North Shore Streamkeepers

Final Report

Water Quality and Watershed Health of MacKay Creek, 2007-2009 Study

March 31, 2009

Executive Summary

The 2007-2008 watershed study on MacKay Creek in North Vancouver BC was a joint project of the North Shore Streamkeepers and North Shore Fish and Game Club. Other contributors were Environment Canada (Environmental Damages Fund), District of North Vancouver (equipment, maps, and technical support), Aquatic Informatics (equipment), City of North Vancouver (maps) and Fisheries and Oceans Canada (technical support). The objectives were to obtain information about water quality, streamflow and aquatic life in MacKay Creek and to increase public education and awareness about the stream.

Water quality data were collected monthly at four sites from the headwaters to the mouth of the stream and stream flow data were collected monthly at one site in lower MacKay Creek to provide information about seasonal trends, relative contaminant loadings, and key water quality issues. Stream health was assessed by evaluating benthic invertebrate communities. The project has also included a public education component.

MacKay Creek is home to coho and chum salmon runs, resident cutthroat trout and many species of wildlife. The stream flows through residential, commercial and industrial areas before entering Burrard Inlet. Runoff from roads and properties contributes various contaminants to the stream and has the potential to negatively affect aquatic life. Samples were analyzed for general water chemistry, total suspended solids, turbidity, nutrients (fertilizers), metals, coliform bacteria, temperature, pH, conductivity and dissolved oxygen. These parameters provide evidence of common pollutants in rain runoff from human activities in the watershed. Stream flow was generally measured on the same day as water quality.

From bottom to top of the developed area, four sites were sampled:

- Site 1: below Marine Drive and upstream of the stream mouth in MacKay Creek Park
- Site 2: in Heywood Park, upstream of Marine Drive
- Site 3: in Upper MacKay Creek Park, a ravine surrounded by residential areas
- Site 4: headwater stream in Sarita Park, above most of the residences, 200 m elevation.

Levels of most analytical parameters were within British Columbia and Canadian water quality guidelines most of the time. The most frequently documented contributors to reduced water quality were:

- elevated fecal coliform (up to >24,000 mean probable number) and *E. coli* bacteria levels (up to 3300 mean probable number) at Sites 1, 2 and 3 year-round with maximum numbers reported at Site 3. Dogs, wildlife and leaks in municipal or residential sanitary sewers are potential sources.
- elevated nutrient levels (up to 0.012 mg/L ammonia, 0.62 mg/L nitrate and 0.006 mg/L orthophosphate during summer). Extensive algal growth was also noted during spring and summer.

Elevated sediment loads were measured during heavy rainfall in June 2008. The source was a poorly managed residential landscape project in the upper developed area of the watershed. This resulted in brown and turbid water (total suspended solids up to 134 mg/L, turbidity of 55 NTU) in 5 km of MacKay Creek for several hours. Levels of cadmium, copper, iron, lead, zinc, total suspended solids and turbidity were also above water quality guidelines at that time.

Benthic invertebrate surveys conducted in 2007 and 2008 indicated a variety of organisms, including pollution sensitive mayflies at all sites sampled. Using Streamkeeper methods, a stream health rating of "acceptable" was obtained. In contrast, earlier studies conducted for the City of North Vancouver and District of North Vancouver using Benthic Index of Biological Integrity methods, commonly using in Integrated Stormwater Management Planning, indicate a rating of "poor" or "very poor", based on low abundance and richness of pollution sensitive organisms.

The presence of coho, chum and cutthroat trout is confirmed in MacKay Creek through surveys of juvenile fish, observations made during the water sampling program, observations of adult coho and chum spawners in the system from 2006 through 2008 and historic records.

Increased local government and public awareness of the environmental values of MacKay Creek was pursued in several ways and is an ongoing legacy of this project:

- three-day workshop for UBC engineering and planning students (sampling for water and benthic invertebrates, challenges of urban development with City and District staff)
- meetings with District of North Vancouver and City of North Vancouver staff about potential influences of municipal operations on water quality and stream habitat
- public events to control spread of invasive plants in riparian areas (Heywood Park in the City, MacKay Ravine Park in the District)
- MacKay Creek newsletter distributed to over 1000 households in upper MacKay Creek in fall 2008
- development of a public report of the MacKay watershed study
- posting reports and notices of events to the North Shore Streamkeepers website
- making presentations at service clubs and other groups
- working with residents surrounding the MacKay Creek ravine to repair and improve habitat to provide off-channel winter habitat for salmonid juveniles.

In addition, the MacKay Creek watershed study will be presented at Council meetings of the District of North Vancouver and City in 2009 and knowledge gained in this project will be shared with volunteers elsewhere in North Vancouver, West Vancouver and Metro Vancouver.

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1 Introduction

MacKay Creek in North Vancouver, British Columbia, is a salmon-bearing stream in an urbanized watershed. This study integrates many aspects of watershed function and health and includes water quality, hydrology, benthic invertebrate, fish population and public awareness components. The project is part of ongoing public awareness and restoration activities, designed to foster an understanding and appreciation of MacKay Creek and other North Shore streams among area residents and businesses.

North Shore Streamkeepers and North Shore Fish and Game Club undertook this one-year study of MacKay Creek with two objectives in mind:

- to provide an assessment of overall watershed health and identify water quality issues of a typical North Vancouver stream
- to raise awareness in the community and local governments about stream conditions and increase understanding of relationships between human activities and health of local streams.

In addition to this introduction, the report includes Section 2 (MacKay Creek watershed), Section 3 (sampling locations), Section 4 (methods), Section 5 (precipitation), Section 6 (hydrology), Section 7 (water quality results), Section 8 (benthic invertebrate monitoring program), Section 9 (other aquatic fauna), Section 10 (public education initiatives) and Section 11 (discussion and recommendations).

2 MacKay Creek

MacKay Creek is a salmon-bearing stream in North Vancouver, with headwaters above the 330 m level on the southwest slope of Grouse Mountain (Figure 1). The creek flows through residential, commercial and industrial areas and enters Burrard Inlet in an area of active port facilities. Riparian areas are relatively intact in some areas, but not in others. Coho and chum salmon and cutthroat trout are known to inhabit the creek now and there are also historic records of steelhead.

The two main environmental challenges to maintaining healthy streams in urban areas are water quality and habitat quality. The physical habitat of MacKay Creek has been maintained in many areas because it flows through ravines, protected parkland and low density residential areas. However, even in residential areas, there are many non-point sources of contaminants that can result in degraded water quality. Water quality is a key factor in the health of aquatic ecosystems. A variety of human activities, including land use change, urbanization, and industrial processes can significantly impact ecosystem health via water quality effects.

North Shore Fish and Game Club volunteers have operated a small hatchery on MacKay Creek for 30 years, with support from Fisheries and Oceans Canada, and currently release chum fry to the stream. They also organize annual stream clean-ups in the lower reaches. SeaSpan (The Washington Group) restored the mouth of MacKay Creek in 2006, moving the stream away from the boat basin, where the municipal government had moved it in the 1970s due to flooding concerns, back to the original estuary.

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Figure 1. Overview of Mackay Creek Watershed and Sampling Sites

0 250 500 1,000 1,500 2,000 Meters

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North Shore Streamkeepers and various neighbourhood groups have undertaken habitat restoration projects, including construction of side channel habitat, removal of invasive plants and planting of native vegetation in riparian areas. However, the success of these efforts to maintain and restore watershed function depends on good water quality, which has not been consistently monitored.

3 Site Locations

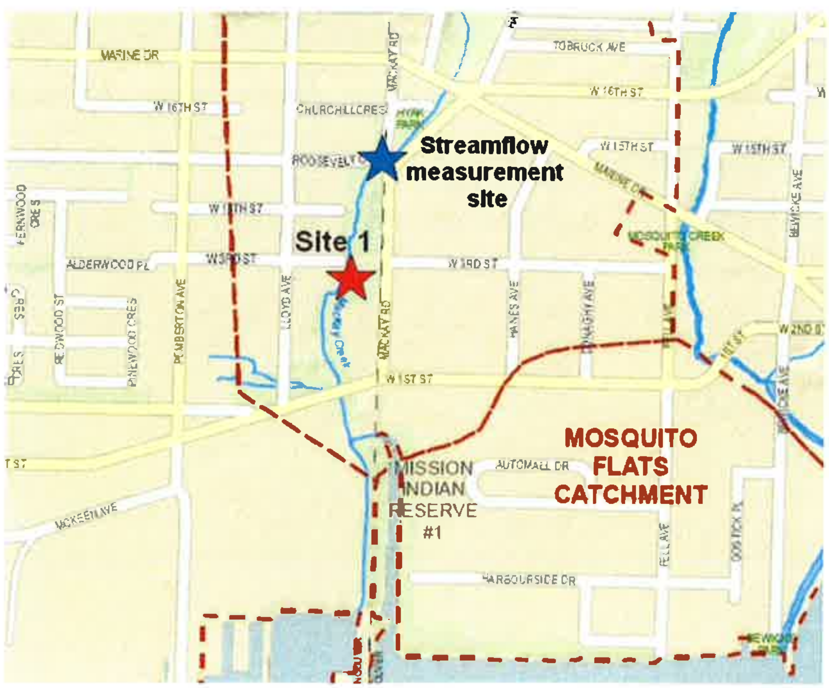
3.1 Routine Sampling Site Locations on MacKay Creek

Four water quality monitoring stations were established for the survey (Figures 1, 2, 3 and 4). These sites were located to identify differences in water quality associated with commercial and industrial activities (between Sites 1 and 2) and residential activities (between Sites 1, 2 and 3). Data from site 1, coupled with discharge measurements, allowed a rough estimation of contaminants loadings from the watershed to Burrard Inlet, to provide information about the watershed and its potential effects on the marine environment.

The sites, from the bottom of the watershed to the top, are:

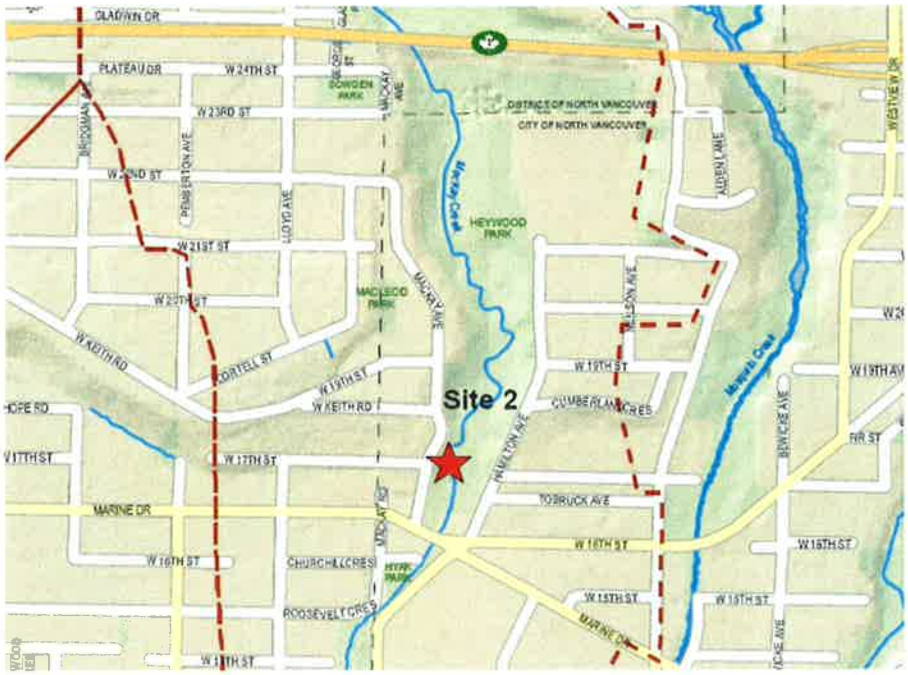
Site 1: MacKay Creek at Third Avenue, in MacKay Creek Park 600 m upstream of the creek mouth, upstream of tidal influence. This site reflects influence of most of the land uses within the watershed, but is located most closely to light industrial activities. The flow monitoring site (see section 6) was located approximately 100 m upstream of the water collection site. The sites are shown in Figure 2.

Figure 2: Location of Site 1 and of the streamflow measurement site, MacKay Creek, 2007-2008



Site 2: MacKay Creek above Marine Drive (upstream of the pedestrian bridge in Heywood Park and volunteer-run hatchery, downstream of low and medium-density housing, commercial and recreational uses and immediately upstream of industrial areas). The location is shown in Figure 3.

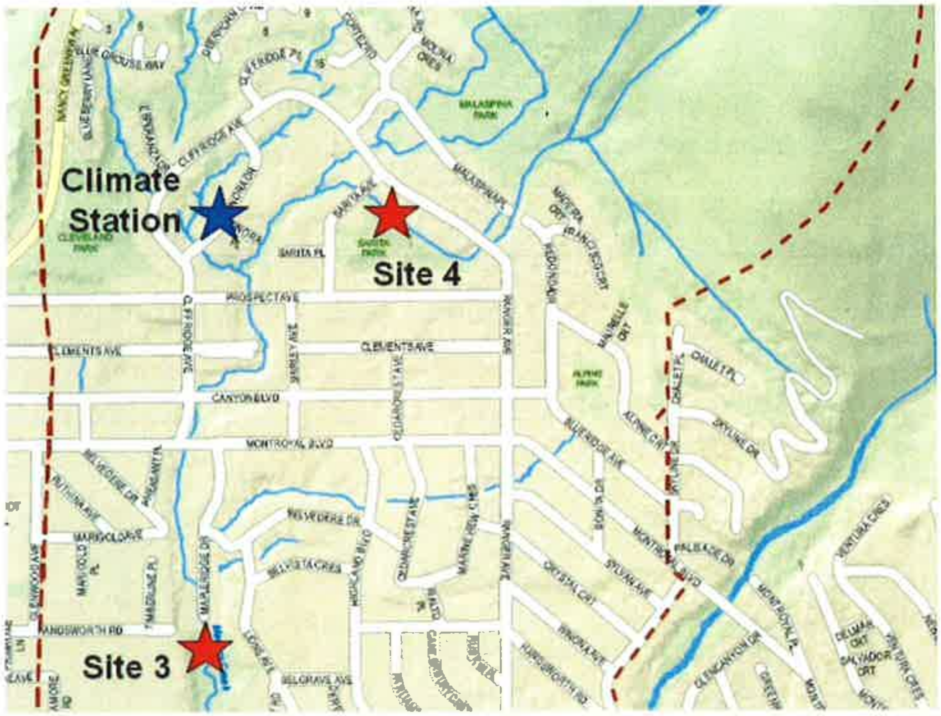
Figure 3: Location of Site 2, MacKay Creek, 2007-2008



Site 3: MacKay Creek above Ridgewood Drive (in Upper MacKay Creek Park, in a forested ravine surrounded by a low density residential area). Site 3 is shown in Figure 4.

Site 4: MacKay Creek at Ranger Avenue (in the headwaters, upstream of most residential land). The location is shown in Figure 4.

Figure 4: Location of Sites 3 and 4 and the Sonora Drive Climate Station, MacKay Creek, 2007-2008



3.2 Headwater Tributaries

Many small tributaries, mostly in the upper watershed, feed into MacKay Creek. They were not included in the monthly survey. However, a round of *in situ* measurements was made in October 2008 to investigate their influence on MacKay water quality, between Site 3 and Site 4 especially.

