DATA REPORT

Water Quality and Stream Invertebrate Assessment

for the Millstone Bypass Channel, Nanaimo, BC,

(Fall 2007)

Report prepared by:

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Disclaimer Note:

1. Background

This report documents a water quality and stream invertebrate assessment conducted on the Millstone Bypass Channel, Nanaimo, BC, during October-November 2007.

The field portion of this study was undertaken by 3rd year undergraduate students attending the Environmental Monitoring (RMOT 306) course at Malapsina University-College, offered as part of the Bachelor of Natural Resources Protection (Davey Cox, Riley Kaminski and Lee Mierau). Students worked under the supervision of the course instructor, Dr. Eric Demers (Malaspina). Logistical support was provided by Fisheries and Oceans Canada (DFO). The BC Conservation Foundation provided funding for field expenses and analytical processing of water samples for the Millstone Bypass Channel. This report was compiled by Dr. Eric Demers based on a student group report.

Specific objectives for this study of the Millstone Bypass Channel included:

- establish 6 water quality sampling stations with proper Global Positioning System (GPS) referencing;
- obtain field measurements of water quality at the 6 sampling stations during two sampling events (October, November 2007);
- obtain water samples from each sampling station during two sampling events (October, November 2007) for detailed laboratory analysis; and,
- collect stream invertebrate samples at 2 sampling stations during one sampling event (October 2007) for analysis at Malaspina University-College.

2. Methods

2.1. Study Site

This project was conducted at the Millstone Bypass Channel located in Bowen Park, in Nanaimo, BC. The 800-metre long bypass channel was constructed during summer 2007 by the Nanaimo Fish and Game Protective Association, in partnership with Fisheries and Oceans Canada and the City of Nanaimo. The bypass channel was built to provide anadromous salmonids with new spawning and juvenile rearing habitat, and access to the watershed above the Deadman Falls barrier in Bowen Park. The bypass channel received water from the Millstone River during early October 2007, about 4 weeks before the first sampling event for this project. Water discharge in the Millstone Bypass Channel is regulated by a weir structure located at the upstream end of the channel.

2.2. Water Quality

2.2.1. Sampling Stations

Six stations were established for sampling water quality on the Millstone Bypass Channel, during October-November 2007 (Tables 1 and 2; Figure 1; Appendix 1). The location of each station was chosen to provide adequate coverage for the length of the Millstone Bypass Channel. Stations were generally numbered from the upstream end to the downstream end of the bypass channel. All stations were easily accessed via foot paths in Bowen Park. Station WQ1 was located at the upstream entrance into the bypass channel and served as a reference station for initial conditions at channel entry. Stations WQ2-4 were located at intervals along the channel and were located near Pond 2, Pond 6 and Pond 12 (Duck Pond), respectively. Station WQ5 was located at the outlet end of the bypass channel, at its confluence with the Millstone River. Station WQ6 was located on the main Millstone River, immediately upstream of the bypass channel outlet (at the inlet of the old fish ladder). This station served as a reference to compare spatial changes that occur within the bypass channel and in the main river channel.

Table 1. Description of the sampling stations used for water quality and stream invertebrate assessments on the Millstone Bypass Channel, during October-November 2007. All northing and easting coordinates are based on zone 10U. The station prefixes are as follows: “WQ” refers to 6 water quality stations, “SI” refers to 2 stream invertebrate stations.

Station	UTM Coordinates		General Location
	Northing	Easting	
WQ1	0429839	5447514	Upstream entrance into the bypass channel
WQ2	0429958	5447411	Upstream end of Pond 2
WQ3	0430040	5447281	Downstream end of Pond 6, 5-m upstream of foot bridge
WQ4	0430255	5447242	Downstream end of Duck Pond, 1-m upstream of foot bridge
WQ5	0430226	5447378	Downstream outlet of the bypass channel
WQ6	0430209	5447388	Millstone River, just upstream of the bypass channel outlet
SI1	0429991	5447337	Downstream end of Pond 4
SI2	0430047	5447279	Downstream of Pond 6, 8-m downstream of foot bridge

Table 2. Water quality sampling activities conducted at each station on the Millstone Bypass Channel, during October-November 2007. The symbols “O” or “N” indicate whether samples / measurements were taken during the October or November sampling events, respectively.

