DATA REPORT

Water quality and stream invertebrate assessment for the Millstone River, Nanaimo, BC

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1.0 EXECUTIVE SUMMARY

Four students from Vancouver Island University conducted a water quality and stream invertebrate assessment project on the Millstone River in Nanaimo, BC. The Millstone River is an urban stream which flows from Brannen Lake to the Nanaimo inner harbour. It supports an annual run of Coho Salmon and is at risk from residential, agricultural, and commercial activities occurring throughout its run. Six sampling stations were identified for the study including a control site on nearby Benson Creek. Sampling occurred during two separate events; the first sampling event occurred on November 2, 2015, and the second sampling event occurred on November 23, 2015. Testing of the samples was conducted in the laboratory at VIU as well as at ALS Laboratories in Burnaby, BC. Water quality parameters tested included temperature, dissolved oxygen, conductivity, pH, alkalinity, hardness, turbidity, coliform, nitrates, and reactive phosphorus. Hydrology parameters were assessed in the field. Invertebrate samples were analyzed in the lab at VIU and used to assess the health of the habitat in the river. ALS Laboratories also tested samples from selected locations for total metals and nutrients. The testing revealed that the Millstone River meets the water quality guidelines for aquatic life established by the province of British Columbia for most parameters. Water temperatures were highest in the headwaters of the river, and decreased progressively downstream. Dissolved oxygen, conductivity, alkalinity, hardness, and turbidity generally increased as the river progressed downstream in both events. During the first event, the river was mostly oligotrophic and had a low sensitivity to acid. Nitrate levels in the Benson Creek site were significantly higher than any site in the Millstone River. During the second sampling event, the increased discharge rate diluted the concentration of ions resulting in decreased conductivity, alkalinity, and hardness. Turbidity was also markedly lower during the second sampling event. The overall

site assessment rating based on invertebrate sampling was between marginal and acceptable. Coliform content was high at all sites, especially those located further downstream. Aluminum levels exceeded the guidelines in the Bowen Park duck pond, warranting further investigation. The source of the excessive nitrate in Benson Creek should also be examined more closely. Funding provided by the Regional District of Nanaimo, Fisheries and Oceans Canada, and the BC Conservation Foundation made these analyses possible, and the findings of this report will be shared with these groups.

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2.0 INTRODUCTION AND BACKGROUND

Four Vancouver Island University students in the Bachelor of Natural Resource Protection program conducted an environmental monitoring project on the Millstone River in Nanaimo, British Columbia. The students who participated in the field project included: Lorelle Sunduk, Andrew Horsfield, Herb Stark, and Andrew Simpson. The environmental monitoring project took place between October and November, 2015. Data obtained through field sampling was collected and compared to the results from previous years. This provided an indication of ecosystem health, water quality, and potential environmental impacts on the Millstone River across multiple years.

The Millstone River flows from Brannen Lake to the Nanaimo inner harbour and out into the Strait of Georgia. The total length of the river is 14 kilometres. The watershed is approximately 100 square kilometres in size and consists of 8 lakes, 16 tributaries, and 26 streams (Nanaimo, 2008). The headwaters that feed the Millstone River begin at high elevation from Lucid Lake. Water flows north from this lake via Benson Creek into Brannen Lake. The Millstone River is the outlet stream from Brannen Lake, flowing out of its south end through agricultural land for the first 12 km. The final 2 km of the river flows through Bowen Park, where the landscape changes from a meandering river bed to cascades and other reach breaks (HCRS, 2015). These obstructions caused difficulty for Coho salmon returning each fall, and led to the construction of a fish ladder. Even with the fish ladder, Coho salmon stocks in the Millstone River continued to struggle (DFO, 2015). To further assist the Coho salmon on their journey to spawn upstream, a side channel was constructed in 2007 (HCRS, 2015).

Due to its urban setting, the Millstone River is at risk of environmental degradation and a decrease in the health of its ecosystem from human activity. On our initial site walk through, we noticed numerous pieces of garbage in the river near the Barsby reach, including a rusty bicycle rim, beer cans, and a can of white acrylic paint which was leaking its contents downstream (see Appendix). Local agriculture operations draw water from Brannen Lake and the Millstone River. In the summer months, the water level in the river can become very low and water temperature increases. The combined effect of these conditions is a reduction in the amount of dissolved oxygen in the river, which can make survival of fish and other aquatic species difficult. The agricultural areas that lie along the Millstone River's path could also be leaching fertilizers and coliforms into the river, posing a threat to the ecosystem (Rolston, 2010).

In regards to the environmental monitoring project, six sample sites were established in the same locations as in years previous. Five of these sites were along the length of the Millstone River and one site was located on Benson Creek- which flows into Brannen Lake. The Benson Creek site acted as a control for water quality and other analyses. All six sites were collectively used to establish water quality, invertebrate densities, and overall ecosystem health.

3.0 PROJECT OBJECTIVE

Since 2006, third year students from Vancouver Island University's Bachelor of Natural Resource Protection program have been compiling data on the Millstone River system applicable to water quality and invertebrate life. The purpose of this project was to continue providing detailed monitoring data to Fisheries and Oceans Canada, the BC Conservation Foundation, and the City of Nanaimo. The sampling commenced from the Millstone River's headwaters at Brannen Lake to the outflow at the Nanaimo harbour estuary and included hydrology, water quality, bacteria (microbiology), and in-stream invertebrate testing. The samples provided data that will cross-examined against figures from previous years, revealing trends and assisting in the effective management of the Millstone River.

4.0 SAMPLING AND ANALYSIS PROCEDURES

4.1 Sampling Sites

Six locations have been chosen for sampling, representing the entire length of the Millstone River. A map of all the sampling sites is shown in Figure 1. Pictures taken from each site on October 14, 2015, can also be found in the Appendix. The first site, referred to as Site 1 (Figure 2), is on Benson Creek below the bridge crossing at Biggs Road (10 U 0422738 mE 5450707 mN). This site was used as the control. During the initial site visit, the creek appeared to be flashy. There was a braided channel under the bridge as well as riffle and glide habitats. There was also a pool upstream of the bridge. The substrate at Site 1 was mostly cobble, with some gravel.

Site 2 was the first site on the Millstone River (Figure 3), located just downstream of the outlet from Brannen Lake. Samples were taken from upstream of the bridge crossing on Biggs Road (10 U 0423341 mE 5450828 mN). Riffle, pool, and glide habitats were observed at this site during the initial site visit. Site 2 substrate was approximately 50% cobble, 30% gravel, and a small portion of silt.

Site 3 was located where Durnin Road crosses the Millstone River (10U 0426304 mE 5448953mN, Figure 4). Water levels were low on the day of the initial site visit, but the cut of the banks suggested a much higher water level was possible. Directly under the bridge there was a glide. Riffle and pool habitats were noted close to the bridge at Site 3. The substrate was predominantly cobble.

