Millstone River Monitoring Project

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Submitted to:
Dr. Eric Demers

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Executive Summary

For 2018 VIU's annual water quality and stream invertebrates monitoring was conducted in 5 Sampling Sites located on the Millstone River, in Nanaimo, British Columbia. Samples were collected on October 22nd and November 21st. The first event was after one of the first heavy rainfalls of the season which created a relatively high flow. Between the first and second event only a moderate amount of rainfall occurred leading to similar water levels in both sampling events. Measurements taken at each site were: pH, hardness, phosphate , nitrate, temperature, conductivity, dissolved oxygen, turbidity, alkalinity, and total metals. The river was also assessed for stream invertebrates(Sites 1,2 and 4), microbiology, and hydrology. Extra Samples were also taken at Sites 1,2, and 4, then sent to the ALS lab in Vancouver, British Columbia for comparative testing and total metals results. Results were analysed and recorded at the VIU lab. VIU results were compared against previous sampling years, and against the results from ALS. The comparison with ALS showed during the first for Site for VIU showed hardness at 104mg/L where ALS showed 49.5mg/L. These results may show an QC issue with the sample taken at Site 4. The remaining results showed all SItes were within the Water Quality Guidelines for aquatic life. Microbiology showed the that Site 4 had the highest presence of fecal coliforms of all Sites. Invertebrate sampling revealed Site 4 to have the lowest health with a high number of pollution tolerant invertebrates and few EPT species present. Sites 1 and 2 showed considerable higher numbers of EPT species but had low level of species richness. Overall the Millstone River did not reveal any abnormal results from previous tests and the health the the stream should be considered acceptable.

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Introduction

A team of students, consisting of Chris Boldt, James Myhill-Jones, and Graydon Bruce, conducted an environmental monitoring project on the Millstone River in Nanaimo, British Columbia under the guidance of Dr. Eric Demers. The sampling and fieldwork were carried out on October 22nd and November 21st, 2018. Five sites were identified to monitor and were visited by the team before the actual sampling day to establish ideal sampling locations at the sites, as well as to take photos and make a safety assessment. This sampling is of interest to and will be submitted to the Department of Fisheries and Oceans, Regional District of Nanaimo, British Columbia Conservation Foundation, and the City of Nanaimo. Environmental monitoring of the Millstone River has been conducted annually for several years, so this data will help to establish trends and determine if there are any environmental or other impacts on the Millstone River. The principle objective of this project was to assess the overall environmental health of the Millstone River by assessing various parameters, including Water Quality and Invertebrate life. This data was added to data already collected since 2006 to establish trends and assess the health of the river over time, as well as to see if there are any emerging concerns that need to be addressed. The samples from all the stations were analyzed at Vancouver Island University (VIU), while the samples from stations 1, 2, and 4 were analyzed by Australian Laboratory Services (ALS Labs) in Vancouver, BC. The work was also especially important because of the run of Coho salmon that return to the river every fall.

Monitoring included hydrology, water quality, microbiology, and invertebrate sampling. Hydrology assessments were conducted at two different stations to assess the discharge rate of the river. Water quality testing included conducting on-site testing of temperature and dissolved

oxygen, as well as taking samples to be assessed off-site for various parameters. Samples were also taken at all five sites for microbiology testing. Finally, sampling was done at three different sites to assess aquatic invertebrates.

The Millstone River is located right within the heart of Nanaimo, British Columbia and runs through several urban areas of the city, as well as Bowen Park in the City of Nanaimo (City of Nanaimo, n.d.). The Millstone is 14 km long and has a watershed that encompasses 100 square kilometres, including 26 streams, 16 tributaries, and 8 lakes (City of Nanaimo, n.d.). The river drains into the Pacific Ocean just North of downtown Nanaimo. The majority of the river is now surrounded by urban areas, with the exception of a golf course and some fields that are located closer to Brannen Lake. The Millstone has a side channel which aids migrating Coho salmon as they return to spawn in the river (City of Nanaimo, n.d.). Various stewardship groups partnered with Fisheries and Oceans Canada in 2007 to construct the side channel, which allows salmon to bypass waterfalls that were previously a barrier (City of Nanaimo, n.d.).

Figure 1: Map of Millstone River watershed (Gaboury and Kehler, 2012)

The river is located in the Coastal Douglas Fir (Moist Maritime subzone) biogeoclimatic zone, and is adjacent to the Coastal Western Hemlock biogeoclimatic zone (Very Dry Maritime subzone) (BC FLNRO, n.d.). The river also runs through the 36-hectare Bowen Park in central Nanaimo, which plays host to hikers, fishermen, dog walkers, and other recreational user groups (City of Nanaimo, n.d.).

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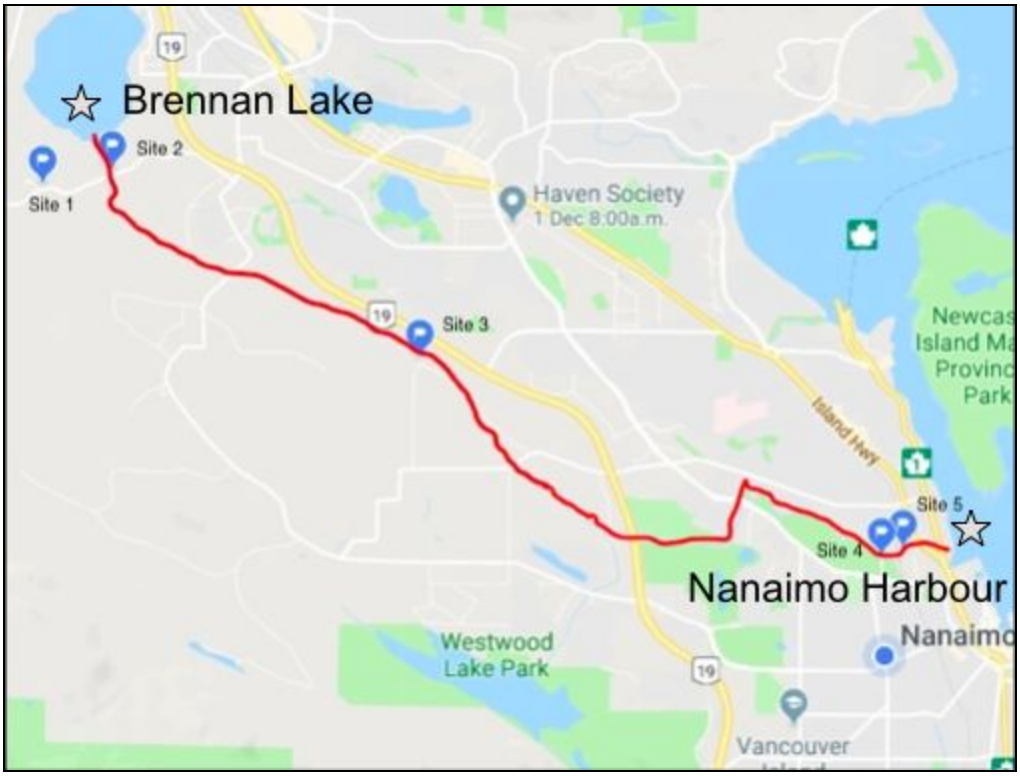

Figure 2: Map of sites on Millstone (Google Maps 2018)

Site Characteristics

The goal of the assessments of Benson Creek and the Millstone River is was to resume the annual process of the environmental monitoring of the watershed. A 3-person crew from Vancouver Island University monitored five sites along these streams (figure 2) while following all data collection procedures conducted since monitoring began in 2006. Following these procedures closely was crucial to the continuity of the data that had been taken in past years and to the data that will be collected for years to come.

Each of the five sites had been chosen based on characteristics which allowed the best representation of the entire length of the streams, as well as ease of access and safety. The five environmental monitoring site locations were chosen in order to conduct water quality, microbiology, and biodiversity assessments. Initial site assessments were carried out on October

13th 2018 where data was taken and stream characteristics were documented. These characteristics are outlined in the following section.

Site 1.

Site one is situated on Benson Creek which runs below the Briggs Rd bridge upstream of Brennan Lake at (10 U 422713mE, 5450675mN) (Figure 2). Access is found down a short steep hill on the right bank at the north side of the bridge. Camp Caillet is just upstream on the right bank of the creek and the surrounding area consists of large rural residential properties. The substrate of Site 1 is dominantly gravel (50%), sub dominantly cobble (45%) a few fines (5%) and no boulders or bedrock. The left and right banks are lined with red alder (*Alnus rubra)* with a canopy coverage of 10%, and the understory consists of mostly himalayan blackberry (*Rubus armeniacus)* and thimbleberry (*Rubus parviflorus)*. Moderate instream vegetation is present and there is a moderate amount of small woody debris. No large woody debris was observed on site. The gradient at Site 1 is 1% and the flow rate on October 13th was low. Hazards found at Site 1 include cars along Briggs Rd and the steep section of hill leading to the Creek which can be slippery. Site 1 is on a curve of Briggs Rd and cars travel around the corner quickly so attention must be paid at all times when making a road crossing.

Site 2.

Site 2 is found on the Millstone River where it runs beneath Briggs Rd bridge downstream of Brennan Lake at (10 U 423370mE, 5450777mN) (Figure 2). Access is easiest down a semi-steep path on the north side of the bridge on the left bank. The area adjacent to Site 1 is farmer's fields on the left and right banks, with some large rural residential properties similar to Site 1. The substrate of Site 2 is dominantly gravel (60%), sub dominantly cobble (35%) a few

fines (5%) and no boulders or bedrock. The banks are lined with deciduous red alder (*Alnus rubra)* with a canopy coverage of 15% and the understory of the left and right bank is dominantly sedges and grasses. Moderate instream vegetation is present and there is a moderate amount of small woody debris. No large woody debris was observed during the site visit. The gradient at Site 2 is 1% and the flow rate on October 13th was moderate. Hazards found at Site 2 include cars along Briggs Rd and the steep section of hill leading to the River which can be slippery. Briggs Rd bridge at the Millstone River is on a straight stretch so although cars can be seen from a distance, drivers tend to exceed the speed limit.

