, the substrate is estimated to be 60% large boulders on top on 40% fines like silt and sand. Nestled within a moist mixed forest habitat, site #1 has a 25% canopy cover composed of Bigleaf Maple (*Acer macrophyllum*) and Red Alder (*Alnus rubra*) (Hawkes et al., 2008). Surrounding site #1 in the riparian areas on both sides of the channel are Salmonberry (*Rubus spectabilis*) and Himalayan Blackberry (*Rubus discolor*) bushes, as well as Reed Canarygrass (*Phalaris arundinacea*) and Common Horsetail (*Equisetum arvense*) in the understory. The steep trail down to the site was muddy and slippery during all three visits.

At the cross section of a moist mixed forest and a "mesic second growth coniferous forest," site #2 is a glide habitat where water enters from a culvert (Hawkes et al., 2008). The majority (60%) of the substrate consists of cobble, while the rest (40%) is evenly distributed between boulders, gravel, and fines. This site has a 20% canopy cover split equally between Douglas-fir (*Pseudotsuga menziesii*) and Bigleaf Maple trees. The diverse riparian area contains Sword Ferns (*Polystichum munitum*), Oceanspray (*Holodiscus discolor*), Salal (*Gaultheria shallon*), Trailing Blackberry (*Rubus ursinus*), and various species of grass.

Site #3 is a pool habitat immediately upstream to a riffle. Due to the heavy rainfall surrounding the time of the initial assessment, the water level within the pool was high; making assessment of the exact composition of the substrate unclear. Approximately 30% of the visible substrate within the pool are boulders, leaving the rest (70%) to what appeared to be fines.

Various large woody debris including four stumps and several fallen trees are scattered in this habitat. A scarce 15% canopy is covered by Douglas-fir, Western Red Cedar (*Thuja plicata*), Red Alder, and Bigleaf Maple trees (Hawkes et al., 2008). Bordering this rich habitat is a large patch of Nootka Rose (*Rosa nutkana*), and Canada Thistle (*Cirsium arvense*), as well as Salmonberry and Common Snowberry (*Symphoricarpos albus*) bushes, and Bracken Ferns (*Pteridium aquilinum*). Also spotted at this site was a Great Blue Heron (*Ardea herodias fannini*), a blue-listed species and a treasured member of the Englishman River Conservation Area (Hawkes et al., 2008).

At site #4, a pool habitat drops off into a rapid riffle due to a moderate gradient. Site #4 is heavily shaded by a 50% canopy cover of large Red Alder, Bigleaf Maple, and Douglas-fir trees. Beneath the water is a perimeter of 40% boulders, filled in with 50% cobble substrate on top of 10% fines. Three stumps also dot this habitat and collect leaves from the shedding autumn canopy. Neighbouring this site, and the trail, are many tall Salmonberry shrubs, a few Thimbleberry (*Rubus parviflorus)* bushes, as well as Sword and Bracken Ferns (Hawkes et al., 2008).

Site #5 differs from the previous sites as it is a riverine flat habitat where the C.W. Young Channel reconnects to the main stem of the Englishman River (Hawkes et al., 2008). Visual habitat characteristics of site #5 could not be gathered during the initial site assessment. However, according to a project conducted by VIU Environmental Monitoring Students (2014), site #5 is clear of any canopy coverage; however, Bigleaf Maple, Red Alder, and Sitka Willow (*Salix sitchensis)* trees frame the area. The substrate here is predominantly (75%) cobble, with the rest comprising a mixture of boulders and fines. These features were confirmed to be accurate during sampling session #1.

3.1.3 Sampling Frequency

Following protocol conducive to the objectives of the monitoring program, two sampling sessions of approximately four hours each were conducted in the field, followed by two analysis sessions in the laboratory consisting of approximately three hours each. The dates of these field sessions were Wednesday, November 1st from 9:00 am to 1:00 pm, and Wednesday, November 22nd during the same time frame. The dates of laboratory analysis of the samples were also November 1st and 22nd, from 2:30 pm to 5:30 pm. The frequency of sampling was spread over 3 weeks to gather data regarding the changes in hydrology and water quality of the channel throughout the fall season, as well as to coincide with previous studies. During both of these field sessions, water quality samples were collected from each of the five sites and further analyzed in a laboratory (Table 1). Microbiology and invertebrate samples were collected at each of the five sites during the first sampling session only. Additionally, hydrology tests were conducted at more than one station during both of the sessions.

Table 1. Sampling activity and frequency conducted at each site during the monitoring program. 'A' indicates sampling session #1 and 'B' indicates sampling session #2 (Demers, 2016).

Station	Hydrology	Site Measurements	Water Quality Samples	VIU Lab Analysis	ALS Lab Analysis	Microbiology	Stream Invertebrates
1	A, B	A, B	A, B	A, B	A, B	A	A
2	A, B	A, B	A, B	A, B	A, B	A	---
3	A	A,	A, B	A, B	---	A	A
4	A, B	A, B	A, B	A, B	A, B	A	A
5	A	A,	A, B	A, B	---	A	---

3.2 Basic Hydrology

(Teagan Wardrop)

The basic hydrology of the C.W. Young Channel was assessed twice at sites 1, 2, and 4 throughout the sampling program; and only assessed once at sites 3 and 5 due to safety concerns. Measurements taken at these sites during these events included: bankfull channel width (m), wetted width (m), maximum and average bankfull depths (cm), gradient (◦), velocity (m/s) determined using the "float method," and discharge (m^3/s) (Silvestri, 2007; E Demers pers. comm. Oct 12, 2017). Furthermore, at each of the five sites, the percentage of canopy coverage, substrate type, and riparian area composition were documented and evaluated as a reflection of the overall stream health.

3.3 Water Quality

(Kalia Van Osch)

3.3.1 Field Measurements

Values for water temperature (°C) and dissolved oxygen (mg/L) were collected in the field using a YSI probe. These values were recorded on November 1st during a low flow event and November 22nd during a high flow event at all five sampling stations. All other measurements were determined using water samples from each station and then analyzed at the VIU laboratory or ALS laboratory (see below).

3.3.2 Water Sample Collection

Water samples were collected and transported using provided, pre-approved containers and contamination was prevented by avoiding contact between the testers hands and the inside of the lid or container. The collection method adhered to the *Ambient Freshwater and Effluent Sampling* (MWLAP 2003) protocol to retain consistency and all bottles were labelled prior to sampling to ensure accuracy. Five samples were taken on November 1st, for low flow analysis and five samples on November 22nd for high flow analysis, beginning at station five and moving upstream to station one. A single replicate sample was collected at a randomly chosen station for comparison to determine accuracy of laboratory testing. The water samples were collected within the station in a representative area of constant water flow and midstream to avoid surface scum or film. Water quality samples were collected in unsterilized VIU provided bottles and the bottles used for the ALS analysis included 3 pre-sterilized bottles per station. A 500-ml white plastic bottle was used for general parameters, 60-ml white plastic bottle for total metals and a 125-ml amber glass bottle for total nutrients. A Nitric Acid preservative was added to the total metals bottle directly after sample collection and likewise, a Sulphuric Acid preservative was added to the total nutrients bottle after sampling. Water samples were acquired by entering the stream downstream of the collection area to avoid disturbing the sediment in the sample area. The lid was removed, avoiding contact with the inner surface of the lid or bottle and then rinsed three times. The individual collecting the sample stood perpendicular to the water flow, facing upstream and plunged the bottle face down before orienting it to the current. The bottle was then removed by forcing it into the current and lifting it upwards out of the water, capping immediately. All samples were transported directly to the VIU laboratory in a cooler with ice packs. This ensured proper temperature maintenance for accurate test parameters.

3.3.3 VIU Laboratory Analyses

The water samples were shipped for analysis at the VIU laboratory within 24 hours of field collection. Laboratory tests were conducted to determine hardness (mg/L as $CaCo_3$), conductivity (µS/cm), turbidity (NTU), pH, alkalinity (mg/L $CaCO_3$, nitrate (mg/L NO_3^-) and phosphate (mg/L PO_4^{3-}). These values were compared with the *Guidelines for Interpreting Water Quality Data* (RISC, 1998), to determine if the water in the C.W. Young Channel and Englishman River, fits within the maximum guidelines for aquatic life.

3.3.4 ALS Laboratory Analyses

Three samples from each of stations 1, 2 and 4 were collected on November 1st and 22nd and shipped to the ALS laboratory in Burnaby, British Columbia. Packing methods included the use of a cooler, packed with ice packs to maintain a temperature of 4°C and sealed with heavy packing tape to prevent tampering. A completed lab requisition form was included; one copy inside the package and another attached to the exterior. Samples arrived at the laboratory within 48 hours of field collection and testing was completed for standard water quality parameters, nutrient analysis and total metals scan for approximately 30 metals.

3.3.5 Quality Assurance/Quality Control

To ensure quality control, a trip blank was brought to the assessment site and remained unopened to test for equipment or transport contamination. Filtration and equipment blanks were analyzed in the laboratory to monitor for contamination and a replicate sample at a random station was taken to test consistency. To ensure quality assurance, all samples were collected at the same five sampling stations used in previous studying from 2008-2016. Samples were collected in the same location at the station on November 1st and 22nd, and collection methods described in this proposal were used on both occasions. Properly sanitized equipment and methods of hygiene including clean hands and using gloves prevented cross-contamination. Methods of storage, refrigeration and incubation were monitored to ensure accurate results are maintained and all samples were processed within 24 hours of collection. These methods for quality control and assurance are outlined in the *Freshwater Biological Sampling Manual* (FBSM 1997).

3.3.6 Data Analyses

The ALS laboratory results in conjunction with the samples analyzed at the VIU laboratory were evaluated according to the *Guidelines for Interpreting Water Quality Data* (RISC 1998). The results determined whether the parameters align with the guidelines and if the area has the proper characteristics to ensure a healthy stream ecosystem. The results were also compared to previous data recorded at the same stations from 2008-2016 to identify changes and trends in the area.

3.4 Microbiology

(Kalia Van Osch)

Microbiology samples were collected at each station on the first sampling occasion, November 1st. Samples collection used pre-sterilized 100-mL Whirlpak bags that were labelled before placing in the water to ensure accuracy. A laboratory error resulted in the water sample being used for coliform testing to come from the water bottles collected, not the Whirlpak bags. This error possibly affected the sterility of the water sample and may have resulted in contaminated results. Analysis was completed using the *Total Coliforms and E. Coli Membrane Filtration Method* (USEPA 2002), by putting the 100-mL water sample through a 47-mm membrane filter. Water samples were then poured into the reservoir funnel, drawn through with a vacuum pump and rinsed with sterile water before removing the membrane. A 50-mm petri plate was prepared with an absorbent pad in the center, saturated with m-ColiBlue24 broth upon which the membrane filter was placed. Incubation of the plate occurred at 35°C ± 0.5°C for 24-hours after which the plate was analyzed for coliform.

Presence of red or blue bacterial colonies was indicative of coliform presence, while white or clear colonies was negative. Furthermore, blue colonies showed a positive growth of *E. Coli* coliforms in comparison to red colonies which are coliform but *E. Coli* negative. A single blue or red colony on the petri plate identified the whole sample as coliform positive and all results were reported as CFU/100 ml.

Quality assurance was maintained by following standard microbial lab safety practices, wearing gloves and using proper sterilization procedures. This method of testing for *E. coli* and/or total coliforms is approved by the United States Environmental Protection Agency

(USEPA) to determine coliform presence in drinking water and is a standardized method of testing. MSDS sheets regarding chemicals used in the procedures was reviewed by all involved and methodical sterilization techniques were administered to all equipment and laboratory surfaces used for testing.

3.5 Stream Invertebrate Communities

(Avryl Brophy)

3.5.1 Invertebrate Sample Collection

Freshwater benthic macroinvertebrate communities can be used to test and monitor water quality to get a comprehensive image of the overall health of an aquatic ecosystem (Demers, 2016). During the water quality testing at Englishman River, we sampled for stream macroinvertebrates using a Hess sampler. All sampling methods were standardized to ensure the greatest accuracy. The sampling took place only once during the first sampling session on November 1, 2017. Stream macroinvertebrate samples were taken from stations 2, 3, and 4 only. Since macroinvertebrate distribution is considered highly patchy it is recommended to collect replicate samples at each site to obtain an accurate representation of the benthic fauna (Demers 2016). One sample per person at each site was taken for a total of twelve macroinvertebrate samples. Each sample was taken from similar substrates using the Hess Sampler which covers 0.09 meters squared for a total of 0.27 meters squared per station. Focusing on consistent sampling similar substrates, depths, and water velocities was chosen when sampling. While sampling, two minutes per sample was spent on vigorously rubbing the substrate within the Hess Sampler to obtain maximum collection. Once sampling was completed the sampler was lifted from the water and the mesh screen was flushed into the prelabeled cup before placing the lid on top. All sampling of invertebrates was aligned with past data as the same stations were used at approximately the same time of year. Following each sample, no preservative was needed as analyzing of the samples was completed that afternoon. Instead the animals were kept in a cooler on ice to keep alive. The samples will then be sealed in a sterile labelled bottle and placed in a cooler to maintain a cool temperature and for safe transportation. The samples were then brought back to the Vancouver Island University lab and analyzed.