Site 4 (10 U 0429076 mE 5447227 mN, Figure 5) was accessed via the Pryde Vista Golf Course parking lot. The golf course granted permission for us to use their parking lot. This section of the river was a long glide. The majority of the substrate was composed of cobble.

Site 5 (Figure 6) was located within Bowen Park at the outlet of the duck pond (10 U 0430233 mE 5447304 mN). This was a high traffic site where the public education skills of the project participants were tested. A glide and a riffle habitat were observed here on the day of the initial site visit. Site 5 substrate was approximately 70% gravel.

The final site, Site 6 (10 U 0430941 mE 5447091 mN), was located at the end of Barsby Avenue below the bridge (Figure 7). This site consisted of a large glide with several riffle sections. Significant amounts of garbage were also observed in the river at this location. The substrate consisted mostly of boulders.

4.2 Hydrology

Hydrological parameters were measured at all sites. An initial assessment of stream velocity taken on October 14, 2015, indicated that low flow conditions existed. Flow conditions were reassessed during both sampling periods. Other hydrological variables that were measured included wetted width, bankfull channel width, water depth, and discharge.

4.3 Water Quality and Microbiology

A total of seven water samples will be collected for water quality assessment at VIU - one water sample from each site, and one duplicate sample from a site that will be chosen at random. The number of stations and sampling events will provide plenty of opportunity for comparison; therefore, no blank samples will be taken. A second set of samples will be taken from Site 1, Site 2, and Site 5 for separate analysis by the ALS Environmental laboratory in Burnaby. Samples were collected first on November 2, 2015, and then a second time on November 23, 2015. Dissolved oxygen (DO) and water temperature were measured and recorded on-site using electronic probes.

All samples were collected following the procedures outlined by the Government of British Columbia's Freshwater and Effluent Sampling guideline. Sampling containers were pre-labeled prior to sampling. Extra containers with blank labels were available in case pre-labelled containers became lost or contaminated. All containers were rinsed three times prior to being filled except those provided by ALS laboratories, which gave specific instructions not to do this. Gloves were worn in the lab by all samplers to prevent contamination of water sampling containers. Once water samples were collected, they were double checked to ensure that they were labelled properly, and that all required samples had been obtained. The water samples were then stored in a cooler at 4°C until they were analyzed at the Biology Laboratory at VIU.

All water samples except those going to ALS were analyzed in the Biology lab at VIU. The following water quality parameters were analyzed for each sample: pH, conductivity, alkalinity, harness, nitrate, total suspended solids, turbidity, and reactive phosphorus levels.

One additional sample was taken from each site during the first sampling event (November 2, 2015) and analyzed for microbiology. These were collected in sterile 100-ml Whirl-Pak plastic bags and sealed in the field. Total coliform and fecal coliform (*Escherichia coli*) will be tested from these samples in the VIU lab.

The water quality and microbiology data generated from each sample were analyzed according to the *Guidelines for Interpreting Water Quality Data* (MELP 1998). This was in addition to the samples sent to the private laboratory (ALS Environmental) in Burnaby, which provided comparisons to our results.

4.4 Stream Invertebrates

The Millstone River's invertebrate community was assessed at three sites (Site 1, Site 2, and Site 5) using the Department of Fisheries and Ocean Stream Keeper's invertebrate sampling guidelines on November 2, 2015 (Fisheries and Oceans Canada, 2000). The invertebrate sampling sites were selected based on ideal substrate, habitat, and flow characteristics. Samples were taken from similar habitat conditions at each site. A total of nine invertebrate samples were taken- three samples per site. Invertebrate samples were stored in clean, sealed containers which were labelled with the date, site number, and name of the sampler.

After collection, the invertebrate samples were transported back to the Biology Department laboratory at Vancouver Island University (VIU). Freshwater was added to the samples so that they could be easily sorted into smaller containers according to their physical appearance. Invertebrates were sorted into taxonomic groups and the number of individuals in each were counted. The results were recorded on an Invertebrate Survey Field Data Sheet (See Appendix). For quality assurance purposes, one quarter of the invertebrate samples were identified and counted a second time by another sampler participating in the project. The abundance, density, water quality, and diversity of each invertebrate sample was then assessed using Invertebrate Survey Interpretation Sheets (See Appendix). Once those assessments were completed, the overall assessment rating of each site was calculated. To ensure quality data was produced, calculations were repeated three times.

5.0 RESULTS AND DISCUSSION

5.1 Hydrology and Field Conditions

Water conditions at the 6 sites varied between the two sampling events (Table 1). A significant amount of precipitation was recorded prior to the first sampling event; 55 mm of rainfall was recorded in the Nanaimo area between October 26 and November 1, 2015. (Environment Canada, 2015). The wetted width of the Millstone increased between the two sampling events due to continued rainfall; 21.6mm of rain fell in Nanaimo between November

16 and November 26, 2015 (Environment Canada, 2015). As a result, water levels during the second sampling event were much higher at some sites. For example, during the first sampling event Site 1 consisted of a braided channel, during the second event the risen water had created one fast flowing channel. The increase in precipitation also increased the wetted depth at each site on the second event. The velocity at each site was taken three times in the centre of the channel. This may have led to inaccurate discharge results which could have been improved if velocity had been measured at the sides of the river as well. The velocity recorded at first sampling event was higher than during the second even though less water was moving through the river; the velocity at the first event was an average of 2.05 m/s, whereas on the second event it was an average of 1.56 m/s. Although less velocity was recorded during the second event, the discharge was greater; the average discharge during the second sampling event was 6.14 m^3/s compared to 4.07 m^3/s during the first sampling event. In comparison to data obtained from the 2014 Millstone River survey by RMOT students (Miller et al., 2014). This year's velocities were much higher. This could be due to more rainfall between sampling events when compared to last year. During our sampling events we noticed that Site #1 (Benson Creek) was quite flashy on the second event as there was much more water flowing. The only site which did not change much in wetted width, depth, velocity, and discharge was Site #5 (Duck Pond). This is likely due to the fact that water flow is regulated in the side channel of the Millstone River.

5.2 Water Quality – VIU Analyses

5.2.1 Field Measurements

Of the nine water quality parameters analyzed in-house during the study, two were completed in the field: temperature and dissolved oxygen. When comparing the results, several trends emerged (Table 2). The control site on Benson Creek had the lowest temperature of all the sampling sites during both sampling events. We expected this as it is located at the downstream end of a higher-elevation watercourse. As we discovered on the Millstone River at Sites 2 through 6, temperatures tended to decrease the further downstream we went. The Millstone River was consistently warmer than Benson Creek. We assumed the water from Benson Creek warms in Brannen Lake because of the higher atmospheric temperatures which occur at lower elevations, the larger surface area of the lake, and the more stagnant nature of the water.