Site 3

Site 3 is found on the Millstone River at the junction of Maxey Rd and the Durnin Rd bridge at (10U 426333mE, 5448958mN) (Figure 2). At this location, the river flows parallel to Maxey road and under Durnin Rd. Access to the site has been granted by the property owner and is found on the right bank on the south side of the bridge. A steep section of hill leads down to the river and can become slippery during wet periods. The surrounding area consists of residential properties on the left bank with a farmer's field on the right bank upstream of the Durnin Rd and an orchard on the right bank downstream of Durnin Rd. The substrate of Site 3 is dominantly cobble (60%), sub dominantly gravel (30%) a few fines (5%) a few boulders (5%) and no bedrock. The canopy is deciduous and consists of red alder (*Alnus rubra)* with a canopy coverage of 5% and the understory is dominantly grasses and lady fern (*Athyrium filix-femina)*. Moderate instream vegetation is present and no small woody debris or large woody debris was observed upon site visit. The gradient at Site 2 is 3% and the flow rate on October 13th was moderate. Hazards observed during the site visit on October 13, 2018 included the unmarked,

steep section down to the river and the traffic on Durnin and Maxey Rds. Maxey Rd is on a straight stretch at this location so cars may be moving at a higher rate of speed. Pedestrians may also need to be considered as they were observed walking along the road shoulders in the area.

Site 4

Site 4 is located on the Millstone River side-channel at the duck pond in Bowen Park, north of the Millstream Parkway parking lot at (10U 430320mE, 5447238mN) (Figure 2). Sampling will take place on the right bank at the downstream outlet on the south side of the walking bridge. Access is down a paved path which runs around the perimeter of the pond and connects to many trails throughout Bowen Park. The substrate of Site 4 is dominantly cobble (45%), sub dominantly gravel (30%) a few fines (5%) and boulders (5%) with no bedrock. The tree canopy coverage is 20% and consists of red alder (*Alnus rubra), bigleaf maple (Acer macrophyllum)* and western red cedar (*Thuja plicata).* The understory of Site 4 is mainly salmonberry *(Rubus spectabilis)* with thimbleberry (*Rubus parviflorus)* lining the left and right banks. Moderate instream vegetation is was present during the site visit along with moderate small woody debris and large woody debris. The gradient at Site 4 is 10% and the flow rate on October 13th was low. Site 4 is in a municipal park and visitors to the park are frequently around so some public education of the survey may be required. The paths are easily walkable and access to the side-channel is directly next to the path. The Millstream Parkway has a small amount of traffic; therefore, caution must be taken when crossing roads and exiting and entering vehicles in the parking lot.

Site 5

Site 5 is located on the Millstone River downstream Barsby Avenue bridge adjacent to the Barsby Park pedestrian path at (10U 430974mE, 5447119mN) (Figure 2). Sampling for Site 5 will be conducted in the step pools approximately 50 metres downstream of the bridge. The substrate on site consists of dominantly bedrock (60%), sub-dominantly cobble (15%), gravel (10%), boulders, (10%) and fines (5%). The 5% canopy cover in Site 5 is mostly red alder (*Alnus rubra) and bigleaf maple (Acer macrophyllum)* with a himalayan blackberry (*Rubus armeniacus)* and thimbleberry (*Rubus parviflorus)* understory. No instream vegetation or small woody debris was observed during the initial site visit, however large woody debris was documented downstream. The gradient of Site 5 was measured to be 12% and the flow rate at time of observation was moderate. The park that surrounds Site 5 has a large amount of pedestrian traffic and many people in the area have pets. While visiting this location attention must be paid to the public in order to achieve a safe working area. Public education of the survey may also need to be carried out.

Methods

Monitoring Frequency

Environmental Monitoring took place from Site 1 to Site 5 or two separate dates within the time allotted. The first monitoring activities took place on October 29, 2018 and the second monitoring activities on November 21, 2018. As equipment was available from Vancouver Island University, a crew travelled to the proposed sites and sampling activities were conducted over each of the two sample periods (Table 1). For each of the 5 stations, water and microbiology samples were taken. Stream invertebrate samples were taken from 3 sites. Due to

safety reasons such as high flow and an inability to successfully conduct sampling activities, microbiology and invertebrate samples were only taken on the initial sampling session.

Table 1: Environmental monitoring and analysis conducted between Sites 1 – 5 on Benson Creek and the Millstone River, during October 29 and November 20, 2018 sampling activities.

Environmental Monitoring Activity Schedule					
Site	Water Quality	Microbiology	Macroinvertebrate sampling	VIU Analysis	ALS Laboratory Analysis
1	A,B	A	A	A,B	A,B
2	A,B	A	A	A,B	A,B
3	A,B	A	---	A,B	---
4	A,B	A	A	A,B	A,B
5	A,B	A	---	A,B	---

The symbols "A" or "B" indicate whether sampling activities were taken during October (A), or November (B).

Basic Hydrology

At each sample station within the survey, the Vancouver Island University crew took hydrological measurements in order to calculate discharge. Discharge changes throughout the year and can affect water quality so it was important to document this throughout the monitoring period. Measurements that were be taken in order to calculate flow include wetted widths and depths, and velocity.

Water Quality

Field measurements

In the field, YSI electronic probes were used for measuring water temperature and dissolved oxygen. Other field measurements taken were pH, and conductivity (uS/cm). All other measurements were conducted at the VIU lab or sent to the ALS lab for analysis.

Water quality samples

Water sampling was conducted twice per site over a duration of one month. The first samples were taken on October 29, 2018 and the second on November 21st, 2018. Sites selected were consistent with Millstone surveys conducted by RMOT 306 students (2006-2017). Water samples were taken from a mid stream location. To avoid contamination, samples were first collected working in a downstream to upstream direction. Each sample bottle was rinsed three times and filled below the surface to assure quality control. As a temperature and bacteria control measure, all samples collected were labeled and placed in coolers containing ice. Once transported to VIU, the samples were placed in a fridge keeping them at a consistent 4℃ and were analysed within 24 hrs of delivery. To remain consistent with BC government testing standards, the reference material used for the site was the "Ambient freshwater and effluent sampling Manual" published by the province of BC.

Lab Analysis

Laboratory testing was conducted in the lab located at VIU and the ALS lab located in Vancouver BC. Measurements were taken for the following parameters: turbidity (mg/L), total alkalinity (mg/L), hardness (mg/L), nitrate (mg/L), reactive phosphorus (mg/L), and total coliforms and fecal coliforms. All five sites samples were tested for the same parameters. The

ALS lab conducted testing for the same parameters. The samples sent to ALS were stored in coolers for temperature control and mailed within 48 hrs of collection. Once the laboratory testing was completed, all the data was reviewed and referenced with the water quality guidelines for freshwater aquatic organisms. The data was inspected for any signs of contamination within the samples.

Quality Assurance and Control VIU

To ensure continuity of all samples collected, trip blanks and replicate samples were taken at a ratio of 10% of total samples taken. Consistent sampling methods were strictly employed at each site and all samples were collected at the same point for each of the two site visits. Prior to collection, all containers were cleaned and inspected for contaminates. Samples were clearly labelled in the field and whenever transported were logged in a chain of custody form.

Quality Assurance and Control ALS

All samples sent to ALS were tracked throughout the sampling process being recorded in a chain of custody form. All time sensitive information was included within the labels and all samples taken were cooled while in transported and stored. ALS confirmed the date and time the samples were received to maintain consistency with time sensitive sampling processes. VIU analysis took replicate samples at Site 1 which showed no variation during the testing phase. These results show that all measurement taken are accurate except for Site 4's hardness measurement within the first sampling event.

Microbiology

Microbiology sampling was only conducted during the first site visit on October 29, 2018. Samples were collected with the use of 100 ml Whirlpak bags. Once the samples were collected and brought to the laboratory, they were pumped through a filter and placed on a petri plate used to test for the presence of coliforms. The samples were covered in m-ColiBlue24 Broth and incubated for 24 hrs at a temperature of 35℃ before being analyzed. After the incubation period the analysis consisted of determining the number of coliforms present in the sample. Blue dots indicated signs of fecal coliforms (E. Coli), while red showed the presence of non-fecal coliforms. The methods used were consistent with those found in *Total Coliforms* and *E.Coli Membrane Filtration Methods* that were developed by the USEPA. All safety procedures were followed during this process and quality control measures were in place to avoid sample contamination.

Invertebrate Sampling

Preliminary site visits determined that a Hess sampler would be the most effective for the size and consistency of substrate throughout the sites. Invertebrate sampling only occurred during the first site visit, and due to changes in habitat type only sites 1, 2, and 4 were sampled. For consistency purposes three samples were taken at each site, one by each member of the survey team. Samples collection was done by agitating the substrate in front of the sampler by hand for exactly one minute, before removal of the sample. All samples were deposited in 100 ml plastic containers and preserved in ethanol for transport to the VIU lab for analysis. A chain of custody form was used to track the samples movements.

Invertebrate Analysis

At the VIU lab, samples were deposited in plastic trays for invertebrate identification. Each sample was reviewed by at least two members to best identify invertebrates present. All invertebrates found were placed in 50 mm petri dishes for microscopic observation and ID. Identification and analysis was done in accordance with the Pacific Streamkeepers procedures. A Shannon-Weiner Diversity index was calculated for the samples collected.