Station	Field Measurements	Malaspina Analyses	ALS Lab Analyses
WQ1	O, N	O, N	O, N
WQ2	O, N	O, N	O
WQ3	O, N	O, N	O, N
WQ4	O, N	O, N	O
WQ5	O, N	O, N	O, N
WQ6	---	---	O, N

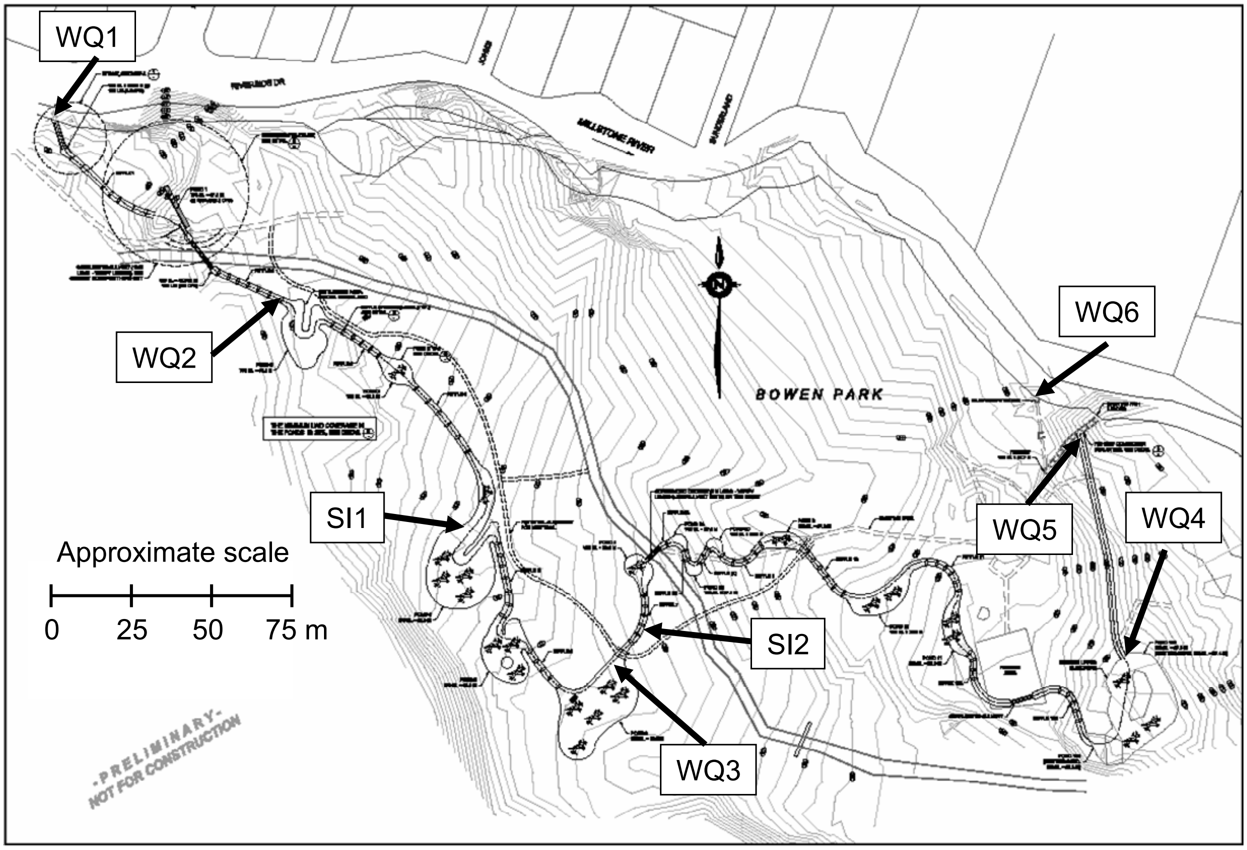

Figure 1. Approximate location of the sampling stations used for water quality and stream invertebrate assessments on the Millstone Bypass Channel, during October-November 2007. Table 1 provides details of the specific location of each station. Table 2 details the sampling activities conducted at each station. This map was obtained from Fisheries and Oceans Canada. Map scale is approximated.

2.2.2. Field Measurements

Water quality sampling events were conducted on 30 October and 21 November 2007. At each sampling station, Universal Transverse Mercator (UTM) coordinates were obtained with a Garmin 12XL Global Positioning System (GPS) receiver. Then, field measurements of water temperature (to the nearest 0.1 ^{o}C) and dissolved oxygen (to the nearest 0.01 mg/L) were obtained with a YSI 550DO probe. The electronic probe was placed directly in the channel water. At least one photograph was taken at each sampling station (see Appendix 1).