3.5.2 VIU Laboratory Analyses

The analysis of macroinvertebrate samples was conducted at the Nanaimo Vancouver Island University campus on November 1, 2017 directly following the morning sampling session. The triplicate samples per station were combined and then divided into four trays and distilled water was added. Visual examinations, division of animals, counts of total number of organisms and number of taxa were completed and documented. Counts of animals were doubled checked and dissecting microscopes and scientific invertebrate ID guides were used for accuracy. Predominant species was also recorded. All information was documented on field data recording forms and kept for further analyzation. Several calculations were completed including the Shannon-Weiner Index to measure water health qualities and give the site an overall rating. All laboratory and identification processes followed the Pacific Streamkeepers guide (Taccogna & Munro, 1995).

3.5.3 Quality Assurance/Quality Control

During the sampling of the macroinvertebrates, proper quality assurance and quality control measures outlined in the Freshwater Biological Sampling Manual was followed to ensure the best samples and eliminate any potential issues (Taccogna & Munro, 1995). For quality assurance, the following measures were taken: preserving samples after collection, using clean specific plastic bottles, properly labelling containers (before arrival to site), and ensuring adequate storage and transportation. For quality control measures, three replicates were collected at each site. Replicate samples are used to detect "heterogeneity within the environment, allow the precision of the measurement process to be estimated, and provide a check on the reproductivity of the sampling" (Web, 2015). For the highest level of accuracy and precision all sample counts, identification of stream invertebrates, and calculations were double checked by multiple team members.

3.5.4 Data Analyses

The processing of samples began with the sorting of macroinvertebrates into taxonomic groups. The animals were placed into petri dishes, and identified using a dissecting microscope and identification keys. These groups were then sorted by order / family and then placed into one of three pollutant tolerant categories. These categories are listed as 1, 2, and 3 with 1 being the most pollutant intolerant (Demers, 2016). All data was recorded onto field data sheets by individual sites and calculated to determining "predominant taxon, abundance & density, water assessment, diversity assessment, and the overall diversity of the stream" (Demers, 2016). The Shannon-Wiener Index calculation was made to determine the overall diversity of stream invertebrate taxa. All data sheet analysis and methods followed the Pacific Stream keeper's procedures to ensure the highest level of quality (Demers, 2016). All data recording forms are included in the appendix for review.

4.0 Results and Discussion

4.1 General Field Conditions

(Teagan Wardrop)

During the initial site assessment on October 18th, 2017 at 09:30 the five monitoring sites along the C.W. Young Channel had a mean air temperature of 8°C and it had been raining for several hours (The Weather Network, 2017). Two weeks later during the first sampling session on November 1st, at 10:30 the ambient temperature was 7°C and the weather was sunny with blue skies. During the second sampling session which took place on November 22nd at 11:00, the rain returned heavily along with fog; however, the temperature rose slightly to an average of 10°C. During the three weeks in between sampling sessions, 180.4 mm of precipitation accumulated in the Parksville area; which resulted in increased turbidity from the first session to the second at all five sites along the C.W. Young Channel (The Weather Network, 2017). The discharge was also anticipated to increase at all sites as a result of the heavy rainfall; however, the flow into the C.W. Young Channel from the Englishman River is measured by a valve and pipe which limits the fluctuation in discharge rates (Demers, 2016; VIU, 2016).

4.1.1 Hydrology

During the first sampling session, hydrology measurements were taken at all five sites along the C.W. Young Channel [Table 3]. These hydrology measurements include: wetted widths (m), bankfull widths (m), maximum depths (cm), average depths (cm), and average velocity (m/s); discharge (m^3/s) was later calculated as well. Due to safety concerns during the second sampling session, hydrology measurements were only taken at sites 1, 2, and 4 [Table 4].

At almost all of the comparative sites it appears that the wetted and bankfull widths actually decreased by the second sampling session. This is likely because the maximum depths at each site were increasing, creating a challenge to measure the widths in the same spots as had previously been measured, thus creating the illusion that the sites were shrinking, when in reality they were expanding due to the added rainfall over the three week period, or remaining constant. As formerly mentioned, wetted widths and discharge rates did not increase as expected due to restricted outflow (Demers, 2016). However, the unhindered flow in the main stem of the

Englishman River at site 5 increased to such a large degree that hydrology measurements would have been impossible to collect safely.

Table 2. Hydrology measurements from 5 sites on the C.W. Young Channel taken on November 1st, 2017.

Stations	Wetted Widths (m)	Bankfull Widths (m)	Maximum Depths (cm)	Average Depths (cm)	Average Velocity (m/s)	Discharge (m^3/s)
1	5.3	7.5	93	73.1	0.32	1.054
2	3.2	7	48	39.5	0.74	0.795
3	7.75	10.4	85	53.7	0.14	0.495
4	11.5	14.2	91	74.7	0.29	2.118
5	100.4	104.9	40	31.6	0.39	10.52

Table 3. Hydrology measurements from 3 sites on the C.W. Young Channel taken on November 22nd, 2017.

Stations	Wetted Widths (m)	Bankfull Widths (m)	Maximum Depths (cm)	Average Depths (cm)	Average Velocity (m/s)	Discharge (m^3/s)
1	4.3	6.8	110+	77.2	0.34	0.959
2	2.84	7.25	56	36.7	0.72	0.638
4	10.2	11.5	100+	74.4	0.56	3.612

While the first and second sites remained at an almost consistent average velocity and discharge over the course of the two sampling sessions, the velocity and discharge rates at the fourth site nearly doubled [Figure 5]. It is important to note that five velocity trials were performed at each of the five stations during the first session, and at sites 1 and 2 during the second session; but only one trial could be taken at the fourth site, since the swift water carried the orange away. Without the ability to compare five trials, the final average velocity and resulting discharge outcomes at site four were likely affected.

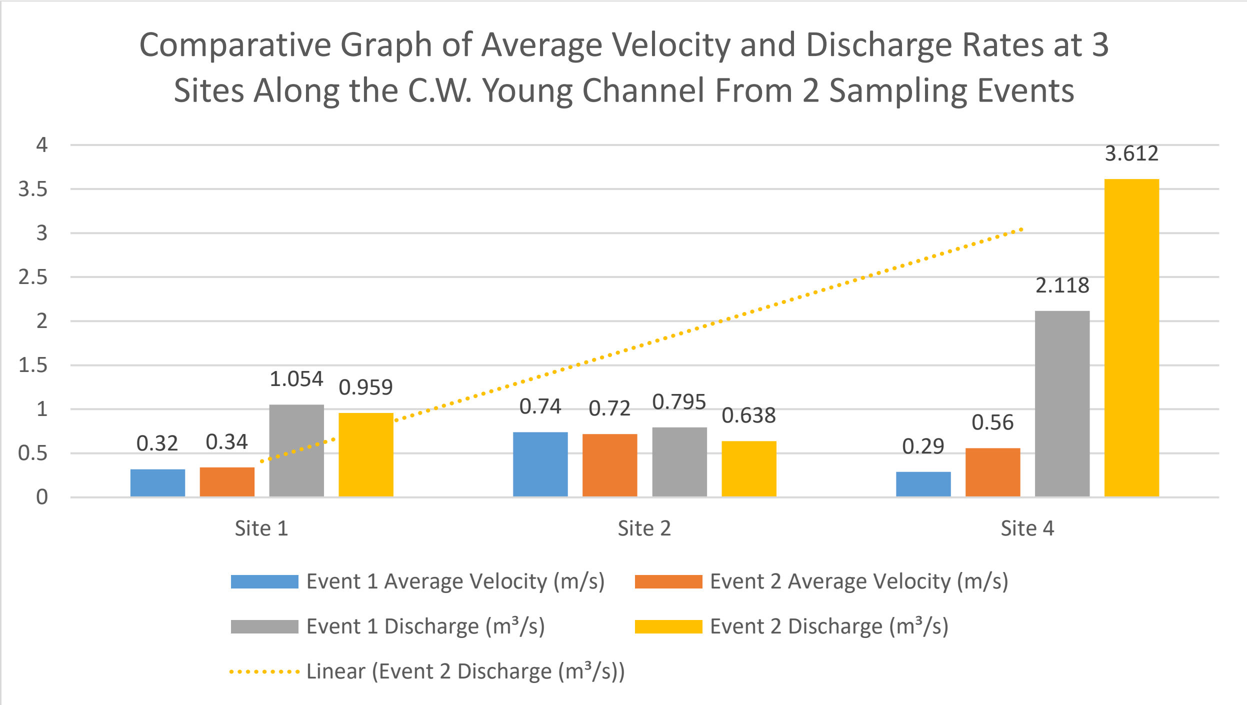

Figure 4. Graph of the comparative average velocity and discharge rates at 3 sites during 2 sampling events.

4.2 Water Quality

4.2.1 Field Measurements

(Teagan Wardrop)

At all five sites, temperature (˚C) and dissolved oxygen (mg/L and %) measurements were taken in the field using a YSI Incorporated 556 Multi Probe System (MPS) electronic handheld probe on November 1st [Table 4] and November 22nd [Table 5].

Table 4. Temperature and dissolved oxygen field measurements taken at 5 sites along the C.W. Young Channel on November 1st, 2017.

Station	Temperature (˚C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)
1	6.0	13.04	104.5
2	6.5	12.85	104.6
3	7.1	12.75	105.4
4	7.7	12.31	100.8
5	6.8	12.91	105.8

Table 5. Temperature and dissolved oxygen field measurements taken at 5 sites along the C.W. Young Channel on November 22nd, 2017.

Station	Temperature (˚C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)
1	6.8	13.24	107.3
2	6.9	12.01	98.3
3	7.8	11.85	99
4	7.5	11.47	95.7
5	7.0	12.90	106.2

Aside from a slight 2˚C drop at site 4, all of the sites increased in temperature by at least 2˚C and up to 8˚C over the course of the three weeks in between sampling sessions. As was to be expected, along with the increase in temperature, the dissolved oxygen level at four of the five sites decreased correspondingly [Figure 6]. Interestingly, despite an 8˚C increase at site 1, the dissolved oxygen level actual increased by 0.20 mg/L; also, regardless of the 2˚C drop at site 4, the dissolved oxygen level still decreased by a significant 0.84 mg/L when it likely should have increased instead. These anomalies could be due to a number of factors, including: errors from the electronic probe, inaccurately recreating the first sampling location, or an uncontrollable factor like Biological Oxygen Demand (BOD) from enhanced or reduced ecosystem respiration (Demers, 2016).

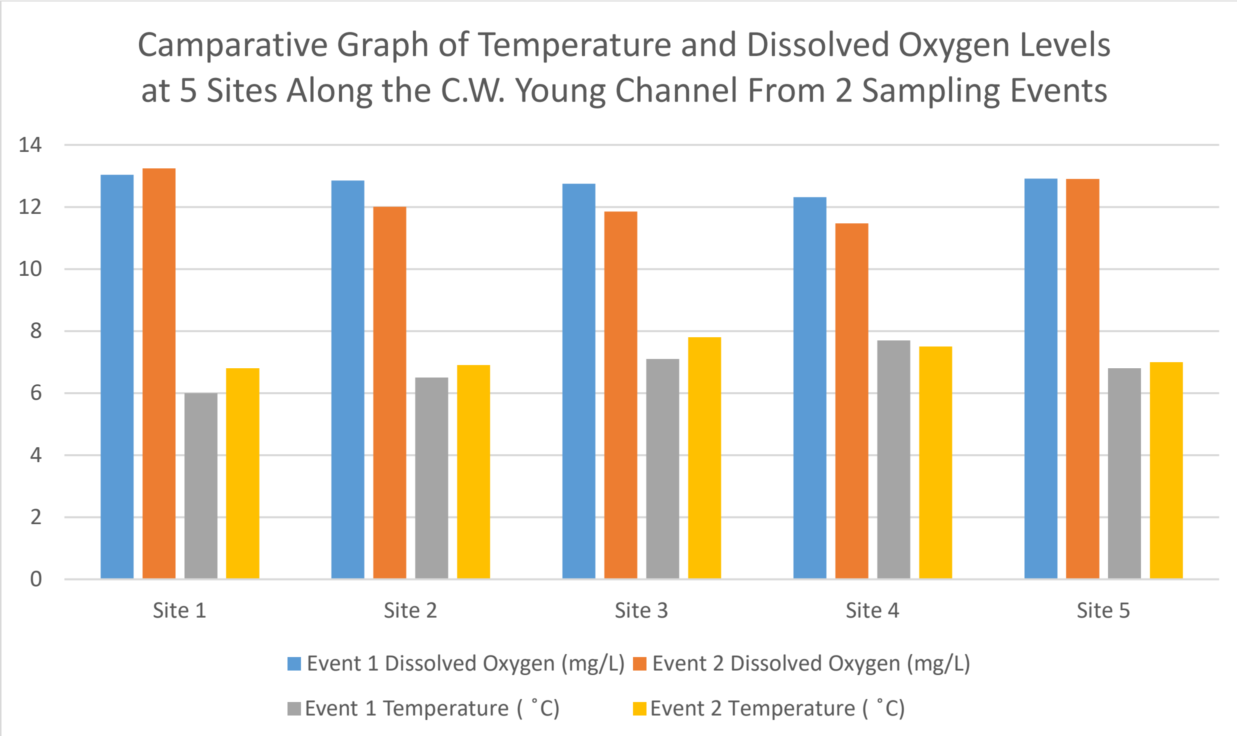

Figure 5. Graph of temperature and dissolved oxygen levels at 5 sites from 2 sampling events.