Results and Discussion

VIU Laboratory Results and Discussion

Hydrology

The two days prior to the first sampling event on October 29, 2018 showed precipitation of 14.5 mm and 13.7 mm (Environment Canada 2018). This was more rain than was documented in the two weeks before. Between October 29 and November 21 there was an average of 3.2 mm of precipitation per day with an average of only 1.8 mm per day in the 2 weeks prior.

As explained in Table 2, a general increase in velocity was documented between Sites 1 and 5. Moving downstream from the agricultural area of Site 1 at Benson Creek, towards the smooth bedrock of Site 5 at Barsby Park, the topography changes from gentle slow meanders to cascades with steeper gradients. The exception to this pattern is found at Site 4 at the outflow of the Bowen Park duck pond. An intake weir at the upstream end regulates the flow of water into the duckpond, decreasing velocity as it transitions back into the side channel.

The discharge rates documented showed variation as well. Sites 2 and 4 displayed much lower discharge rates than those of Sites 1, 3 or 5. Site 2 is directly downstream of Brennan Lake and Site 4, as stated above, is directly downstream of the Bowen Park duck pond. These two

water bodies hold a large volume of water and have the ability to limit their outflows. As the flow moves downstream away from these basins, discharge begins to increase.

Table 2: Mean water velocity and discharge recorded on October 29, 2018.

Site	Left Bank Depth (cm)	Thalweg Depth (cm)	Right Bank Depth (cm)	Average Depth (cm)	Wetted Width (m)	Mean Velocity (m/s)	Total Discharge (m^3/s)
1	22	45	20	29	10.75	0.39	1.22
2	18	35	14	22.3	6.6	0.5	0.74
3	16	35	17	22.7	9.3	0.54	1.14
4	16	35	12	21	4.1	0.46	0.4
5	20	40	25	28.3	8.4	0.75	1.79

Hydrology measurements were not taken during the second sampling event as no significant rainfall occurred between the two sampling dates.

Water Quality - Field

Temperature

During the two sampling dates on October 29, 2018 and November 21, 2018, water temperature of all sites decreased between the first and second sampling dates (Figure 3) as the air temperature dropped.

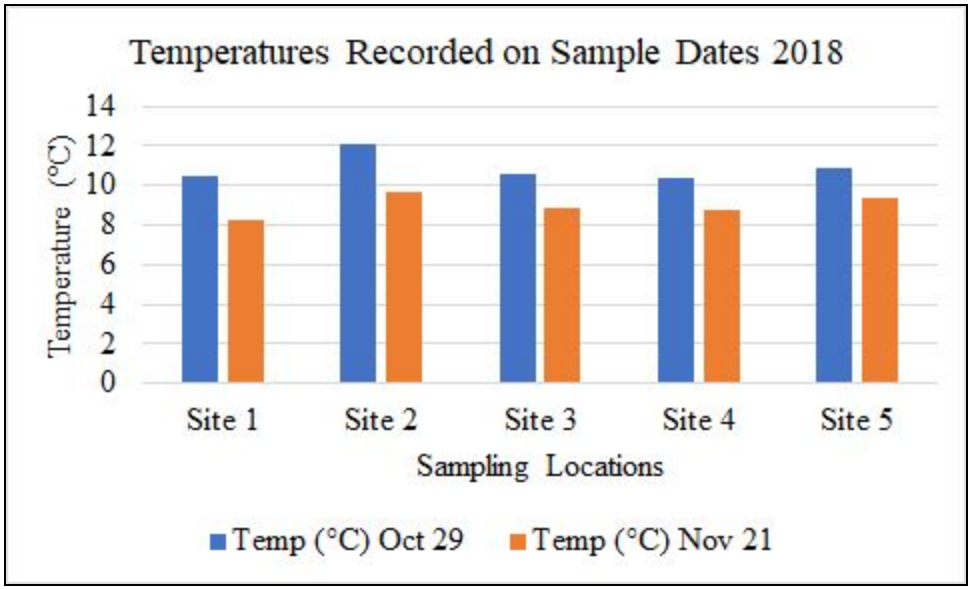

Figure 3: Water temperatures recorded during two sample dates (October 29 and November 21, 2018).

Dissolved Oxygen

Figure 4 displays a decrease in dissolved oxygen between the two sampling dates in four of the five sites, similar to what is shown for temperature in figure 3. Dissolved oxygen generally increases as water temperatures decrease, however this pattern may be due to a drop in flow rate that occured over this time (Table 2). Site 2 showed an increase in dissolved oxygen, most likely due to the regulation of flow by Brennan Lake.

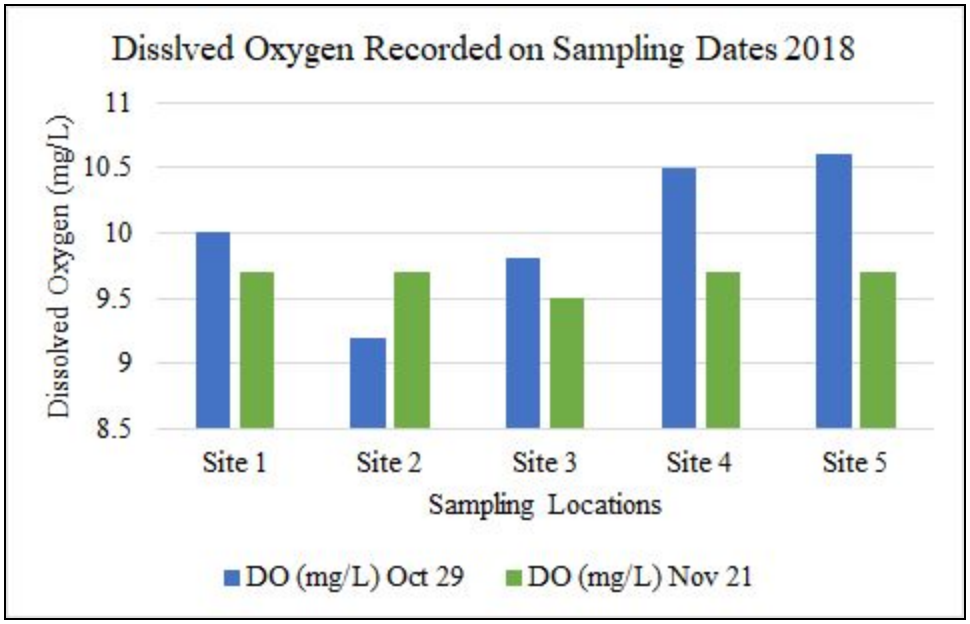

Figure 4: Dissolved oxygen recorded during two sample dates (October 29 and November 21, 2018).

The dissolved oxygen levels shown in figure 4 are above the minimum guideline of 9.0 mg/L for early fish life stages, according to the Ministry of Environment, Land and Parks – MELP – (1998).

Water Quality - VIU Lab Analysis

pH

During laboratory analysis, Potential Hydrogen (pH) ranged from 7.3 - 7.5 during the first sampling event and 7.3 - 7.6 during the second sampling event. Both sampling events showed high pH values in Sites 1 and 2 and decreased beginning at Site 3. All pH levels fell comfortably within aquatic life criteria of 6.5-9.0 (MELP, 1998).

Conductivity

Conductivity increased gradually from Sites 1 through 5 on each of the sampling dates as shown in figures 5 and 6. On the first sampling event, conductivity increased from 27 µS/cm at

Site 1 to 148 µS/cm at Site 5. Following a similar pattern, during the second sampling event it increased from 36 µS/cm to 114 µS/cm. This pattern is due to an increase in dissolved ions obtained from the substrate, as the water flows downstream.

Alkalinity

Alkalinity also increased on both events (Figures 5 and 6). On October 29, levels ranged from 7.5 mg/L at Site 1 to a peak of 32.8 mg/L at Site 4, then decreasing slightly at Site 5 to 30 mg/L. During the November 21 event, a similar model was observed ranging from 14.6 mg/L to 36 mg/L, then again decreasing slightly at Site 5 to 35.2 mg/L. Average alkalinity levels for sampling events 1 and 2 were 25 mg/L and 26.8 mg/L respectively. According to the water quality guidelines (MELP, 1998) Site 1 at Benson Creek has high acid sensitivity, whereas acid sensitivity at Sites 2 - 5 on the Millstone River is low.

Hardness

Hardness values also increased downstream, however there was a noticable difference between events. Sites 1 - 5 ranged from 16 mg/L to 112 mg/L during the October sampling event (Figure 5) but only 18 mg/L to 48 mg/L during the November event (Figure 6). This was most likely caused by a "washout", a rainfall occurring prior to the first sampling event, pushing dissolved, bicarbonate minerals downstream. With all of the samples being less than 120 mg/L the water quality guidelines (MELP 1998), state that it cannot be determined soft. During regular flows, water at all sites was found to be soft and after washouts it was still only marginal.