Four tributaries were assessed: (See Figure 5)

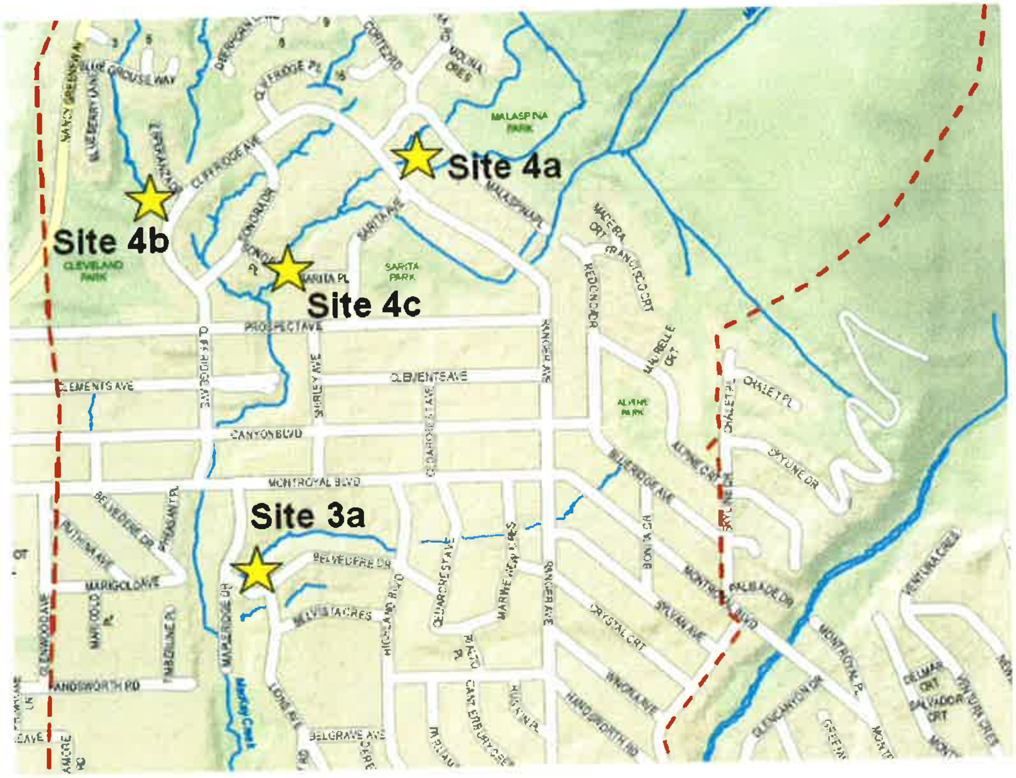
Site 4a: Montroyal school tributary, at Ranger near Malaspina

Site 4b: Tributary at Cliffridge Avenue, near Esperanza Drive, downstream of playing fields

Site 4c: Footbridge between Sarita Place and Sonora Place - downstream of Site 4 and 4a

Site 3a: Tributary from the northeast end of the watershed, at Belvedere Drive and Mapleridge Drive

Figure 5: Location of the four additional sites where in situ data were taken in October 2008



4 Water Quality Sampling

4.1 Sampling Schedule

The sampling schedule was initially once a month around mid-month, independent of weather conditions but dependent on the availability of the sampling crew. Samples were taken between the 9th to the 18th of each month from November 2007 to November 2008 with the exception of October 2008. During October, no sampling was done and another sampling was re-scheduled for the next rainfall to obtain further data regarding the influence of rain on water quality. Samples were collected in the early to late afternoon. Based on availability of volunteers, samples were initially collected on Sunday afternoons; however, from June onward, sampling was moved to Mondays to assess conditions during the work week.

4.2 Parameters

General water characteristics (temperature, dissolved oxygen, pH and conductivity) were measured on site (*in situ* parameters). Water samples were analyzed for general chemistry and for parameters that reflect human activities in the watershed, including nutrients (fertilizers), metals (from a variety of sources) and fecal coliform bacteria. The parameters studied, and analytical detection limits, are provided in Table 1. Water samples were analyzed by ALS Environmental Laboratory, Vancouver BC. In March 2008, when a sheen was visible on the water surface, samples were also collected for analysis of total petroleum hydrocarbons (C10 to C32), but results were below analytical detection limits.

Table 1: Water chemistry parameters and detection limits (DL), MacKay Creek, 2007-2008

In Situ Data	General Characteristics	Nutrients	Turbidity	Bacteria	Metals		
Dissolved Oxygen (DL = 0.1 mg/L)	**Alkalinity** (DL = 2 mg/L)	**Ammonia** (DL = 0.01 mg/L)	**Turbidity** (DL = 0.1 NTU)	**Total Coliforms** (DL = 10)	**Aluminium** (DL = 0.01 mg/L)	**Copper** (DL = 0.01 mg/L)	**Selenium** (DL = 0.01 mg/L)
Dissolved Oxygen (DL = 1 %)	**Bromide** (DL = 0.05 mg/L)	**Nitrate** (DL = 0.01 mg/L)	**Total Suspended Solids** (DL = 3 mg/L)	**Escherichia coli** (DL = 1)	**Arsenic** (DL = 0.5 µg/L)	**Iron** (DL = 0.03 mg/L)	**Silver** (DL = 0.02 µg/L)
Conductivity (DL = 2 µS/cm)	**Chloride** (DL = 0.5 mg/L)	**Nitrite** (DL = 0.001 mg/L)			**Antimony** (DL = 0.5 µg/L)	**Lead** (DL = 0.3 µg/L)	**Sodium** (DL = 2 mg/L)
pH (DL = 0.01)	**Fluoride** (DL = 0.02 mg/L)	**Orthophosphate** (DL = 0.001 mg/L)			**Barium** (DL = 0.02 mg/L)	**Lithium** (DL = 0.01 mg/L)	**Thalium** (DL = 0.2 µg/L)
Temperature	**Hardness** (DL = 0.7 mg/L)	**Sulfate** (DL = 0.5 mg/L)			**Beryllium** (DL = 0.001 mg/L)	**Magnesium** (DL = 0.1 mg/L)	**Tin** (DL = 0.5 µg/L)
		Total dissolved Phosphate (DL = 0.002 mg/L)			**Boron** (DL = 0.1 mg/L)	**Manganese** (DL = 0.02 mg/L)	**Titanium** (DL = 0.01 mg/L)
		Total Phosphate (DL = 0.002 mg/L)			**Cadmium** (DL = 0.017 µg/L)	**Mercury** (DL = 0.2 µg/L)	**Uranium** (DL = 0.2 µg/L)
					Calcium (DL = 0.1 mg/L)	**Molybdenum** (DL = 0.01 mg/L)	**Vanadium** (DL = 0.01 mg/L)
					Chromium (DL = 0.001 mg/L)	**Nickel** (DL = 0.01 mg/L)	**Zinc** (DL = 0.01 mg/L)
					Cobalt (DL = 0.3 µg/L)	**Potassium** (DL = 2 mg/L)	

4.3 Sampling Equipment

Clean sampling bottles were provided by ALS Laboratory in Vancouver. The District of North Vancouver provided a YSI 556 MPS meter for collection of *in situ* data on water quality. In addition, Aquatic Informatics™ Inc. supplied a Hydrologic Services P/L Model CMC 200 current counter meter and Scientific Instruments Model 1215 Price-type current meter for flow measurements.

Figure 6 shows the YSI meter in use.

Figure 6: Sampling crew using the YSI meter at Site 1

4.4 Sampling Protocol

In situ data were collected first, using the YSI meter. Subsequently, three sampling bottles were filled at each site for bacteria, metals and anions/nutrients. Figure 7 shows the filling of a sample bottle.

Figure 7: Filling of sample bottles midstream at Site 2

All the measurements and water samples were collected in the middle of the creek, in fast running flow to avoid stagnant areas where the water could be altered. Care was taken to avoid contamination during sampling, by following defined protocols (preventing contact with the insides of bottles and lids, keeping the samples refrigerated to stop bacterial development).

Samples were held on ice or refrigerated overnight, then delivered to ALS laboratory in Vancouver for analysis. All samples were submitted within 24 hours and analyzed within recommended hold times.

Quality assurance / quality control measures included analysis of one travel blank (January 2008) and two field duplicates (February 2008 at site 4, May 2008 at Site 3). There were no measurable levels in the blank (a sample of de-ionized water supplied by the laboratory and carried on the field survey). The field duplicates contained similar levels of analytes to those measured in the corresponding sample (within 10% of the mean value for parameters with levels greater than ten times the detection limit).

5 Rainfall patterns

Precipitation can affect the concentration of many elements present in streams. On the one hand, some elements naturally found in the water, such as calcium, can show a dilution during a rainfall. On the other hand, pollutants such as cadmium and nitrite can originate from run-off waters via the storm drain system. In order to assess the differences that occurred from one sampling session to the other, a closer look at the precipitation archives is useful.

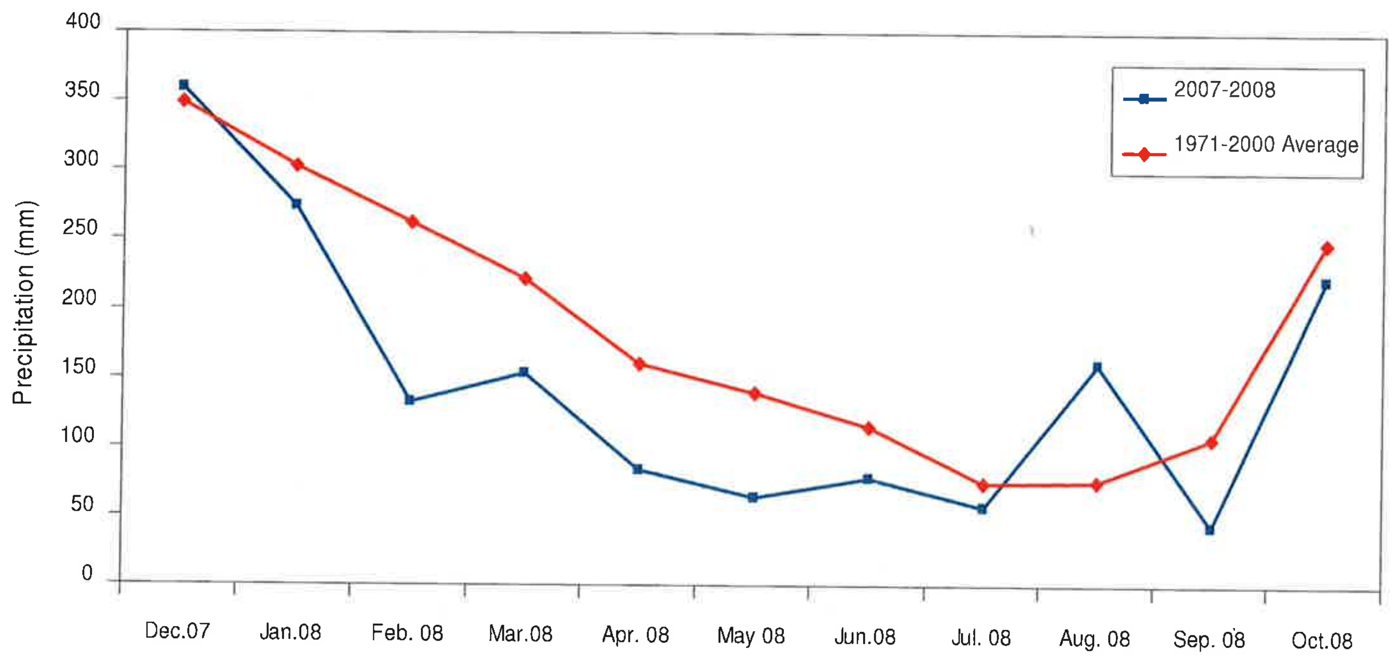
Weather archives can be found at the Canada's National Climate Data and Information Archive (www.climate.weatheroffice.ec.gc.ca). The closest climate station to MacKay Creek is located in the upper portion of the study area at Sonora Drive, roughly 300 metres west of the creek (See Figure 4):

Latitude: 49° 21.600' N   Longitude: 123° 6.000' W   Elevation: 183 m

Despite a high amount of rainfall each year on the North Shore, only one sampling session happened during a rainfall between November 2007 and September 2008. In order to be more representative of the usual weather conditions on the North Shore, a decision was made to delay taking the final data set until the next heavy rainfall. Thus, no sampling occurred in October 2008 and the last sampling was performed November 11th, 2008.

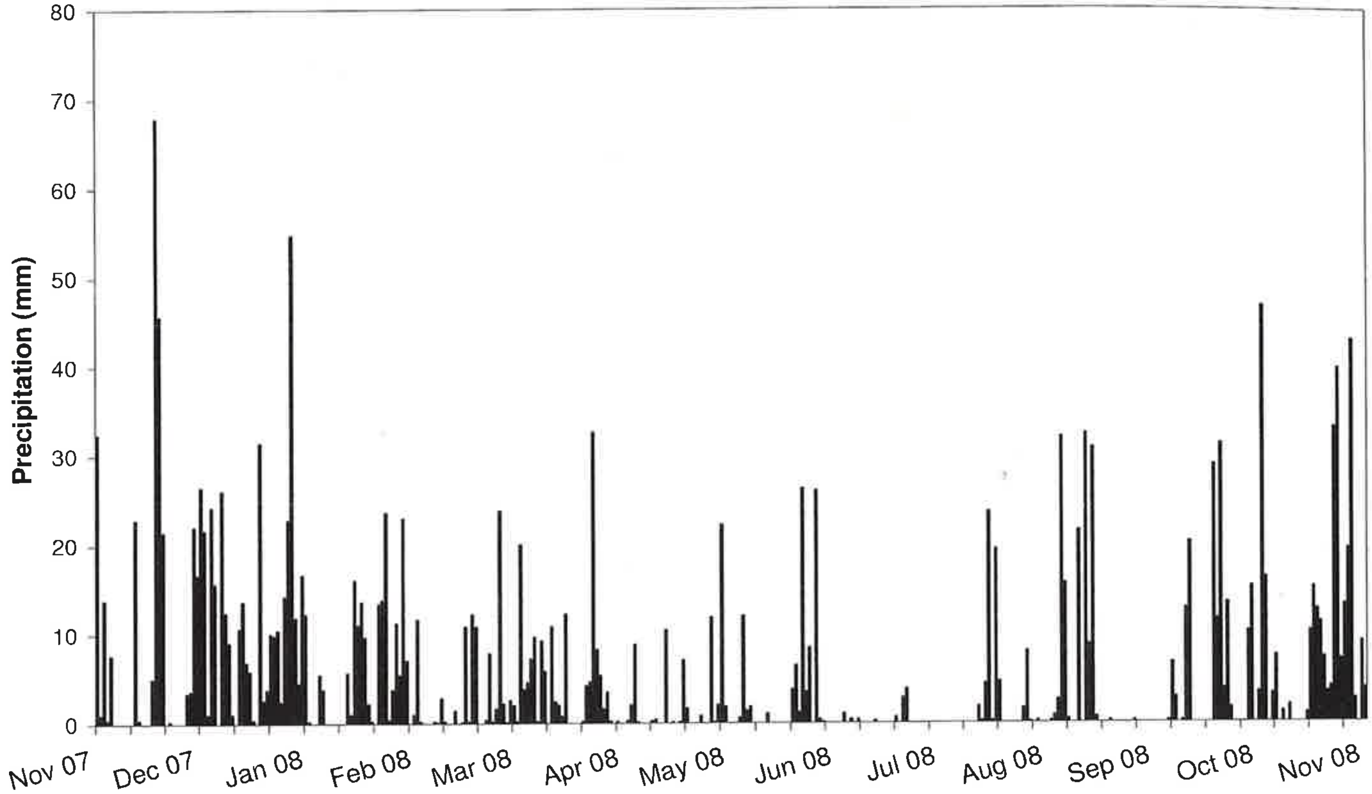
The period over which the survey was performed was much drier than usual on the North Shore and elsewhere in British Columbia. As shown in Figure 8, monthly amounts of precipitation were below the 1971-2000 period average, except for December 2007 and August 2008. August was a much wetter month than average, with three of the heaviest daily rainfall events recorded over the year (>30 mm). November 2007 and February 2008 showed the biggest difference from the average with roughly half of the average monthly amount of precipitation.

Figure 8: Monthly amount of precipitation recorded at the Sonora Drive weather station from December 2007 to October 2008.



In the 2007-2008 study period, 156 days of precipitation ≥ 1mm were recorded, for an annual amount of precipitation of 1837 mm. This is 25% below the 2438 mm average annual amount of precipitation recorded from 1971 to 2000. Figure 9 shows the daily amount of precipitation recorded over the study period.

Figure 9: Daily amount of precipitation recorded at the Sonora Drive weather station from November 1, 2007 to November 15, 2008.



The maximum daily rainfall recorded over the study period was 67.8 mm in December 2007. However, this was far below the maximum daily rainfall recorded since 1971, with 132 mm of rain October 30, 1981.

6 Hydrology

6.1 Site Description

The streamflow measurement site was located approximately 100 m upstream of Site 1 and 2 m downstream from the downstream edge of a pedestrian bridge between Capilano Mall and MacKay Road (See Figure 2). From GPS measurements, the site is located at approximately 49º 19.324' N, 123º 06.125' W (WGS84); or 5463267N, 492581 W (UTM NAD83). Site elevation is approximately 10 m ASL. This location was selected because it was believed to be the furthest-downstream site technically suitable, logistically convenient, and safe for volunteer-performed streamflow measurements.

6.2 Methods

A cross-section was established on each measurement day using a tape measure. Measurements started at the right bank (looking upstream) and proceeded serially across the cross-section to the left bank. About one to two dozen measurements were taken over the cross-section, depending on the width of the stream on the measurement day. At each location along the cross-section, both depth and velocity were estimated. Velocity was measured at 0.6 of the depth downward from the water surface (0.4 the depth upward from the streambed). Velocity was measured in the field as the number of counts over 50 s. Conversion to velocity in m/s using the equipment manufacturer's guidelines, and calculation of a volumetric flow rate in m3/s, were performed later.