According to the Resources Inventory Standards Committee (1998), surface water temperatures can range from 0˚C to 40˚C and aquatic life prefer the temperature to remain within +/- 1˚C of the natural conditions. During the two sampling events, all five sites ranged from 6.0˚C to 7.8˚C, which is well within the guideline range for aquatic life. On the other hand, dissolved oxygen is often about 10 mg/L in surface waters and invertebrates require at least 4 mg/L to survive, but beyond 8 mg/L is also fine. Meanwhile, fish require a 30-day mean of 11 mg/L of dissolved oxygen (DO) which indicates that, despite minor seasonal fluctuations, the C.W. Young Channel is excellent fish and invertebrate habitat with a 22-day mean of 7.0˚ and 12.53 mg/L DO.

4.2.2 VIU Laboratory Analyses

(Teagan Wardrop)

One VIU water sample was collected from each site during both of the sampling events. A replicate sample was also filled at site 3 during both events, and trip blanks were filled prior to sampling and brought along to each site. Once samples had been collected on the mornings of November 1st and 22nd, they were kept cold in a cooler with ice packs for less than five hours until they could be returned to the VIU water quality analysis laboratory in building 370, room 218 of the Vancouver Island University Nanaimo campus. Each of the five site samples and the replicates were tested for pH levels, conductivity (µS/cm), turbidity (NTU), alkalinity (mg/L), hardness (mg/L ppt $CaCO_3$), nitrate (mg/L NO_3^-), and phosphate (mg/L PO_4^{-3}). The trip blanks were only tested for nitrate and phosphate levels. All VIU water quality tests were performed at 14:00 on November 1st [Table 7] and November 22nd [Table 8].

Table 6. VIU water quality results for 7 parameters tested on November 1st, 2017.

Parameters	Site 1	Site 2	Site 3	Site 4	Site 5	Replicate (Site 3)	Trip Blank	Water Quality Guidelines
pH	8.0	7.6	6.9	6.8	6.8	7.0	N/A	6.5 - 9.0
Conductivity (µS/cm)	77	73	72	80	79	74	N/A	= 100
Turbidity (NTU)	0.56	1.12	0.49	1.45	0.28	0.84	N/A	<9.4
Alkalinity (mg/L)	87.6	78.8	73.6	90	72	75.2	N/A	>20
Hardness (mg/L; ppt $CaCO_3$)	15	16	15	17	15	15	N/A	<60 = soft water
Nitrate (mg/L NO_3^-)	0.02	0.02	0.02	0.09	0.02	0.01	0.02	<200, avg = 40
Phosphate (mg/L PO_4^{-3})	0.05	0.28	0.09	0.10	0.05	0.05	0.57	5-15 µg/L

Table 7. VIU water quality results for 7 parameters tested on November 22nd, 2017.

Parameters	Site 1	Site 2	Site 3	Site 4	Site 5	Replicate	Trip Blank	Water Quality Guidelines
pH	7.8	7.5	7.0	6.9	7.0	6.7	N/A	6.5 – 9.0
Conductivity (µS/cm)	24	28	34	23	34	48	N/A	= 100
Turbidity (NTU)	12.5	8.10	9.71	7.35	14.5	8.32	N/A	<10.2
Alkalinity (mg/L)	51.6	49.6	50.8	52	68	51.2	N/A	>20
Hardness (mg/L; ppt $CaCO_3$)	15	16	17	28	16	18	N/A	<60 = soft water
Nitrate (mg/L NO_3^-)	0.09	0.08	0.09	0.16	0.03	0.06	0.03	<200, avg = 40
Phosphate (mg/L PO_4^{-3})	0.55	0.17	0.26	0.19	0.29	0.41	0.29	5-15 µg/L

4.2.2.1 pH & Alkalinity

Coastal streams often have a pH between 5.5 and 6.5; pH levels above 7 are considered basic, while levels below 7 are considered acidic (RISC, 1998). Sites 1 through 5 ranged between pH levels of 6.7 to 8.0 over two sampling events which lies within the aquatic life guidelines of 6.5 and 9.0. These steady pH ranges are likely a result of excellent alkalinity levels above 20 mg/L, indicating that the channel has a low sensitivity to acidification. High alkalinity levels may reflect that the channel receives deposits of bases like calcium and magnesium from mineral weathering and runoff (VIU, 2014). The ALS results confirm that calcium levels are above the guideline at sites 1, 2, and 4. Although the alkalinity levels at all 5 sites decreased [Figure 7] by a minimum of 4 mg/L and up to as much as 38 mg/L at site 4, they all still remained above 20 mg/L. It is possible that this general decrease along the channel is a result of increased acidic precipitation between sampling events which has been known to impede alkalinity (RISC, 1998).

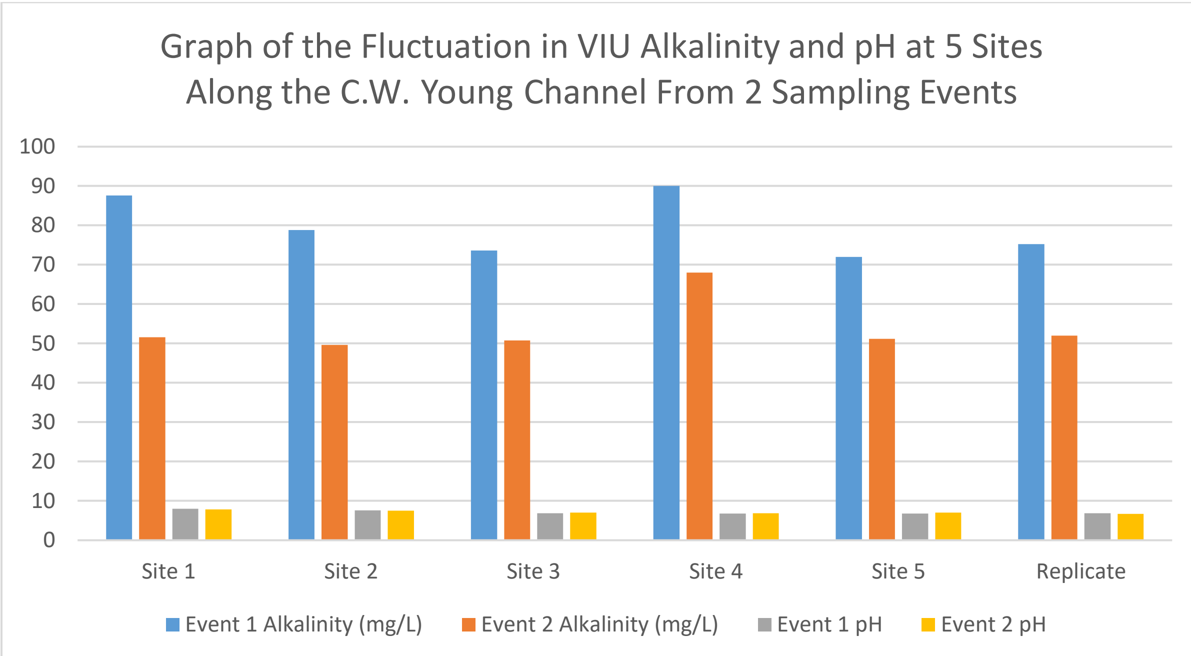

Figure 6. Graph of the VIU alkalinity and pH levels at the 5 sites from 2 sampling events.

4.2.2.2 Turbidity & Conductivity

During the first sampling event at site 1 the bottom of the stream was visible, despite a maximum depth measurement of 93 cm, which allowed for an estimation of the substrate content to be made. Three weeks later during the second sampling session, the maximum depth at site 1 had risen at least 17 cm and the substrate was not visible through the density of suspended particles in the water column. During the first sampling session, all five turbidity measurements remained below 2 nephelometric turbidity units (NTUs) [Figure 8]. However, three weeks later, the turbidity levels at each site skyrocketed to between 7 and 13 NTUs; likely as a result of rainfall sweeping sediment into the waterway and reducing the clarity. Clay bank erosion and urban-runoff in the main stem of the Englishman River may also be contributing factors (Barlak et al., 2010).

The guideline for turbidity and aquatic life suggests that it should not rise more than 5 NTUs above the background level. Considering that over the previous 8 years, the average background level in the C.W. Young Channel has been 0.2 – 4.4 NTUs in late October and 1.1 – 5.2 NTUs during mid-November, then the suggested guideline would be less than 9.4 NTUs for the first sampling event and less than 10.2 NTUs for the second sampling event (E Demers, pers. comm. Dec 13, 2017; RISC, 1998). Based on these parameters, the turbidity results from the first sampling session are well within the reasonable guidelines for aquatic life. However, sites 1 and 5 exceed the guideline for the second sampling session (likely because these sites are most closely connected to the main stem where turbidity levels are higher). If increased turbidity persists, it can negatively affect aquatic plants and fish.

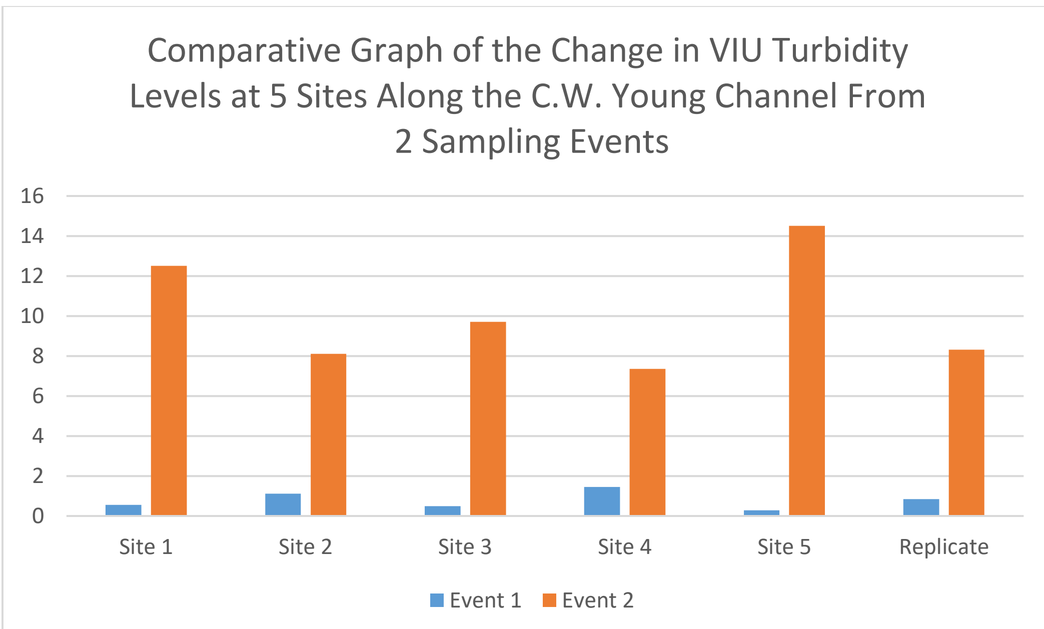

Figure 7. Comparative graph of the change in VIU turbidity levels at 5 sites between 2 sampling events.

In contrast, the conductivity at all five sites decreased by at least 26 µS/cm and as much as 57 µS/cm between the two sampling events. This was likely caused by the added rainfall which diluted the conductivity concentration of the channel (Demers, 2016). Conductivity is also reduced by higher discharge rates which may indicate why site 4 has the greatest drop in conductivity, which coincides with site 4's increase in velocity and discharge between the two sampling events. Although there is no specific guideline for ideal conductivity for aquatic life, often coastal BC streams have a conductivity of approximately 100 µS/cm (RISC, 1998).

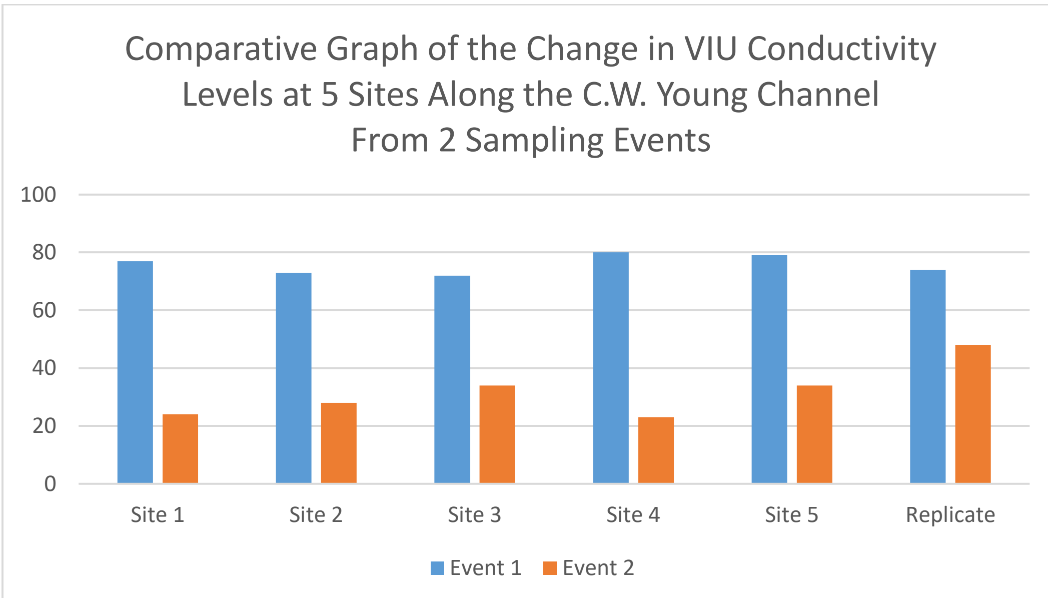

Figure 8. Comparative graph of the change in VIU conductivity levels at 5 sites between 2 sampling events.