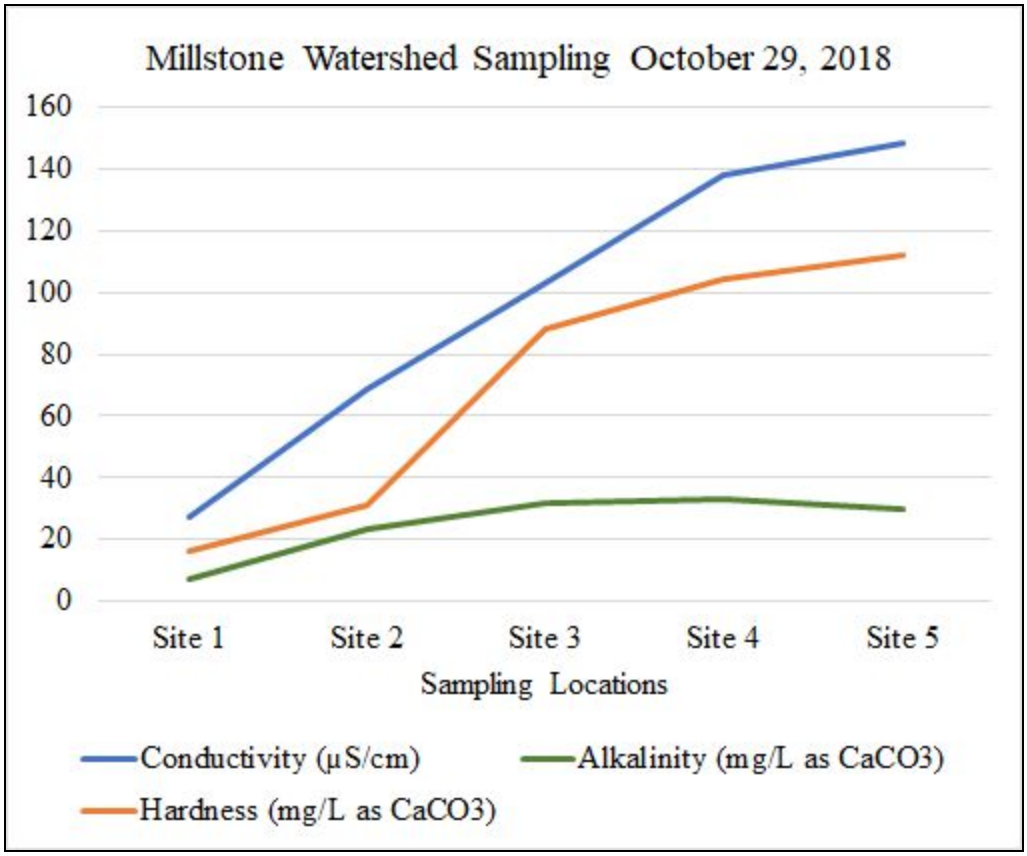

Figure 5: Increasing conductivity, alkalinity and hardness observed from samples collected on October 29, 2018

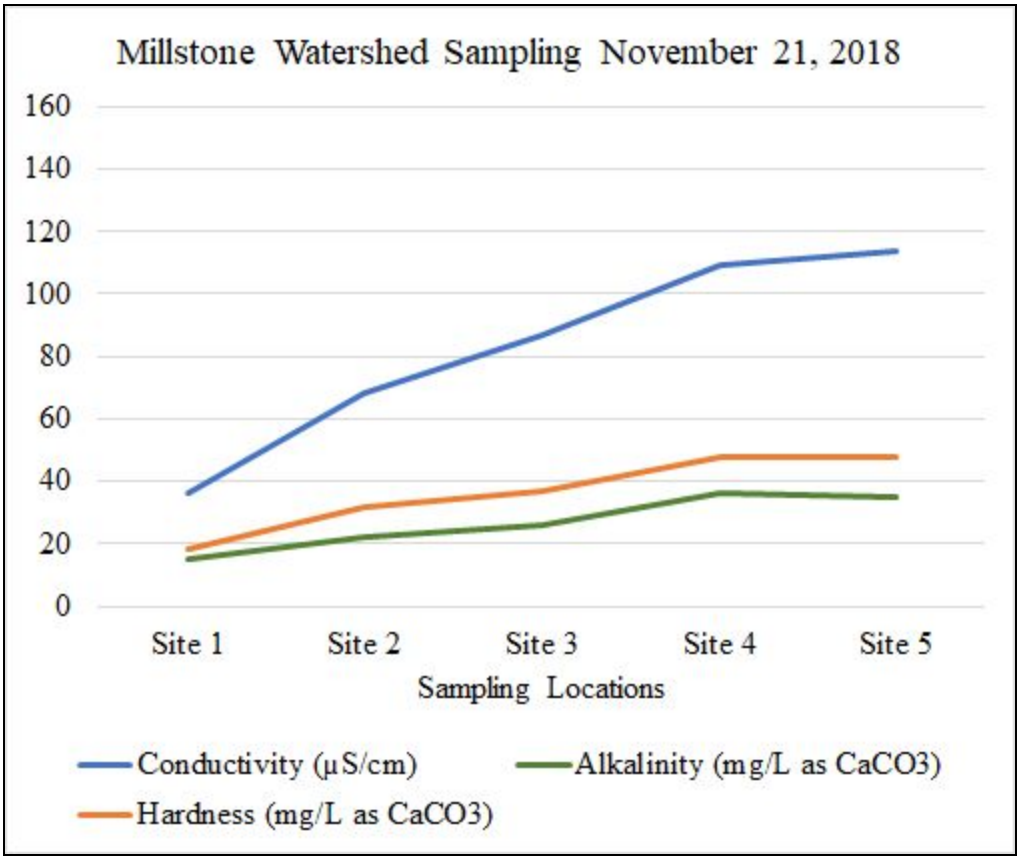

Figure 6: Increasing conductivity, alkalinity and hardness observed from samples collected on November 21, 2018

Turbidity

There were some variations to the levels found between the two sampling events conducted on October 29, 2018 and November 21, 2018. During the first sampling event, levels were much higher, specifically in Sites 1, 3 and 5 with an average of 2.7 NTU. The second sampling event measured average levels of 1.6 NTU. Sites 2 and 4 measured nearly the same on both sampling events (Figure 7). As mentioned previously, they are both located after water reservoirs which allows any turbidity in the water to settle prior to outflow.

There was no increase higher than 5 NTU during any of the sampling events, as stipulated by the guidelines for aquatic life, when the background is equal or lesser than 50 NTU

(MELP, 1998).

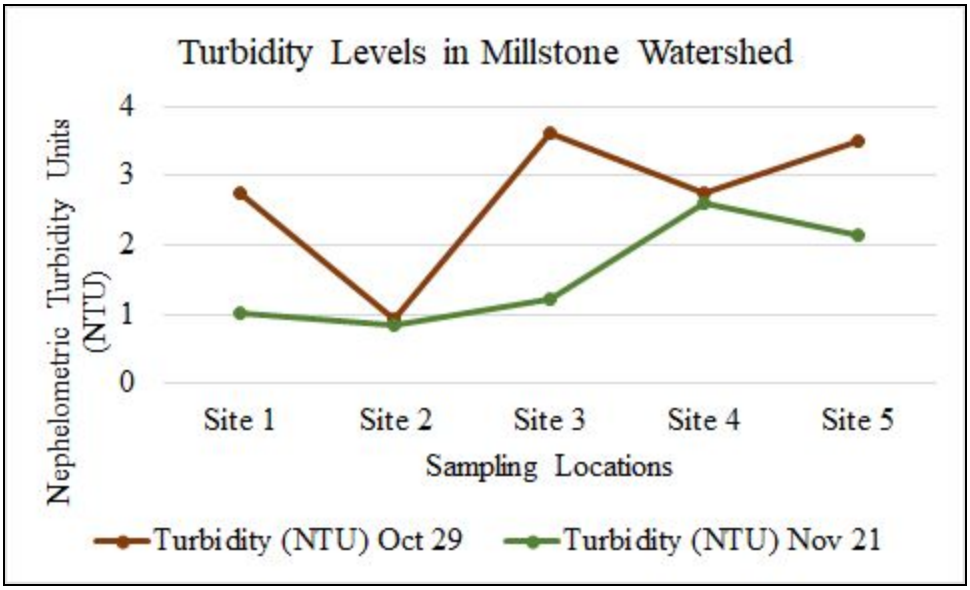

Figure 7: Turbidity levels measured during sampling events on October 29, 2018 and November 21, 2018.

Nitrate

Levels of Nitrate (NO_3^-) were tested in the VIU laboratory following water sampling events in the Millstone Watershed on October 29 and November 21, 2018. Analysis of nitrate levels found from the first sampling event ranged from 0.01 mg/L - 0.25 mg/L, with an average of 0.148 mg/L. The second sampling event saw levels raging from 0.11 mg/L - 0.43 mg/L and averaging 0.268 mg/L. In general, levels were higher during the second event, however sampling at Site 1 showed a slightly higher level during the first event. Site 2 displayed a large drop in levels on both events due to it being located immediately downstream from Brannen Lake. Levels were the lowest in this survey at this location with concentrations of 0.01 mg/L and 0.11 mg/L. Moving downstream from Site 2, levels increased until the gradually decreasing again around Sites 3 and 4. The nitrate levels documented during the two events suggest that an

increase in urban/rural runoff carrying organic compounds (sewage) may be responsible for the results observed.

All nitrate results were well under the aquatic life criteria that establishes a maximum concentration of 200 mg/L and average of 40 mg/L (MELP 1998).

Total Phosphate

Low levels of total phosphate were observed during analysis of water samples taken on both sampling events. Event 1 had levels ranging from 0.03 mg/L to 0.09 mg/L and Event 2 from 0.01 mg/L - 0.06 mg/L. The increase in water flow caused by the rain on October 27 and 28 may have introduced decaying organic matter into the Millstone watershed from its banks, causing the increase in phosphorus. While interpreting the ALS and VIU laboratory results as well following the BC Water Quality Guidelines (MELP 1998), it was determined that the Millstone watershed is very dynamic. The ALS results showed the Millstone to be oligotrophic/mesotrophic and the VIU results showed it to be mesotrophic/eutrophic. The one constant in both event was the familiar drop in levels at Site 2 downstream from Brennan Lake.