Instrumentation was loaned by Aquatic Informatics Inc. as an in-kind contribution to the project, and consisted of a Scientific Instruments top-setting wading rod, Hydrologic Services P/L Model CMC 200 current counter meter, and Scientific Instruments Model 1215 Price-type current meter.

Flow estimates were obtained only as spot measurements and therefore speak solely to hydrological conditions at the specific times that the measurements were taken. The nominal goal was to obtain flow measurements once per month over November 2007 through October 2008 inclusive, but a few measurements were missed. As measurements were collected by a volunteer outside of normal working hours, and additionally had to be collected during daylight hours, field work was conducted on normal non-working days (i.e., weekends). Measurement days were in general coordinated with volunteers conducting water sampling.

6.3 Results

The manual streamflow data presented here were taken by community volunteers for preliminary informational purposes only and are not to be used for any other purpose, such as engineering design.

The estimated flows at each measurement date are shown in Table 2. Flows ranged from 0.05 to 1.15 m3/s, with lowest flows in August and September and highest flows in January.

Table 2: Estimated flows and observations, MacKay Creek, 2007-2008.

Date	Flow (m3/s)	Other at site environmental observations
12/11/2007	0.96	Water clear
01/12/07	n/a	
12/01/2008	1.15	
17/02/08	0.28	Much garbage in the stream
01/03/2008	n/a	
12/04/2008	0.27	Streambed clearly visible throughout cross-section for first time since the beginning of the survey. Green algal growth visible
11/05/2008	0.21	Green algal growth visible
08/06/2008	0.20	Water very clear (measurements taken one day before water samples). No green algal growth visible. Insect hatch on.
01/07/2008	n/a	
18/08/2008	0.05	Water clear. Some algal growth on bed. Lots of water skippers.
15/09/2008	0.06	Water clear. Some algal growth. A few mosquitoes and water skippers. Observed one live crayfish.
26/10/2008	0.11	Water clear. Some algal growth.

Three of the scheduled streamflow measurement dates were missed. This includes the high rainfall events in June and November 2008, due to logistical difficulties coordinating streamflow and water quality measurements. Some additional salient observations of environmental conditions at the flow measurement site are also listed where relevant.

7 Water Quality Results

Results are summarized here for all parameters, with all data provided in Appendix A (*in situ* data) and Appendix B (water chemistry).

7.1 In Situ Data

Some parameters, such as dissolved oxygen concentration and saturation and water temperature, are too time-sensitive to be analysed at the laboratory. Others, such as pH and conductivity, are measured in the field and the laboratory. *In situ* water chemistry data were collected at each site with a YSI meter. Occasionally, some measurements were not taken due to calibration problems with the probes.

Water temperature is an important parameter in freshwater ecosystems as it affects the life cycles of many organisms, from algae to salmon fry. Temperature also directly affects water chemistry measures, such as dissolved oxygen and conductivity. For example, water temperatures below 3ºC or above 17ºC can affect salmon juvenile survival rates to differing degrees depending on where they are in the juvenile life cycle. During summer, adequate base flows and shading from tree canopy protect organisms from high temperatures and large daily fluctuations in temperature.

The BC Guidelines for Protection of Freshwater Life (Table 3) describe the optimum temperature ranges of the different salmonids species as a function of their life history stages.

Table 3: Optimum temperature ranges of life history stages of salmonids present in MacKay Creek

Species	Incubation	Rearing	Migration	Spawning
Chum	4.0-13.0 ºC	12.0-14.0 ºC	8.3-15.6 ºC	7.2-11.8 ºC
Coho	4.0-13.0 ºC	9.0-16.0 ºC	7.2-15.6 ºC	4.4-12.8 ºC
Cutthroat	9.0-12.0 ºC	7.0-16.0 ºC	—	9.0-12.0 ºC

Source: the BC Approved Water Quality Guidelines 2006 edition

MacKay Creek water temperatures ranged from 3.8 to 17ºC over the year and met the BC Guidelines most of the time. The highest temperatures were observed in July and August, and the lowest were observed in December and February. However, due to the small size of the stream, water temperature changes quickly within the same day during summer, which can affect the salmon fry survival rate. The summer maximum value is just above the guideline limit and indicates the importance of shading from streamside vegetation in protecting rearing salmonids from elevated temperatures. Higher values than those measured could have a negative effect on salmon and trout life cycles.

Dissolved oxygen is a measure the amount of oxygen dissolved in water (concentration and per cent saturation). Oxygen is essential to the respiratory metabolism of most aquatic organisms. It affects the solubility and availability of nutrients, and therefore the productivity of aquatic ecosystems. The BC Water Quality Guidelines for Protection of Aquatic Life gives a 9 mg/L limit during the embryo/alevin life stages and 5 mg/L at other stages. Below these limits, the concentration of dissolved oxygen is not sufficient to sustain salmonids and many species of aquatic insects.

The concentration and saturation of dissolved oxygen met these guidelines throughout the survey. Levels ranged from 8.2 to 14.6 mg/L and from 73 to 122% saturation with the lowest values recorded in June during a heavy rainfall. The minimum levels during heavy rain were surprising, given the water velocity and likely aeration, and may have been related to calibration issues with the meter or perhaps to higher organic loads associated with the silt.

There were few differences among sites or from one date to the other. The most substantial difference was measured in August with a 3 mg/L difference between Site 4 and Site 1, probably due to higher air temperatures and lower flows during summer.

pH is a measure of the acidity (pH<7) or the alkalinity (pH>7) of the water. Whereas the pH of pure water is neutral (pH=7) and natural rainwater is slightly acidic, stream water pH can range naturally between 6.5 and 9. MacKay Creek water pH appears to be close to neutrality with values ranging from 6.2 to 7.8. There were few differences among sites or sampling dates. All values were within BC water quality guidelines (6.5<pH<9).

Conductivity expresses the ability of the water to conduct electricity and is related to the concentration of dissolved salts (ions). The amount of ions in the headwaters depends mainly on the geology of the watershed and the solubility of rocks and minerals, whereas conductivity downstream will likely depend on both natural catchment characteristics and human activities that may contribute higher ionic concentrations to the stream through pollution.

Due to natural variability, there is no particular guideline for conductivity. Specific conductivity in MacKay Creek ranged up to 280 µS/cm and was lowest at Site 4, where values ranged from 19 to 92 µS/cm. A consistent difference in conductivity was observed between Site 4 and Site 3 over the year, with at least a 2.7 fold increase at Site 3, and a smaller increase at downstream sites. Higher conductivity in one of the headwater tributaries contributed to differences between Sites 3 and 4 (see section 7.2).

7.2 Headwater Tributaries In Situ Data

To understand the origin of the chemical differences noted between Site 4 and Site 3, some complementary *in situ* data were collected in October 2008 on four tributaries that feed into upper MacKay Creek (Figure 5), and also at Site 4. The results are shown in Table 4:

Table 4: In situ water quality in headwater tributaries of MacKay Creek, October 2008

	Site 4	Site 4a	Site 4b	Site 4c	Site 3a
Temperature (°C)	8.6	9.4	8.4	8.8	10
Oxygen Saturation (%)	97	86	88	98	92
Oxygen Concentration (mg/L	11.2	9.9	10.5	11.4	10.5
Conductivity (µS/cm)	37	24	78	51	239

The results varied only slightly from one tributary to the other except for Site 3a (Belvedere Drive and Mapleridge Drive) which showed a substantially higher conductivity and, to a lesser extent, warmer waters. This tributary confluence explains the conductivity difference observed between Site 4 and Site 3. Differences in water quality may be related to different geology and groundwater characteristics in the eastern watershed, which were not examined.

7.3 General Characteristics

Alkalinity is the measure of the water's ability to neutralize acids. It usually indicates the presence of carbonate, bicarbonates or hydroxides. Waters with low alkalinity, such as in BC coastal streams, have little capacity to buffer acidic inputs and are susceptible to acidification (decreased pH).

There is no BC guideline for the Protection of the Aquatic Life for alkalinity. Nevertheless, Swain (1994) established that water with an alkalinity above 20 mg/L presented a low sensitivity to acidification. Conversely, water with an alkalinity below 10 mg/L, such as Site 4 most of the year, had a high sensitivity.

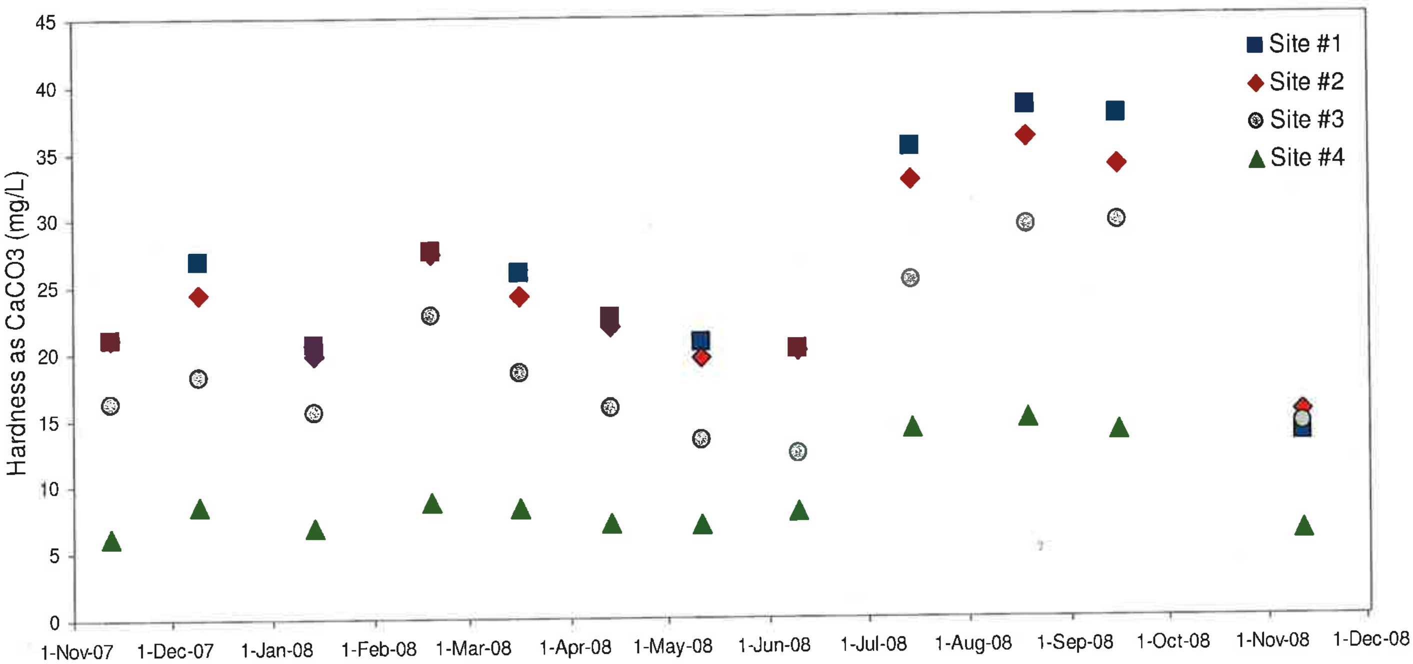
Alkalinity ranged from 4.1 to 13.4 mg/L at Site 4 and from 13.0 to 30.3 mg/L at Site 1. The values observed were generally below 20 mg/L showing a moderate to high sensitivity to acidification. Alkalinity was around 30 mg/L from July to September at the two lower sites only.

Hardness of water is mostly due to the presence of calcium and magnesium in the water. Other metallic ions may contribute to hardness as well. It is reported in terms of calcium carbonate (CaCO3) equivalents. Waters with values exceeding 120 mg/L are considered hard, while values below 60 mg/L are considered soft.

Hard or soft water is not considered harmful for people or aquatic life. Consequently, there is no particular BC guideline for the Protection of Aquatic life for hardness. Nonetheless, water with hardness greater than 500 mg/L needs special treatments before being used for drinking. The toxicity of many metals such as cadmium, copper, nickel and lead varies with hardness. Indeed, harder water reduces the toxicity of metals dissolved in the water.

Hardness measured on MacKay Creek was very low (typical of many lower mainland streams) and ranged from 6.25 to 14.9 mg/L at Site 4 and from 13.7 to 38.2 mg/L at Site 1. Hardness was highest in summer, when flows were at a minimum. Values at Sites 1, 2 and 3 were relatively close and were up to 2.5 times higher than at Site 4. The contribution of many tributaries between Sites 3 and 4, particularly Site 3a (Figure 5), explains this difference. Figure 10 shows hardness concentrations in MacKay Creek over the year.

Figure 10: Hardness in MacKay Creek, 2007-2008



Chloride concentrations changed slightly during the survey. The highest concentration was observed in February 2008 with 44.1 mg/L, not associated with any particular flow or weather condition. Chloride is found naturally and in chemicals used to melt ice or snow in winter, which may help explain the occurrence of this peak. This maximum value remained far below the BC Water Quality Guideline of 600 mg/L.

The highest concentration of chloride occurred at Site 3 for most of the sampling sessions. This may be related to natural biogeochemistry of the Site 3a tributary, which had higher conductivity than other tributaries.

Sulphate is naturally present in freshwater. Concentrations vary, depending on the geology of the watershed. It can also be discharged into the aquatic environment in wastes from industries that use sulphate and sulphuric acid, such as mining and smelting operations, paper and textile mills. Some fertilizers also contain sulphate.

With a maximum of 5.75 mg/L measured over the year, the concentration of sulphate is far below the BC Water Quality Guideline of 100 mg/L. Sulphate concentrations were lowest during rainfall events and highest at minimum stream flows in summer. Consequently, the sulphate concentration recorded at Site 4 during the period of low flow in July should be close to that of the groundwater.

Sulphate concentration increased from Site 4 to Site 1 to the same extent for each sampling session, except during June and November 2008 rainfalls, where the values ranged within a smaller interval.

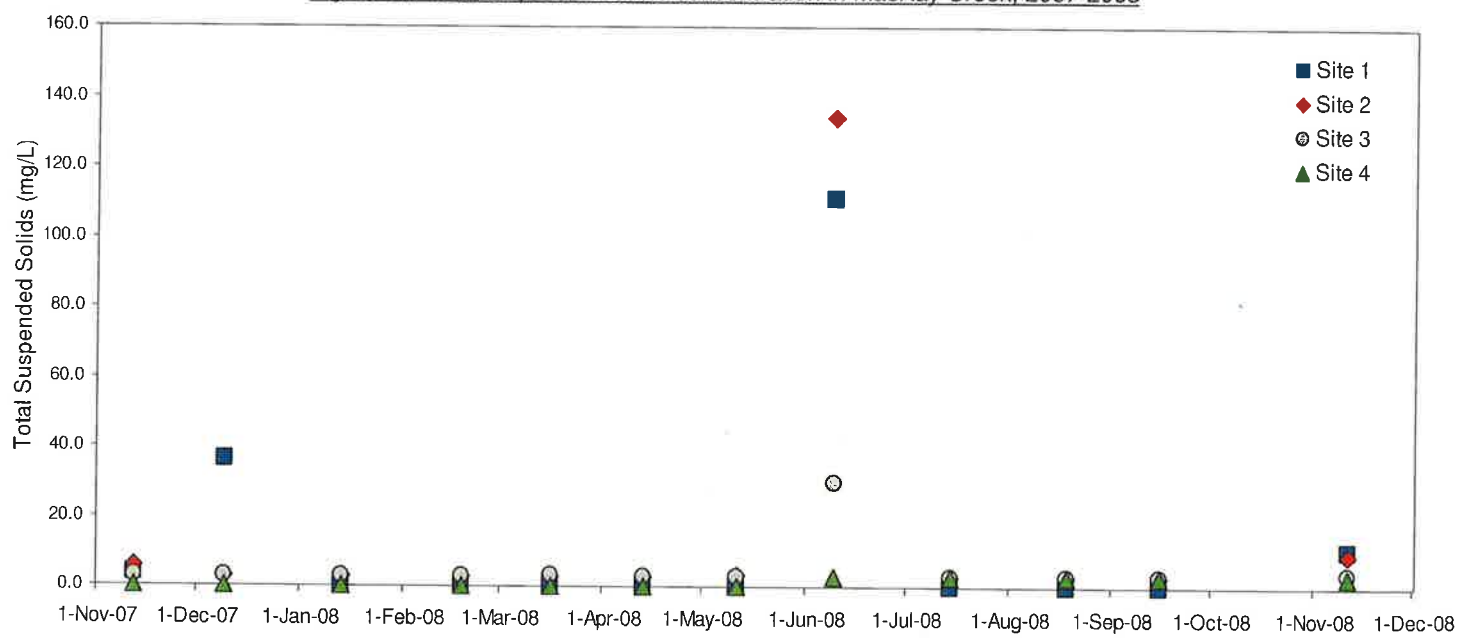
Bromide and **fluoride** concentrations were above the detection limit during the survey.