2.2.3. Water Sampling

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

Samples for analysis at Malaspina University-College were collected from stations WQ1-5 (Table 2). At each station, a clean pre-labelled 500-ml plastic bottle was rinsed 3 times and then used to collect a water sample (Table 3). Samples were obtained while standing on the stream bank by immersing the containers with a gloved hand just below the water surface while facing upstream. Care was taken not to disturb the bottom sediments. All water samples were transported to Malaspina University-College within 1 hours and stored at $4^{o}C$ until laboratory analysis, which were subsequently conducted within 24 hours.

Samples for analysis by ALS Laboratory were collected from stations WQ1-6 during the October sampling event, and from stations WQ1, WQ3, WQ5 and WQ6 during the November sampling event (Table 2). At each station, water samples were collected in three clean laboratory-supplied and pre-labelled sample containers (Table 3). All samples were obtained while standing on the stream bank by directly immersing the containers with a gloved hand just below the water surface while facing upstream. Care was taken not to disturb the bottom sediments. Samples for analysis of nutrients and total metals were preserved with laboratory-supplied sulphuric acid and nitric acid, respectively. Bottles with preservatives were inversed five times for adequate mixing. All water samples were stored in a cooler with ice packs and shipped within 24 hours for laboratory analyses at ALS Laboratory.

A travel blank was also submitted for analysis by ALS Laboratory. The travel blank was prepared by ALS Laboratory and consisted of deionized water placed in the three types of sample container. The travel blank bottles were transported to the sampling stations, but they remained unopened.

Table 3. Sampling containers and preservatives used for water quality samples taken at the Millstone Bypass Channel during October-November 2007. All containers and preservatives for analysis by ALS Laboratory were provided by ALS Laboratory, Vancouver, BC.

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

2.2.4. Malaspina Laboratory Analyses

Water samples transported to Malaspina University-College were analysed for conductivity, pH, total hardness, total alkalinity and total suspended solids. Conductivity was measured to the nearest 0.1 μSiemens/cm with a Hydrolab DataSonde probe attached to a Hydrolab Surveyor 4 datalogger. Measurements of pH were obtained with a Sper Scientific Model 850081 pH probe to the nearest 0.01 pH unit. Total hardness (as $CaCO_3$) was measured using a HACH HA-71A test kit to the nearest 1 mg/L. Total alkalinity (as $CaCO_3$) was measured using the HACH AL-DT digital titration method to the nearest 1 mg/L. Total suspended solids was measured using a HACH DR2800 Spectrophotometer (Method 8006) to the nearest 1 mg/L.

2.2.5. *ALS Laboratory Analyses*

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

2.2.6. *Quality Assurance / Quality Control*

Throughout this study, measures were taken to ensure that potential contamination of water samples was minimized. This included wearing gloves to collect all samples, using only clean and rinsed containers, preserving samples as prescribed by the analytical laboratory, and storing collected samples in well-labelled containers. The inclusion of a travel blank provided a means of detecting any widespread contamination resulting from the container (including caps) and preservative during transport and storage.

2.2.7. *Data Analyses – Comparison with Applicable Guidelines*

Water quality results were compared with the provincial and federal water quality guidelines for the protection of freshwater life. The BC Water Quality Guidelines are the maximum allowable concentration (for potential acute effects) and the 30-day average concentration (for potential chronic effects) (BCMWLAP 1998a, 1998b). The guidelines from the Canadian Council of Ministers of the Environment were also used for water quality comparisons (CCME 1999). Both sets of guidelines were applicable to all sampling stations.

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

2.3. Stream Invertebrates

2.3.1. *Sampling Stations*

Stream invertebrate samples were collected from 2 sampling stations on 30 October 2007 (Table 1; Figure 1). The sampling stations were selected based on hydrological characteristics, apparent substrate uniformity, space available for replicate samples and site access. At the time of sampling, both stations consisted of shallow riffles (water depth ~15-20 cm), with water velocity of ~0.5-1.0 m/s, and primarily sand and gravel substrate.

2.3.2. *Invertebrate Sampling*

At each station, three replicate samples (triplicates) were obtained using kick-and-sweep method as per the Pacific Streamkeepers procedures (Taccogna and Munro 1995). Each site was approached by walking from downstream. A 30-cm wide D-net was placed on the downstream edge of a 30 cm x 30 cm (~0.09 m^2) sampling area. All stones and debris 5 cm or larger within the sampling area were held under water in front of the net and rubbed gently by hand to dislodge invertebrates. Cleaned stones and debris were then placed downstream of the sampling area. The streambed was then gently agitated to a depth of 5 cm to loosen any remaining invertebrates. The content of the D-net was then turned inside out in a 125-ml plastic sample jar. The net was carefully inspected to ensure all content was transferred into the sample jar. Samples were then preserved with 70% ethanol and transported to Malaspina University-College for laboratory analyses.