ALS Lab Results and Discussion

ALS samples were taken during the same sampling events as VIU and displayed consistent methodology and execution of collection and processing. ALS results were restricted to Site's 1,2 and 4. The samples were compared to the BC Water Quality Guidelines for aquatic life (MELP 1998) to verify the overall health of the Millstone. Results were compared to VIU's analysis to test for any variation in QC/QA. ALS's results consisted of three sections: physical tests, anions and nutrients and total metals. All parameters will be commented below and referenced to tables within the appendix. Special attention will be payed to areas exceeding the

Water Quality Guidelines (MELP 1998). ALS results will then be discussed and compared to the results from the VIU lab.

Physical Tests

In the first sampling event conductivity was observed to increase from Site 1(34.2 µS/cm) to Site 4(149 µS/cm) (table 4). During the second sampling event there was a decrease in Site 2(77.7 to 76 µS/cm) and Site 4's (149 to 120 µS/cm) conductivity with Site 1 increasing(42.9 µS/cm) (table 5). A decreasing trend in conductivity was observed in previous years sampling of the the Millstone. The trend is likely due to increasing water levels/flow later in the season. 2018's sampling event did not see significant water level change which is likely the cause of the results observed.

Hardness displayed similar behavior to conductivity from Site 1(15.1 mg/L) to Site 4(49.5 mg/L) showing an increase (tables 4 and 5). Hardness showed a decrease in all but Site 1(changed by 2 mg/L) in the second sampling event. Hardness results for all sites stayed at <60 mg/L which classifies all Sites as having "soft water" (tables 4 and 5) (MELP 1998).

pH was observed to increase from Site 1(7.07 pH) to Site 4(7.66 pH) and this was a consistent trend in the first sampling event (table 4). In the second sampling event pH was observed to increase becoming more alkaline within all three Sites. All sites pH on both events was well within the Water quality Guidelines for Aquatic Life (MELP 1998).

Anions and Nutrients

Ammonia in the first sampling event was below the detection limit in all Sites (MELP 1998) but Site 4 (0.0060 mg/L) (table 4). For the second sampling event ammonia was below the detection limit in Sites 2 and 4 but was above in Site 1 (0.0078 mg/L)(MELP 1998)(table 5). The Water Quality Guidelines (MELP 1998) show a variable maximum amount of ammonia based on pH and temperature ranging between 19.7-23.2 mg/L, from this it was determined that all Sites are well within the guidelines.

Nitrate was highest during the first event in Site 4 (0.43 mg/L)(table 4) this is likely due to the presence of the duck pond in Bowen Park, as this location produced a high amount of fecal matter. At the beginning of the project it was presumed that there would be higher levels of both nitrate and phosphorus in Sites 1 and 2 as they are both located in agricultural areas. The trend was suspected but not observed, as both Sites 1 and 2 showed lower levels of both elements. During the second sampling event lower levels of nitrate were observed in Site 4 (0.236 mg/L)(table 5) but still higher than the other two Sites. Results of both tests had all Sites within the Water Quality guidelines of <200 mg/L (MELP 1998).

Nitrite was slightly above the minimum detection limit during the first sampling event for Site 4 (0.0016 mg/L)(table 4). All other Sites in the first event showed below the Minimum detection limit of 0.0600 mg/L (MELP 1998) and all Sites in the second event showed the same.

Orthophosphate was above the minimum detection limit of 0.0010 mg/L in Site 4 (0.0049 mg/L) (table 4) during the first sampling event. All other Sites in the event were below. In the second event, Site 4 (0.0032 mg/L) and Site 1 (0.0011 mg/L) were observed above the minimum

detection limit (table 5) (MELP 1998). Orthophosphates presence is related to algae blooms, which makes sense as a large amount of brown algae is observable in Site 4 the duck pond.

Total phosphorus similar to nitrate was expected to be higher in Sites 1 and 2. There is potential for there be an increase if the tests were conducted directly after a heavy rainfall event as runoff from the agricultural area may increase the detectable amount. The three classifications for total phosphorus are oligotrophic (<0.010 mg/L), mesotrophic (0.010-0.025 mg/L) and eutrophic (≥0.025 mg/L) (MELP 1998). Of the surveyed Sites in event 1 Site 1(0.0210 mg/L) was classified as mesotrophic, Site 2(0.0075 mg/L) oligotrophic and Site 4(0.0235 mg/L) mesotrophic(table 4). For Sampling event 2 Site 1(0.0027 mg/L) classified as oligotrophic, Site 2(0.0054 mg/L) also was oligotrophic and Site 4(0.0198 mg/L) was mesotrophic(table 5).

Total Metals

Aluminum during the first sampling event exceeded the maximum guidelines of 0.10 mg/L when pH ≥ 6.5 in Site 1(0.21 mg/L) and Site 4(0.024 mg/L) (table 4) but was below detection limits (MELP 1998) in Site 2. This trend did not continue into the second event as all Sites showed below detection limits for aluminum (table 5).

The amount of calcium is related to the stream's ability to tolerate acid concentration and is rated by 3 classifications: high sensitivity(≤4 mg/L), moderate sensitivity(4-8 mg/L) and low sensitivity(≥8 mg/L) (MELP 1998). For the first sampling event Site 1(4.20 mg/L) was the only Site that did not have a low sensitivity to acid (table 4). For the second sampling event calcium was classified as Site 1 having moderate sensitivity, Site 2 low and Site 4 low (table 5).

VIU vs ALS

The following figures reflect the change observed when comparing ALS and VIU's Physical tests for Sampling event 1 and 2.

Figure 8: Comparison of VIU and ALS Results

When comparing the VIU lab analysis to ALS's results there is some variation in almost all measurements (figure 8). For both sampling events VIU showed lower conductivity than the

results from ALS, this likely has more to do with higher level of accuracy in testing done at the ALS lab and not a quality control error as the results stayed consistent. VIU's analysis showed hardness for Site 4 at 104 mg/L where ALS was 49.5 mg/L this shows there may have been a QC error in either the sampling process at Site 4 or the analysis done at the VIU lab for this sample (figure 8). This is supported by the second sampling event which showed some variation in hardness but by a far less significant number. Finally, pH showed variation in both events. The first event showed VIU's Site 1 and 2 pH higher than ALS's results while Site 4 showed ALS with a higher pH (figure 8). In the second event Site 2 and 4 under the VIU analysis were higher with Site 1 being lower. The variation seen is not enough to bring QC into question as the differences were <0.6 pH. All Site's results remained within the Water Quality Guidelines.

Microbiology

On October 29, 2018 microbiology samples were collected following the procedures explained in the methods portion of this report. Samples were taken from all five sites to determine presence and proportion of fecal and non-fecal coliform. Results are shown in table 3 and figure 9.

Table 3: Coliform analysis results from sampling on October 29, 2018.

Site	Fecal (CFU/100ml)	Non-Fecal (CFU/100ml)	Total Coliform (CFU/100ml)	Percent Fecal (%)
1	20	313	323	6
2	20	141	161	12
3	71	545	616	12
4	61	293	354	17
5	40	413	453	9
*Replicate	20	414	434	5

*Replicate sample taken from Site 1.

No definite pattern was found when analyzing the fecal and non-fecal coliform results obtained from sampling activities on October 29, 2018. Sites 1 and 2 showed the lowest amount of fecal coliform as well as total coliform, however the proportion of fecal coliform to non-fecal coliform in Site 2 was quite high at 12 %. As the stream passes through the agricultural areas of Sites 1 through 3, fecal coliform abundance and proportion rises. Surprisingly, the total coliform count in Site 4, the Bowen Park duck pond was similar to that of Benson Creek. The difference though is the total proportion of fecal coliform present at 17 %, the most of all five sites. Downstream of Bowen Park, at Site 5, non-fecal coliform was present in relatively high abundance however fecal coliform counts began to decrease and the proportions were quite low at 9 %.

According to the guidelines for interpreting water quality data, water from the Millstone could be used for general livestock use, irrigation, and recreation (MELP, 1998).

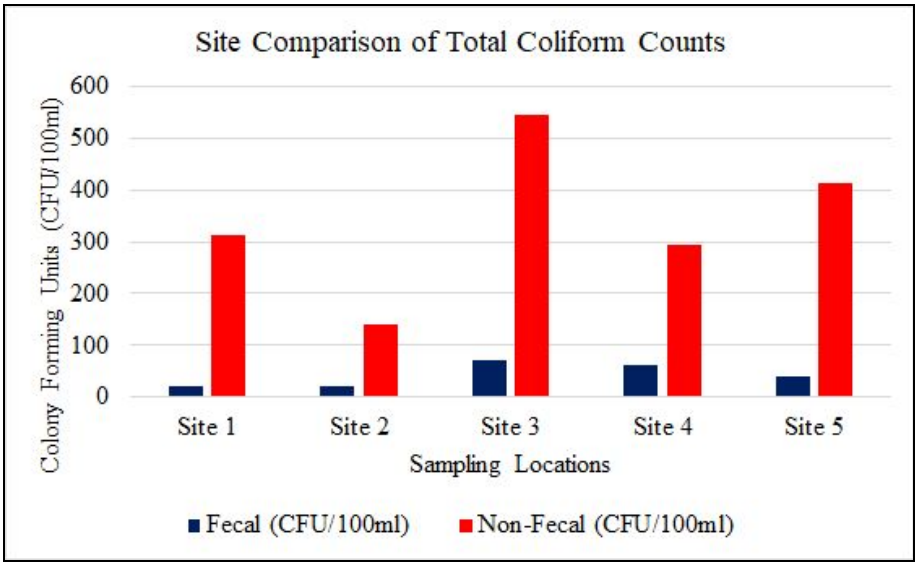

Figure 9: Presence of fecal and non-fecal coliform documented from October 29 sampling activities in Millstone Watershed.