7.4 Turbidity and Total Suspended Solids

Turbidity and **Total Suspended Solids (TSS)** are linked parameters. They characterize the clarity of the water as well as the amount of fine particles suspended in waters. Levels are influenced by stormwater runoff, which can convey silt and sediment from the roads and from improperly managed construction and landscaping operations. These parameters were low throughout the year except during periods of rain, when fine soil particles and other debris were washed into the creek.

The BC Water Quality Guideline for Protection of Aquatic Life is reported as amount above background levels: 8 NTU for Turbidity and 25 mg/L for TSS for typical conditions on MacKay Creek. These levels were greatly exceeded in June 2008, with a maximum of 55.7 NTU and 134 mg/L Sites 1 and 2 and 19.4 NTU and 29.7 mg/L at Site 3. A small peak in values was also noted in December 2007 at Site 1. The two peaks in TSS are shown in Figure 11. A parallel trend was shown for turbidity.

Figure 11: Total suspended solids concentration in MacKay Creek, 2007-2008



Unlike the June peak, the TSS and turbidity peaks recorded in December 2007 at Site 1 were not associated with rainfall; however, an odour (like a cleaning compound) and cloudy water were observed when sampling. Efforts were made to find the source upstream, but none was identified. Despite rainfall during the November 2008 sampling session, TSS and turbidity remained low, likely because the first flush of runoff during the rain had already conveyed the majority of silt during the previous days.

The record high TSS and turbidity levels reported during the June rainfall event at Sites 1, 2 and 3 were associated with a heavy rainstorm, with a strong brown colour in the stream. The source was tracked to a landscaping project in the upper watershed, between Site 3 and Site 4, which resulted in sediment input to several kilometres of creek over several hours (See Figure 12). The contractor did not have any sediment or erosion control measures in place.

Regardless of intensity of rainfall, turbidity and TSS at Site 4 always remained under the detection limit.

Figure 12: Poor sediment control during landscaping was the major source of TSS and turbidity in June 2008.

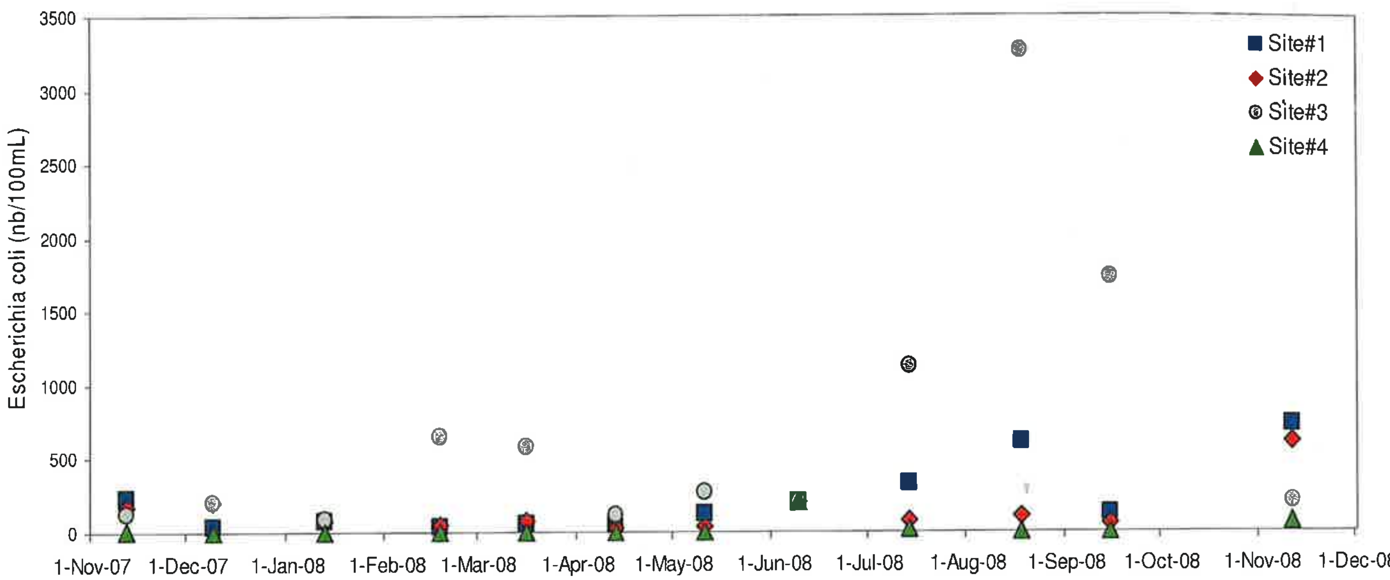
7.5 Bacteria

Coliform bacteria are abundant in the feces of warm blooded animals, including humans. They can naturally be found in soil and aquatic environment as well. ***Escherichia coli* (*E. coli*)** is one type of coliform bacteria, and is exclusively of fecal origin. The presence of *E. coli* indicates the potential for presence of other disease-causing organisms and some *E. coli* strains can cause serious gastro-intestinal or urinary infection. These bacteria can enter streams through direct discharge of waste from mammals and birds, from agricultural and storm runoff, and from untreated human sewage. The survival time of *E. coli* in stream waters depends on many factors such as temperature, exposure to sunlight and presence and types of other microflora. In general terms, *E. coli* survives less than one day at water temperatures reported for MacKay Creek (up to 18℃) (Kristen Welgan, ALS Laboratory, pers. comm.).

Neither coliform bacteria nor *E. coli* are mentioned in the BC Water Quality Guidelines for Protection of Aquatic Life. However, due to the potential risk to human health, the maximum acceptable *E. coli* number in drinking water is 0 bacteria per 100 mL, and 77 bacteria per 100 mL in recreational waters (geometric mean based on at least five samples). Although the MacKay Creek survey did not follow the protocol used to measure *E. coli* for recreational purposes, the 77 bacteria per 100 mL limit can be used as a reference.

E. coli levels were lowest at Site 4 (<1 to 201 bacteria/100 mL), intermediate at Sites 1 and 2 (33 to 727 bacteria/100 mL) and highest at Site 3 (91 to 3290 bacteria/100 mL). Highest numbers were reported in the summer months. *E. coli* levels exceeded the 77 bacteria/100 mL reference value once at Site 4, eight times at Sites 1 and 2 and twelve times (all sampling events) at Site 3. Figure 13 shows *E. coli* levels over the year. Trends for *fecal* coliforms were similar to those for *E. coli*, with maximum values in August (>24,000 bacteria/100 mL at Site 1 and 11,200 bacteria/100 mL at Site 3).

Figure 13: Escherichia coli levels in MacKay Creek, 2007-2008



Abundant fecal waste from dogs was noted at the four sampling sites, all of which are located in municipal parks, and it is obvious that dog owners not picking up after their dogs contribute to the fecal contamination of MacKay Creek. However, the high levels year round suggest a continuous source such as a sewage leak from the municipal system or a private property, and the maximum levels during dry weather indicates less dilution when flows are low. The higher levels at Site 3 than downstream also suggest a source upstream of Site 3, with dilution downstream as additional tributaries contribute cleaner water.

The District of North Vancouver included MacKay Creek Site 3 in its coliform source assessment study of North Shore Creeks. This Bacterial Source Tracking (BST) study included analysis of *E. coli* levels and an assessment of DNA of the *E. coli* to identify sources in selected streams. Preliminary results indicate that *E. coli* from human, ungulate (deer) and an unidentified mammal source are present, but further testing to refine the analysis for some animals is needed (Britta Ng and Richard Boase, District of North Vancouver, pers. comm.).

In light of these results, it is important to keep in mind that drinking or playing in water from MacKay Creek has the potential to result in gastro-intestinal or urinary infections (refer to Public Health Authority).

7.6 Nutrients

Nutrients are chemical molecules that are used by organisms, from bacteria to mammals, to live and grow, and which must be taken in from the environment. These molecules are mainly composed of carbon, hydrogen, nitrogen, oxygen, phosphorus and sulphur.

Nutrients are naturally present in stream water as dissolved molecules. Indeed, headwaters acquire their own chemical identity depending on the geology of the watershed. However, an excessive amount of nutrients (mainly phosphorus and nitrogen) can lead to algal blooms and changes to aquatic life. This is known as eutrophication and it originates mainly from human activity.

7.6.1 Nitrogen Compounds

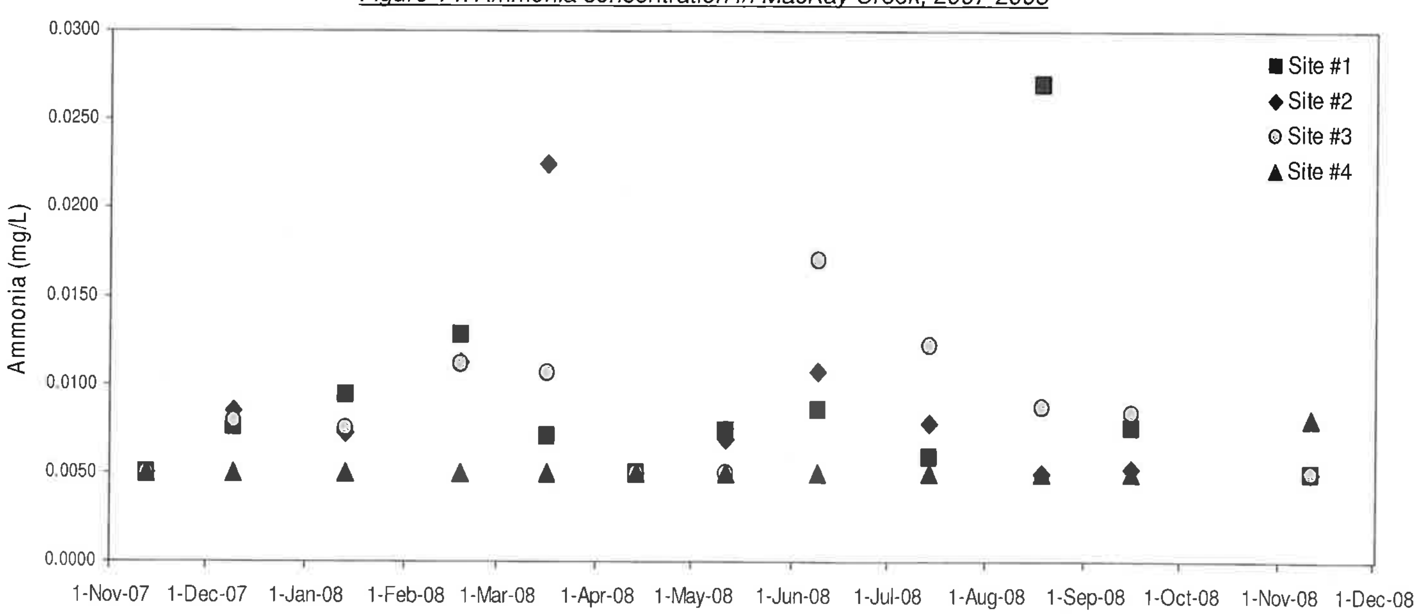
Nitrate is the most stable and the principal form of combined nitrogen in the water. Its concentration is, therefore, much higher than the other nitrogen compounds. In aquatic habitat, ammonia is a soluble gas, mainly originating from organic matter degradation. It is transformed into nitrite and then into nitrate through bacterial processes. Nitrite and nitrate can also originate from the degradation of ammonium (not included in the parameter list). Human urine is rich in ammonium and the presence of this element in freshwater often indicates a leak in the sewage collection system.

The concentrations of ammonia, nitrite and nitrate in MacKay Creek were well below the BC Water Quality Guidelines. However in a healthy stream, ammonia concentrations are close to the detection limit over the year, which was not the case.

Ammonia concentrations were found to be below the detection limit at Site 4 over the year, and slightly increased downstream. As shown in Figure 14, two peaks were observed: at Site 2 in March and at Site 1 in August with 0.022 mg/L and 0.027 mg/L respectively. However, these numbers stayed within what is considered to be natural water concentrations.

During the summer months, Site 3 showed higher ammonia concentrations than at the other sites, indicating a source of ammonia upstream.

Figure 14: Ammonia concentration in MacKay Creek, 2007-2008



The presence of **nitrite** in MacKay Creek was noticeable mostly during the summer months, from June to September. Nitrite production can be favoured by a higher bacterial activity during this warmer and low flow period of the year. The highest concentrations were observed in August 2008 at Sites 1 and 3. Nitrite concentrations were 0.0059 mg/L and 0.0051 mg/L respectively, or more than five times what is considered to be a typical presence (<0.0010 mg/L). Nitrite is toxic to aquatic life at low concentrations (<0.1 mg/L).

Nitrate concentration did not show a peak of any kind during the survey. In addition, the concentration of nitrate seemed to evolve in a similar manner at all sites during the survey, and likely reflected natural processes (increased groundwater effect) downstream through the watershed. The low concentrations observed during the June rainstorm showed dilution of nitrate with no contribution due to heavy rainfall.

7.6.2 Phosphorus compounds

Phosphorus is naturally present at very low concentrations in freshwater, particularly in coastal streams. However, the presence of some phosphorus compounds, like orthophosphate, in urban stream water is mainly due to fertilizers, while detergents, sewage and agricultural activity (cattle raising) are common sources elsewhere. Phosphorus addition is a major cause of excessive algal growth (eutrophication) in freshwater.

There is no BC water Quality guideline for phosphorus compounds in streams. However, in a healthy stream, the concentration of the different forms of phosphorus should be close to the detection limit over the year, which was not the case.

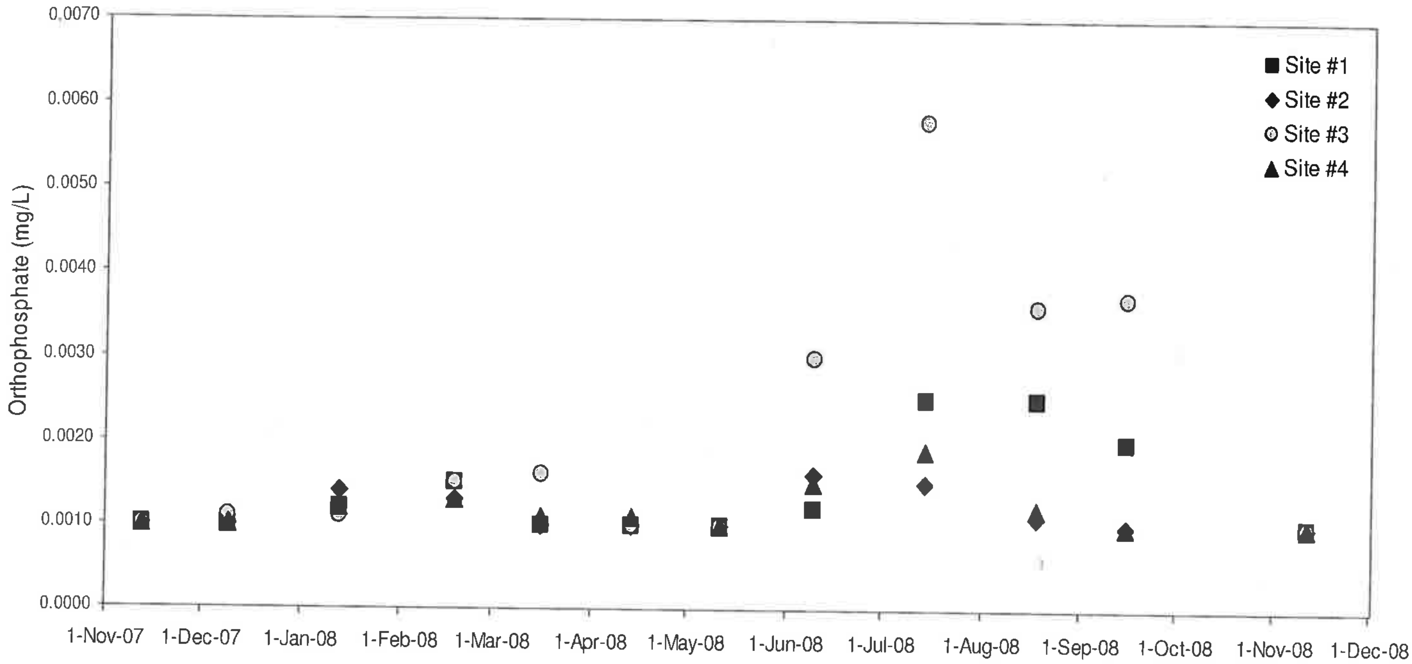
Total phosphorus is a measure of all the different forms of phosphorus present in the water, dissolved and particulate (bound to other particles like silt for example). This latter form explains the peak in total phosphorus concentration observed in June. Concentrations of 0.148 mg/L and 0.172 mg/L were measured at the two lower sites on this date, whereas they ranged from 0.0036 to 0.0310 mg/L over the rest of the survey.