4.2.2.3 Hardness

Hardness values below 60 mg/L indicate soft water (RISC, 1998). Each hardness level recorded at all five sites falls below this value, indicating that the water in the C.W. Young Channel is soft, which is acceptable for aquatic life. However, only hard water (>120 mg/L) can diminish the toxicity of metals in the water (RISC, 1998). The hardness values did appear to increase slightly from the second sampling event. Mid-November fluctuations of hardness, conductivity, and alkalinity are common, as can be seen in the results of this study, since these are all measurements of dissolved ions (Demers, 2016). Interestingly, while 9 of the 10 hardness measurements fall between 15 and 18 mg/L, the measurement taken from site 4 on November

22nd was nearly double at 28 mg/L. A similar study conducted by VIU Environmental Monitoring students in 2016 found that hardness levels were also higher at site 4; however, the difference is not high enough to be of concern, in fact harder water would reduce the likelihood of acidification (VIU, 2016).

4.2.2.4 Nitrate & Phosphate

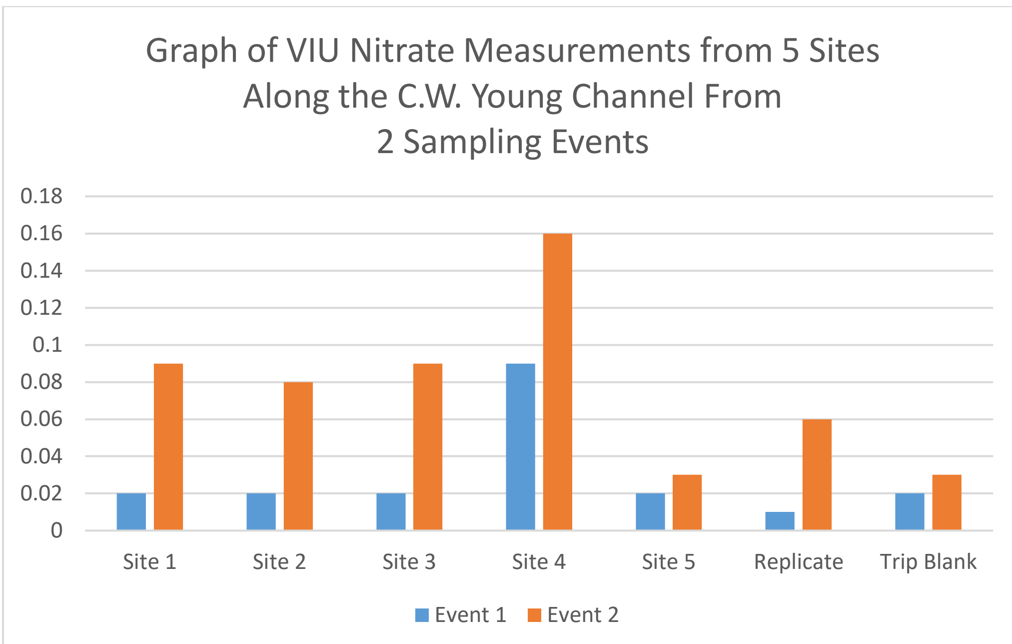

Figure 9. Graph of VIU nitrate measurements at 5 sites from 2 sampling events.

The nitrate (mg/L NO_3-) measurements taken during the first sampling session average around 0.02 mg/L except for site 4 which reaches 0.09 mg/L [Figure 10]. Nitrate measurements from the second sampling session are more scattered between values of 0.03 mg/L up to 0.16 mg/L. It appears that between the 2 sampling events, site 4 records the highest nitrate levels on both accounts and last year, site 4 was also found to have the highest nitrate concentration (VIU, 2016). According to Demers (2016) it is normal for nitrate levels to increase by mid-November.

BC Water Quality Guidelines convey that surface waters which are free from anthropogenic inputs remain below 0.3 mg/L (RISC, 1998). This shows that the C.W. Young

Channel is likely not being affected by anthropogenic inputs such as effluent, at any of the five sites. Aquatic life can handle up to a maximum of 200 mg/L of nitrate and an average of 40 mg/L. These results indicate that the channel is well within a normal, healthy range for nitrate concentrations, and is even within the nitrate guidelines for drinking water (<10 mg/L).

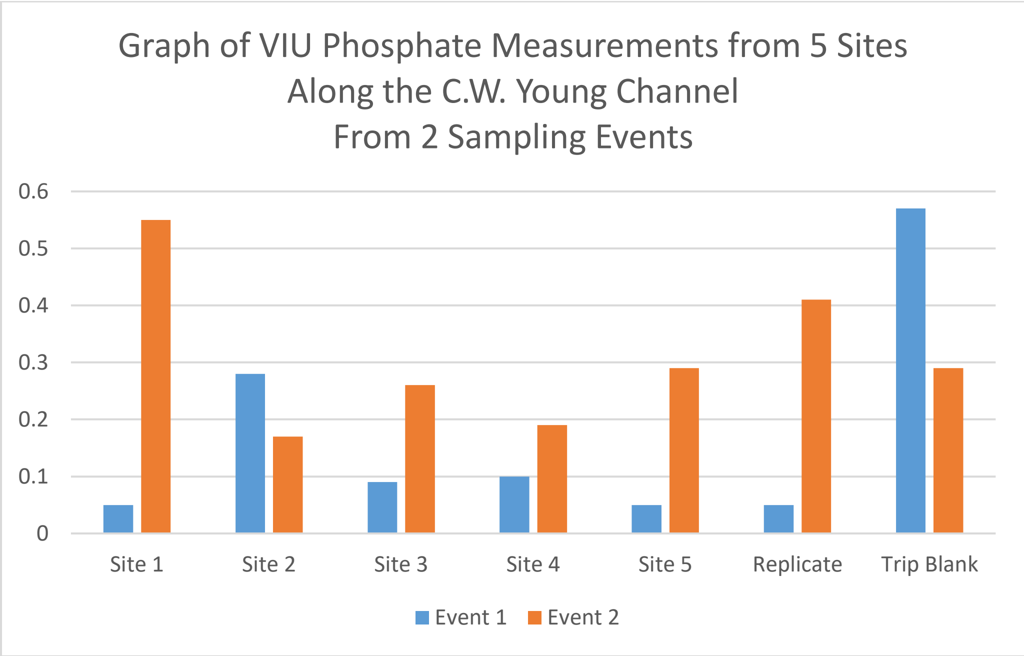

Figure 10. Graph of VIU phosphate measurements at 5 sites from 2 sampling events.

The phosphate (mg/L PO4-³) measurements from the five sites and the replicate during the first sampling session range from 0.05 mg/L up to 0.28 mg/L. Interestingly, the trip blank had the highest phosphate reading at 0.57 mg/L out of all of the tests done from both sessions. The source of the trip blanks were unknown, meaning that the increased phosphate results could be attributed to contamination. The phosphate measurements from the five sites and the replicate during the second sampling session have a higher range of 0.17 mg/L to 0.55 mg/L. The second trip blank had a phosphate value of 0.29 mg/L.

Although the VIU lab tested for phosphate, the Water Quality Guidelines discuss suitable levels for total phosphorous. According to the guidelines, phosphorous levels above 0.01 mg/L suggest the water has been affected by anthropogenic inputs (RISC, 1998). Ideally, total phosphorous levels should be between 0.005 mg/L and 0.015 mg/L for aquatic life. Since all of the VIU water quality tests recorded phosphate levels above 0.25 mg/L, it appears that the C.W. Young Channel would be considered eutrophic, as it is rich in nutrients. Some of these excess nutrients may be accredited to the decomposing remains of spawning salmon (Demers, 2016). However, it is important to note that the ALS results for orthophosphate are much lower (below 0.003 mg/L) and indicate that the stream is not eutrophic. It's possible that this contrast in results is due to errors in the VIU water quality testing methods, or contamination in the VIU lab, since the accuracy standards are not as high as they are in the ALS laboratory. In this instance, the ALS results should be interpreted as the true concentrations of phosphate.

4.2.3 ALS Laboratory Analyses

(Kalia Van Osch)

Water samples were collected at stations 1, 2 and 4 on both November 1st and 22nd and shipped to the ALS Laboratory. Results were submitted back to VIU and summarized in comparison with the BC Water Quality Guidelines in Table 8. Testing was completed for conductivity, hardness, pH, anions, nutrients and total metals present for quality assurance purposes. By comparing the ALS results to the BC Water Quality Guidelines for aquatic life and to the VIU laboratory results, we can analyze whether the levels are within the guidelines and identify any possible sources of error or deviation in laboratory procedures.

Hardness and pH ALS values were comparable to VIU laboratory results, though they were slightly higher on average. Values for pH at VIU varied between 6.8-7.8 and ALS pH ranged from 7.2-7.4. Conductivity was higher than the VIU results on sample event 1 but parallel for sample event 2 results and consistently increased in value downstream on both occasions. Hardness and conductivity decreased on the second sampling event, which relates to the larger volume of water present in the water shed, diluting the ions.

All anion and nutrient values were below the guidelines except November 1st, station 2 and November 22nd, station 2 and 4 total phosphate values. The guidelines for aquatic life limit total phosphate to 0.005-0.015 mg/L at spring overturn, which shows that these samples may have exceeded the maximum phosphate concentrations at 3 stations. However, guidelines list all of the phosphate values within the mesotrophic category (0.10-0.025 mg/L), meaning the concentrations have not caused the water to reach a eutrophic level. Minor discrepancies were present between the VIU and ALS nitrate values, but this could be attributed to an increased accuracy in equipment used at the ALS laboratory.

All metals were identified to be below the BC Water Quality Guidelines except aluminum. The aluminum concentration was slightly above the guidelines on November 1, 2017, at an average of 0.24 mg/L and increased to 0.64 mg/L on November 22, 2017. This is possibly due to an increased amount of rainfall and heightened water flow causing an excess of runoff and input of contaminants. Aluminum contamination and presence comes from anthropogenic sources including construction, industrial areas and sewage in the water shed. It is likely the surrounding human developments are adding aluminum to the channel and river that fluctuates input and concentrations when the water flow and rainfall increases. It is important to note that the maximum concentration for a variety of metals tested (i.e. cadmium, chromium and silver) was below the minimum detection limit of the laboratories testing. These metals may require further testing to determine presence or absence in minute amounts.

Table 8. ALS laboratory results for water samples collected at 3 stations on the C. W. Young Channel on 1 November 2017 and 22 November 2017. No samples were collected at Stations 3 and 5 on either sampling event. All values are recorded in mg/L unless stated otherwise. Additional notes are provided below the table.

	BC Water Quality Guidelines[a]		**1 November 2017**			**22 November 2017**		
Parameter	**BC Max mg/L**	**BC 30-day Mean mg/L**	**1**	**2**	**4**	**1**	**2**	**4**
Physical Tests								
Conductivity (uS/cm)			48.6	50.0	66.9	29.3	33.7	54.8
Hardness (as CaCO3)			19.5	20.2	29.5	13.7	14.6	23.8
pH (pH Units)	6.5-9.0		7.49	7.40	7.47	7.29	7.22	7.29
Anions and Nutrients								
Ammonia, Total (as N)	Variable[b]		0.0268	0.0285	0.0547	<0.0050	0.0057	0.0110
Nitrate (as N)	200		0.0671	0.0520	0.150	0.0568	0.0628	0.349
Nitrite (as N)	0.06[c]	0.02	0.0018	0.0018	0.0046	<0.0010	<0.0010	<0.0010
Total Nitrogen			0.265	0.236	0.452	0.162	0.186	0.617
Orthophosphate-Dissolved (as P)			0.0083	0.0044	0.0071	0.0021	0.0024	0.0038
Phosphorus (P)-Total	0.005-0.015[d]		0.0137	0.0118	0.0163	0.0154	0.0111	0.0168
N:P (N/A)			19.3	20.0	27.7	10.5	16.8	36.7
Total Metals								
Aluminum (Al)	0.10[e]	0.05	0.29	0.21	0.21	0.86	0.49	0.56
Antimony (Sb)[n]	0.009		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic (As)[n]	0.005		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium (Ba)	5.0	1.0	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Beryllium (Be)[n]	0.00013		<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)[n]	0.00002[f]		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (Ca)			6.20	6.50	8.29	4.21	4.59	6.52
Chromium (Cr)[n]	0.001[g]		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt (Co)[n]	0.11	0.004	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu)[n]	0.002[h]	0.002	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron (Fe)	1.0		0.256	0.302	0.336	0.893	0.513	0.556
Lead (Pb)[n]	0.012[i]	0.004	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium (Li)	0.75	0.096	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium (Mg)			0.98	0.96	2.12	0.78	0.76	1.81
Manganese (Mn)	Variable[j]	0.70	<0.0050	0.0108	0.0081	0.0150	0.0147	0.0122
Molybdenum (Mo)	2.0	1.0	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel (Ni)[n]	0.025[k]		<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)[n]		0.002	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon (Si)			3.51	3.48	4.50	3.30	3.14	4.59
Silver (Ag)[n]	0.0001[l]	0.00005	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium (Na)			2.7	2.9	3.4	<2.0	<2.0	2.7
Strontium (Sr)			0.0262	0.0270	0.0320	0.0147	0.0174	0.0257
Thallium (Tl)[n]	0.008		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin (Sn)[n]	0.000022		<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium (Ti)			0.015	<0.010	0.012	0.047	0.026	0.029
Vanadium (V)	0.05		<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc (Zn)	0.033[m]	0.0075	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

Table 8. (Continued)

NOTES:

"<" means the value is below the minimum detection limit

All results are shown in mg/L except for pH and conductivity

[a] BC Water Quality Guidelines (WQG) summarized from:
https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-guidelines/approved-water-quality-guidelines
https://www.for.gov.bc.ca/hts/risc/pubs/aquatic/interp/intrptoc.htm

[b] Ammonia maximum concentration is dependent on the pH and temperature values of the tested water.