One exception to the downstream cooling trend was Site 5 on the November 2 sampling event, which was 0.01°C higher than the preceding site (Site 4). We suspect the temperature variation at Site 5 during the first event was random, because it did not reoccur during the second event.

As we know that DO increases as temperature decreases, we expected to see DO levels increasing as we headed downstream. This was true except for Site 4 on the first sampling day, where DO was slightly lower than Site 3 (Table 2). However, on the second sampling event, DO consistently increased downstream, so once again we believe this variation was random. On both November 2 and November 23, 2015, DO levels were well within the guidelines for all stages life stages of fish and invertebrates (MELP, 1998).

5.2.2 VIU Laboratory Analyses

Seven water quality parameters were tested in the lab using the samples taken during the two sampling events. The results of each test can be found in Table 3. The first test was conductivity. In general, conductivity in BC coastal streams is around 100 µS/cm (MELP, 1998). During the first sampling event, conductivity values within the Millstone River were between 39-180 µS/cm, with a mean of 126 µS/cm. Samples taken on November 23, 2015, had lower conductivity levels, ranging from 24-86 µS/cm, with a mean of 68 µS/cm. Conductivity was generally higher the further downstream we went. These values are consistent with those found in previous years.

The second parameter tested, pH, was relatively stable between sampling stations on the Millstone River on both sampling days (Table 3). The second sampling event had lower pH values than the first, with a mean of pH 7.1 versus a mean pH of 7.6 on the first event. This was likely related to the dilution resulting from the higher discharge rate during the second event. There was a slight spike in pH at Site 2 on the first sampling day, with a value of 7.8. However, this spike was not reflected in either the second sampling event or the samples sent to ALS, and therefore it was likely a natural variation. The pH values detected at all sites on both sampling days were within the 6.5-9.0 guideline for aquatic life set by the province (MELP, 1998).

Alkalinity levels were tested and showed the control site at Benson Creek had moderate sensitivity to acid (Table 3). However, it was more sensitive than the Millstone River. In fact, the Millstone had alkalinity values above 20 mg/L $CaCO_3$ at all sites during both sampling events, demonstrating low acid sensitivity. Alkalinity was slightly higher during the first sampling event, which we would expect given the higher conductivity values on that day. The higher discharge rate on the second sampling day was probably diluting the concentration of ions in the stream. A slight increase in alkalinity occurred as we moved downstream, although not significant.

Hardness also tended to increase downstream (Table 3). This is likely because the water picked up ions as it headed downstream, as indicated by the increased conductivity levels. According to the BC Water Quality Guidelines, water with hardness levels below 60 mg/L are considered soft, and those above 120 mg/L are hard (MELP, 1998). During the first event, the average hardness in the Millstone River was 78.6 mg/L $CaCO_3$, with only Site 2 falling below 60 mg/L. Samples collected on the second sampling day were all soft, with an average hardness of 38 mg/L. This is once again related to the dilution factor associated with the increased discharge. The control site on Benson Creek had soft water and the lowest overall hardness of any site on both sampling days. These results show that if the Millstone River was subject to heavy metal inputs, those metals may remain dissolved in the water and be hazardous to aquatic life.

Turbidity was also measured at each site (Table 3). Turbidity generally increased the further downstream we went on both days. Turbidity levels in the Millstone River varied from 1.24-5.23 NTU on the first sampling, with an average of 3.51 NTU. The duck pond (Site 5), at 5.23 NTU, had the highest turbidity measurement. Benson Creek measured 1.73 NTU on the same day. In the second sampling, Benson Creek measured 0.24 NTU while the Millstone River had lower overall turbidity with an average of 1.6 NTU. The duck pond 2.29 NTU on this day, not as high as Site 6 but significantly higher than Site 4, which measured 1.11 NTU. It seems that the presence of ducks in the duck pond stirs up turbidity in the river. According to the guidelines, aquatic life can tolerate a turbidity increase of 5 NTU in streams with a background of 50 NTU or less (MELP, 1998). Therefore, none of the turbidity levels measured on either sampling day are of concern to aquatic life.

Nitrate (NO_3) levels were also tested in the lab (Table 3). On the first event, Millstone River nitrate concentrations ranged from 0.04 mg/L at Site 2 to 2.15 mg/L at Site 6. Samples from the second event had lower nitrates, ranging from 0.12-0.53 mg/L. Nitrate levels trended upward the further downstream we went on the Millstone.

Benson Creek had higher nitrate concentrations than the Millstone River in the first event and actually exceeded the maximum detection limit of our testing equipment, measuring >2.22 mg/L. During the second event, levels in Benson Creek were still among the highest of all sites at 0.30 mg/L, exceeded by only Site 3 and Site 5. There is more agricultural land in the area surrounding Benson Creek, including a Christmas tree farm within 100m of the stream bed. In addition, VIU spreads biosolids from the sewage treatment plant on to a wooded area near to the creek (Nanaimo Biosolids, 2015). It may be worth investigating whether these activities are having an effect on the nitrate levels in Benson Creek. However, even if the creek is receiving nitrate inputs from these operations, the levels detected are still below the provincial average and maximum guidelines of 40 mg/L and 200 mg/L, respectively.

The final parameter tested in the VIU laboratory was reactive phosphorus (PO_3) (Table 3). The average concentration detected from the first set of samples was 0.05 mg/L. The second event had a higher average at 0.146 mg/L. The highest level detected on either day was 0.23 mg/L and occurred at Site 4 (Pryde Vista Golf Course) during the second sampling. Comparing reactive phosphorus concentrations from either day to the water quality guidelines indicated that the river was eutrophic (MELP, 1998). However, there were no obvious indicators of a eutrophic river (such as algal blooms) observed during the sampling events. Phosphorus testing completed by ALS laboratories indicated much lower levels of phosphorus at each site sampled. We believe that the ALS tests are more reliable indicators of phosphorus concentrations as they are able to test for total phosphorus as P, whereas our equipment was only able to test for reactive phosphorus. Therefore, the Millstone River is most likely oligotrophic, and borders on mesotrophic under lower flow conditions.

5.2.3 Microbiology

Water samples were collected at each sampling station on the November 2, 2015, sampling event. All samples had high coliform content (Table 4). There was no site which had levels suitable for human drinking water or livestock use, defined in the guidelines as concentrations of 0 and 200 CFU/100mL, respectively (MELP, 1998). Sites 4, 5, and 6 exceeded 1000 CFU/100mL and the guidelines for even general irrigation use (MELP, 1998). However, a less accurate method involving estimation and extrapolation was used in order to determine coliform concentrations for these sites. Interestingly, while fecal coliform made up >20% of total coliform at Sites 4 and 6, Site 5 had just 6.8% fecal coliform. We expected Site 5 to have extremely high fecal coliform levels due to the large numbers of ducks which frequent the pond here. To obtain better coliform data, we would recommend sampling for coliform on both sampling days.