Invertebrates

As stated previously in the methods section, invertebrate sampling was conducted three times each at three different sites for a total of nine samples. The sampling was done at site 1 (Benson Creek at Biggs Road.), site 2 (Millstone River at Biggs Road), and site 4 (downstream outlet of the Bowen Park duck pond). The invertebrate sampling at site 1 resulted in the collection of 34 Stonefly Nymphs, 17 Aquatic Worms, and 14 Cranefly Larva (figure 10). Site 1 had 34 invertebrates which were pollution intolerant, 14 that were somewhat pollution tolerant, and 19 that were pollution tolerant. A total of 7 taxa were counted for this site. This site had a high percentage of EPT species at 52%, which can be indicative of lower pollution levels. The Pollution Tolerance Index was 13 (Marginal), the EPT Index was 2 (Marginal), and the EPT to Total Ratio Index and the Predominant Taxon Ratio Index were both 0.523 (Acceptable). The invertebrate density per total area sampled was 722.2 per square metre. This site received an assessment rating of 2.5, which was also the highest of all of our sites and carries a classification of marginal to acceptable. The Shannon-Weiner diversity index score for site 1 was 0.929. Site 1 probably experiences lower pollution levels because it is a quieter agricultural area and receives less traffic, coupled with less pollution from runoff than our site near downtown Nanaimo would get.

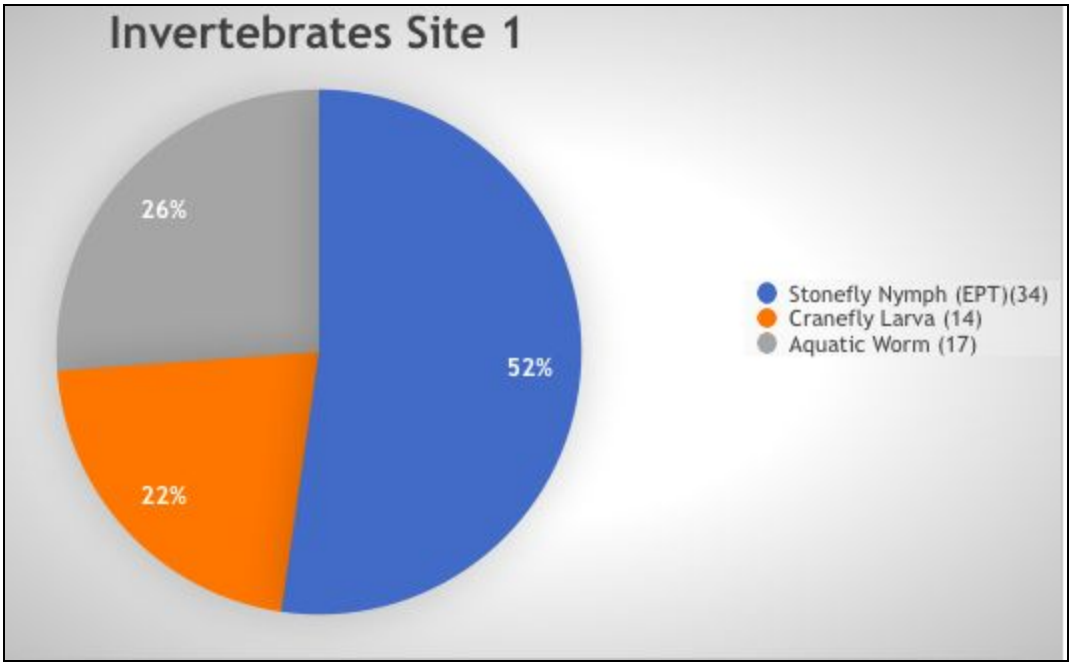

Figure 10: Invertebrates Counts for Site 1

The next site at which invertebrate sampling was conducted was site 2, which was where Biggs Road crosses the Millstone River. The invertebrate count for this site was as follows: 338 Caddisfly Larvae, 56 Aquatic Worms, 15 Amphipods, and 11 Freshwater Clams (figure 11). We counted a total of 338 pollution intolerant invertebrates, 26 that were somewhat tolerant, and 56 which were pollution tolerant. There were a total of 7 taxa counted at this site. The Invertebrate Density per Total Area Sampled was 4666.67 per square metre. This site had the highest percentage of EPT species at 80% and received a classification rating of 2.25, which is also marginal to acceptable. The Pollution Tolerance Index was 15 (Marginal), the EPT Index was 3 (Marginal), the EPT to Total Ratio Index was 0.805 (Good), and the Predominant Taxon Ratio Index was 0.805 (Poor). The Shannon-Weiner Diversity index score for site 2 was 0.475. As a side note, there was some green algae observed in the samples. As with site 1, the high number of Caddisfly larvae here could be indicative of lower pollution levels.

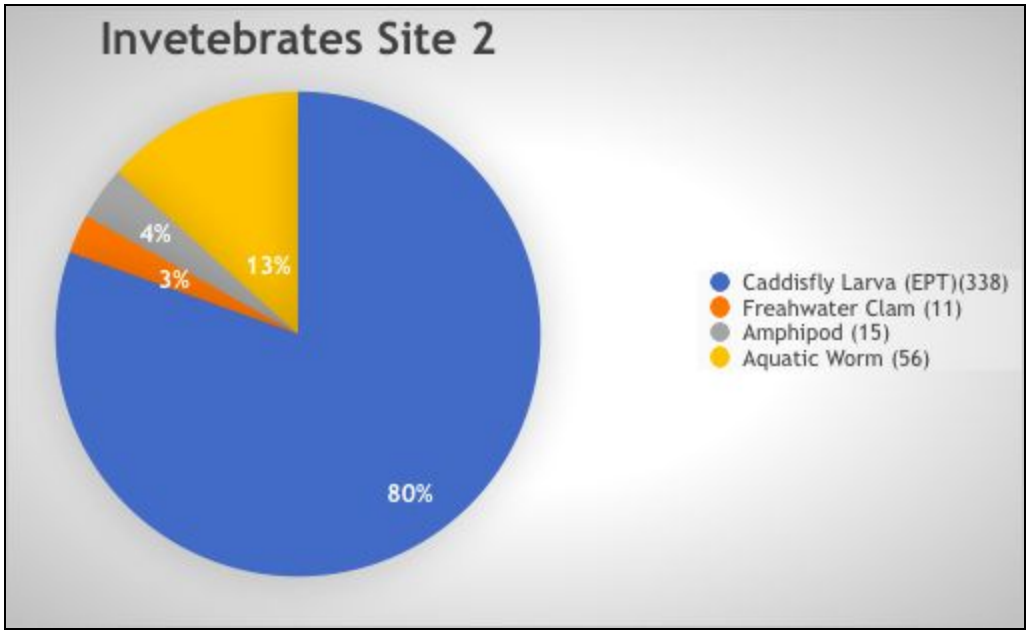

Figure 11: Invertebrate Counts for Site 2

The final site which received invertebrate sampling was site 4, which also scored the lowest rating of the three sites. We counted 215 Amphipods, 79 Aquatic Worms, 19 Dobsonflies, 5 Caddisfly Larvae, and 1 Leech (figure 12). We counted 24 pollution intolerant invertebrates, 215 that were somewhat pollution tolerant, and 80 which were pollution tolerant. There were a total of 10 taxa counted at this site. The Invertebrate Density per Total Area Sampled was 3544.44 per square metre. This site had a large percentage of worm and Amphipod species, while EPT species only constituted 2% of the invertebrates collected. The Pollution Tolerance Index was 18 (Acceptable), the EPT Index was 1 (Poor), the EPT to Total Ratio Index was 0.015 (Poor), and the Predominant Taxon Ratio Index was 0.67 (Marginal). Site 4 received an assessment rating of 1.75, which translates to poor bordering on marginal. The Shannon-Weiner

Diversity Index score for site 4 was 0.616. This could be indicative of higher pollution levels, which is consistent with the high conductivity observed at this site.

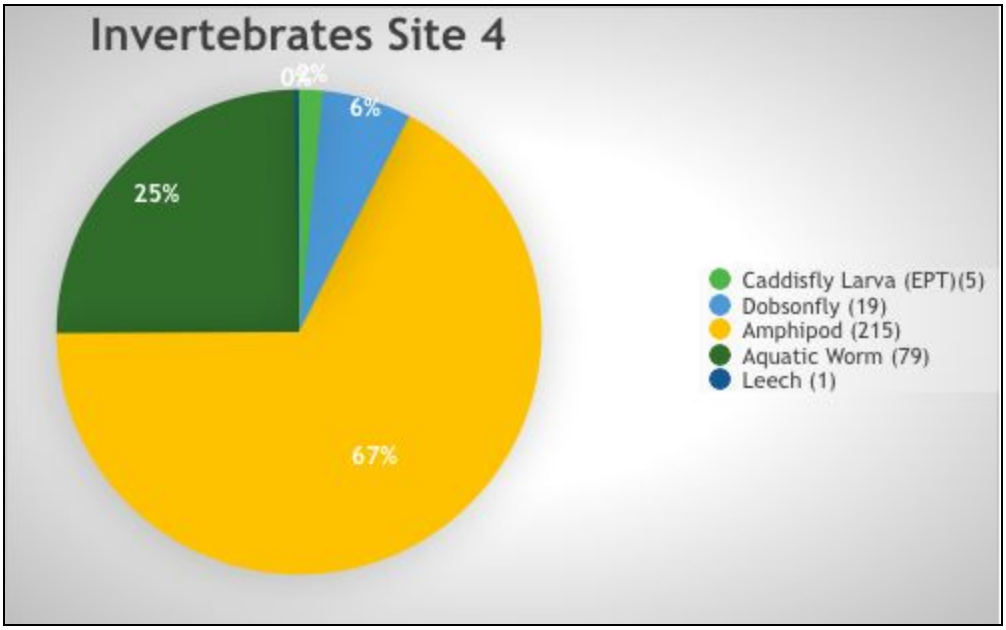

Figure 12: Invertebrate Counts for Site 4

Conclusion

The 2018 water quality results for the Millstone River showed all parameters sampled to be within the Water Quality Guidelines for Aquatic Life (MELP 1998). The health of the stream is consistent with previous years sampling efforts(Demers 2016). Invertebrate results showed stream health to be lowest in Site 4, however the area still manages to support productive salmon runs of chum, coho and steelhead salmonids. All Sites showed positive results for fecal coliform, with SIte 4 showing the highest amount. Unlike previous sampling events aluminum was only detected above the minimum detection limit during the first sampling event in Site 4. In the second sampling event aluminum was below the minimum detection limit. ALS and VIU lab results were compared and a large variation in water hardness was observed during the first

sampling event. Having reviewed these findings, QA and QC were considered and no significant variation was observed during the second sampling event.