Total dissolved phosphorus and **orthophosphate** remained close to the detection limit except from June to September. The total dissolved phosphorus maximum was 0.0085 mg/L and for orthophosphate was 0.0058 mg/L, whereas the detection limits are 0.0020 mg/L and 0.0010 mg/L, respectively.

The highest concentrations were systematically measured at Site 3, indicating a source of phosphate upstream. The concentrations of the two compounds decreased notably at Site 2, likely due to dilution from other tributaries and groundwater, and uptake by algae. Concentrations increased again at Site 1, to a lesser extent, indicating another source of phosphorus.

Given the similarity in spatial trends for *E. coli*, fecal coliforms, ammonia and phosphate, the source of all these constituents are consistent with sewage from an ongoing leak.

Figure 15: Orthophosphate concentration in MacKay Creek, 2007-2008



7.7 Metals

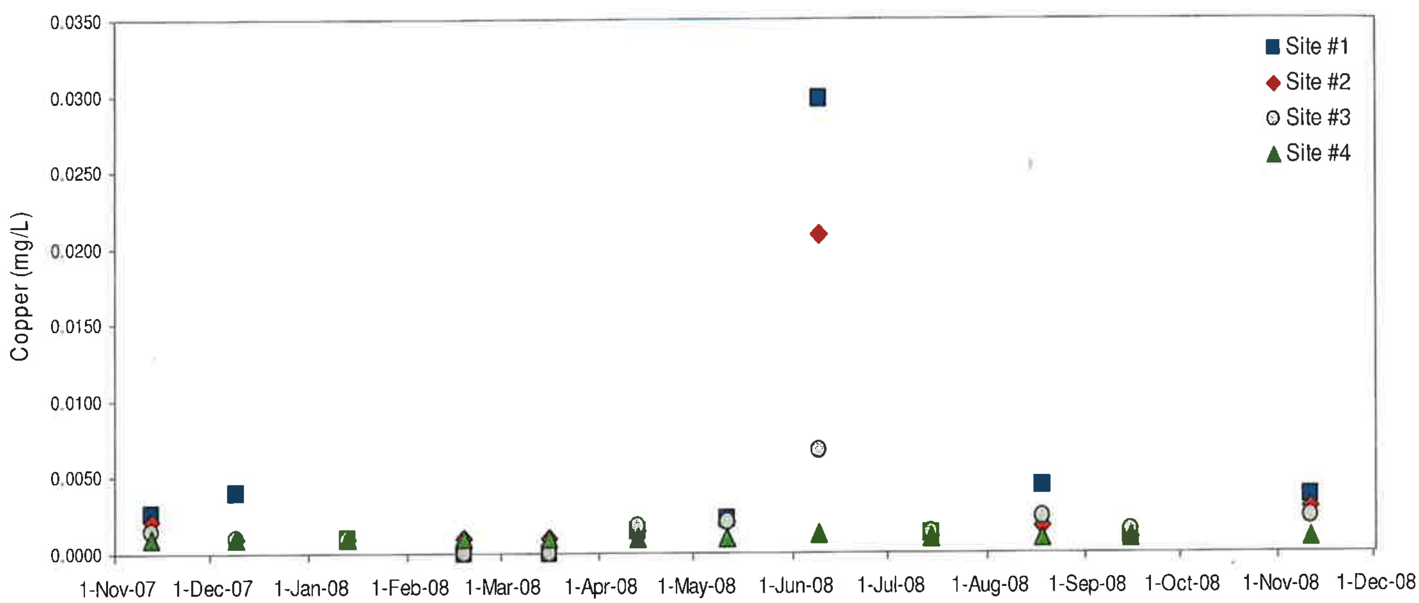
Generally speaking, metals are substances with a high electrical and thermal conductivity, lustre, malleability and positive charge (cation). These substances are often recovered from the earth during mining processes in pure elemental form such as iron, and can also be extracted from ore.

Undisturbed streams generally have low levels of metals, although streams in mineralized areas may have naturally elevated levels. In urban streams, runoff from streets, residential and industrial areas can contribute many types of metals, cadmium, copper, lead and zinc among them. Common sources include galvanized fences, roof and lawn treatments to manage moss growth, and wear and tear of vehicles. Metals can be found dissolved or bonded to silt particles in streams. Iron and aluminum are common constituents of silt particles.

Some metals such as zinc, copper and calcium are essential to plant and animal metabolism. However, a high concentration of these metals can be toxic to aquatic life, just as non-essential metals like cadmium can be toxic even at low concentrations. Dissolved metals are more likely to be toxic for aquatic life as they can be directly absorbed by organisms during respiration or feeding. Among metals, arsenic, cadmium and lead are the more likely to be toxic to aquatic life. These elements have a cumulative effect on plants and resident salmonids (trouts and coho fry). Essential metals such as copper and zinc can have negative effects as well if their concentrations remain high over a long period.

Figure 16 shows the concentrations measured over the study period for copper. Metals levels generally met the BC Water Quality Guidelines. Nevertheless, exceedances were noted for **aluminium**, **cadmium**, **copper**, **iron**, **lead** and **zinc** during the June rainstorm. These peaks originated from the runoff waters in urbanized and industrial areas. Higher concentrations were observed at the two lower sites especially, with trends similar to those noted for turbidity and total suspended solids. Other metals, such as titanium and vanadium, also increased in concentration during that rain event. Sampling on a rainy day in November 2008 did not indicate such a large peak, and metal concentrations remained close to the detection limits or showed moderate peaks. As discussed for turbidity and TSS and shown in Figure 11, the source of particulate matter, including metals, in the June 2008 rain event was a poorly managed landscaping project in the upper watershed; the silt would contribute mainly particulate forms of metals, while levels of dissolved metals (typically the most toxic form) would remain low.

Figure 16: Copper concentration in MacKay Creek, 2007-2008



Almost all of the metals measured during the survey were reported at or close to the detection limit at least once. **Calcium**, **magnesium** and **sodium** are the only elements that were detected in all samples. The presence of these elements is linked to the geology of the watershed, as they are a component of many rocks. The groundwater running across different types of rock dissolve the minerals and create their own chemical identities. The concentration of these elements increased consistently from Sites 4 to 1 as the influence of groundwater increases downstream. The various tributaries contribute to this enrichment as well. These three metals reached their lowest concentration during the two rainfall events sampled, in June and November 2008. This dilution, due to the heavy rain, underlines the natural presence of calcium, magnesium and sodium in MacKay Creek. The peak in sodium levels observed in February 2008 is undoubtedly related to the chlorine peak at the same date. Sodium chloride (NaCl) is frequently used for melting ice or snow on roads and sidewalks.

Dissolved levels were not measured routinely; however, two sets of analyses were performed for the entire suite of metals, and eight were performed for copper and zinc. The concentration of dissolved metals was at or very close to the detection limits.

7.8 Loading Estimates for Metals to Burrard Inlet

One of the study objectives was to estimate pollutant loads to Burrard Inlet from MacKay Creek. There are several limitations to this approach, based on extrapolating results from one sample per month to a value for annual loading. To be accurate, such an estimate would require rigorous and ongoing monitoring, including frequent sampling and streamflow measurements throughout the year. However, a rough estimate of the annual load can be made using the monthly collected data.

7.8.1 Method

To estimate the yearly pollutant load to Burrard Inlet of a given metal, the first step is to calculate its instantaneous loading rate (I) in units of mg/s and then multiply this rate by the number of seconds in a year. The calculation of I for a given metal is based on its concentration (C), in units of mg/L, multiplied by the streamflow (F), in units of m^3/s, measured on the same day and by a conversion factor for litres and m^3, using the following formula:

$$I\ (mg/s) = C\ (mg/L) \times F\ (m^3/s) \times 1000\ (L/m^3)$$

Because several values in the annual dataset were at the detection limit for a given metal, the average of the instantaneous load rate (I ave) was calculated then multiplied by the number of seconds per year to obtain a yearly pollutant load (L). A value of one-half the detection limit was used when data were reported at less than the detection limit (a common convention for water quality work). The formula used to calculate L was:

$$L\ (mg/year) = I\ ave.\ (mg/s) \times 31536000\ (s)$$

7.8.2 Results

An estimate of the pollutant load was made for several metals that can be toxic to humans and wildlife at low concentrations. These metals are: arsenic, copper, cadmium, lead and zinc.

To provide a context for a "tolerable" metal load for various aquatic fauna, the B.C. Water Quality Guidelines can be used to calculate a reference yearly load for each metal, by following the method described above. The results are summarized in Table 5.

Table 5: Estimated yearly loads of five metals to Burrard Inlet from MacKay Creek, and estimated guidelines

Metal	Annual Load, MacKay Creek (kg)	Annual Load, calculated using water quality guidelines (kg)
Arsenic	205	5,764
Cadmium	10	23
Copper	875	4,667
Lead	205	13,602
Zinc	2,691	38,043

Estimates of metal loads from MacKay Creek to Burrard Inlet are quantified in the range of 10 to 2,691 kg/year for the metals considered. Considering the rough estimates made for the calculations, the yearly loads are well within the range of loads estimated using the guidelines.

Metals loads to Burrard Inlet from all the streams on the North Shore and in other urban watersheds, along with discharges from the Lions Gate wastewater treatment plant, combined sanitary – storm sewer overflows, and industrial sources around the harbour would be in the range of tens to hundreds of tonnes. While some of the load from MacKay Creek is attributable to natural sediment erosion and transport processes, human activities, as documented in this report, contribute a substantial amount of the metals loads.

Although measurement of metals levels in sediment was beyond the scope of the current study, the Burrard Inlet Environmental Action Program (BIEAP) used sediment copper levels as an environmental indicator in its 2008 report (Jacques Whitford AXYS 2008). While copper levels have decreased since 1985 throughout Burrard Inlet, levels in the Inner Harbour remained above sediment quality guidelines in 2005, the last year for which data were included. The decreases in copper levels were attributed to decreases in loads from permitted effluents, combined sewer overflows and industrial sources and to the addition of buffering capacity to drinking water (less acidic water results in less leaching of copper from household pipes). Further reductions in metals levels in lower MacKay Creek and Burrard Inlet sediment would be a slow process, and would depend on reducing the sources of the loads and covering of contaminated sediment with clean sediment.

8 Aquatic Invertebrates

Aquatic invertebrates such as insects, worms and fresh water crustaceans complete their entire life or part of their life cycle in freshwaters. They can be sensitive or tolerant to chemical or physical habitat changes that occur in a stream. Consequently, aquatic invertebrates are good biological indicators of the quality of a stream over the aquatic stage of their life cycle. Studying the abundance, the variety and the sensitivity or tolerance of the aquatic invertebrates is an interesting complement to a water quality program, as the water samples only provide information about the specific time of sampling.

Aquatic invertebrates were sampled at various sites on MacKay Creek, following the instructions from the module 4 "Stream Invertebrate Survey" of the Streamkeepers Handbook (Taccogna and Munro, 1994, available at www.pskf.ca). A Surber sampler was used to collect one sample per site (composite of three Surber areas). The samples were sorted live into major taxonomic groups and counted. Results were assessed in terms of the pollution tolerance index, EPT index (Ephemeroptera, Plecoptera, Trichoptera, an indication of number of pollution sensitive taxa), EPT to total ratio (proportion of EPT organisms in the sample) and predominant taxon ratio (an indicator of biological diversity of the sample). An overall score for each site was then calculated. Samples were collected in September 2007 from Sites 1 and 2, in February 2008 from Site 3 and again in September 2008 from Site 2.

Using the Streamkeeper method, the condition of the benthic invertebrate community was ranked "acceptable", based on scores of 2.75 to 3.5 out of 4 for the four samples. Results were influenced by a high proportion of Ephemeroptera (mayfly) larvae in the samples. While most of mayflies are considered pollution sensitive organisms and provide food for salmonids, their predominance in the samples indicated reduced diversity.

A study conducted by Raincoast Applied Biology (2007) using the Benthic Index of Biological Integrity (B-IBI) approach recommended by Metro Vancouver for Integrated Stormwater Management Planning (EVS 2003) was reviewed. Four samples were collected in September 2006 from the lower watershed downstream of Marine Drive (near our Site 1) using a Surber sampler, and results were assessed using ten metrics of biological condition. The B-IBI score was calculated as 16 to 24 (mean of 20) out of 40, and corresponded to very poor to poor, based on low numbers of pollution sensitive taxa and low proportions of these taxa. Similar scores were obtained in samples collected in 2002 and 2003. The 2003 study was a comparison study of B-IBI and CABIN (Canadian Biomonitoring Network) protocols for several Metro Vancouver streams (Page and Sylvestre 2006).

Differences between the B-IBI and CABIN assessments and those made using the Streamkeeper method may have been related to sample location (generally, the samples collected for the current program were obtained from higher in the watershed, where substrates would contain a lower proportion of fine sediment and corresponding higher proportions of pollution sensitive organisms than the lower elevation areas below Marine Drive sampled for B-IBI) or to variation from one year to another. The former is supported by observations of relatively high mayfly numbers in the samples collected for the current study, compared to the earlier B-IBI samples. It is also possible that the ten metrics used to calculate the B-IBI score provide a more sensitive measurement of stream condition than do the four metrics used in the Streamkeeper assessment.

9 Other Aquatic Fauna

Data related to other aquatic fauna comes from the sampling crew, North Shore Fish and Game Club members sightings and from Fisheries and Ocean (DFO) fisheries inventories. In addition, spawner surveys were conducted on MacKay Creek from 2006 through 2008, from mid-November to early January.

Nine species of fish and one species of crayfish have been observed in MacKay Creek over the years:

- Coho salmon
- Chum salmon
- Prickly Sculpin
- Slimy Sculpin

- Cutthroat trout
- Rainbow trout
- Coastrange Sculpin
- Threespine Stickleback
- Western Brook Lamprey
- Signal Crayfish

9.1 Trout and Salmon

Surveys for spawning salmon are conducted annually in upper and lower MacKay Creek. Over the past three years, salmon spawner surveys were performed weekly through November and December on Upper MacKay Creek by North Shore Streamkeepers volunteers and the DFO Community Advisor. No adult salmon were seen during the 2006 and 2007 spawning seasons, although resident adult and juvenile cutthroat trout were observed. After two unsuccessful years, the observation of four coho spawners was a major event in the 2008 season.

The North Shore Fish and Game Club also conduct weekly spawner surveys in the lower creek, in Heywood Park during the fall. In most years, adult chum salmon and a few coho are observed. Chum numbers vary greatly from one year to another. Although as many as fifty chum salmon spawners have been seen in previous years, only six were observed on lower MacKay Creek in 2007 (Terry Bragg, North Shore Fish and Game Club, pers. comm.). The presence of an active beaver dam downstream of the survey reach may have introduced access issues for fish during some flow conditions.

Numerous juvenile salmon and juvenile (Figure 17) and adult cutthroat trout were observed throughout the summer water quality surveys at Sites 1, 2 and 3 and trout were observed at Site 4. Fry trapping in previous years indicated the presence of juvenile salmon and trout even when no adult coho had been seen the year before.

Figure 17: Coho salmon fry, MacKay Creek 2008

9.2 Signal Crayfish

The signal crayfish (Figure 18) is the only crayfish species native to British Columbia. This is the largest freshwater invertebrate in BC with an adult length of up to 15 cm. The natural range of this species extends from the southern part of BC to the northern part of California and eastward to parts of Montana and Utah (Hobbs Jr. 1988). In B.C., the signal crayfish has a known range from Vancouver Island eastward to the Kootenays and as far north as Okanagan Lake (Bondar et *al.* 2005b). It can be found in a variety of lower gradient streams with organic debris on which it feeds and with shelter opportunities like log jams or tree roots close to the bank.