[c] Nitrite guideline is applicable when the tested water has a chloride concentration < 2 mg/L.

[d] Total Phosphorus is measured as Oligotrophic (<0.010), Mesotrophic (0.010-0.025), or Eutrophic (≥ 0.025). The guidelines value of 0.005-0.015 mg/L is valid at spring overturn.

[e] Aluminum guideline value of 0.10 mg/L is applicable when the pH is ≥ 6.5.

[f] Cadmium guideline is 0.00002 when hardness is 30 mg/L and is calculated as 10 ^ [0.86 x LOG(hardness) -3.2) / 1000.

[g] Chromium guideline is for the more toxic version Chromium VI.

[h] Copper guideline is 0.002 mg/L when hardness is 50 mg/L and is calculated as (0.094 x (hardness) + 2] / 100.

[i] Lead guideline is calculated as 0.2108 x (hardness) ^ 1.293) / 100

[j] Manganese guidelines are variable and are calculated for the sample are using 0.01102 x (hardness) + 0.5.

[k] Nickel guideline is 0.025 mg/L when hardness is ≤60 mg/L.

[l] Silver guideline 0.0001 mg/L when hardness ≤100 mg/L.

[m] Zinc guideline is 0.033 mg/L when hardness ≤ 90 mg/L

[n] The minimum detection limit was greater than the applicable guidelines for these tests.

4.2.4 Quality Assurance/Quality Control

(Kalia Van Osch)

Replicate samples at station 3 and a trip blank were used to test for quality assurance and control of field and laboratory procedures. Both replicate samples showed no significant difference in levels measured compared to the other water samples tested. The nitrate amount in the trip blank was low and similar to levels sampled at all stations on November 1, 2017 and slightly lower than amounts sampled at each station on November 22, 2017 (Table 9). Orthophosphate levels in the trip blank from November 1, 2017 were significantly higher than at the sample stations. However, orthophosphate levels on November 22, 2017 in the trip blank were slightly lower and consistent with those found in field samples which were higher on the second sampling event. This suggests that the trip blank was successful in quality control for nitrate but inconsistent with the levels of orthophosphate which may be a sign of contamination.

Table 9. Trip Blank levels of Nitrate and Orthophosphate measured in the VIU laboratory

Trip Blank	Nitrate (mg/L)	Orthophosphate – Dissolved (as P) (mg/L)
1 November 2017	0.02	0.57
22 November 2017	0.05	0.29

The ALS laboratory is a professional facility with standardized procedures and trained personnel. Quality control and assurance methods are applied throughout the laboratory process by maintaining a sterile environment and following properly outlined procedures. Testing methodology is provided in the ALS report received, describing procedures used for each analysis. Replicate analysis and a quality control lot were completed on the Englishman River water samples taken on 1 November 2017 and all samples met the ALS Data Quality Objectives. Hold time evaluation was exceeded for sample event 1 analysis of pH, Nitrate, Nitrite and Orthophosphate prior and for pH from sample event 2. This hold time was surpassed prior to the samples arriving at the laboratory. The report recommended that pH be field tested for more reliable measurements, but all other samples were deemed acceptable despite the hold time exceedance.

4.3 Microbiology

(Kalia Van Osch)

A water sample was collected at all five stations, including a replicate at station 3 to test for coliform presence on November 1, 2017 during event 1. Total coliforms were overall lower than in previous sampling sessions and remained relatively consistent between all stations. Non-fecal and fecal coliforms were present in each water sample except at station 2 (Table 10) and the replicate sample from station 3 showed the highest amount of *E. coli*. The percentage of *E. coli* was below 7% at all stations and gradually increased from 2 to 9 colony forming units (CFU) per 100-ml from station 3 through to station 5.

Table 10. Coliform counts collected at 5 stations on the C.W. Young Channel and Englishman River. Samples were taken on 1 November 2017 and no samples were collected on 22 November 2017. All results are recorded as number of CFU per 100-ml.

Station	Total Coliform	*E. coli*	% *E. coli*
1	95	1	1.1
2	107	0	0
3	93	2	2.2
4	148	4	2.7
5	195	6	3.1
3 Replicate	146	9	6.2

Figure 11 shows a comparison of fecal coliform counts at each station in 2014, 2016 and 2017. The coliform data for 2014 and 2017 was similar with percentage of *E. coli* below 10% at all stations. 2016 showed a vastly higher amount of *E. coli* present in the water than other years with 20-47%. This suggests that a dramatic decrease in *E. coli* presence has occurred between the testing periods in 2016 and 2017 which could be associated with changes in rainfall events and inputs of waste or contaminated substances in the area. None of the stations had water quality levels that were suitable for human drinking water consumption which is 0 CFU/100mL (RISC, 1998). Since the Englishman River is a source of drinking water for residence of the Parksville area, it is important that proper water treatment is maintained to remove all coliforms before consumption. The surrounding area is affected by anthropogenic usage including agriculture, recreation and industrial development as well as wildlife. All sampling stations are easily accessible by trails in the park and human use may contribute to the presence of coliforms in the water shed.

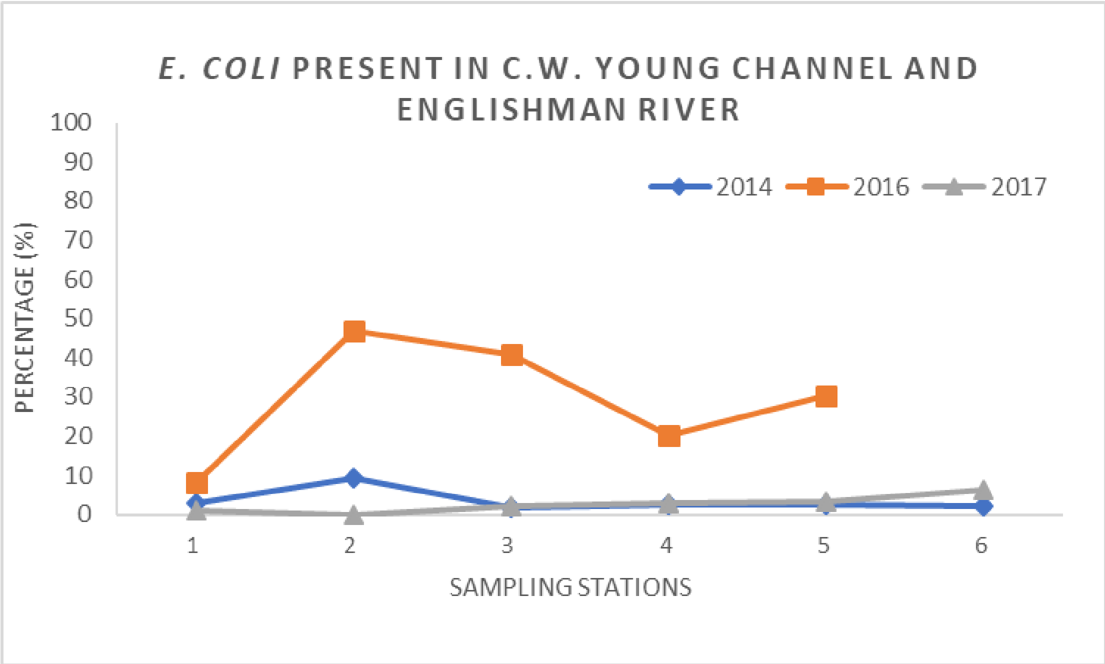

Figure 11. The percentage of total coliforms that were *E. coli* found in water samples collected on the C.W. Young Channel and Englishman River in 2014, 2016 and 2017. Samples 1-5 taken at pre-determined stations and sample 6 was a replicate sample.

4.4 Stream Invertebrate Communities

(Avryl Brophy)

4.4.1 Abundance & Density

Collectively a total of 175 invertebrates were collected within the three-station resulting in a total density of 648.17/m2. Station 1 was the most abundant in numbers and taxa with a total of ten families and thirty-nine taxa. A total of 113 invertebrates were found at station 1 and a density of 418.5/m2 was recorded. Station 3 was not as productive and only had a total of six families and eight taxa. There was a total of 19 invertebrates collected at station 3 and a density of 70.37/m2 was recorded. Station 4 had a total of seven families and ten taxa. There was a total of 43 invertebrates collected at station 4 and a density of 159.3/m2 was recorded. Overall numbers of invertebrates collected within the twelve samples among the three sites was good.

Abundancy and density was variable per station but showed some consistency with a minimum of six families, eight taxa, and 19 individuals collected per station. No samples resulted in zero animals.

4.4.2 Diversity and Site Rating

There was a total of twelve families counted and fifty-seven taxa collected during sampling. Category 1, 2, & 3 were found at all three stations sampled. The predominant taxon found at station 1 was aquatic worms. The average site rating for station 1 was 3.35 which is considered between average and good. The predominant taxon for station 3 was stonefly nymphs. The average site rating for station 3 was 2.75 which is between marginal and average. The predominant taxon for this station 4 was amphipods. The average site rating for station 4 was 3.25 which is between acceptable and good.

The average site rating for sites 1, 3, and 4 was calculated at 3.08, which is stated as acceptable to good on the assessment rating rubric. The Shannon-Wiener Index was averaged at 0.848 from the sites sampled, showing a positive diversity index. The overall sampling of benthic macroinvertebrates showed an average rating consistent with past years' data. The channel water quality indicated by stream invertebrates is between acceptable and good according to the site assessment rating and Shannon-Weiner Index calculations. All three categories were found at each station showing that pollution intolerant invertebrates can and are living within the C. W. channel that is connected to the Englishman River. Below I have included a graph showing the presence and abundance of invertebrates in category 1,2, & 3 at each site.

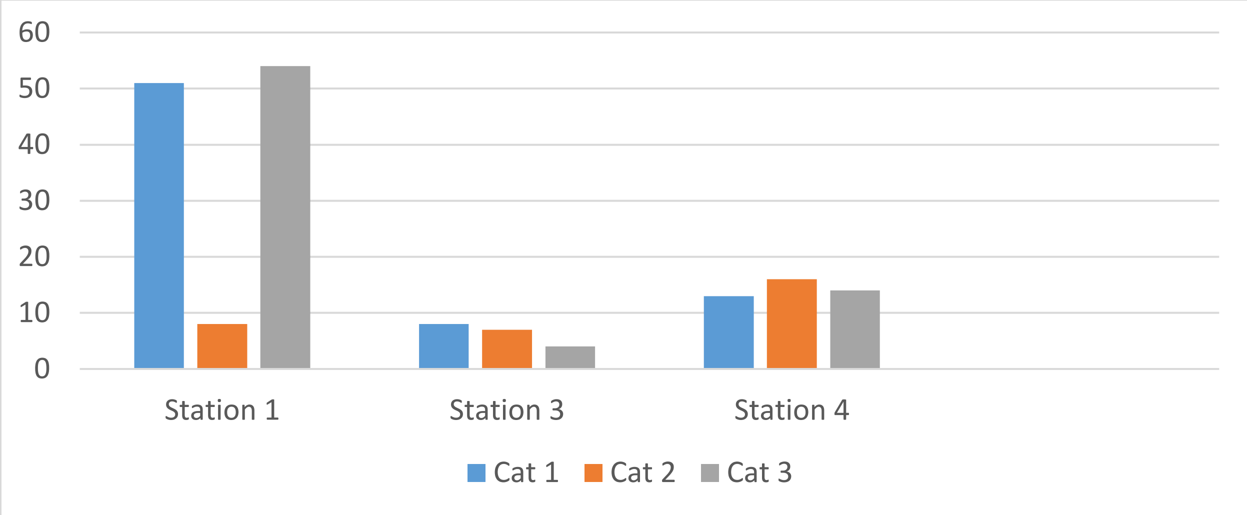

Figure 12. Shannon-Weiner Diversity Index 2017C.W. Channel Englishman River
Table 1, 2, & 3 is presenting the results of our findings per station. The calculations per station are also included in the appendix for reference.