Recommendations

Since 2006, a great deal of work has gone into surveying the Millstone Watershed. Through sampling activities and surveys compiled from various agencies, there is a large amount of data archived. Having this data helps in the continuing process of keeping this water system healthy for years to come.

With greater finances, additional opportunities to conduct sampling could take place. Increased sampling efforts would give a better representation of the Millstone Watershed as a whole. When sampling water quality, increasing the amounts of sites could be beneficial. Creating additional sites in tributaries and within the current survey area would allow one to find out precisely where chemical changes occur. One of the areas which saw a lot of the change was in Bowen Park. Another site at the inflow to the duck pond could determine if the changes observed were due to the pond itself or upstream characteristics.

Increasing invertebrate sampling activities at Sites 1 – 5 could give you a better depiction of the invertebrate life within the river. These activities could be spread across the width of the river so shallow water and deeper water areas would be included. Increasing replicates of water quality and invertebrates would increase the confidence in the samples analyzed.

Acknowledgements

We would like to take this opportunity to thank Dr. Eric Demers of Vancouver Island University for his assistance and guidance throughout this project. We would also like to

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Appendices
Appendix 1: Site Photos

Photo 1: View of access to Site 1 at the downstream side of Briggs Rd bridge.

Photo 2: View upstream of Benson Creek at Site 1.

Photo 3: View downstream of Benson Creek at Site 1.

Photo 4: View of downstream side of Briggs Rd bridge at Site 2.

Photo 5: View upstream at Site 2 on the Millstone River.

Photo 6: View downstream from Site 2 on the Millstone River.

Photo 7: View of access to Site 3 on the downstream side of the Durnin Rd. bridge.

Photo 8: View upstream from the north side of the Durnin Rd bridge at Site 3.

Photo 9: View from the right bank showing increase in flow velocity downstream of the Durnin Rd bridge at Site 3.

Photo 10: View of the Bowen Park duck pond from the upstream side of the bridge at Site 4.

Photo 11: View downstream from the Site 4 pedestrian bridge.

Photo 12: View upstream from the right bank of the Millstone River at Site 5.

Appendix 2: ALS Results
Table 4: ALS Sampling event 1

Physical Tests	Units	Site 1	Site 2	Site 4	Guidelines
Conductivity	uS/cm	34.2	77.7	149	-
Hardness (as CaCO3)	mg/L	15.1	32.2	49.5	-
pH	pH	7.07	7.35	7.66	6.5-9.0

Anions and Nutrients	Units	Site 1	Site 2	Site 4	Guidelines
Ammonia, Total (as N)	mg/L	<0.0050	<0.0050	0.0060	19.7 - 23.2
Nitrate (as N)	mg/L	0.298	0.0081	0.435	200

Nitrite (as N)	mg/L	<0.0010	<0.0010	0.0016	0.06
Total Nitrogen	mg/L	0.527	0.187	0.691	-
Orthophosphate-Dissolved (as P)	mg/L	<0.0010	<0.0010	0.0049	-
Phosphorus (P)-Total	mg/L	0.0210	0.0075	0.0235	-
N:P		25.1	24.9	29.4	

Total Metals	Units	Site 1	Site 2	Site 4
Aluminum (Al)-Total	mg/L	0.21	<0.20	0.24
Antimony (Sb)-Total	mg/L	<0.20	<0.20	<0.20
Arsenic (As)-Total	mg/L	<0.20	<0.20	<0.20
Barium (Ba)-Total	mg/L	<0.010	<0.010	0.020
Beryllium (Be)-Total	mg/L	<0.0050	<0.0050	<0.0050
Bismuth (Bi)-Total	mg/L	<0.20	<0.20	<0.20
Boron (B)-Total	mg/L	<0.10	<0.10	<0.10
Cadmium (Cd)-Total	mg/L	<0.010	<0.010	<0.010
Calcium (Ca)-Total	mg/L	4.20	8.62	14.4
Chromium (Cr)-Total	mg/L	<0.010	<0.010	<0.010
Cobalt (Co)-Total	mg/L	<0.010	<0.010	<0.010

Copper (Cu)-Total	mg/L	<0.010	<0.010	<0.010
Iron (Fe)-Total	mg/L	0.187	0.150	0.511
Lead (Pb)-Total	mg/L	<0.050	<0.050	<0.050
Lithium (Li)-Total	mg/L	<0.010	<0.010	<0.010
Magnesium (Mg)-Total	mg/L	1.13	2.59	3.31
Manganese (Mn)-Total	mg/L	0.0064	0.0215	0.0389
Molybdenum (Mo)-Total	mg/L	<0.030	<0.030	<0.030
Nickel (Ni)-Total	mg/L	<0.050	<0.050	<0.050
Phosphorus (P)-Total	mg/L	<0.30	<0.30	<0.30
Potassium (K)-Total	mg/L	<2.0	<2.0	<2.0
Selenium (Se)-Total	mg/L	<0.20	<0.20	<0.20
Silicon (Si)-Total	mg/L	3.81	3.09	4.08
Silver (Ag)-Total	mg/L	<0.010	<0.010	<0.010
Sodium (Na)-Total	mg/L	<2.0	5.0	13.5
Strontium (Sr)-Total	mg/L	0.0171	0.0361	0.107
Thallium (Tl)-Total	mg/L	<0.20	<0.20	<0.20
Tin (Sn)-Total	mg/L	<0.030	<0.030	<0.030
Titanium (Ti)-Total	mg/L	<0.010	<0.010	0.014

Vanadium (V)-Total	mg/L	<0.030	<0.030	<0.030	
Zinc (Zn)-Total	mg/L	<0.0050	<0.0050	<0.0050	

Table 5: ALS Sampling event 2:

Physical Tests	Units	Site 1	Site 2	Site 4	Guidelines
Conductivity	uS/cm	42.9	76.0	120	-
Hardness (as CaCO3)	mg/L	17	29.8	41.5	-
pH	pH	7.44	7.65	7.84	6.5-9.0

Anions and Nutrients	Units	Site 1	Site 2	Site 4	Guidelines
Ammonia, Total (as N)	mg/L	0.0078	<0.0050	<0.0050	19.7 – 23.2
Nitrate (as N)	mg/L	0.211	0.0847	0.236	200
Nitrite (as N)	mg/L	<0.0010	<0.0010	<0.0010	0.06
Total Nitrogen	mg/L	0.323	0.269	0.484	-
Orthophosphate-Dissolved (as P)	mg/L	0.0011	<0.0010	0.0032	-
Phosphorus (P)-Total	mg/L	0.0027	0.0054	0.0198	-
N:P	N/A	119.6	49.8	24.4	

Total Metals (Water)	Units	Site 1	Site 2	Site 4

Aluminum (Al)-Total	mg/L	<0.20	<0.20	<0.20
Antimony (Sb)-Total	mg/L	<0.20	<0.20	<0.20
Arsenic (As)-Total	mg/L	<0.20	<0.20	<0.20
Barium (Ba)-Total	mg/L	<0.010	<0.010	0.012
Beryllium (Be)-Total	mg/L	<0.0050	<0.0050	<0.0050
Bismuth (Bi)-Total	mg/L	<0.20	<0.20	<0.20
Boron (B)-Total	mg/L	<0.10	<0.10	<0.10
Cadmium (Cd)-Total	mg/L	<0.010	<0.010	<0.010
Calcium (Ca)-Total	mg/L	4.76	8.02	11.8
Chromium (Cr)-Total	mg/L	<0.010	<0.010	<0.010
Cobalt (Co)-Total	mg/L	<0.010	<0.010	<0.010
Copper (Cu)-Total	mg/L	<0.010	<0.010	<0.010
Iron (Fe)-Total	mg/L	0.033	0.098	0.354
Lead (Pb)-Total	mg/L	<0.050	<0.050	<0.050
Lithium (Li)-Total	mg/L	<0.010	<0.010	<0.010
Magnesium (Mg)-Total	mg/L	1.25	2.36	2.96
Manganese (Mn)-Total	mg/L	<0.0050	0.0163	0.0314