Figure 18: Signal crayfish. August 2008, Site 2

The signal crayfish is a better bioindicator of the physical quality and structure of the aquatic habitat than of the quality of water, as it depends on healthy riparian vegetation for survival and requires a large amount of physical cover and heterogeneous habitat to hide themselves from predators. Crayfish feed mostly on vegetal debris. Signal crayfish specimens were observed at Sites 1 and 2, during the summer. Unlike salmon and trout, no crayfish survey has ever been done on MacKay Creek. Health and abundance of the signal crayfish population is currently unknown.

9.3 Other wildlife

Evidence of beavers was regularly observed on the lower part of MacKay Creek, up to the Upper Levels Highway. The beaver habit to build and maintain its dam may have a negative effect on salmon migration, especially on a small stream such as MacKay Creek, although beaver activity also provides benefits by increasing complexity of fish habitat. MacKay Creek is also home to river otters, bears, deer, raccoons, skunks and coyotes.

10 Public Education

While the first goal of the MacKay Creek study was to obtain scientific information about conditions in the watershed, the second, and equally important, goal was to raise awareness in the community about the condition of this stream, as well as others in North Vancouver, and increase public understanding of the relationship between human activities and health of the streams. Several public events have occurred and communication tools have been developed and will continue after publication of this report. Some of these include:

- providing a three-day learning experience for 15 engineering and planning students from the University of British Columbia (UBC) to experience stream sampling for water and benthic invertebrates, and to discuss the challenges of urban development with City and District staff
- holding meetings with District and City of North Vancouver staff about potential influences of municipal operations on water quality (e.g., leakage from and cross connections of sanitary and storm sewer systems, source tracking of coliforms) and stream habitat (e.g., invasive plants management on public land, riparian areas protection)
- organizing several public events to control spread of invasive plants in riparian areas (Heywood Park at Site 2 in the City, MacKay Ravine Park at Site 3 in the District)
- developing and distributing public relations information (MacKay Creek newsletter in fall 2008, distributed to over 1000 households in upper MacKay Creek), provided in Appendix C
- preparing and distributing the photo report of the MacKay watershed study (Appendix D), and posting it on the North Shore Streamkeepers website to provide information to a general audience
- making presentations at service clubs and other groups about stream health, water quality, and things residents can do themselves to protect the stream and watershed
- presenting the technical and photo reports of the MacKay Creek watershed study at Council meetings of the District and City of North Vancouver
- working with residents surrounding the MacKay Creek ravine to repair and improve a habitat restoration project to provide off-channel winter habitat for salmonid juveniles.
- sharing knowledge with volunteers elsewhere in North Vancouver, West Vancouver and Metro Vancouver about challenges for urban streams.

The public awareness campaign will continue to grow. The technical and photo reports of the MacKay Creek watershed study will be presented at Council meetings of the District and City of North Vancouver in 2009. Issue-specific brochures (on proper management of landscaping projects, proper dog waste management to control fecal coliform sources) will be developed and distributed, more presentations will be made to groups, water quality issues will be raised at other North Shore Streamkeeper events, and additional postings will be made to the website.

There are many ways to spread the message of stream protection, in addition to the action, policy and scientific approaches discussed above. Art is a powerful medium to bring people together and to express feelings and ideas in a concrete way. The MacKay Creek Community Art Project is being developed by artist Ron den Daas, one of the key North Shore Streamkeeper volunteers for the water quality project. This project has support from many partners (North Shore Fish and Game Club, Fisheries and Oceans Canada, the City and District of North Vancouver) and is funded by The North Shore Office of Cultural Affairs, the Pacific Salmon Foundation and the City of North Vancouver. The goal of the project is to create awareness of sustainable environmental practices in North Shore watersheds and to underline these values by creating a public art project. The community will be invited to participate in habitat restoration events and a multi-cultural community art project. Workshops will be held to develop ecosystem-related images and concepts that will be used to create an installation/mural on an existing site in Heywood Park. The created artwork will be a symbol that supports the concept of protecting the long-term health of the MacKay Creek ecosystem. (For more details visit: http://ecosystem.shawwebspace.ca/).

11 Discussion and Recommendations

Several water quality issues were identified during the MacKay Creek watershed study, and are listed in Table 6. Similar issues are reported for many urban streams, and are likely common on other North Vancouver streams.

Table 6: Key issues and potential solutions, MacKay Creek

Issue	Recommended Solutions
Release of sediment to the stream from poorly managed sites (landscaping in this example, but also at construction sites); while there are by-laws and requirements to control sediment and erosion, not all contractors are aware of their obligations and it can be challenging to monitor for compliance	• NSSK to work with City and District to develop and distribute a brochure to landscaping firms, discussing sediment control requirements • City and District to include inspection of construction sites at all stages until the landscaping is complete, and to hold back the performance bond until that stage
Fecal coliforms in creek from a variety of sources (including dog waste, wildlife and sanitary sewers)	• District to further investigate potential sanitary waste sources of coliforms for MacKay Creek upstream of the ravine • NSSK to work with City and District to augment existing signage and public relations information aimed at dog owners to pick up waste
Increased levels of nutrients from watershed runoff (garden fertilizers)	• Public awareness campaign, perhaps in conjunction with other partners (municipal, Metro Vancouver)
Water temperatures near the upper limit for salmonid survival during summer	• Continue to promote high quality riparian vegetation on private land and to improve vegetation in parks

The first priority is to identify the source of elevated coliform bacteria, which can be narrowed down through examination of municipal sewer maps, stream walks, and focused sampling of coliforms in tributaries upstream of Site 3. Other future studies should focus on water quality at the beginning of a heavy rainfall, as this first flush of water carries the bulk of the pollutants from the roads and rooftops to the stream. It would also be useful to assess levels of metals and persistent hydrocarbons (Polycyclic Aromatic Hydrocarbons) in depositional areas near the mouth of MacKay Creek; results could be compared with the metals loading estimates developed for the current study, and with levels in Burrard Inlet, into which MacKay Creek empties.

12 References

Bondar, C. A., The conservation status of the freshwater crayfish, *Pacifastacus leniusculus*, in British Columbia. Ministry of Water, Land and Air Protection. Fisheries Management Report No 117

Hobbs, H. H., Jr. 1988. Crayfish Distribution, Adaptive Radiation and Evolution. Pages 52 - 82 in D. M. Holdich and R. S. Lowery (editors), Freshwater Crayfish: Biology, Management and Exploitation. London: Croom Helm

Ministry of Environment. 2006. British Columbia Approved Water Quality Guidelines, 2006 Edition. Science and Information Branch. Available at: http://www.env.gov.bc.ca/wat/wq/BCguidelines/approv_wq_guide/approved.html

Nagpal, N.K., L.W. Pommen and L.G. Swain. 2006. A compendium of working water quality guidelines for British Columbia. Environmental Protection Division, Ministry of Environment. Available at: www.env.gov.bc.ca/wat/wq/BCguidelines/working.html

Page N. and S. Sylvestre. 2006. Comparison of two benthic invertebrate sampling and analysis methods for streams in Greater Vancouver. Report Prepared for Greater Vancouver Regional District, Environment Canada, District of North Vancouver and Township of Langley. Available at: http://www.raincoastappliedecology.ca/pdf/B-IBI%20-%20CABIN%20Comparison%20Study%202006.pdf

Raincoast Applied Biology. 2007. Technical Memorandum to City of North Vancouver: 2006 Benthic Invertebrate (B-IBI) Sampling in MacKay, Mosquito, and Wagg Creeks in North Vancouver, BC

Taccogna, G. and K. Munro. 1995. *The Streamkeepers Handbook: a Practical Guide to Stream and Wetland Care*. Salmonid Enhancement Program, Fisheries and Oceans Canada, Vancouver. Available at: www.pskf.ca

Appendix A:

In situ water quality, MacKay Creek, 2007-2008

APPENDIX A: *IN SITU* WATER QUALITY, MACKAY CREEK, 2007-2008

Parameter	Site #	12-Nov-07	09-Dec-07	13-Jan-08	18-Feb-08	16-Mar-08	13-Apr-08	11-May-08	09-Jun-08	18-Jul-08	18-Aug-08	15-Sep-08	26-Oct-08	11-Nov-08
Water Temperature (ºC)	Site 1	9.1	4.9	6.8	4.6	6.3	9.9	9.8	12.4	16.4	17.0	13.8	8.9	ND
	Site 2	8.9	4.7	6.8	4.4	6.1	9.7	11.3	11.0	16.4	17.0	14.2	9.1	ND
	Site 3	8.7	5.0	6.3	5.0	5.4	8.3	8.4	10.3	16.1	17.0	14.8	9.2	ND
	Site 4	7.3	3.8	5.2	4.3	ND	7.0	6.8	7.8	12.7	14.3	13.1	8.6	ND
Air Temperature (ºC)	Site 1	9.0	2.8	9.7	5.2	5.4	10.7	14.0	ND	ND	17.3	15.9	16.0	ND
	Site 2	8.9	1.5	7.2	5.2	5.4	ND	11.0	ND	ND	17.2	15.0	13.5	ND
	Site 3	8.7	1.5	5.5	7.5	4.6	12.0	10.0	ND	ND	ND	ND	ND	ND
	Site 4	7.0	0.5	5.2	4.2	ND	9.4	6.9	ND	ND	ND	15.0	9.4	ND
Specific Conductivity (µS/cm temp. Corrected)	Site 1	ND	105.0	100.0	99.3	86.0	122.0	96.0	ND	225.0	260.0	256.0	119.0	ND
	Site 2	73 / 69	103.0	99.0	103.0	85.0	119.0	99.0	ND	221.0	248.0	255.0	121.0	ND
	Site 3	56.0	93.0	81.0	114.0	82.0	112.0	82.0	ND	219.0	256.0	279.0	113.0	ND
	Site 4	19.0	29.0	26.0	25.0	22.0	27.0	24.0	ND	81.0	92.0	75.0	37.0	ND
pH	Site 1	8 / 7.5	7.8	6.8	6.3	7.0	7.5	6.9	7.1	6.6	6.6	6.7	ND	ND
	Site 2	7.6 / 6.9	7.8	6.5	6.2	7.6	7.1	7.0	7.1	6.7	7.0	7.0	ND	ND
	Site 3	7.7	7.5	7.0	6.6	7.2	7.4	7.3	7.2	7.0	7.2	7.0	ND	ND
	Site 4	6.8	7.1	6.3	6.1	7.2	6.7	6.8	7.0	6.8	7.5	7.2	ND	ND
Dissolved Oxygen (%)	Site 1	90.0	93.0	ND	107.0	91.0	ND	100.0	76.0	98.0	98.7	85.0	98.0	ND
	Site 2	92.0	94.0	ND	112.0	91.0	ND	96.0	75.0	100.0	114.0	90.0	96.0	ND
	Site 3	96.0	87.0	ND	111.0	86.0	ND	90.0	73.0	98.0	106.0	89.0	92.0	ND
	Site 4	94.0	87.8	ND	112.0	87.0	ND	ND	74.0	99.0	122.0	93.0	86.0	ND
Dissolved Oxygen (mg/L)	Site 1	10.4	11.8	ND	13.8	11.3	ND	11.3	8.6	ND	9.5	8.8	11.5	ND
	Site 2	10.7	12.2	ND	14.6	11.2	ND	10.7	8.5	ND	11.0	9.2	11.2	ND
	Site 3	11.1	11.1	ND	14.2	10.9	ND	10.5	8.2	ND	10.2	9.0	10.5	ND
	Site 4	11.3	11.6	ND	14.6	11.3	ND	ND	8.8	ND	12.6	9.9	11.2	ND

Legend:

ND: No Data

Appendix B:

Water quality analysis per site, MacKay Creek, 2007-2008

APPENDIX B-1: WATER QUALITY ANALYSIS, SITE 1, MACKAY CREEK, 2007-2008

Date Sampled	12/11/07	09/12/07	13/01/08	18/02/08	16/03/08	13/04/08	11/05/08	09/06/08	14/07/08	18/08/08	15/09/08	11/11/08
Physical Tests												
Hardness (as CaCO3)	21	26.9	20.6	27.6	25.9	22.6	20.7	20.1	35.2	38.2	37.5	13.7
Conductivity	79.1	109	105	173	128	115	88.6	57.1	131	137	137	53.8
pH	7.37	7.38	7.33	7.52	7.56	7.05	6.72	7.09	7.8	7.77	7.87	7.23
Total Suspended Solids	3.8	36.2	<3.0	<3.0	<3.0	<3.0	<3.0	111	<3.0	<3.0	<3.0	10.4
Turbidity	3.3	6.31	1.09	1.14	1.85	1.59	1.61	55.7	1.63	2.26	1.53	5.02
Anions and Nutrients												
Ammonia as N	0.0050	0.0076	0.0094	0.0128	0.0071	0.0050	0.0074	0.0086	0.0059	0.0270	0.0076	<0.0050
Alkalinity, Total (as CaCO3)	15.3	19.6	15.3	17.9	18.7	17.3	16.2	13	29.2	33.6	30.3	11.7
Bromide (Br)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride (Cl)	10.4	15.1	17.1	34.2	21.4	19.1	12.8	6.59	15.6	15.4	16.5	5.91
Fluoride (F)	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.020	<0.020	<0.020
Sulfate (SO4)	4.04	4.74	3.81	4.89	4.56	3.88	3.94	2.19	5.29	5.75	5.33	2.28
Nitrate (as N)	0.442	0.595	0.462	0.580	0.451	0.401	0.464	0.259	0.555	0.623	0.577	0.259
Nitrite (as N)	<0.0010	<0.0010	<0.0010	0.0013	<0.0010	0.0016	0.0019	0.0041	0.0023	0.0059	0.0027	<0.0010
Ortho Phosphate as P	<0.0010	<0.0010	0.0012	0.0015	<0.0010	<0.0010	<0.0010	0.0012	0.0025	0.0025	0.0020	<0.0010
Total Dissolved Phosphate As P	0.0027	0.0020	0.0025	0.0024	0.0020	0.0020	0.0024	0.0026	0.0042	0.0061	0.0035	0.0040
Total Phosphate as P	0.0161	0.0310	0.0053	0.0045	0.0046	0.0071	0.0063	0.1720	0.0088	0.0136	0.0054	0.0240
Bacteriological Tests												
Coliform Bacteria - Total	2420	>201	365	276	866	1990	461	>201	>2420	>24200	7700	14100
E. coli	228	34	79	40	55	45	127	201	326	613	126	727

APPENDIX B-1: WATER QUALITY ANALYSIS, SITE 1, MACKAY CREEK, 2007-2008

Date Sampled	12/11/07	09/12/07	13/01/08	18/02/08	16/03/08	13/04/08	11/05/08	09/06/08	14/07/08	18/08/08	15/09/08	11/11/08
Total Metals												
Aluminum (Al)-Total	0.1340	1.3200	0.0485	0.0331	0.0411	0.0522	0.0445	2.28	0.0309	<0.040	0.0184	0.21
Antimony (Sb)-Total	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00117	<0.00050	<0.00050	<0.00050	<0.00050
Arsenic (As)-Total	0.00061	0.00072	<0.00050	<0.00050	<0.00050	<0.00050	0.00069	0.00408	<0.00050	<0.00050	<0.00050	0.00097
Barium (Ba)-Total	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.03	<0.020	<0.020	<0.020	<0.020
Beryllium (Be)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Boron (B)-Total	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium (Cd)-Total	0.000029	0.000051	0.000019	0.000020	<0.000017	<0.000017	<0.000017	0.000213	0.000018	0.000022	<0.000017	0.000028
Calcium (Ca)-Total	7.1	9.09	7.06	9.46	8.73	7.67	7.04	6.44	11.8	12.7	12.5	4.7
Chromium (Cr)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0054	<0.0010	<0.0010	<0.0010	<0.0010
Cobalt (Co)-Total	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	0.00109	<0.00030	<0.00030	<0.00030	<0.00030
Copper (Cu)-Total	0.0026	0.0040	<0.0010	<0.0010	<0.0010	0.0015	0.0022	0.0298	0.0013	0.0044	0.0011	0.0037
Iron (Fe)-Total	0.266	1.020	0.141	0.176	0.209	0.234	0.242	7.080	0.295	0.369	0.295	0.408
Lead (Pb)-Total	0.00061	0.00316	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.0149	<0.00050	<0.00050	<0.00050	0.00120
Lithium (Li)-Total	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Magnesium (Mg)-Total	0.81	1.02	0.71	0.98	0.99	0.84	0.77	0.97	1.41	1.58	1.51	0.48
Manganese (Mn)-Total	0.01150	0.03860	0.00727	0.00946	0.00934	0.00890	0.00992	0.1240	0.0113	0.0134	0.0115	0.0152
Mercury (Hg)-Total	<0.000020	<0.000020		<0.000020	<0.000020	<0.000020	<0.000020	0.000037	<0.000020	<0.000020	<0.000020	<0.000020
Molybdenum (Mo)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Nickel (Ni)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0022	<0.0010	<0.0010	<0.0010	<0.0010
Potassium (K)-Total	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Selenium (Se)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Silver (Ag)-Total	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	0.000095	<0.000020	<0.000020	<0.000020	<0.000020
Sodium (Na)-Total	6.4	9.9	10.6	19.6	12.5	13	8.3	4.9	10.5	10.6	10.7	4.3
Thallium (Tl)-Total	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Tin (Sn)-Total	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00077	<0.00050	<0.00050	<0.00050	<0.00050
Titanium (Ti)-Total	<0.010	0.022	<0.010	<0.010	<0.010	<0.010	<0.010	0.083	<0.010	<0.010	<0.010	<0.010
Uranium (U)-Total	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	0.00028	<0.00020	<0.00020	<0.00020	<0.00020
Vanadium (V)-Total	<0.0010	0.0019	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0073	<0.0010	<0.0010	<0.0010	<0.0010
Zinc (Zn)-Total	0.0080	0.0119	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0559	<0.0050	<0.0050	<0.0050	0.0133