Table 11. Station 1 Assessment & Rating

ASSESSMENT	RATING
Pollution Tolerance Index	4
EPT Index	4
EPT to total ratio	2
Predominant taxa ratio	3
AVERAGE RATING	**3.25**
Total number of organisms collected	113
Total number of taxa	39
Predominant species	**Aquatic worm (*Oligochaete*)**

Table 12. Station 3 Assessment & Rating

ASSESSMENT	RATING
Pollution Tolerance Index	3
EPT Index	2
EPT to total ratio	2
Predominant taxa ratio	4
AVERAGE RATING	**2.75**
Total number of organisms collected	19
Total number of taxa	8
Predominant taxon	**Stone Fly (EPT)**

Table 13. Station 4 Assessment & Rating

ASSESSMENT	RATING
Pollution Tolerance Index	4
EPT Index	4
EPT to total ratio	2
Predominant taxa ratio	3
AVERAGE RATING	**3.25**
Total number of organisms collected	113
Total number of taxa	39
Predominant species	**Aquatic worm (*Oligochaete*)**

4.4.3 Quality Assurance/Quality Control

Proper measures were used to ensure quality assurance and quality control of all the stream invertebrate collection and analysis including using a stream invertebrate ID guide to divide invertebrates into family groups and following the procedures in the *Streamkeepers Handbook.* Replicate samples were taken at each site to maximize sampling diversity as stream invertebrate sampling can be highly variable due to patchy distribution. Clean containers were utilized when sampling and a trip blank was brought along and tested to rule out any contamination factors. Samples were stored in a cooler with ice packs to keep samples fresh while in transport. Samples were processed within hours after sampling to minimize any negative effects. Samples analysis and calculations were completed by multiple members to ensure highest accuracy.

5.0 Conclusions and Recommendations

(Jaylene Harper)

After a comprehensive evaluation of both water quality and stream invertebrate results, it was found that the C.W. Young channel continues to subsist as a healthy and successful ecosystem. The channel, as recognized in previous years, continues to encompass the parameter levels needed in order for fish, such as Coho salmon, to thrive. Although all of our sampling and subsequent results are specific to the C.W. Young channel, they indicate that the Englishman River's mainstem also remains to be in good health, despite the potential environmental concerns that encompass portions of the river and its corresponding watersheds.

Water quality parameters, with the exception of a few station's turbidity and total phosphorus (P) levels, were all within the B.C. water guidelines, and therefore considered good quality. The substantial increase in turbidity levels in the second sampling session (in comparison to the first sampling session) was likely caused by recent rainfall events that occurred just prior to November 22nd, as storm cycles are known to be correlated with high turbidity. This stems from the notion that a rise in water levels, which triggers intensified erosion along the river, decreases the water's clarity (Barlak et al., 2010; Lee et al., 2016). Similarly, the increased levels of total phosphorus during the second sampling session, which may have caused a slight increase in plant and animal productivity, was likely correlated to heavy rainfall (Barlak et al., 2010). These levels, however, are not eutrophic, and therefore do not cause reason for concern at this time (RISC, 1998). Furthermore, the detection of aluminum during the second sampling event was expected, as past studies have had similar levels, which are reportedly a result of local geology, and also likely influenced by the rain (Barlak et al., 2010). The presence of less than 1mg/L of aluminum in the watershed is furthermore not considered to be a danger to pubic health or the plants and animals that inhabit the channel (RISC 1998).

Coliform counts, particularly fecal coliform, were exceptionally low, especially in comparison to the previous year's results. Comparably low results have, however, been found in the past, as levels tend to fluctuate in the area (Demers, 2016). Due to processes, which include membrane filtration, ultra-violet light, and chlorine disinfection, that the Englishman River's water goes though in a water treatment plant, the current levels of fecal coliform are well below the applicable guidelines for partially treated drinking water (RISC 1998; AWS. 2017).

Pollution intolerant invertebrate species (caddisfly, mayfly, and stonefly) were identified at all three samplings stations, providing additional evidence that the channel is in good health. Overall site assessments that ranged from 2.75-3.25 (out of 4.0) deemed the channel to be more closely rated as acceptable (3.0) than good (4.0). Stream invertebrate sampling, however, can be highly variable, and misidentifying macroinvertebrates during analysis has also been documented to commonly cause error (Haase et al., 2006). A large quantity of past studies showed mayflies as being the predominant taxon, whereas our counts of this pollution intolerant species were moderately low. Considering that water quality results exhibited ideal levels for aquatic life, and juvenile salmon (which rely on invertebrates for food) are documented by Hawkes et al. (2008), as well as commonly seen by the public to have success rearing in the area, conclusions can be drawn that mayflies are likely still abundant within the channel, and a more precise site assessment rating (more samples and better expertise) could indicate that the channel is actually closer to good, than acceptable.

While all results exhibited that the C.W. Young Channel continues to be a healthy and clean waterway for aquatic life, potential environmental concerns that continue to threaten the Englishman River's health justifies the need for continued data accumulation. With global warming levels predicted to steadily increase, and residential areas in Parkville continuing to expand (including proposals for large commercial buildings only 7km from the river's mainstem), the risks of large pollution events within the river are as high as ever (Rardon, 2017). With this in mind, we recommend that the C.W. Young Channel's annual monitoring project continue for as long as possible.

6.0 Acknowledgments

(*Jaylene Harper on behalf of the group)*

The authors would like to first and foremost thank Dr. Eric Demers for guiding us to attain the skills and knowledge needed to fulfill this monitoring project, as well as Kim Ives who assisted in laboratory analysis. Furthermore, a thank-you goes to Vancouver Island University's Resource Management Officer Technology (RMOT) and Science-Biology departments, who facilitated in supplying the equipment needed, both in the field and in the laboratory. Lastly, thank-you to ALS for examining our samples and providing us with accurate results.

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8.0 Appendices

Appendix A: Photos taken on October 18, 2017 at four of the pre-established sampling sites along the C.W. Young Channel.

(Teagan Wardrop)

Figure A1. Site #1, located in the C.W. Young Channel. Facing mid-stream. Note the outflow pipe and valve.

Figure A2. Site #2, located along the C.W. Young Channel.
Facing downstream and showing the culvert

Figure A3. Site #3, located along the C.W. Young Channel.
Facing downstream and showing the large woody debris.

Figure A4. Site #4, located along the C.W. Young Channel.
Facing upstream and showing the bars of the metal walking bridge.

*Please note: Site #5 could not be accessed during the initial site assessment on October 18th, please see Figure B5.

Appendix B: Photos taken on November 1, 2017 at the five sampling sites along the C.W. Young Channel. *(Teagan Wardrop)*

Figure B1. Site #1, located at the entrance to the C.W. Young Channel. Facing mid-stream. Note the outflow pipe and valve.

Figure B2. Site #2, located along the C.W. Young Channel.
Facing downstream and showing the culvert.

Figure B3. Site #3, located along the C.W. Young Channel.
Facing downstream and showing the large woody debris.

Figure B4. Site #4, located along the C.W. Young Channel.
Facing upstream and showing the bars of the metal walking bridge.

Figure B5. Site #5, located at the downstream union of the C.W. Young Channel and the Englishman River. Facing mid-stream. Note the relatively low water level.

Appendix C: Photos taken on November 22, 2017 at four of the five sampling sites along the C.W. Young Channel.
(Teagan Wardrop)

Figure C1. Site #1, located at the entrance to the C.W. Young Channel. Facing upstream. Note the outflow pipe and valve and increased water level.

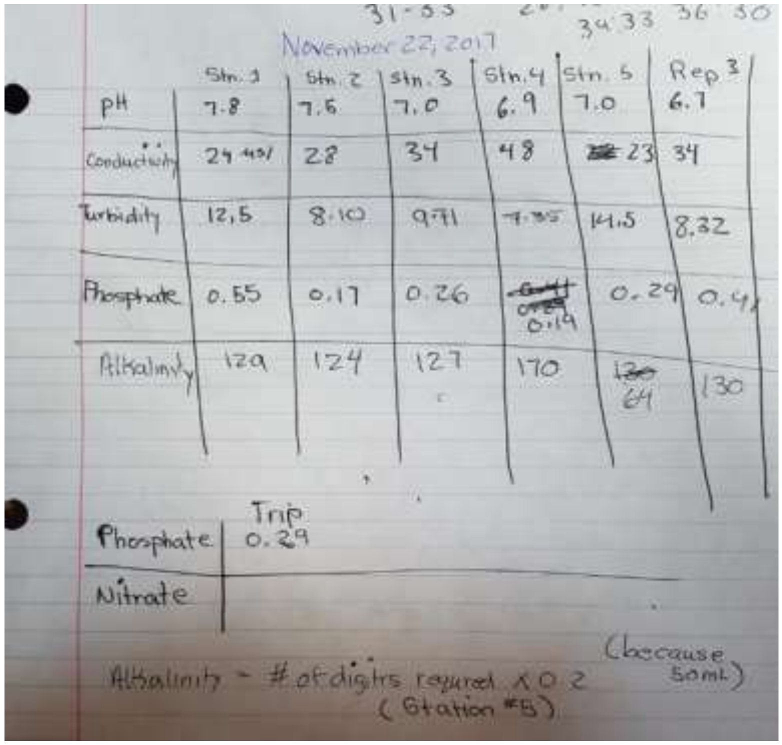
Figure C2. Site #2, located along the C.W. Young Channel.
Facing midstream and showing the culvert.

*Please note: due to safety issues at Site #3 on November 22nd, no clear photos were taken.

Figure C4. Site #4, located along the C.W. Young Channel. Facing upstream.

Figure C5. Site #5, located at the downstream union of the C.W. Young Channel and the Englishman River. Facing downstream. Note the drastic increase in water level and reduced clarity compared to Figure B5.

Appendix D: Rough calculations from lab analysis
(*whole group)*



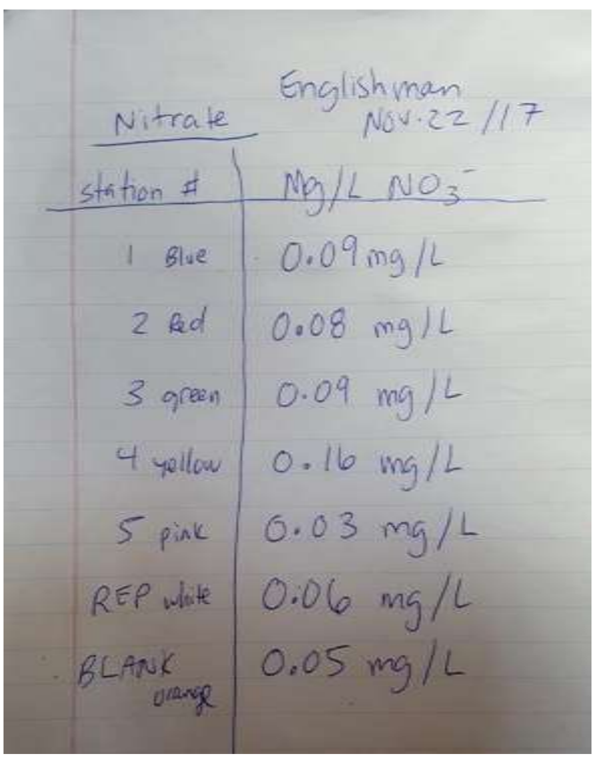
31-33 34 33 36 30

November 22, 2017

	Stn. 1	Stn. 2	Stn. 3	Stn. 4	Stn. 5	Rep 3
pH	7.8	7.6	7.0	6.9	7.0	6.7
Conductivity	24 431	28	34	48	23	34
Turbidity	12.5	8.10	9.71	7.35	14.5	8.32
Phosphate	0.55	0.17	0.26	0.14	0.29	0.4
Alkalinity	129	124	127	170	~~130~~ 64	130

	Trip
Phosphate	0.29
Nitrate	

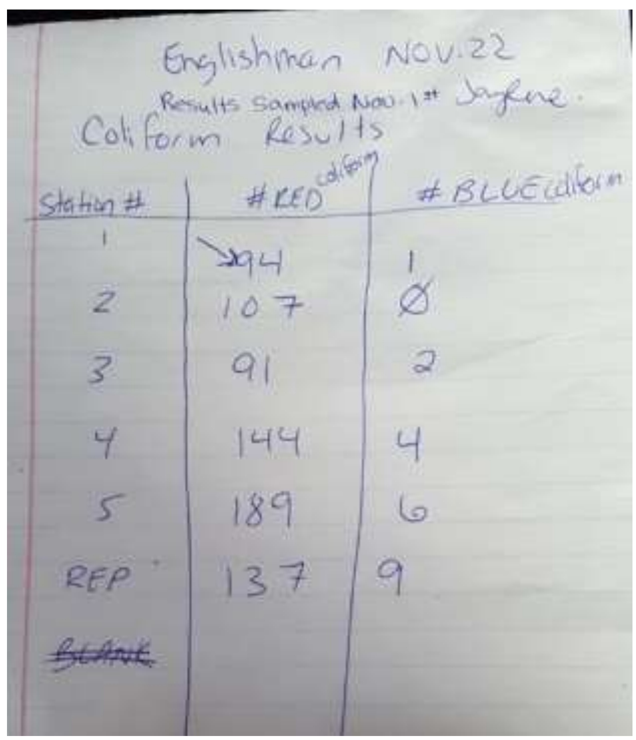
Alkalinity - # of digits required x 0.2 (because 50mL)
(Station #5)