5.3 Water Quality – ALS Laboratory Analyses

ALS physical water analysis included conductivity, pH and hardness. Full results are available in the appendix of this report. Conductivity was higher during the first sampling, when flow was significantly lower, ranging from 50.3-190 μS/cm (See Appendix). The second sampling event, when water flow was much greater, ranged from 40.2-113 μS/cm. The decrease in conductivity when water levels are higher may be attributed to the dilution factor with greater water quantity. The pH of the river remained relatively stable throughout the sample period. The first sampling had pH ranges from 7.02-7.67, while the second event ranged from 7.2-7.62. The pH from both the control, Benson Creek, and the Millstone River were well within the British Columbia water guidelines for aquatic life which range from 6.5-9.0 (BCMELP, 2105). Hardness (as $CaCO_3$) was fairly unique in that during the first sampling event there was a significant increase at station five, the duck pond, which resulted in a hardness of 60.4. This figure, although consistent with water guidelines, is much higher than the 34.6 at station two, headwaters of the Millstone River. When compared to VIU water quality results ALS's results were all lower, but the spike at the Bowen Park duck pond was still significant.

Anions and nutrient levels were all within the guidelines for aquatic life (See Appendix). However, certain measurements are noteworthy. Ammonia was commonly below the 0.0050 detection limits but there was an increase at the duck pond during both sample periods. Event one revealed a 0.0236 mg/L of ammonia while event two was slightly lower at 0.0195 mg/L. Both of these figures are well under the ammonia toleration ranges for aquatic life (BCMELP, 2015). Although nitrogen was below the guidelines, it is interesting that at Benson Creek, the control, there was a significantly higher level of nitrogen over the Millstone. It may be worthwhile to further investigate this occurrence in the future if levels tend to increase. It is known that VIU uses organic solid wastes as a woodlot fertilizer in the Benson Creek area and organic wastes such as sewage can spike nitrogen and phosphorus levels, making a water source eutrophic. At this time however, the nitrogen and phosphorous levels are well under the guidelines. The general trend for phosphorus was 0.0027 mg/L at its lowest to 0.0246 mg/L at the highest level. These figures correlate with being oligotrophic to mesotrophic within the British Columbia aquatic life guidelines (BCMELP, 2015).

Many of the metals that were tested at the ALS Environmental Laboratory were not listed in the guidelines or below the detection limits (See Appendix). Aluminum was over the detection limit at the Bowen Park duck pond, and this appears to be a trend with VIU's analysis from previous years. British Columbia's water guidelines have a 0.1 mg/L maximum concentration for aluminum. Site 3 (duck pond) was at 0.23 mg/L, significantly above the 0.1 mg/L guideline. It should be considered that the minimum detection limit for aluminum at ALS was 0.20 mg/L, above the British Columbian guideline. It is recommended that if aluminum concentrations are problematic, as they appear to be, a more accurate test with a lower minimum detection level should be conducted. That being said, calcium was relatively high at all sample locations, ranging from 5.4-17.6 mg/L during the first sampling event and 4.06-10.1 mg/L during the second. The guidelines indicate that a concentration of calcium above 8 mg/L has a low acid sensitivity. These figures correlate to the VIU water quality analysis where it was determined that the Millstone River had a fairly high alkalinity. The remaining metals listed in the ALS results were either not listed in the guidelines or well below allowable quantities. Generally, the ALS Environmental results indicated that the Millstone River was suitable for aquatic life.

5.4 Quality Control and Assurance

The purpose of conducting a stream assessment is to provide meaningful data needed for agencies such as the Department of Fisheries and Oceans Canada (DFO) and any other organization involved with the Millstone River's protection and productivity. The quality of the data analysis is important because the Millstone River supports an abundance of flora and fauna.

Quality control and assurance was attained through a number of factors, which included labeling of bottles prior to sample collection, ensuring there was not a mix-up of sample bottles. Bottles were rinsed three times before samples were collected, removing of any contaminants. Gloves were worn during water analysis and coliform preparation, maintaining sample purity. Replicate samples were taken at Site 2 on November 2, 2015, and Site 3 on November 23, 2015. These replicates were compared to the results from the first samples taken at those sites and were found to be within the acceptable margin of error. Lastly, ALS Environmental analysis gave the team a good understanding of what nutrients, metals, and water properties exist in the Millstone River system.

5.5 Invertebrate Community

Stream invertebrates are commonly assessed during stream surveys because the health of an invertebrate community is a strong indicator of overall stream health (Beatty et. al, 2006). Stream invertebrates are used to assess stream health because they are sentinel species which are usually abundant, easy to identify, have adequately long lifespans, and are relatively sessile (Beatty et. al, 2006). Stream invertebrates are also commonly used because they can be more or less resistant to pollution depending on their taxa (Beatty et. al, 2006). For example, invertebrates classified as Ephemeroptera, Plecoptera, and Trichoptera (otherwise known as EPT taxa) are completely intolerant to pollution so finding a high density of EPT taxa in a stream is a good indication that the waterbody is lacking in pollution.

A total of 90 invertebrates were found among the three sampling site on the Millstone River. Site #2 contained the highest number of invertebrate found out of the three sites; a total of 35 invertebrates were collected at Site #2 (Figure 9). The highest density of invertebrates occurred at Site #2 (Brennan Lake) while the lowest invertebrate density occurred at Site #1 (Benson Creek). Site #2 was found to be more diverse in invertebrate taxa (12 different taxa) whereas both of the other sites contained the same number of different invertebrate taxa (Figure 10). Invertebrates sampled from Site #1 (Benson Creek) had a higher ratio of category 1/pollutant intolerant invertebrate taxa in comparison to the other sampling sites (Figure 10). Based on the invertebrate sampling on the Millstone River Site #2 was the only site given an overall site assessment rating of acceptable; both of the other sites were given overall assessment ratings between marginal and acceptable.

In comparison to previous years fewer invertebrates were found in Millstone River (Miller et. al, 2014). This may have been due to the high volume of precipitation found in the watershed in the days prior to the first sampling event (Environment Canada, 2015). Based on the invertebrate survey of the three sites the Millstone was given an average overall site assessment rating of 2.67 meaning that the Millstone River overall assessment rating was slightly below acceptable parameters.