APPENDIX B-2: WATER QUALITY ANALYSIS, SITE 2, MACKAY CREEK, 2007-2008

Date Sampled	12/11/07	09/12/07	13/01/08	18/02/08	16/03/08	13/04/08	11/05/08	09/06/08	14/07/08	18/08/08	15/09/08	11/11/08
Physical Tests												
Hardness (as CaCO3)	21	24.4	19.8	27.4	24.2	21.9	19.5	20	32.7	35.9	33.8	15.3
Conductivity	75.4	108	104	173	127	113	93.3	60.5	124	133	137	60
pH	7.33	7.43	7.33	7.42	7.52	7.14	7.06	7.16	7.84	7.80	7.81	7.07
Total Suspended Solids	5.8	<3.0	<3.0	<3.0	<3.0	<3.0	3.4	134	<3.0	<3.0	<3.0	9.1
Turbidity	3.01	0.81	1.21	0.94	1.18	1.83	1.78	55.1	1.83	3.10	2.41	3.98
Anions and Nutrients												
Ammonia as N	0.0050	0.0085	0.0072	0.0112	0.0224	0.0050	0.0069	0.0107	0.0078	0.0050	0.0052	<0.0050
Alkalinity, Total (as CaCO3)	16.4	19.3	14.4	17.3	18	14.3	16.8	12.2	27.5	30.5	29.3	13.1
Bromide (Br)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride (Cl)	8.78	15.3	17.3	35.5	21.9	19.3	14.2	7.24	16.2	16.2	17.4	6.75
Fluoride (F)	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Sulfate (SO4)	3.93	4.48	3.71	4.64	4.25	3.55	3.66	2.09	4.86	4.69	5.24	2.51
Nitrate (as N)	0.477	0.579	0.450	0.563	0.432	0.373	0.389	0.264	0.550	0.548	0.561	0.308
Nitrite (as N)	<0.0010	<0.0010	<0.0010	0.0016	<0.0010	<0.0010	<0.0010	0.0028	0.0015	0.0013	0.0012	<0.0010
Ortho Phosphate as P	<0.0010	<0.0010	0.0014	0.0013	<0.0010	<0.0010	<0.0010	0.0016	0.0015	0.0011	<0.0010	<0.0010
Total Dissolved Phosphate As P	0.0028	0.0020	0.0029	0.0024	0.0026	0.0020	0.0024	0.0028	0.0030	0.0047	0.0027	0.0033
Total Phosphate as P	0.0098	0.0036	0.0058	0.0045	0.0040	0.0060	0.0065	0.1480	0.01	0.01	0.0048	0.0190
Bacteriological Tests												
Coliform Bacteria - Total	>2420	>201	411	261	435	1200	921	>201	>2420	3080	2420	2720
E. coli	179	200	82	45	79	33	37	201	79	105	54	613

APPENDIX B-2: **WATER QUALITY ANALYSIS, SITE 2, MACKAY CREEK, 2007-2008**

)ate Sampled	12/11/07	09/12/07	13/01/08	18/02/08	16/03/08	13/04/08	11/05/08	09/06/08	14/07/08	18/08/08	15/09/08	11/11/08
'otal Metals												
\luminum (Al)-Total	0.0625	0.0304	0.0534	0.0284	0.0325	0.0665	0.0677	2.4200	0.0524	<0.040	0.0270	0.2000
ıntimony (Sb)-Total	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00070	<0.00050	<0.00050	<0.00050	<0.00050
ırsenic (As)-Total	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00543	<0.00050	<0.00050	<0.00050	0.00091
;arium (Ba)-Total	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.03	<0.020	<0.020	<0.020	<0.020
;eryllium (Be)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
;oron (B)-Total	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
;admium (Cd)-Total	<0.000017	<0.000017	<0.000017	0.000029	<0.000017	0.000024	<0.000017	0.000220	<0.000017	<0.000017	<0.000017	0.000024
;alcium (Ca)-Total	7.15	8.27	6.79	9.37	8.14	7.43	6.62	6.55	10.90	11.90	11.20	5.22
;hromium (Cr)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0048	<0.0010	<0.0010	<0.0010	<0.0010
;obalt (Co)-Total	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	0.00115	<0.00030	<0.00030	<0.00030	<0.00030
;opper (Cu)-Total	0.0021	<0.0010	<0.0010	<0.0010	<0.0010	0.0015	<0.0020	0.0208	0.0011	0.0017	<0.0010	0.0029
on (Fe)-Total	0.130	0.165	0.138	0.156	0.180	0.260	0.305	6.400	0.421	0.374	0.329	0.374
ead (Pb)-Total	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00053	<0.00050	0.0117	<0.00050	<0.00050	<0.00050	0.00085
ithium (Li)-Total	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
1agnesium (Mg)-Total	0.77	0.9	0.69	0.96	0.93	0.82	0.73	0.89	1.33	1.51	1.42	0.55
1anganese (Mn)-Total	0.00617	0.00972	0.00701	0.00876	0.00886	0.00941	0.01090	0.15400	0.01590	0.01220	0.01330	0.01420
1ercury (Hg)-Total	<0.000020	<0.000020		<0.000020	<0.000020	<0.000020	<0.000020	0.000034	<0.000020	<0.000020	<0.000020	<0.000020
1olybdenum (Mo)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
lickel (Ni)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0016	<0.0010	<0.0010	<0.0010	<0.0010
otassium (K)-Total	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
elenium (Se)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
ilver (Ag)-Total	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	0.000031	<0.000020	<0.000020	<0.000020	<0.000020
odium (Na)-Total	5.8	10.0	11.0	20.5	12.6	13.3	8.7	5.2	10.8	10.9	12.3	4.9
hallium (Tl)-Total	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
in (Sn)-Total	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
itanium (Ti)-Total	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.076	<0.010	<0.010	<0.010	<0.010
ranium (U)-Total	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	0.00040	<0.00020	<0.00020	<0.00020	<0.00020
anadium (V)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0077	<0.0010	<0.0010	0.0025	<0.0010
inc (Zn)-Total	0.0051	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0418	<0.0050	<0.0050	<0.0050	0.0075

APPENDIX B-3: WATER QUALITY ANALYSIS, SITE 3, MACKAY CREEK, 2007-2008

Date Sampled	12/11/07	09/12/07	13/01/08	18/02/08	16/03/08	13/04/08	11/05/08	09/06/08	14/07/08	18/08/08	15/09/08	11/11/08
Physical Tests												
Hardness (as CaCO3)	16.3	18.2	15.6	22.8	18.5	15.8	13.3	12.3	25.2	29.3	29.6	14.5
Conductivity	58.3	96.9	96.1	188	124	106	78.3	50.1	126	136	149	64
pH	7.28	7.42	7.23	7.27	7.37	6.99	7.03	7.33	7.73	7.70	7.73	6.98
Total Suspended Solids	<3.0	<3.0	<3.0	<3.0	3.4	<3.0	<3.0	29.7	<3.0	<3.0	<3.0	3.8
Turbidity	1.90	0.55	0.8	0.83	0.66	1.58	0.75	19.40	1.46	0.77	1.11	2.45
Anions and Nutrients												
Ammonia as N	0.0050	0.0079	0.0075	0.0111	0.0106	0.0050	0.0050	0.0170	0.0122	0.0087	0.0084	<0.0050
Alkalinity, Total (as CaCO3)	12.6	14.6	11.2	12.4	12.5	9.5	9.5	9.9	21.2	23.9	24.5	13.1
Bromide (Br)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride (Cl)	6.37	2.95	18.2	44.1	25.5	22.2	14.3	6.36	20.3	21.1	25.1	8.42
Fluoride (F)	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Sulfate (SO4)	3.16	2.63	2.84	3.33	3.06	2.46	2.66	1.37	3.66	3.47	3.94	2.5
Nitrate (as N)	0.353	0.069	0.266	0.312	0.207	0.210	0.155	0.179	0.395	0.501	0.449	0.293
Nitrite (as N)	<0.0010	<0.0010	<0.0010	0.0013	<0.0010	<0.0010	<0.0010	0.0028	0.0040	0.01	0.0033	<0.0010
Ortho Phosphate as P	<0.0010	0.0011	0.0011	0.0015	0.0016	<0.0010	<0.0010	0.0030	0.0058	0.0036	0.0037	<0.0010
Total Dissolved Phosphate As P	0.0027	0.0026	0.0027	0.0026	0.0022	0.0020	0.0036	0.0033	0.0075	0.0085	0.0061	0.0036
Total Phosphate as P	0.0079	0.0040	0.0048	0.0042	0.0065	0.0050	0.0068	0.0621	0.0121	0.0121	0.0090	0.0152
Bacteriological Tests												
Coliform Bacteria - Total	1990	>201	1200	2420	>2420	1990	1550	>201	>2420	11200	5480	2420
E. coli	128	201	91	649	579	115	276	201	1120	3260	1730	201

APPENDIX B-3: **WATER QUALITY ANALYSIS, SITE 3, MACKAY CREEK, 2007-2008**

Date Sampled	12/11/07	09/12/07	13/01/08	18/02/08	16/03/08	13/04/08	11/05/08	09/06/08	14/07/08	18/08/08	15/09/08	11/11/08
Total Metals												
Aluminum (Al)-Total	0.1660	0.0275	0.0416	0.0275	0.0278	0.0635	0.0463	0.7360	0.0450	<0.040	0.0294	0.1690
Antimony (Sb)-Total	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Arsenic (As)-Total	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00373	<0.00050	<0.00050	<0.00050	0.00088
Barium (Ba)-Total	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Beryllium (Be)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Boron (B)-Total	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium (Cd)-Total	0.000021	<0.000017	<0.000017	0.000018	<0.000017	0.000021	<0.000017	0.000059	0.000022	<0.000017	<0.000017	0.000021
Calcium (Ca)-Total	5.64	6.31	5.44	7.96	6.38	5.43	4.58	4.20	8.80	10.20	10.30	5.03
Chromium (Cr)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0027	<0.0010	<0.0010	<0.0010	<0.0010
Cobalt (Co)-Total	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	0.00038	<0.00030	<0.00030	<0.00030	<0.00030
Copper (Cu)-Total	0.0015	<0.0010	<0.0010	<0.0010	<0.0010	0.0017	<0.0020	0.0067	0.0014	0.0023	0.0015	0.0023
Iron (Fe)-Total	0.129	0.094	0.081	0.111	0.102	0.154	0.132	1.500	0.245	0.238	0.199	0.255
Lead (Pb)-Total	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00069	<0.00050	0.0027	<0.00050	<0.00050	<0.00050	<0.00050
Lithium (Li)-Total	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Magnesium (Mg)-Total	0.53	0.59	0.49	0.72	0.64	0.53	0.45	0.45	0.79	0.94	0.96	0.48
Manganese (Mn)-Total	0.00777	0.00830	0.00583	0.00892	0.00773	0.00809	0.00692	0.04550	0.01450	0.01140	0.01200	0.01070
Mercury (Hg)-Total	<0.000020	<0.000020		<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020
Molybdenum (Mo)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Nickel (Ni)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Potassium (K)-Total	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Selenium (Se)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Silver (Ag)-Total	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020
Sodium (Na)-Total	4.8	10.3	11.2	24.4	14.1	13.9	8.8	4.8	13.0	14.1	15.8	5.9
Thallium (Tl)-Total	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Tin (Sn)-Total	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Titanium (Ti)-Total	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.027	<0.010	<0.010	<0.010	<0.010
Uranium (U)-Total	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	0.00030	<0.00020	<0.00020	<0.00020	<0.00020
Vanadium (V)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0020	<0.0010	<0.0010	<0.0010	<0.0010
Zinc (Zn)-Total	0.0103	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0130	<0.0050	<0.0050	<0.0050	0.0058

APPENDIX B-4: WATER QUALITY ANALYSIS, SITE 4, MACKAY CREEK, 2007-2008

Date Sampled	12/11/07	09/12/07	13/01/08	18/02/08	16/03/08	13/04/08	11/05/08	09/06/08	14/07/08	18/08/08	15/09/08	11/11/08
Physical Tests												
Hardness (as CaCO3)	6.25	8.52	6.87	8.82	8.31	7.15	7.00	7.98	14.10	14.9	13.9	6.47
Conductivity	21	32.1	28.9	39.1	35.4	27.9	22.1	27.9	47.8	58.3	49.4	24.4
pH	7.09	7.22	6.92	7.02	7.14	6.83	6.95	7.08	7.51	7.60	7.55	6.67
Total Suspended Solids	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	4.3	<3.0
Turbidity	0.67	0.17	0.23	0.4	0.33	0.47	0.41	1.30	0.20	0.19	0.92	1.05
Anions and Nutrients												
Ammonia as N	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0081
Alkalinity, Total (as CaCO3)	4.1	7.1	5.2	6.8	7.5	7.5	5.3	7.5	11.8	12.8	13.4	5.5
Bromide (Br)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride (Cl)	2.07	2.95	3.28	5.95	4.06	2.49	1.76	1.51	4.25	4.37	3.78	2.26
Fluoride (F)	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Sulfate (SO4)	2.15	2.62	2.17	2.74	2.47	1.94	1.91	1.59	3.14	3.00	2.84	2.01
Nitrate (as N)	0.050	0.068	0.048	0.066	0.051	0.072	0.080	0.084	0.151	0.238	0.158	0.049
Nitrite (as N)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Ortho Phosphate as P	<0.0010	<0.0010	0.0012	0.0013	0.0011	0.0011	<0.0010	0.0015	0.0019	0.0012	<0.0010	<0.0010
Total Dissolved Phosphate As P	0.0020	0.0020	0.0021	0.0025	0.0020	0.0020	0.0020	0.0020	0.0022	<0.0020	0.0022	0.0030
Total Phosphate as P	0.0035	<0.0020	0.0025	0.0026	<0.0020	0.0023	0.0024	0.0050	0.0024	0.0028	0.0053	0.0068
Bacteriological Tests												
Coliform Bacteria - Total	411	83	44	53	88	132	261	>201	>2420	2420	2420	579
E. coli	5	1	4	<1	<1	1	1	201	19	3	41	71

APPENDIX B-4: WATER QUALITY ANALYSIS, SITE 4, MACKAY CREEK, 2007-2008

ate Sampled	12/11/07	09/12/07	13/01/08	18/02/08	16/03/08	13/04/08	11/05/08	09/06/08	14/07/08	18/08/08	15/09/08	11/11/08
etals												
luminum (Al)-Total	0.0901	0.0305	0.0416	0.0319	0.0299	0.0582	0.0636	0.1150	0.0236	<0.040	0.0262	0.1440
ntimony (Sb)-Total	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
rsenic (As)-Total	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
arium (Ba)-Total	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
eryllium (Be)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
oron (B)-Total	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
admium (Cd)-Total	<0.000017	<0.000017	<0.000017	<0.000017	<0.000017	<0.000017	<0.000017	<0.000017	<0.000017	<0.000017	<0.000017	<0.000017
alcium (Ca)-Total	2.01	2.76	2.20	2.84	2.66	2.29	2.26	2.60	4.61	4.85	4.54	2.07
hromium (Cr)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
obalt (Co)-Total	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
opper (Cu)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0013	<0.0010	<0.0010	<0.0010	<0.0010
on (Fe)-Total	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	0.052	<0.030	<0.030	<0.030	0.050
ead (Pb)-Total	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
ithium (Li)-Total	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
agnesium (Mg)-Total	0.30	0.40	0.33	0.42	0.41	0.34	0.33	0.36	0.64	0.68	0.64	0.32
anganese (Mn)-Total	<0.0020	0.00039	0.00068	0.00052	0.00046	0.00094	0.00083	0.00364	0.00134	0.00174	0.00122	0.00308
ercury (Hg)-Total	<0.000020	<0.000020		<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020
olybdenum (Mo)-Total	<0.0010	0.0010	<0.0010	0.0010	0.0011	0.0011	<0.0010	<0.0010	0.0011	0.0013	0.0012	<0.0010
ickel (Ni)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
otassium (K)-Total	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
elenium (Se)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
ilver (Ag)-Total	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020
odium (Na)-Total	<2.0	2.5	2.5	4.4	3.0	2.5	<2.0	<2.0	3.7	4.3	3.9	<2.0
hallium (Tl)-Total	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
in (Sn)-Total	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
itanium (Ti)-Total	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
ranium (U)-Total	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	0.00020
anadium (V)-Total	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
inc (Zn)-Total	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

Appendix C:
MacKay Creek newsletter, fall 2008

MacKay Creek, North Vancouver
The momentum to protect the beautiful Mackay Creek ecosystem for future generations continues to grow. The Mackay ravine is a beautiful green oasis in the middle of our city.