2.3.3. Malaspina Laboratory Analyses

Laboratory procedures and identification also followed the Pacific Streamkeepers procedures (Taccogna and Munro 1995). The triplicate samples from each station were combined into a single composite sample per station. The contents of the all invertebrate sample jars from a station were poured into a shallow white tray. Invertebrates were sorted into apparent taxonomic groups. Identification to the appropriate taxonomic level (as prescribed by the Pacific Streamkeepers procedures) was confirmed using a dissecting microscope. The number of invertebrates and the number of distinguishable subgroups within each broad taxonomic group were recorded on a Pacific Streamkeeper Invertebrate Survey Field Data Sheet. From these records, various useful metrics were calculated for each station, including: total density (number per m^2), total number of taxonomic groups, predominant taxonomic group, Pollution Tolerance Index, EPT (Ephemeroptera-Plecoptera-Trichoptera) Index, EPT to Total Ratio Index, Predominant Taxon Ratio Index, and overall Site Assessment Rating.

3. Results

Before the first sampling event for this project, the Millstone Bypass Channel had been receiving Millstone River water for approximately 4 weeks. A significant rainfall event occurred during 18-19 October 2007, when approximately 48 mm of precipitation fell within a 24 hour period (data for Victoria Airport retrieved from http://www.theweathernetwork.com). Precipitation levels were more uniform between the first and second sampling event when approximately 74 mm of precipitation fell during the 22-day interval.

As part of a student project for the Environmental Hydrology (FISH 307) course at Malapsina University-College, water discharge through the Millstone Bypass Channel was estimated at 0.121 and 0.149 m^3/s on 25 October and 15 November, 2007, respectively.

During this sampling program, weather conditions were sunny with clouds, no precipitation, wind calm and air temperature of 5-8^{o}C.

3.1. <u>Water Quality</u>

3.1.1. Field Measurements and Malaspina Laboratory Analyses

Water temperature averaged 8.9^{o}C and 6.5^{o}C during the October and November sampling events, respectively, and there was little variation among stations (Table 4). All dissolved oxygen levels were above the minimum guideline of 9.0 mg/L for early fish life stages (RISC 1998). During the October sampling event, dissolved oxygen concentrations were at 78-98% saturation, with the lowest level observed at station WQ3 (9.05 mg/L). Dissolved oxygen levels were near or above saturation (97-108%) during the November sampling event. Conductivity ranged from 75.4 to 85.7 µS/cm among station and sampling events. Slight variability among station may indicate differential groundwater seepage along the length of the bypass channel. Water pH was near neutral throughout this study, and averaged 7.21 and 6.84 during the October and November sampling events, respectively. Total hardness and total alkalinity were similar throughout this study, and declined slightly between the October and November sampling events. Total alkalinity levels were above 20 mg/L, indicating "low acid sensitivity" as defined by RISC (1998). Total suspended solids were below detection limits during the October sampling event, and averaged 8 mg/L during the November sampling event. This change was also observed as a very slight brownish colouration during the November sampling event.

Table 4. Field measurements (water temperature, dissolved oxygen) and laboratory results for water samples taken from 5 stations at the Millstone Bypass Channel on 30 October and 21 November 2007. No field measurements or water samples were taken at station WQ6.

Station	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH	Total Hardness (mg/L $CaCO_3$)	Total Alkalinity (mg/L $CaCO_3$)	Total Suspended Solids (mg/L $CaCO_3$)
			30 October 2007				
WQ1	8.9	10.27	83.3	7.22	32	35	<1
WQ2	8.8	10.63	77.3	7.20	33	32	<1
WQ3	8.8	9.05	78.5	7.18	32	35	<1
WQ4	8.9	10.27	75.4	7.21	33	35	<1
WQ5	8.9	11.33	85.4	7.24	35	32	<1
WQ6	---	---	---	---	---	---	---
			21 November 2007				
WQ1	6.6	11.89	85.7	6.83	27	28	8
WQ2	6.6	12.12	78.4	6.76	27	29	8
WQ3	6.5	12.29	79.7	6.78	28	29	7
WQ4	6.4	12.33	77.5	6.78	28	29	8
WQ5	6.5	13.34	82.3	7.06	27	26	7
WQ6	---	---	---	---	---	---	---

3.1.2. ALS Laboratory Analyses

Water quality results were compared to the BC Provincial water quality guidelines and the federal CCME guidelines for the protection of aquatic life (Table 5).