6.0 CONCLUSION AND RECOMMENDATIONS

When taking into consideration that the Millstone River system runs through an array of environments, including agricultural and urban settings, it was reassuring to find that the River meets British Columbia's Water Guidelines for aquatic life. There were a couple of noticeable spikes in aluminum and nitrates during the sampling period. Both of these appear to be an ongoing trend, as this was also noted in previous years. Invertebrate counts were significantly lower this year as compared to previous years. A possible reason for this could be the increased discharge prior to sampling, which may have washed invertebrates downstream. When taking all three invertebrate sample sites into consideration, the Millstone falls between marginal and acceptable in the overall invertebrate site assessment rating.

The health of the Millstone River is adequate and acceptable for aquatic life, but further research should be conducted to determine the cause of the aluminum spike at the Bowen Park duck pond and the nitrogen count in Benson Creek. The ALS Environmental laboratory's aluminum detection limit is above the B.C. guideline and was only noticed because aluminum was detected at a significant level. In order to answer the question of the exact quantity and origin, a more accurate test should be administered. The nutrient spike is suspicious because of the proximity Benson Creek shares with Vancouver Island University’s woodlot, where biosolids are spread as a fertilizer for tree growth.

7.0 ACKNOWLEDGMENTS

The Millstone River’s Environmental Monitoring crew of 2015 would like to acknowledge the following contributors for their support of the Millstone River water quality assessment. First and foremost, we would like to thank Dr. Eric Demers for his knowledge, undivided attention, and concern for accurate results with this year’s students. The Department of Fisheries and Oceans Canada has granted Vancouver Island University funding for ALS Environmental water quality analysis, ensuring accurate water quality testing. Without their contributions, professional water quality analysis would not be possible. The Pryde Vista Golf Course has supported Vancouver Island University students by allowing repeated access to Site 4 through their property. Lastly, we would like to thank Dr. John Morgan for providing us initial instruction in how to properly complete a hydrological stream survey.

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9.0 APPENDIX

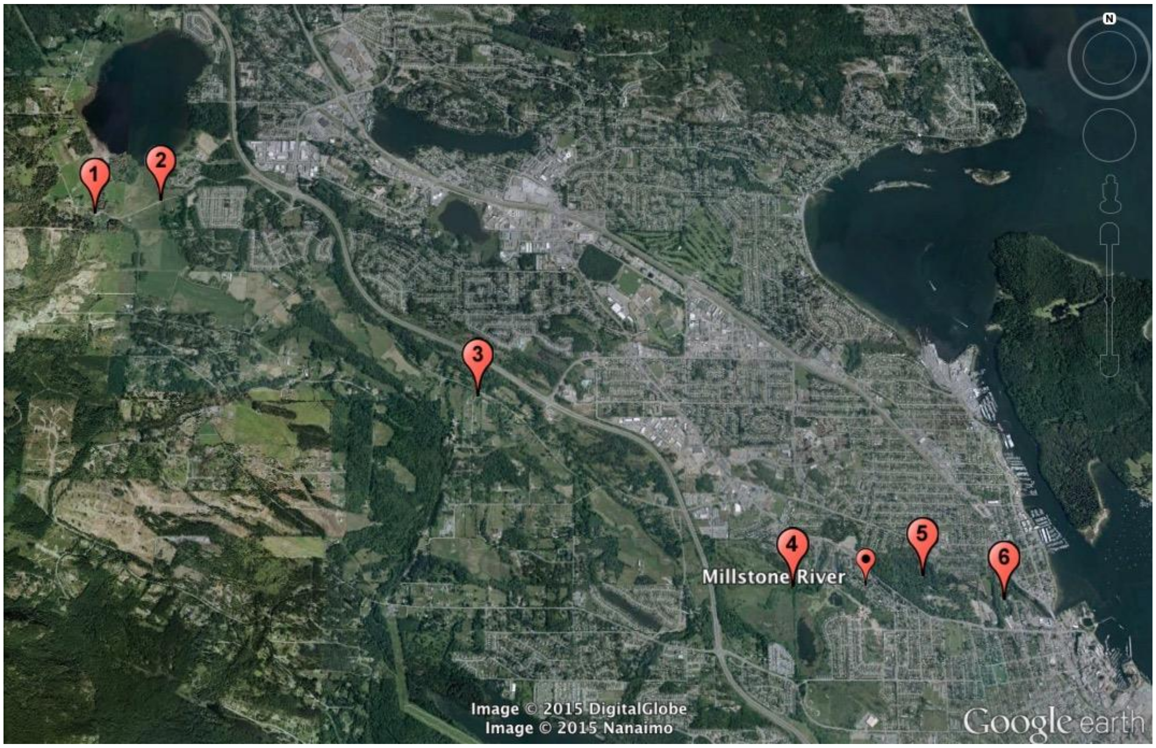

Figure 1: Google Map of site locations 1 to 6, which are shown in the following figures.

Figure 2: Site 1. Benson Creek control location at Biggs Road crossing. October 14, 2015.

Figure 3: Site 2. The Millstone River looking upstream at Biggs Road. October 14, 2015.

Figure 4: Site 3. Millstone River under Durnin Road, October 14, 2015. The river runs from the right of the frame to the left.

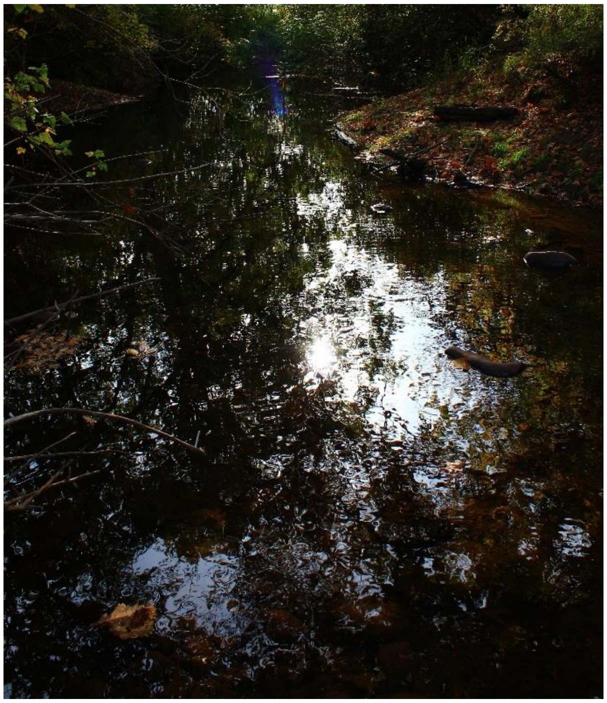

Figure 5: Site 4. Looking downstream on the Millstone River near Pryde Vista Golf Course. October 14, 2015.