Molybdenum (Mo)-Total	mg/L	<0.030	<0.030	<0.030
Nickel (Ni)-Total	mg/L	<0.050	<0.050	<0.050
Phosphorus (P)-Total	mg/L	<0.30	<0.30	<0.30
Potassium (K)-Total	mg/L	<2.0	<2.0	<2.0
Selenium (Se)-Total	mg/L	<0.20	<0.20	<0.20
Silicon (Si)-Total	mg/L	3.97	3.24	3.85
Silver (Ag)-Total	mg/L	<0.010	<0.010	<0.010
Sodium (Na)-Total	mg/L	<2.0	3.7	8.5
Strontium (Sr)-Total	mg/L	0.0189	0.0316	0.0807
Thallium (Tl)-Total	mg/L	<0.20	<0.20	<0.20
Tin (Sn)-Total	mg/L	<0.030	<0.030	<0.030
Titanium (Ti)-Total	mg/L	<0.010	<0.010	<0.010
Vanadium (V)-Total	mg/L	<0.030	<0.030	<0.030
Zinc (Zn)-Total	mg/L	<0.0050	<0.0050	<0.0050

Appendix 3: Invertebrate Sampling Sheets

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: M. Ugstone			Date: Oct. 29, 2018
Station Name: 1			Flow status: Low
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.09 m^2	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)	EPT1	EPT4
	Mayfly Nymph (EPT)	EPT2	EPT5
	Stonefly Nymph (EPT)	EPT3 34	EPT6 2
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 34	D1 2
Category 2 Somewhat Pollution Tolerant	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	14	2
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)		
	Watersnipe Larva		
Sub-Total		C2 14	D2 2
Category 3 Pollution Tolerant	Aquatic Worm (oligochaete)	17	3
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 17	D3 3
TOTAL		CT 65	DT 7

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

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

CT: 65

DENSITY: Invertebrate density per total area sampled:

65 ÷ From page 1: 0.09 m^2 = 722.2 / m^2

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (in Col. C)

S1: Stonefly Nymph (34)

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 2 + 2 x 2 + 3 =

S2: 13

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

0 + 0 + 2 =

S3: 2

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

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

(EPT1 + EPT2 + EPT3) / CT

(0 + 0 + 34) / 65 =

S4: 0.523

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** (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

34 / 65 =

S5: 0.523

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

Average Rating
Average of R1, R2, R3, R4
2.5

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Millstone			Date: Oct. 29, 2018
Station Name: 2			Flow status:
Sampler Used: Hess	Number of replicates: 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates: 0.09 m^2	m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	EPT1 338	EPT4 3
	Mayfly Nymph (EPT)	EPT2	EPT5
	Stonefly Nymph (EPT)	EPT3	EPT6
Pollution Intolerant	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 338	D1 3
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel	11	1
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	15	1
	Watersnipe Larva		
Sub-Total		C2 26	D2 2
Category 3	Aquatic Worm (oligochaete)	56	2
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
Pollution Tolerant	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 56	D3 2
TOTAL		CT 420	DT 7

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

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

CT: 420

DENSITY: Invertebrate density per total area sampled:

420 ÷ From page 1: 0.09 m^2 = 4666.67 $/m^2$

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (in Col. C)

S1: Caddisfly Larva 338

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 2 + 2 = S2: 15

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

3 + 0 + 0 = 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

(338 + 0 + 0) / 420 = S4: .805

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** (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

338 / 420 = S5: .805

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

Average Rating

Average of R1, R2, R3, R4

2.25

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Millstone			Date: Oct 29, 2018
Station Name: 4			Flow status:
Sampler Used: Hess	Number of replicates: 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates: 0.09 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)	EPT1 5	EPT4 1
	Mayfly Nymph (EPT)	EPT2	EPT5
	Stonefly Nymph (EPT)	EPT3	EPT6
	Dobsonfly (hellgrammite)	19	1
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 24	D1 2
Category 2 Somewhat Pollution Tolerant	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	215	4
	Watersnipe Larva		
Sub-Total		C2 215	D2 4
Category 3 Pollution Tolerant	Aquatic Worm (oligochaete)	79	3
	Blackfly Larva		
	Leech	1	1
	Midge Larva (chironomid)		
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 80	D3 4
TOTAL		CT 319	DT 10

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

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

CT: 319

DENSITY: Invertebrate density per total area sampled:

319 ÷ 0.09 (From page 1) m^2 = 3544.44 $/m^2$

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (in Col. C)

S1: Amphipod

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 2 + 2 x 4 + 4 =

S2: 18

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

1 + 0 + 0 =

S3: 1

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

(5 + 0 + 0) / 319 =

S4: 0.015

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

215 / 319 =

S5: 0.67

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

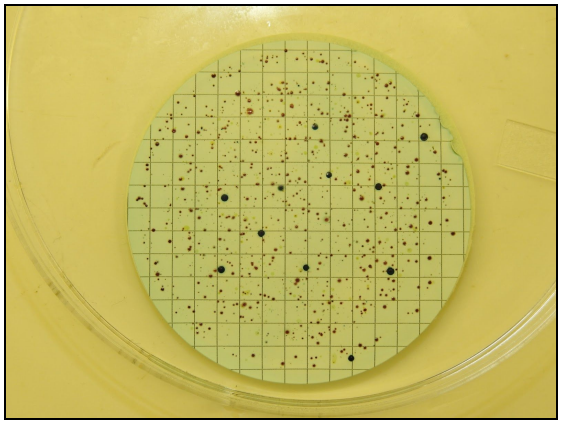
Assessment	Rating
Pollution Tolerance Index	R1 3
EPT Index	R2 1
EPT To Total Ratio	R3 1
Predominant Taxon Ratio	R4 2

Average Rating

Average of R1, R2, R3, R4

1.75

Appendix 4: Bacterial Growth Plates



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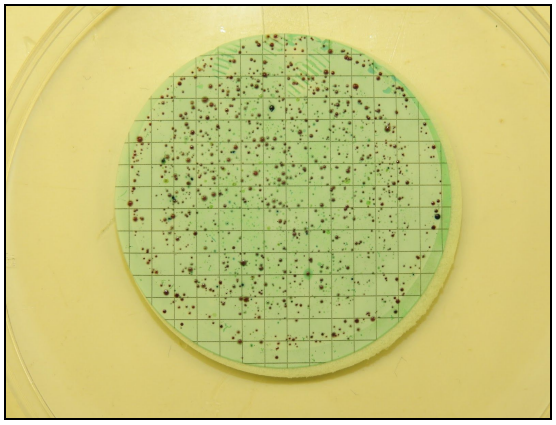
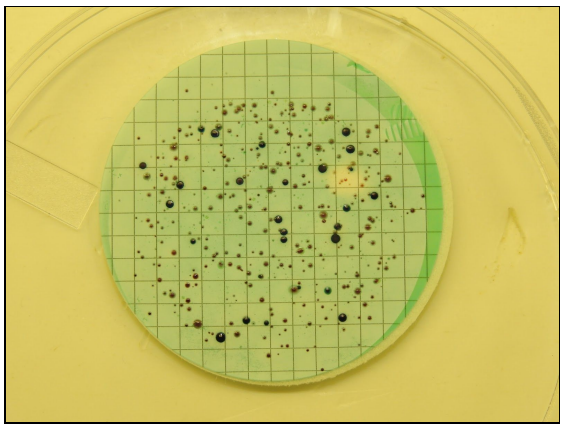
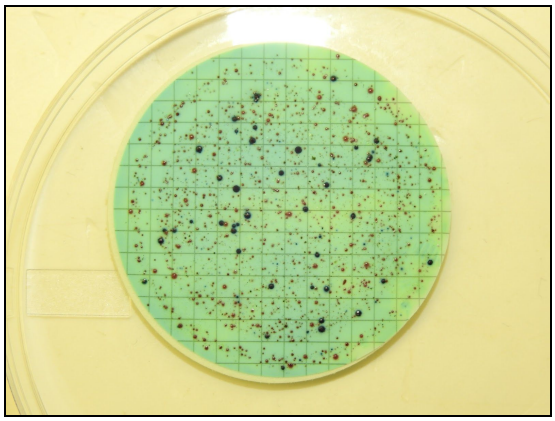


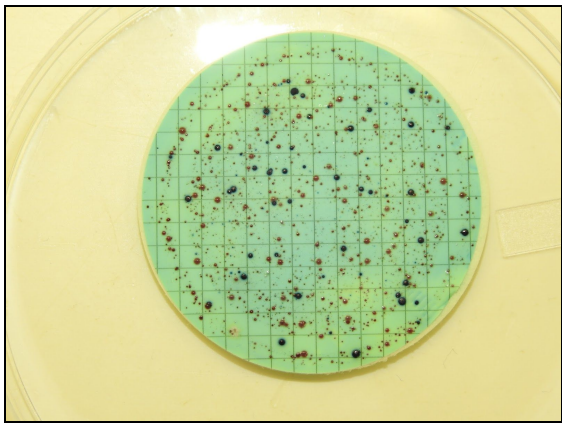
Site 1 (replicate)



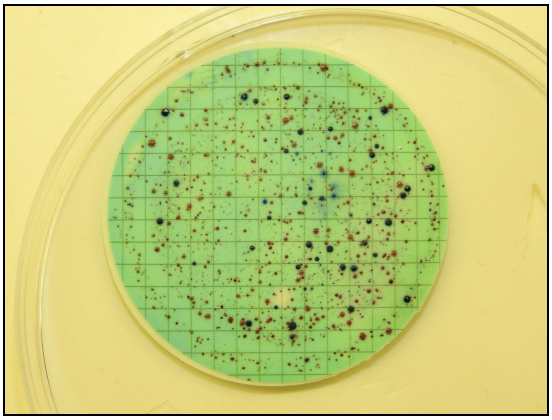
Site 2



Site 3



Site 4



Site 5