Except for pH, the concentrations of all substances analysed in the travel blank were below minimum detection limits as expected.

The pH measurements from ALS Laboratories varied by less than 0.40 pH unit among sampling stations and events. In general, pH measurements from ALS Laboratories were higher than the Malaspina laboratory measurements by 0.25-0.90 pH units. This discrepancy possibly reflects differences in air space content among sampling containers and in time elapsed between sampling and laboratory analysis. There was little variation in total hardness among stations (average: 36.6 mg/L), as also suggested by the Malaspina laboratory results.

Nutrient values were well below minimum applicable guidelines for ammonia, nitrate and nitrite. Nitrate levels increased 2.9-fold between the October and November sampling events. There was no apparent trend in total Kjeldahl nitrogen (TKN) among sampling stations or events. For both sampling events, there was a gradual increasing trend in total phosphate levels from upstream to downstream. Total phosphate levels were 1.9-2.3 times (or 98-133%) higher at the downstream end of the channel (station WQ5) compared to the upstream end (station WQ1). This increase did not appear to occur in the Millstone River, where total phosphate levels increased by 3-14% between station WQ1 and WQ6. Overall, nutrient levels were indicative of oligotrophic to mesotrophic nutrient levels (Kalff 2002).

All total metal concentrations were below the applicable water quality guidelines during the October sampling event. During the November sampling event, most total metal concentrations were below the applicable guidelines, with the exception of aluminium and iron. Aluminium exceeded all applicable guidelines at station WQ5. Iron exceeded all applicable guidelines at stations WQ1, WQ5 and W6. The single exceedance for aluminium suggests possible contamination of this sample since all other measurements were below minimum detection limit. The exceedances for iron partly reflect higher background iron concentration levels in the Millstone River during the November sampling event.

It should be noted that total metals analyses measure the combined amount of metals dissolved in water and bound to particles. In general, dissolved metals are more bio-available (hence toxicologically available) than metals that are bound to particles. The dissolved fraction of total iron in water is often much lower than 100%.

Table 5. Laboratory results (ALS Laboratory) for water samples taken from 6 stations at the Millstone Bypass Channel on 30 October and 21 November 2007. No water samples were analysed for stations WQ2 and WQ4 during the November sampling event. Total hardness was not analysed during the November sampling event. "TB" refers to travel blank. The values enclosed in boxes exceeded at least one of the applicable water quality guidelines. See additional notes on the next page.

	BC Water Quality Guidelines [a]														
	BC Max	BC 30-day Mean	CCME [b]	30 October 2007							21 November 2007				
Variable	mg/L	mg/L	mg/L	TB	WQ1	WQ2	WQ3	WQ4	WQ5	WQ6	WQ1	WQ3	WQ5	WQ6
General/Physical															
Hardness, Total				<0.50	36.7	36.7	36.1	36.4	37	36.6	---	---	---	---
pH	6.5 - 9.0		6.5 - 9.0	5.54	7.58	7.52	7.48	7.46	7.85	7.49	7.73	7.56	7.62	7.54
Nutrients															
Ammonia as N	7.04 - 15.00 [c]	1.35 - 1.92 [c]	0.715	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.024	0.028	<0.020
Nitrate as N	200	40	13	<0.0050	0.0638	0.0579	0.0555	0.0562	0.0561	0.0564	0.167	0.163	0.17	0.172
Nitrite as N	0.06 [d]	0.02 [d]	0.06	<0.0010	0.0025	0.0026	0.0011	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Total Kjeldahl Nitrogen				<0.050	0.164	0.184	0.215	0.169	0.219	0.119	0.134	0.139	0.22	0.15
Total Phosphate as P				<0.0020	0.0091	0.0094	0.0097	0.0154	0.018	0.0094	0.0111	0.0121	0.0259	0.0126
Total Metals															
Aluminum (Al) [n]	0.10 [e]	0.05 [e]	0.10 [e]	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.52	<0.20
Antimony (Sb) [n]	0.02			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic (As) [n]	0.005			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium (Ba)	5	1		<0.010	<0.010	<0.010	<0.010	0.014	0.015	<0.010	<0.010	<0.010	0.017	<0.010
Berylium (Be)	0.0053			<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth (Bi)				<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron (B)	1.2			<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium (Cd) [n]	0.00001 [f]		0.00001 [f]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (Ca)				<0.050	10.2	10.2	9.93	10	10.2	10.2	9	8.98	8.92	8.32
Chromium (Cr) [n]	0.001 [g]		0.001 [g]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt (Co) [n]	0.11	0.004		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu) [n]	0.0045 - 0.0056 [h]	0.002 [h]	0.002 [h]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron (Fe)	0.3		0.3	<0.030	0.203	0.207	0.198	0.203	0.227	0.202	0.317	0.291	0.759	0.399
Lead (Pb) [n]	0.010 - 0.025 [i]	0.004 [i]	0.001 [i]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium (Li)				<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium (Mg)				<0.10	2.74	2.74	2.74	2.76	2.77	2.73	2.39	2.39	2.44	2.27
Manganese (Mn)	0.84 - 0.96 [j]	0.72 - 0.78 [j]		<0.0050	0.0174	0.0161	0.013	0.0112	0.0118	0.0143	0.0275	0.0211	0.0489	0.0263
Molybdenum (Mo)	2	1	0.073	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel (Ni) [n]	0.025 [k]		0.025 [k]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus (P)				<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)				<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Selenium (Se) [n]		0.002	0.001	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon (Si)				<0.050	3.44	3.46	3.44	3.49	3.57	3.45	3.76	3.75	4.11	3.55
Silver (Ag) [n]	0.0001 [l]	0.00005 [l]	0.0001	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium (Na)				<2.0	6.9	6.9	7	7	7	6.9	5.5	5.5	5.6	5.3
Strontium (Sr)				<0.0050	0.0715	0.0713	0.0703	0.0696	0.0701	0.0709	0.0647	0.0634	0.063	0.0615
Thallium (Tl)				<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin (Sn)				<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium (Ti)				<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.028	0.011
Vanadium (V)				<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc (Zn)	0.033 [m]	0.0075 [m]		<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