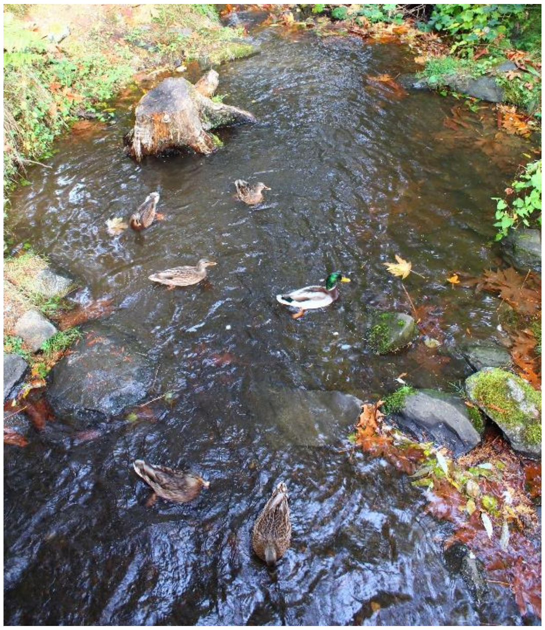

Figure 6: Site 5. Millstone River, looking downstream from the outflow from the duck pond in Bowen Park. October 14, 2015.

Figure 7: Site 6. Millstone River under Barsby Avenue bridge, looking upstream. October 14, 2015.

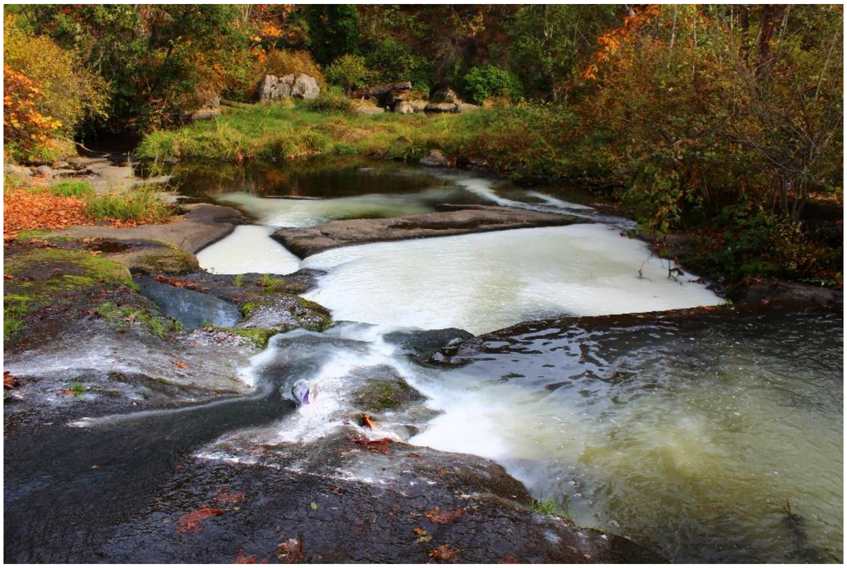

Figure 8: Paint spill observed at 11:15HR, October 14, 2015, looking downstream at Barsby reach.

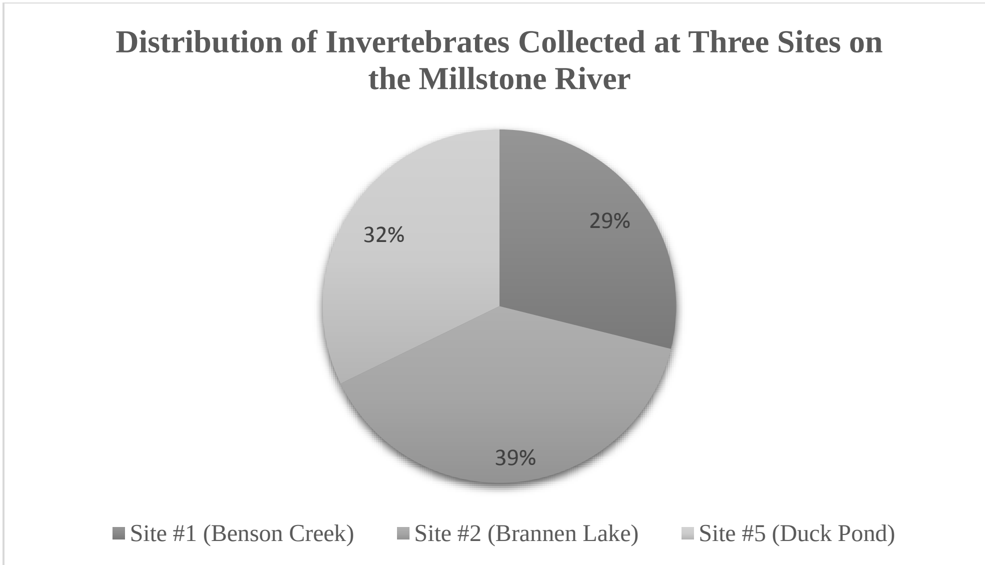

Figure 9. Distribution of invertebrates collected from the three sampling sites in the Millstone River on November 2, 2015

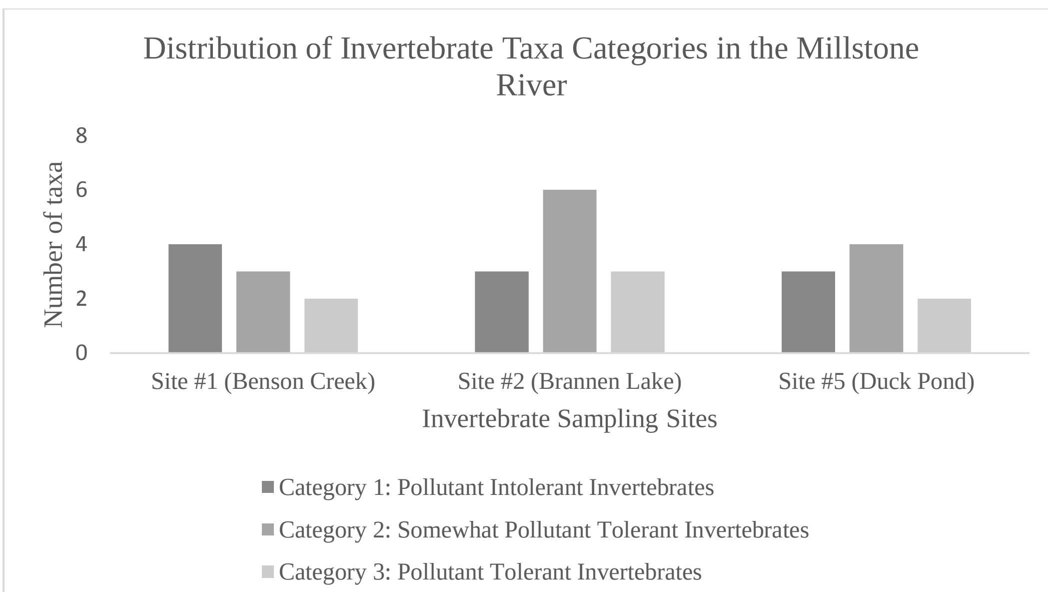

Figure 10. Distribution of invertebrate taxa categories collected from three sites in the Millstone River on November 2, 2015.