Nitrate

Englishman Nov. 22 /17

station #	Mg/L NO_3^-
1 Blue	0.09 mg/L
2 Red	0.08 mg/L
3 green	0.09 mg/L
4 yellow	0.16 mg/L
5 pink	0.03 mg/L
REP white	0.06 mg/L
BLANK orange	0.05 mg/L



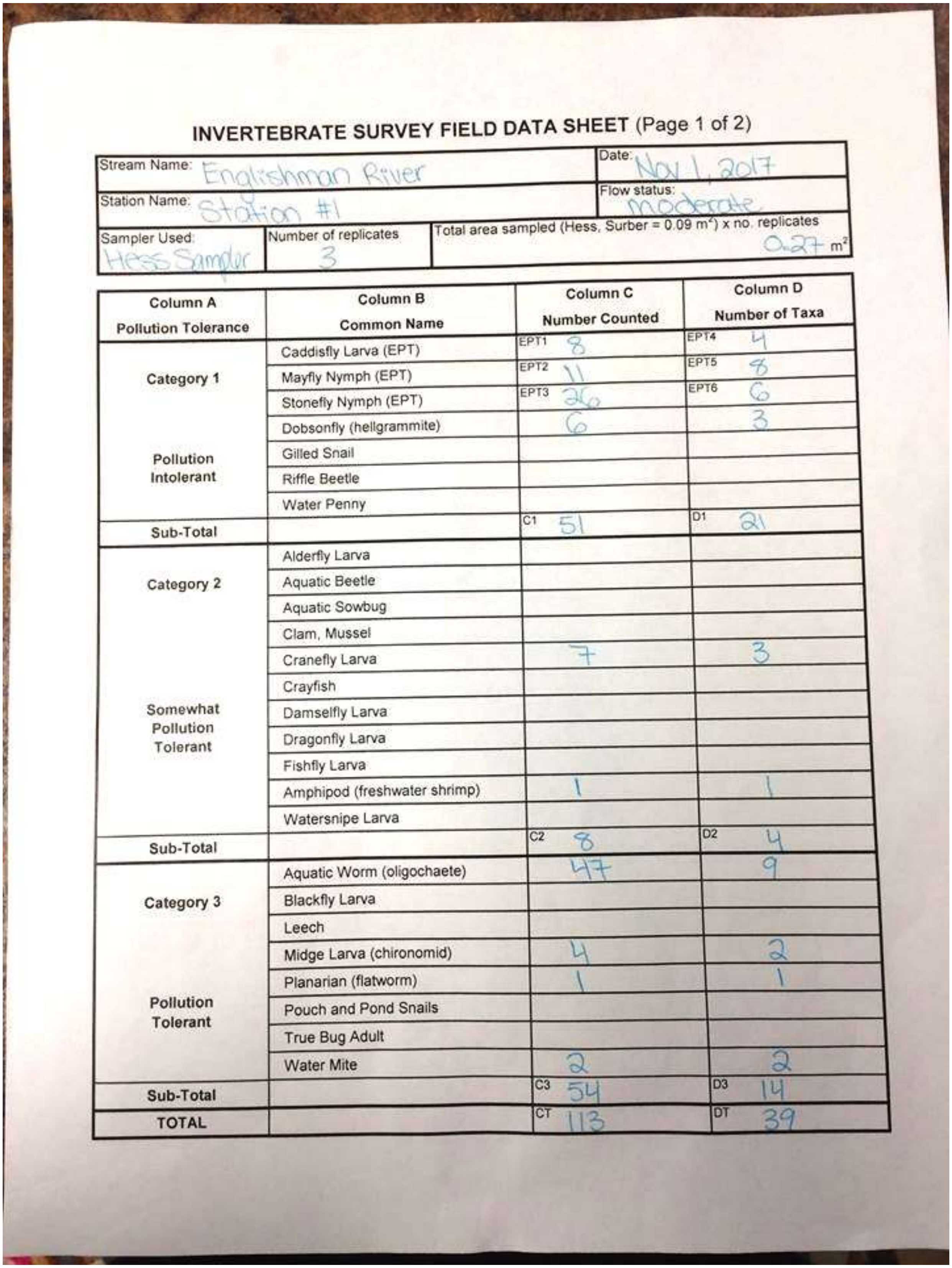
Englishman NOV. 22

Results Sampled Nov. 1st Jayne.

Coliform Results

Station #	# RED coliform	# BLUE coliform
1	94	1
2	107	Ø
3	91	2
4	144	4
5	189	6
REP	137	9
~~BLANK~~		

Appendix E: Invertebrate Survey Data and Interpretation sheets
(*Data- Group effort; Interpretation- Jaylene Harper)*



INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Englishman River		Date: Nov 1, 2017
Station Name: Station #1		Flow status: moderate
Sampler Used: Hess Sampler	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)	EPT1 8	EPT4 4
	Mayfly Nymph (EPT)	EPT2 11	EPT5 8
	Stonefly Nymph (EPT)	EPT3 26	EPT6 6
	Dobsonfly (hellgrammite)	6	3
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 51	D1 21
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	7	3
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	1	1
	Watersnipe Larva		
Sub-Total		C2 8	D2 4
Category 3	Aquatic Worm (oligochaete)	47	9
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	4	2
	Planarian (flatworm)	1	1
Pollution Tolerant	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	2	2
Sub-Total		C3 54	D3 14
TOTAL		CT 113	DT 39

STATION #1

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: CT 113

DENSITY: Invertebrate density per total area sampled:

113 ÷ 0.27 m^2 = 418.5 / m^2 (0.27 is from page 1)

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (in Col. C): S1 Aquatic Worm (Oligochaete)

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 21 + 2 x 4 + 14 =
63 + 8 + 14 =

S2 85

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

4 + 8 + 6 =

S3 18

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

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

(EPT1 + EPT2 + EPT3) / CT

(8 + 11 + 26) / 113 =
45 ÷ 113 =

S4 0.398

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 39

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S1) divided by CT.

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

Col. C for S1 / CT

47 / 113 =

S5 0.42

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2, S3, S4, S5), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

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

Average Rating
Average of R1, R2, R3, R4
3.25

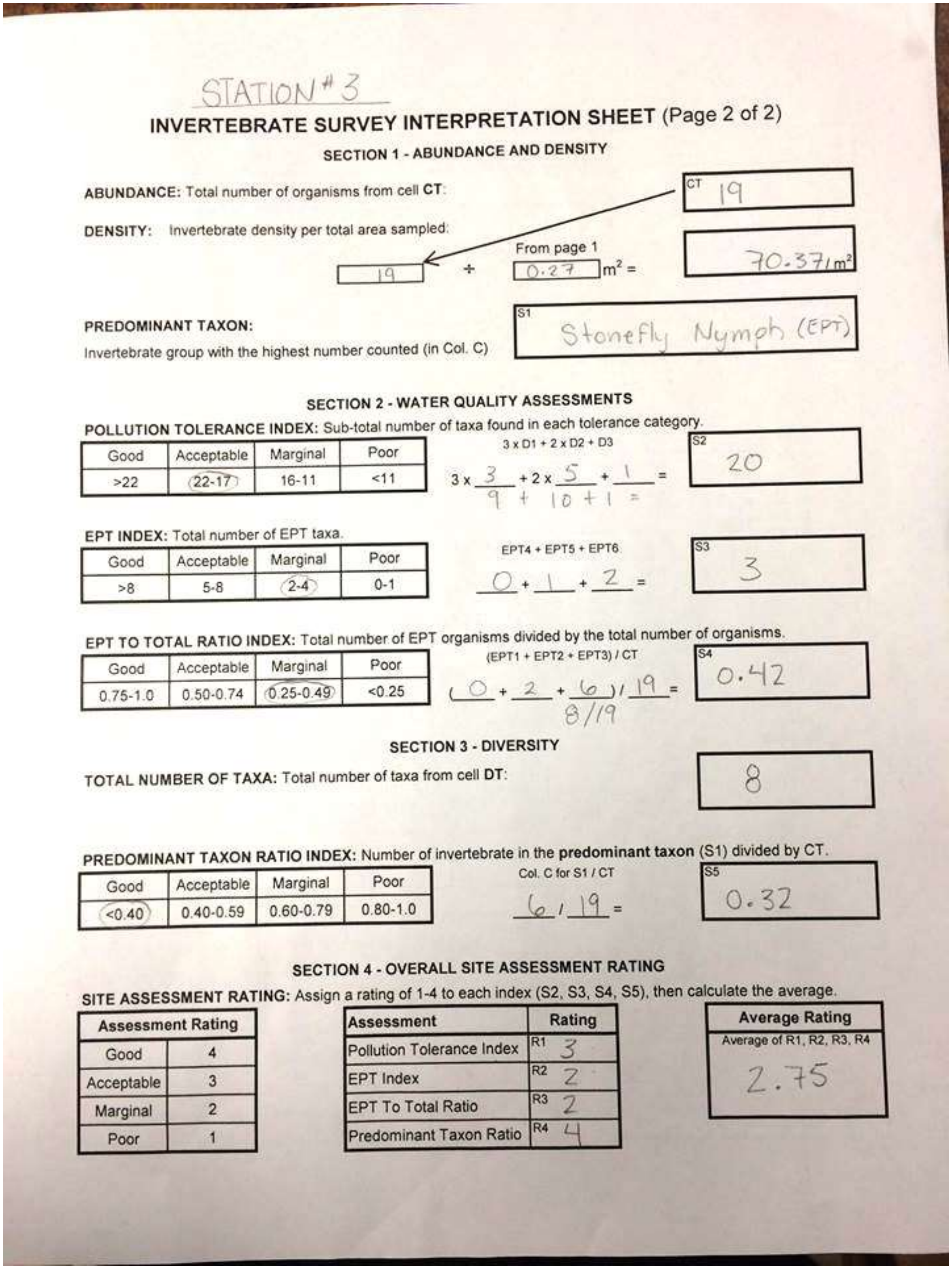
* cronomid midges bright red x15

station #1.

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Englishman River		Date: Nov. 1st/17.
Station Name: Station # 3		Flow status: low
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m²) x no. replicates 0.09m² x 3 = 0.27m²

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	EPT1	EPT4 ∅
	Mayfly Nymph (EPT)	EPT2 2	EPT5 1
	Stonefly Nymph (EPT)	EPT3 6	EPT6 2
Pollution Intolerant	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 8	D1 3
Category 2	Alderfly Larva	4	2
	Aquatic Beetle		
	Aquatic Sowbug	1	1
	Clam, Mussel		
	Cranefly Larva	2	2
Somewhat Pollution Tolerant	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)		
	Watersnipe Larva		
Sub-Total		C2 7	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 19	DT 8



STATION # 3

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: CT 19

DENSITY: Invertebrate density per total area sampled:

19 ÷ From page 1 0.27 m² = 70.37/m²

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (in Col. C) S1 Stonefly Nymph (EPT)

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 3 + 2 x 5 + 1 =
9 + 10 + 1 =

S2 20

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

0 + 1 + 2 =

S3 3

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

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

(EPT1 + EPT2 + EPT3) / CT

(0 + 2 + 6) / 19 =
8/19

S4 0.42

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 8

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S1) divided by CT.