Table 5. (Continued)

NOTES:

Results are expressed as mg/L except for pH.
"<" means less than the detection limit.

[a] BC Water Quality Guidelines (WQG) compiled from http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html#approved.

[b] Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines (WQGs) compiled from CCME (1999).

[c] Ammonia guideline is dependent on temperature and pH. Guideline range shown is based on temperatures of 6 to 9°C and pH of 7.4 to 7.9 for the tested water.

[d] Nitrite guideline is dependent on chloride concentration. Guideline shown is based on chloride concentrations of <2 mg/L.

[e] Aluminium guidelines for pH ≥ 6.5.

[f] Cadmium guideline = 0.001 * 10 {0.86[log(hardness)]-3.2} mg/L. Guideline shown is based on hardness of 27 to 38 mg/L for the tested water.

[g] Chromium guideline is for the more toxic Chromium VI. The guideline for Chromium VI is 0.0089 mg/L.

[h] The BC maximum copper guideline is (0.000094(hardness)+2) mg/L. Guideline shown is based on hardness of 27 to 38 mg/L for the tested water.
The BC 30-day mean copper guideline is 0.002 mg/L for hardness <50 mg/L.
The CCME guideline for copper is 0.002 mg/L at hardness of 1-120 mg/L.

[i] The BC maximum lead guideline is 0.010-0.025 mg/L for hardness 20-40 mg/L.
The BC 30-day mean lead guideline is 0.004 mg/L for hardness 20-40 mg/L.
The CCME guideline for lead = 0.001 mg/L for hardness = 0-60 mg/L.

[j] The BC maximum manganese guideline is 0.01102*(hardness)+0.54 mg/L. Guideline shown is based on hardness of 27 to 38 mg/L for the tested water.
The BC 30-day mean manganese guideline is 0.0044*(hardness)+0.605 mg/L.

[k] Nickel guideline is 0.025 mg/L for hardness = 0-60 mg/L.

[l] The BC maximum silver guideline is 0.0001 mg/L for hardness ≤100 mg/L. The BC 30-day mean silver guidelines is 0.00005 mg/L for hardness ≤100 mg/L.

[m] The BC maximum zinc guideline is 0.033 mg/L for hardness ≤90 mg/L. The BC 30-day mean zinc guidelines is 0.0075 mg/L for hardness ≤90 mg/L.

[n] Analytical detection limits were above applicable guidelines for these metals.