Table 1. Hydrology parameters measured during sampling events in the Millstone River on November 2, 2015 and November 23, 2015.

Site Number	Bank full Channel Width (m)	Wetted Width (m)	Wetted Depth (m)	Velocity (m/sec.)	Discharge (m^3/sec.)
		02 November 2015			
1	12.05	3.60	0.38	0.79	1.08
2	10.00	5.60	0.39	2.00	4.34
3	16.70	10.30	0.39	2.26	9.26
4	11.91	6.36	0.31	2.49	4.86
5	3.90	6.70	0.17	1.58	0.98
6	10.30	5.70	0.35	1.93	3.89
		23 November 2015			
1	12.05	10.20	0.16	0.71	1.19
2	10.00	8.40	0.43	0.97	3.52
3	16.70	11.40	0.54	2.33	14.34
4	11.91	7.40	0.56	1.32	5.45
5	3.90	3.80	0.18	1.84	1.25
6	10.30	8.90	0.51	1.34	6.10

Table 2. Temperature and dissolved oxygen readings measured in Benson Creek and the Millstone River on November 2, 2015 and November 23, 2015.

	Field Measurements	
Site	Temperature (°C)	Dissolved Oxygen (mg/L)
	November 2, 2015	
1	8.2	11.5
2	12.4	10.03
3	9.9	10.23
4	9.5	10.17
5	9.6	11.09
6	9.4	11.29
	November 23, 2015	
1	5.1	12.09
2	7.9	9.61
3	7.3	10.96
4	7.2	11.06
5	7.1	11.83
6	7.1	12.06

Table 3. Results of water quality samples taken from Benson Creek and the Millstone River. Analysis completed at Vancouver Island University laboratory.

VIU Lab Analyses							
Site	Conductivity (µS/cm)	pH	Alkalinity (mg/L $CaCO_3$)	Hardness (mg/L $CaCO_3$)	Turbidity (NTU)	Nitrate (mg/L NO_3)	Reactive Phosphorus (mg/L PO_3)
November 2, 2015							
1	39	7.4	11.8	34.2	1.73	2.22*	0.08
2	72	7.8	28.4	51.3	1.24	0.04	0.03
3	129	7.5	29	68.4	2.63	1.79	0.09
4	163	7.6	31	85.5	3.80	2.10	0.04
5	171	7.7	33	102.6	5.23	2.00	0.05
6	180	7.7	32	85.5	4.65	2.15	0.07
November 23, 2015							
1	24	7.1	11.1	17	0.24	0.30	0.15
2	58	7.1	26	34	0.78	0.12	0.09
3	71	7.1	27.5	37	1.21	0.28	0.16
4	82	7.1	30.8	40	1.11	0.33	0.23
5	86	7.1	30.9	40	2.29	0.29	0.09
6	85	7.3	31.6	39	2.72	0.53	0.16

*Exceeded maximum detection level of testing equipment

Table 4. Coliform analysis of samples taken from Benson Creek and the Millstone River on November 2, 2015.

Coliform			
Site	Total Coliform (CFU/100mL)	Fecal Coliform (CFU/100mL)	Fecal coliform as portion of total (%)
1	932	60	6.4
2	476	32	6.7
3	792	64	8.1
4	2908	644	22.1
5	3040	208	6.8
6	3512	768	21.9

ALS ENVIRONMENTAL RESULTS

Parameter	MDL	Units	2-Nov-15 Site 1	2-Nov-15 Site 2	2-Nov-15 Site 5	23-Nov-15 Site 1	23-Nov-15 Site 2	23-Nov-15 Site 5
Physical Tests (Water)								
Conductivity	2.0	uS/cm	50.3	85.6	190	40.2	80.8	113
Hardness (as CaCO3)	0.50	mg/L	19.3	34.6	60.4	14.5	31.1	36.2
pH	0.10	pH	7.02	7.54	7.67	7.20	7.45	7.62
Anions and Nutrients (Water)								
Ammonia, Total (as N)	0.0050	mg/L	<0.0050	<0.0050	0.0236	<0.0050	0.0075	0.0195
Nitrate (as N)	0.0050	mg/L	1.05	<0.0050	1.08	0.311	0.0813	0.345
Nitrite (as N)	0.0010	mg/L	<0.0010	<0.0010	0.0063	<0.0010	<0.0010	0.0013
Total Nitrogen	0.030	mg/L	1.39	0.199	1.52	0.402	0.271	0.563
Orthophosphate-Dissolved (as P)	0.0010	mg/L	0.0011	<0.0010	0.0080	<0.0010	<0.0010	0.0029
Phosphorus (P)-Total	0.0020	mg/L	0.0112	0.0054	0.0246	0.0027	0.0041	0.0167
TN:TP			124.1	36.9	61.8	148.9	66.1	33.7
Total Metals (Water)								
Aluminum (Al)-Total	0.20	mg/L	<0.20	<0.20	0.23	<0.20	<0.20	0.23
Antimony (Sb)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic (As)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium (Ba)-Total	0.010	mg/L	<0.010	<0.010	0.021	<0.010	<0.010	0.011
Beryllium (Be)-Total	0.0050	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth (Bi)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron (B)-Total	0.10	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium (Cd)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (Ca)-Total	0.050	mg/L	5.40	9.31	17.6	4.06	8.39	10.1
Chromium (Cr)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt (Co)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron (Fe)-Total	0.030	mg/L	0.067	0.090	0.462	<0.030	0.165	0.385
Lead (Pb)-Total	0.050	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium (Li)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium (Mg)-Total	0.10	mg/L	1.41	2.76	4.00	1.07	2.46	2.67
Manganese (Mn)-Total	0.0050	mg/L	<0.0050	0.0090	0.0305	<0.0050	0.0262	0.0245
Molybdenum (Mo)-Total	0.030	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel (Ni)-Total	0.050	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus (P)-Total	0.30	mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)-Total	2.0	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Selenium (Se)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon (Si)-Total	0.050	mg/L	3.77	2.83	4.05	3.54	3.25	3.72
Silver (Ag)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium (Na)-Total	2.0	mg/L	2.2	3.9	13.2	<2.0	3.6	7.4
Strontium (Sr)-Total	0.0050	mg/L	0.0213	0.0359	0.121	0.0161	0.0331	0.0658
Thallium (Tl)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin (Sn)-Total	0.030	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium (Ti)-Total	0.010	mg/L	<0.010	<0.010	0.016	<0.010	<0.010	0.014
Vanadium (V)-Total	0.030	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc (Zn)-Total	0.0050	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Millstone River		Date: 04-Nov-15
Station Name: Station #1- Benson Creek		Flow status: Moderate
Sampler Used: Hess Sampler	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.09 m2 X 3 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 2	EPT5 1
	Stonefly Nymph (EPT)	EPT3 6	EPT6 2
Pollution Intolerant	Dobsonfly (hellgrammite)	0	0
	Gilled Snail	0	0
	Riffle Beetle	0	0
	Water Penny	0	0
Sub-Total		C1 11	D1 4
Category 2	Alderfly Larva	0	0
	Aquatic Beetle	2	1
	Aquatic Sowbug	0	0
	Clam, Mussel	0	0
	Cranefly Larva	1	1
	Crayfish	0	0
Somewhat Pollution Tolerant	Damselfly Larva	0	0
	Dragonfly Larva	0	0
	Fishfly Larva	0	0
	Amphipod (freshwater shrimp)	8	1
	Watersnipe Larva	0	0
Sub-Total		C2 11	D2 3
Category 3	Aquatic Worm (oligochaete)	4	2
	Blackfly Larva	0	0
	Leech	0	0
	Midge Larva (chironomid)	0	0
	Planarian (flatworm)	0	0
Pollution Tolerant	Pouch and Pond Snails	0	0
	True Bug Adult	0	0
	Water Mite	0	0
Sub-Total		C3 4	D3 2
TOTAL		CT 26	DT 4