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

Col. C for S1 / CT

6 / 19 =

S5 0.32

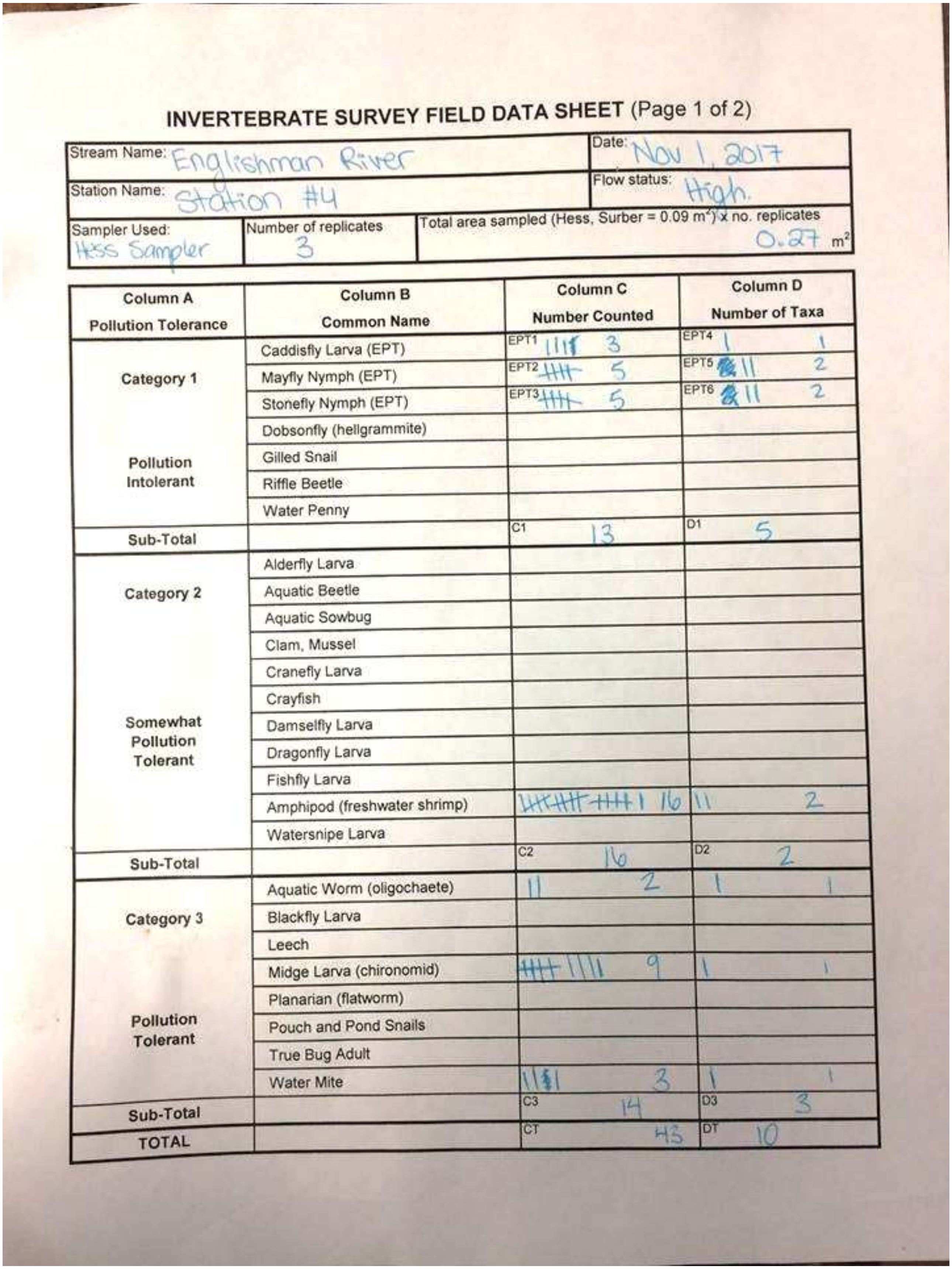
SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2, S3, S4, S5), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

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

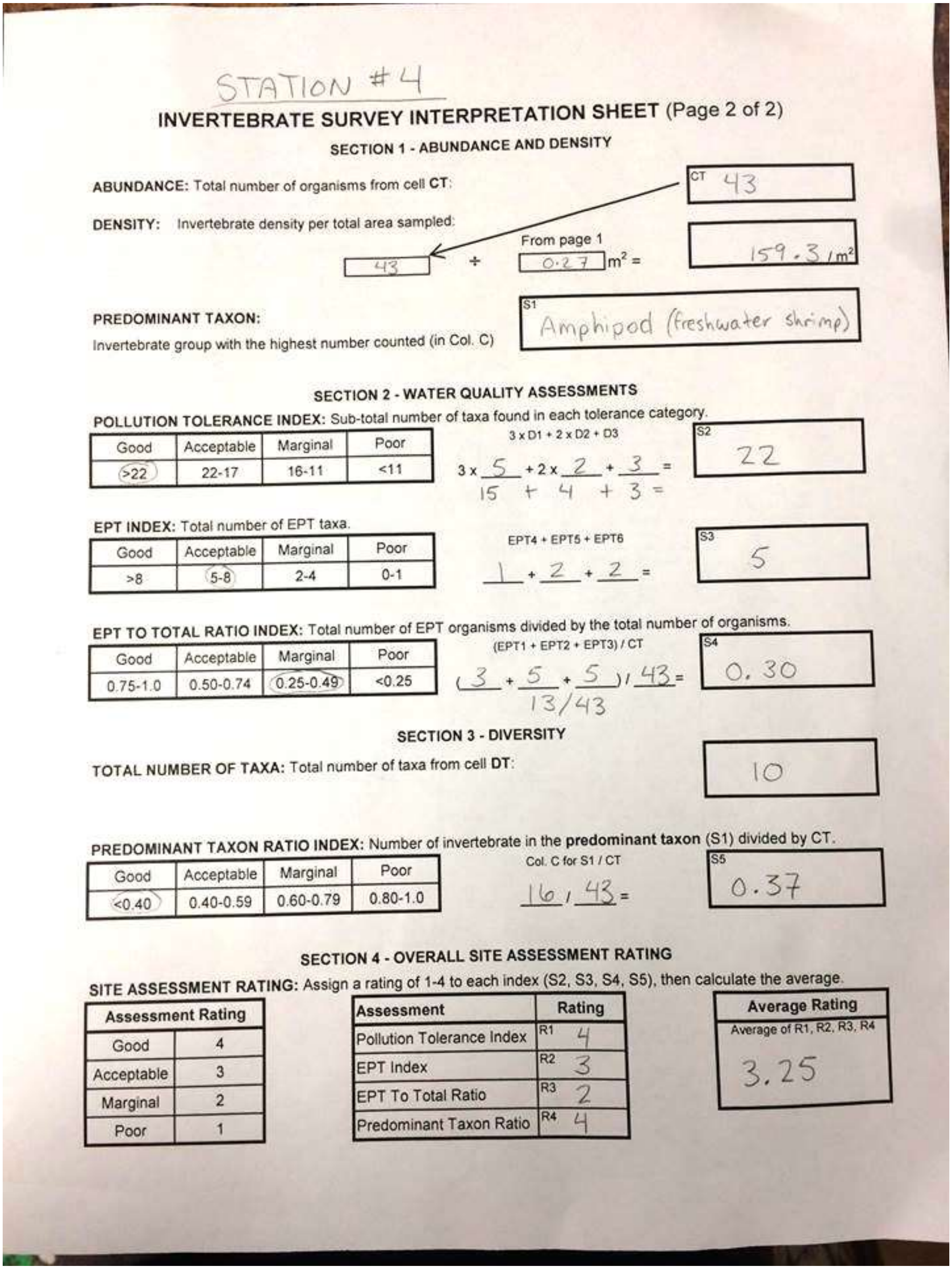
Average Rating
Average of R1, R2, R3, R4
2.75



INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Englishman River		Date: Nov 1, 2017
Station Name: Station #4		Flow status: High.
Sampler Used: Hess Sampler	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)	EPT1 3	EPT4 1
	Mayfly Nymph (EPT)	EPT2 5	EPT5 2
	Stonefly Nymph (EPT)	EPT3 5	EPT6 2
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 13	D1 5
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	16	2
	Watersnipe Larva		
Sub-Total		C2 16	D2 2
Category 3	Aquatic Worm (oligochaete)	2	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	9	1
	Planarian (flatworm)		
Pollution Tolerant	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	3	1
Sub-Total		C3 14	D3 3
TOTAL		CT 43	DT 10



STATION #4

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: CT 43

DENSITY: Invertebrate density per total area sampled:

43 ÷ From page 1 0.27 m² = 159.3 /m²

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (in Col. C) S1 Amphipod (freshwater shrimp)

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 5 + 2 x 2 + 3 =
15 + 4 + 3 =

S2 22

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

1 + 2 + 2 =

S3 5

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

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

(EPT1 + EPT2 + EPT3) / CT

(3 + 5 + 5) / 43 =
13/43

S4 0.30

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** (S1) divided by CT.

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

Col. C for S1 / CT

16 / 43 =

S5 0.37

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2, S3, S4, S5), 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 2
Predominant Taxon Ratio	R4 4

Average Rating
Average of R1, R2, R3, R4
3.25

Appendix F: Shannon-Wiener Index Calculations

(Avryl Brophy)

Table F1. Station 1 Shannon-Wiener Index Table

Pollution Tolerance Category	Species Common Name	Column C	Pi (C / T)	ln (pi)	Pi * ln(pi)
1	Caddisfly Larva	8	0.071	-2.64	-0.188
1	Mayfly Nymph	11	0.097	-2.33	-0.226
1	Stonefly Nymph	26	0.230	-1.47	-0.335
1	Dobsonfly Larva	6	0.053	-2.94	-0.156
2	Cranefly Larva	7	0.062	-2.78	-0.172
2	Amphipod	1	0.009	-4.71	-0.042
3	Aquatic Worm	47	0.416	-0.88	-0.365
3	Midge Larva	4	0.035	-3.35	-0.117
3	Planarian	1	0.009	-4.71	-0.042
3	Water Mite	2	0.018	-4.02	-0.072
Total	--------	113	1.00	--------	1.718

H = -(-1.718)

------------------- = 0.746

ln(10)

Table F2. Station 3 Shannon-Wiener Index Table

Pollution Tolerance Category	Species Common Name	Column C	Pi (C / T)	ln (pi)	Pi * ln(pi)
1	Mayfly Nymph	2	0.105	-2.25	-0.236
1	Stonefly Nymph	6	0.316	-1.15	-0.363
2	Alderfly Larva	4	0.211	-1.56	-0.329
2	Aquatic Sawbug	1	0.053	-2.94	-0.156
2	Cranefly Larva	2	0.105	-2.25	-0.236
3	Aquatic Worm	4	0.211	-1.56	-0.329
Total	---------	19	1.00	--------	-1.649

H = -(-1.649)

------------------- = 0.920

ln(6)

Table F3. Station 4 Shannon-Wiener Index Table

Pollution Tolerance Category	Species Common Name	Column C	Pi (C / T)	ln (pi)	Pi * ln(pi)
1	Caddisfly Larva	3	0.069	-2.67	-.018
1	Mayfly Nymph	5	0.116	-2.15	-.0249
1	Stonefly Nymph	4	0.116	-2.15	-.0249
2	Amphipod	16	0.372	-0.989	-.0368
3	Aquatic Worm	2	0.047	-3.06	-.0144
3	Midge Larva	9	0.209	-1.57	-.0328
3	Water Mite	3	0.069	-2.67	-.0184
Total	---------	43	1.00	--------	1.706

H = -(-1.706)

------------------- = 0.877

ln(7)

Appendix G: Revised Health and Safety Plan

(Avryl Brophy)

A detailed safety plan was created to outline safety precautions that must follow during site visits at Englishman River. During the initial visit, we assessed the site conditions and identified potential safety hazards and decided that Englishman River site is remote, has minimal access, and has potential dangerous wildlife in the area. Self-awareness and team communication was key when working in these field conditions. Several safety concerns were present at all stations which are outlined below in Table.2.

Table 2: Preliminary site safety concerns for environmental monitoring at the Englishman River. These site safety concerns were recorded during the initial visit to the site on October 18, 2017 (Demers, 2016).

Englishman River Site Location #	**#1**	**#2**	**#3**	**#4**	**#5**
Access	Service Road 8 m trail	Service Road	Service Road 5 m trail	Service Road Cross small metal bride	Did not locate
Hazards	Slippery & tripping hazards	- Large woody debris Slippery boulders -Service traffic	-Dangerous wildlife concerns	-Slippery boulders -Possible danger trees	Did not locate
Embankment	Steep / Slippery	Short / Moderately Steep	Very Remote Grassy Trail	Short / Slippery	Did Not Locate
In-stream Footing	Poor	Fair	Poor	Poor	Did Not Locate
Flow Rate / Depth	Deep / Slow	Moderate / Fair	Slow & deep	Slow deep pool into strong rifle	Did Not Locate
Description of Sample Site.	Steep trail down to access. Deep Pool & unable to see the bottom. Metal grate on the right side of pool.	Easy access right off the service road. Large boulders on each side of access points. Culvert under access road leads into site.	Concealed access behind two large stumps down a grass. Open area, but surrounded by trees & shrubs with limited places to retreat.	Easy access to site off service road across a small metal bridge. Large water course area that pools and then pushes into a fast rifle on the other side of the bridge.	Did not Locate

Risks and hazards were noted and discussed to create a safe work plan to ensure optimal operations and minimize any safety issues encounter while working. Safety requirements while conducting work on this site include: contacting our instructor Dr. Eric Demers before and after working in the field, having at least one cell phone on us at all time, and having at least one cell phone on us at all time, and providing Dr. Demers with a list of these contacts numbers (attached to this document). Travel to and from site will be in an appropriate vehicle with 4x4 capabilities that can handle the service road during unforeseen weather conditions. A description of this vehicle and license plate number is included. Appropriate apparel will be worn while working in the field by all team members. Work will never be conducted before dawn or after dusk, and no wading or sampling will take place in extreme weather conditions. Anticipated stream flow and levels will be monitored and assessed regularly dependent on weather conditions to ensure safety during all sampling Work will never be executed alone and a minimum of three people will be together always. Wildlife precautions will be considered and followed (dependent on the species encountered) in the case of a wildlife-human conflict interaction. Since there has been several bear sightings near one of the stations bringing bear spray would be safe measure if possible. Physical exposure to external elements and signs of fatigue will be constantly monitored as a group to ensure team health. A basic first aid kit will be kept in the transporting vehicle while on site. All individuals working on this project have completed their basic first aid requirements and at least one team member is trained in swift water rescue. For emergency egress, there are two access / exit points at the Englishman River site. Depending on where we are located during a possible emergency, our emergency egress plan would fluctuate. Depending on the nature of the emergency and our location during the event, we will evaluate an egress plan per situation, however, all situations will focus on staying on the main service road and staying collected as a group until emergency responders arrive.

Contact Numbers

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Vehicle Description and License Plate

2015 White Jeep Cherokee

LP # 952 SRK