3.2. Stream Invertebrates

A small number of stream invertebrates were obtained from each station (Table 6; Appendix 2). Midge larvae (chironomid) were the most abundant stream invertebrates at both stations. Only one caddisfly larva was obtained, representing an EPT taxon. Overall, total densities were very low at these stations. The low abundance and diversity observed at these two stations were expected since the bypass channel had received Millstone River water for less than a month at the time of this sampling. Instead, it is perhaps surprising that there were already any stream invertebrates present in this newly available habitat. The dominance of chironomid larvae is consistent with other observed reports of their ability to rapidly colonize newly available habitats (Giller and Malmqvist 1998). Numerous mosquito larvae were also observed in Pond 4 on 13 October 2007 (E. Demers, personal observation).

Table 6. Abundance and density of stream invertebrates obtained from triplicate samples taken on 31 October 2007 at two stations on the Millstone Bypass Channel. Invertebrate Survey Field Data Sheets are included in Appendix 2.

	Station	
Invertebrate Taxa	**SI1**	**SI2**
Caddisfly Larvae	0	1
Aquatic worm (oligochate)	1	1
Midge Larvae (chironomid)	3	16
Total Abundance	4	18
Density (number / m^2)	15	67

4. Acknowledgements

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5. References

BCMWLAP. 1998a. British Columbia Approved Water Quality Guidelines (Criteria): 1998 edition updated August 24, 2001. British Columbia Ministry of Water, Land and Air Protection. Victoria, BC.

BCMWLAP. 1998b. A Compendium of Working Water Quality Guidelines for British Columbia: 1998 edition updated August 23, 2001. British Columbia Ministry of Water, Land and Air Protection. Victoria, BC.

CCME. 1999. Canadian Environmental Quality Guidelines. Updated 2004. Canadian Council of Ministers of the Environment, Winnipeg.

Kalff, J. 2002. Limnology: Inland Water Ecosystems. Prentice Hall, Upper Saddle River, New Jersey. 592 p.

Giller, P.S., and B. Malmqvist 1998. The Biology of Streams and Rivers. Oxford University Press, Oxford. 296 p.

RISC. 1998. Guidelines for Interpreting Water Quality Data. Resources Information Standards Committee, Victoria, BC.

Taccogna, G., and K. Munro (eds). 1995. The Streamkeepers Handbook: a Practical Guide to Stream and Wetland Care. Salmonid Enhancement Program, Dept. Fisheries and Oceans, Vancouver, BC.

6. Appendices

APPENDIX 1. Photographs showing the sampling stations at the Millstone Bypass Channel.

Photo 1. Station WQ1 (yellow arrow) at the inlet of the Millstone Bypass Channel (concrete structure), looking upstream along the Millstone River. The red arrows indicate the direction of water flow.

Photo 2. Station WQ2 (yellow arrow) at the upstream end of Pond 2 of the Millstone Bypass Channel, looking downstream towards Pond 2. The red arrow indicates the direction of water flow.

APPENDIX 1. (Continued)

Photo 3. Station WQ3 (yellow arrow) at the downstream end of Pond 6 of the Millstone Bypass Channel, looking downstream towards a pedestrian bridge. The red arrow indicates the direction of water flow.

Photo 4. Station WQ4 (yellow arrow) at the downstream end of Duck Pond of the Millstone Bypass Channel, looking towards a pedestrian bridge. The red arrow indicates the direction of water flow.

APPENDIX 1. (Continued)

Photo 5. Station WQ5 (yellow arrow) at the outlet end of the Millstone Bypass Channel, looking downstream towards the Millstone River. The outlet of the old fish ladder is visible on the left (concrete structure). The red arrow indicates the direction of water flow.