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: S1 26

DENSITY: Invertebrate density per total area sampled:

S1 26 ÷ 0.27 m^2 = S2 96.3/ m^2

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

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x ___4__ + 2 x __3___ + __2___ = S4 20

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

___1__ + __1___ + __2___ = S5 4

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

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

(EPT1 + EPT2 + EPT3) / CT

(__3___ + __2___ + 6) / _26____ = S6 0.42

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: S7 9

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

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

Col. C for S3 / CT

___8__ / _26____ = S8 0.31

SECTION 4 - OVERALL SITE ASSESSMENT RATING

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

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

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

Average Rating
Average of R4, R5, R6, R8
2.75

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Millstone River	Date:	04-Nov-15
Station Name:	Station #2- Brannen Lake	Flow status:	Moderate

Sampler Used:	Number of replicates	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates
Hess Sampler	3	0.09 m2 X 3 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 20	EPT4 3
	Mayfly Nymph (EPT)	EPT2 0	EPT5 0
	Stonefly Nymph (EPT)	EPT3 0	EPT6 0
Pollution Intolerant	Dobsonfly (hellgrammite)	0	0
	Gilled Snail	0	0
	Riffle Beetle	0	0
	Water Penny	0	0
Sub-Total		C1 20	D1 3
Category 2	Alderfly Larva	0	0
	Aquatic Beetle	1	1
	Aquatic Sowbug	0	0
	Clam, Mussel	3	2
	Cranefly Larva	0	0
	Crayfish	0	0
Somewhat Pollution Tolerant	Damselfly Larva	0	0
	Dragonfly Larva	0	0
	Fishfly Larva	0	0
	Amphipod (freshwater shrimp)	7	3
	Watersnipe Larva	0	0
Sub-Total		C2 11	D2 6
Category 3	Aquatic Worm (oligochaete)	2	1
	Blackfly Larva	0	0
	Leech	0	0
	Midge Larva (chironomid)	2	2
	Planarian (flatworm)	0	0
Pollution Tolerant	Pouch and Pond Snails	0	0
	True Bug Adult	0	0
	Water Mite	0	0
Sub-Total		C3 4	D3 3
TOTAL		CT 35	DT 12

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

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

S1 35

DENSITY: Invertebrate density per total area sampled:

S1 35 ÷ $0.27m^2$ =

S2 $129.63/m^2$

PREDOMINANT TAXON:

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

S3 Caddisfly Larva

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x __3__ + 2 x __6___ + __3___ =

S4 24

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

___3__ + __0___ + __0___ =

S5 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

(__20___ + __0___ + 0) / _35____=

S6 0.57

SECTION 3 - DIVERSITY

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

S7 12

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

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

Col. C for S3 / CT

___20__ / _35____ =

S8 0.57

SECTION 4 - OVERALL SITE ASSESSMENT RATING

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

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

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

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

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Millstone River		Date: 04-Nov-15
Station Name: Station #5- Duck Pond		Flow status: Moderate
Sampler Used: Hess Sampler	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.09 m2 X 3 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 1	EPT4 1
	Mayfly Nymph (EPT)	EPT2 3	EPT5 1
	Stonefly Nymph (EPT)	EPT3 1	EPT6 1
Pollution Intolerant	Dobsonfly (hellgrammite)	0	0
	Gilled Snail	0	0
	Riffle Beetle	0	0
	Water Penny	0	0
Sub-Total		C1 5	D1 3
Category 2	Alderfly Larva	0	0
	Aquatic Beetle	7	2
	Aquatic Sowbug	0	0
	Clam, Mussel	0	0
	Cranefly Larva	0	0
	Crayfish	0	0
Somewhat Pollution Tolerant	Damselfly Larva	0	0
	Dragonfly Larva	0	0
	Fishfly Larva	0	0
	Amphipod (freshwater shrimp)	15	2
	Watersnipe Larva	0	0
Sub-Total		C2 22	D2 4
Category 3	Aquatic Worm (oligochaete)	2	2
	Blackfly Larva	0	0
	Leech	0	0
	Midge Larva (chironomid)	0	0
	Planarian (flatworm)	0	0
Pollution Tolerant	Pouch and Pond Snails	0	0
	True Bug Adult	0	0
	Water Mite	0	0
Sub-Total		C3 2	D3 2
TOTAL		CT 29	DT 9

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: S1: 29

DENSITY: Invertebrate density per total area sampled:

S1 29 ÷ $0.27m^2$ = S2: $107.4/m^2$

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

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x ___3__ + 2 x __4___ + __2___ = S4: 19

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

___1__ + __1___ + __1___ = S5: 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

(__1___ + __3___ + 1) / _29____= S6: 0.17

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: S7: 9

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

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

Col. C for S3 / CT

___13__ / _29____ = S8: 0.52

SECTION 4 - OVERALL SITE ASSESSMENT RATING

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

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

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

Average Rating
Average of R4, R5, R6, R8
2.25