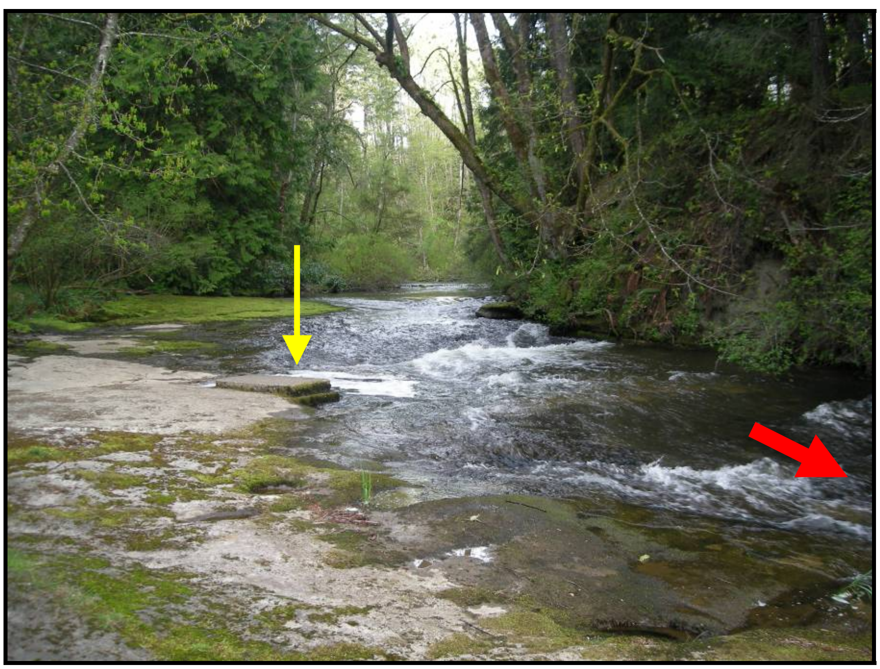

Photo 6. Station WQ6 (yellow arrow) on the Millstone River, looking upstream towards the entrance of the old fish ladder. The red arrow indicates the direction of water flow.

APPENDIX 1. (Continued)

Photo 7. Station SI1 (yellow arrows) downstream of Pond 4 of the Millstone Bypass Channel, looking upstream towards Pond 4. The red arrow indicates the direction of water flow.

Photo 8. Station SI2 (yellow arrow) downstream of Pond 6 of the Millstone Bypass Channel, looking upstream towards a pedestrian bridge. The red arrow indicates the direction of water flow.

APPENDIX 2. Invertebrate Survey Field Data Sheet completed for triplicate stream invertebrate samples collected at Station SI1 and SI2 on the Millstone Bypass Channel during 30 October 2007.

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Millstone Bypass Channel	Date: 31 October 2007
Station Name: **SI1**	Flow status: Riffle
Sampler Used: D-net, kick-and-sweep	Area sampled (Hess, Surber = 0.09): 0.09 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)		
	Mayphly Nymph (EPT)		
	Stonefly Nymph (EPT)		
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		0	0
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)		
	Watersnipe Larva		
Sub-Total		0	0
Category 3	Aquatic Worm (oligochaete)	1	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	3	1
	Planarian (flatworm)		
Pollution Tolerant	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		4	2
TOTAL		4	2

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: **4**

DENSITY: Invertebrate density per square metre:

4 ÷ 0.27 = **15**

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (Col. C): **Midge Larva (chironomid)**

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3: **2**

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6: **0**

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

Good	Accpetable	Marginal	Poor
0.75-1.0	0.50-0.75	0.25-0.50	0-0.25

(EPT1 + EPT2 + EPT3) / CT: **0.00**

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: **2**

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

Good	Accpetable	Marginal	Poor
0-0.40	0.40-0.60	0.60-0.80	0.80-1.0

Col. C for S3 / CT: **0.75**

SECTION 4 - OVERALL SITE ASSESSMENT RATING

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

Assessment Rating	
Good	4
Accpetable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	1
EPT Index	1
EPT To Total Ratio	1
Predominant Taxon Ratio	2

Average Rating
1.3

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Millstone Bypass Channel	Date: 31 October 2007
Station Name: **SI2**	Flow status: Riffle
Sampler Used: D-net, kick-and-sweep	Area sampled (Hess, Surber = 0.09): 0.09 m^2

Column A **Pollution Tolerance**	**Column B** **Common Name**	**Column C** **Number Counted**	**Column D** **Number of Taxa**
Category 1	Caddisfly Larva (EPT)	1	1
	Mayphly Nymph (EPT)		
	Stonefly Nymph (EPT)		
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		1	1
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)		
	Watersnipe Larva		
Sub-Total		0	0
Category 3	Aquatic Worm (oligochaete)	1	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	16	2
	Planarian (flatworm)		
Pollution Tolerant	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		17	3
TOTAL		18	4

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 18

DENSITY: Invertebrate density per square metre (abundance / (0.09 m^2 x 3 replicates)):

18 ÷ 0.27 = 67

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

Midge Larva (chironomid)

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

6

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

1

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

Good	Accpetable	Marginal	Poor
0.75-1.0	0.50-0.75	0.25-0.50	0-0.25

(EPT1 + EPT2 + EPT3) / CT

0.06

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 4

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

Good	Accpetable	Marginal	Poor
0-0.40	0.40-0.60	0.60-0.80	0.80-1.0

Col. C for S3 / CT

0.89

SECTION 4 - OVERALL SITE ASSESSMENT RATING

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

Assessment Rating	
Good	4
Accpetable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	1
EPT Index	1
EPT To Total Ratio	1
Predominant Taxon Ratio	1

Average Rating
1.0