North Shore Streamkeepers and North Shore Fish and Game Club have been busy with several projects in the past year. We are introducing habitat restoration workshops and a community art project that will raise awareness about environmental impacts on the fragile creek ecology and provide sustainable stewardship strategies.

There are salmon in MacKay Creek
Fall spawner surveys for adults and summer surveys for fry show chum and coho in MacKay Creek. This summer, there were lots of coho fry in the lower creek and throughout the ravine.

Coho live for a year and a half in the stream before migrating to the ocean. They must survive a lot of stresses, including winter floods, summer droughts and year-round pollution from our streets and homes that enters the creek through the storm drains.

North Shore Fish and Game Club raises 30,000 chum fry every year at the Heywood Park hatchery. Families attend the Adopt-a-Fish event every April in Edgemont Village, where children carry baggies with chum fry down to the creek and release them, where they continue their journey to the ocean.

MacKay Creek is full of life
Cutthroat trout, crayfish and aquatic bugs are found throughout the creek. Deer, bears, raccoons, skunks, owls and all sorts of birds live in the ravine.

Invasive plants continue to be a problem, taking over ravine habitat and smothering native plants
Many of the invasive plants creep in from our gardens. Common invasive plants along MacKay Creek include ivy, lamium, Japanese knotweed, holly and Himalayan blackberry. Lamium is a particular problem in the ravine near Mapleridge Drive, where garden escapes have carpeted the forest floor.

Repel the Aliens

North Shore Streamkeepers has several ongoing projects with volunteers from the community and with various partners to "repel the aliens" along the stream corridor.

In MacKay ravine downstream of Mapleridge Drive, there are work parties to remove lamium and ivy, and replant with ferns and shrubs.
In Heywood Park (lower MacKay Creek), there was a major campaign in 2007 and followup in 2008 to remove ivy and other invasive plants and replant with native species. The City of North Vancouver is working on long term plans for the park.

District of North Vancouver Parks is restoring streamside habitat upstream of Montroyal Blvd., removing invasive plants, replacing them with native plants and cedar fencing to protect this sensitive habitat. They are also improving habitat at the lower end of MacKay Creek near First Ave., with a re-aligned trail, removal of ivy, and planting with many native trees and shrubs.

VOLUNTEER to help your local creek: Contact North Shore Streamkeepers at www.nssk.ca or ns-sk@shaw.ca to find out more information and learn how you can help protect Mackay Creek and to volunteer on various projects

What's New on MacKay Creek Fall 2008

North Shore Streamkeepers

Established 1993

Clean water is essential
North Shore Streamkeepers is conducting a one year study of water quality, stream flow and aquatic organisms in 2007-2008. Environment Canada's Environmental Damages Fund provides funding for chemical analysis and the District of North Vancouver provides equipment.

Samples are analyzed for nutrients (from fertilizers), sediment, fecal coliform bacteria and metals, which enter the stream via the storm drains. Common household sources and road runoff create these pollutants.

Common problems include high coliform bacteria counts, particularly in the ravine (wildlife and dogs are the most likely sources). Sediment from improperly managed construction sites and landscaping work damages fish and fish habitat. Nutrients from fertilizer and manure use in gardens contributes to the heavy growth of algae in the creek.

Arts, Science and People
The North Vancouver Office of Cultural Affairs has provided funds to assist North Shore Streamkeepers in a habitat restoration project that will culminate in a Community Art Project at the Mini Fish Hatchery site at Heywood Park. Watch for announcements about how to contribute to this project.

Partners on MacKay Creek
We thank the many people and organizations working together to maintain the beautiful and functioning ecosystem of MacKay Creek.

Residents
North Shore Streamkeepers
North Shore Fish and Game Club
Fisheries and Oceans Canada
District of North Vancouver
City of North Vancouver
Pacific Streamkeepers Federation
Pacific Salmon Foundation (funding for invasives removal and replanting projects in upper and lower MacKay)
Evergreen Canada – Home Depot (funding for lower MacKay Creek invasives removal and replanting)
Environment Canada Environmental Damages Fund (funding for water quality study)
North Vancouver Office of Cultural Affairs (funding for community art project)

VOLUNTEER to help your local creek: Contact North Shore Streamkeepers at www.nssk.ca or ns-sk@shaw.ca to find out more information and learn how you can help protect Mackay Creek and to volunteer on various projects

Appendix D:

MacKay Creek watershed study, photo report

North Shore Streamkeepers
MacKay Creek Watershed Study
Photo Report, 2007 – 2009

March 31, 2009

Summary

The 2007-2009 water quality project on Mackay Creek in North Vancouver BC was a joint project of the North Shore Streamkeepers and North Shore Fish and Game Club. Water samples were collected once a month for one year at four sites from the headwaters to the creek mouth. Flow data were collected at the same time to provide information about seasonal trends and contribute to an estimate of contaminant loadings. Stream health was also assessed by evaluating benthic invertebrate communities and by conducting surveys for spawning salmon in the fall. Ongoing public awareness campaigns were another important project activity.

MacKay Creek is home to coho and chum salmon runs, resident cutthroat trout and many species of wildlife. The stream flows through residential, commercial and industrial areas before entering Burrard Inlet, which contribute runoff from roads and properties. Samples were analyzed for general water chemistry, total suspended solids, turbidity, nutrients (fertilizers), metals and coliform bacteria and on site measurements were made of temperature, pH, conductivity and dissolved oxygen. These parameters provide evidence of common pollutants in rain runoff from human activities in the watershed.

This photo report shows sampling sites, methods and common water quality concerns identified during the study, and complements the technical report, which contains all the data obtained in the study. From bottom to top of the developed area, four sites were sampled:

- Site 1: in MacKay Creek Park, below Marine Drive and upstream of the mouth
- Site 2: in Heywood Park, upstream of Marine Drive
- Site 3: in Upper MacKay Creek Park, a ravine surrounded by residential areas
- Site 4: headwater stream in Sarita Park, above most of the residential areas

Common contributors to reduced water quality included:

- consistently elevated fecal coliform (up to >24,000 mean probable number) and *E. coli* bacteria levels (up to 3,000 mean probable number) at Sites 1, 2 and 3, with highest numbers reported at Site 3. Dogs, wildlife and leakage from the sanitary sewers are potential sources of coliforms.
- elevated nutrient levels (up to 0.012 mg/L ammonia, 0.62 mg/L nitrate and 0.006 mg/L ortho phosphate during summer), also indicated by extensive algal growth
- sediment from poorly managed residential construction and landscape projects (in June, 5 km of MacKay Creek ran brown for several hours during heavy rain, total suspended solids up to 134 mg/L and turbidity of 55 NTU, well above water quality guidelines)
- metals levels within BC and CCME water quality guidelines most of the time, with exceedances noted for cadmium, copper, iron, lead and zinc during the June rainstorm, concurrent with the poorly managed landscape project in upper watershed.

This project's success is due to the efforts of volunteers from the North Shore Streamkeepers and North Shore Fish and Game Club (including a professional biologist and hydrologist) and partners who provided grants and inkind professional services:

Environment Canada (Environmental Damages Fund)
District of North Vancouver (equipment usage, maps, technical support)
Aquatic Informatics (equipment usage)
City of North Vancouver (maps)
Fisheries and Oceans Canada (technical support and logistics)
Students from the University of British Columbia (civil engineering and planning, through the Community Service Learning Initiative)

Photo1 **Mackay Site 1, January 2008, low water. This site is in the lower watershed in MacKay Creek Park, with industrial and commercial activities nearby. Margaret Phelan, Environment Canada Project Liaison, joined us.**

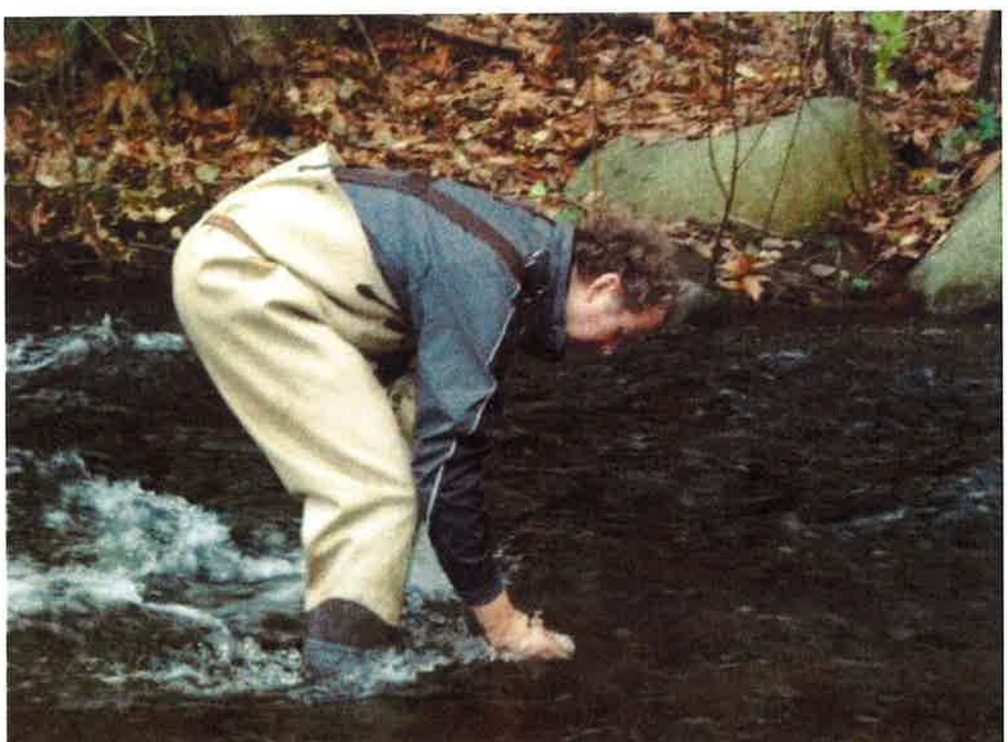


Photo 2 **MacKay Site 2, March 2008, in Heywood Park collecting a water sample. This site is downstream of residential areas.**

Photo 3 **MacKay Site 3, February 2008, is in the ravine upstream of Edgemont Village. UBC students helped collect water and benthic invertebrate samples. High quality fish and wildlife habitat in the ravine is threatened by spread of invasive plants and recreational use.**

Photo 4 **MacKay Site 4, is in a headwater tributary in Sarita Park, above most of the residential development. The flows year round and supports trout.**

Photo 5 Using the YSI meter to measure water temperature, pH, dissolved oxygen and conductivity, August 2008 at MacKay Site 2. Britta Ng from District of North Vancouver joined us.

Photo 6 Preparing bottles for sampling, December 2007 at MacKay Site 1.

Photo 7 Cutthroat trout, coho and chum salmon are common in MacKay Creek. The upper limit of salmon distribution is just upstream of Site 3, due to instream barriers (culvert and flood repair works).

Photo 8 Crayfish inhabit the stream and are considered a sign of good water quality.

Photo 9 **Benthic invertebrates were collected in September 2007 and February 2008 (see photo 3). UBC students assisted in sample sorting in February. Benthic communities provide information about stream health.**

Photo 10 **Filamentous green algae growth was common at all sites in the spring.**

Photo 11 Dense algae growth (diatoms) was present in summer, reflecting relatively high nutrient loads (up to 0.012 mg/L ammonia, 0.62 mg/L nitrate and 0.006 mg/L ortho phosphate during summer).

Photo 12 June 2008 – we sampled in the rain, too, when turbid water is expected, but were surprised to see such brown water at Sites 1 (above), 2 and 3.

Photo 13 June – this improperly managed landscaping site was unprepared for rain and was the source of highly turbid water – 5 km of stream ran brown for several hours (total suspended solids up to 134 mg/L, turbidity of 55 NTU, well above water quality guidelines). Silt damages fish gills and clogs stream substrates.

Photo 14 Storm drains are the main pathways for pollutants from road runoff to enter a stream. This was from the June rainstorm at landscape site.

Photo 15 Fecal coliform bacteria levels were elevated at Sites 1, 2 and 3 throughout the year and were highest at Site 3 in the MacKay ravine. E. coli numbers up to 3000 (mean probable number) were reported. Potential sources are dogs, wildlife and sanitary sewer leaks.

Photo 16 An oil – grit separator near Site 1, provides some treatment of road runoff in commercial and industrial area. These structures require periodic maintenance to remove accumulated oil and sediment.

Photo 17 Inside the oil – grit separator.

Photo 18 Oily sheens were observed on some sampling dates, especially at MacKay Site 1 (in photo), downstream of Marine Drive.

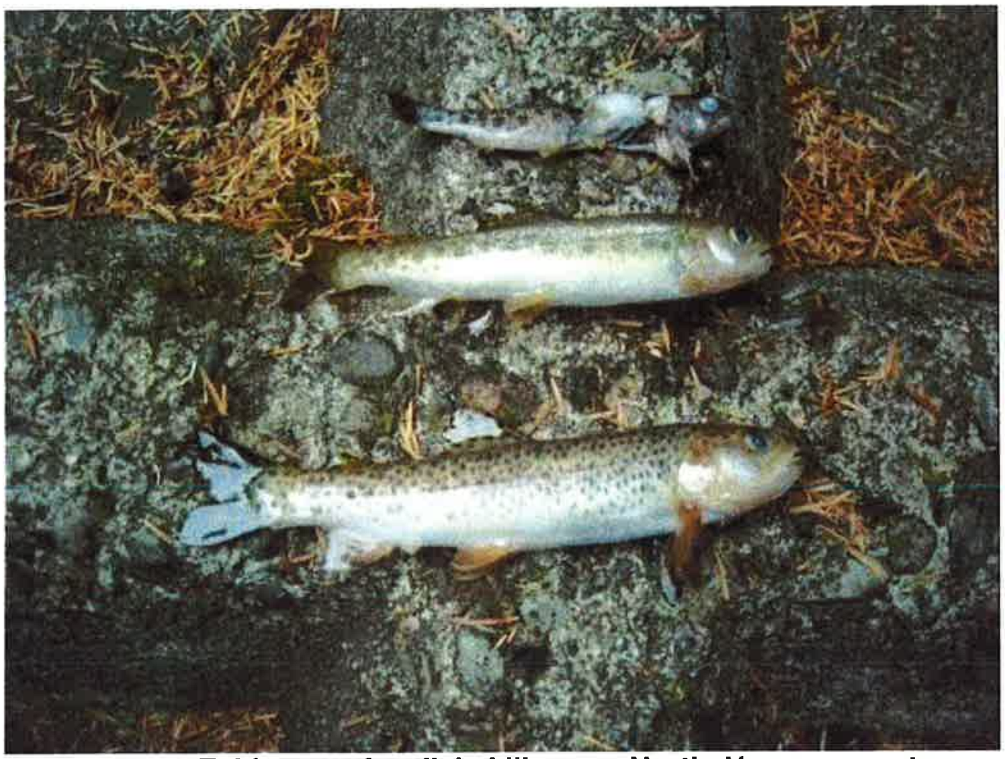


Photo 19 Evidence of a fish kill on a North Vancouver stream. Fish kills result from the discharge of toxic substances, including harsh cleaners, swimming pool and hot tub water, wash water from cement work, and other sources, either accidentally or on purpose.

Photo 20 Storm drains lead to fish habitat in streams or the ocean. The storm drain marking program (Fisheries and Oceans Canada) encourages volunteers to paint the yellow fish to remind people about this.

Photo 21 Public awareness projects help connect residents to the beauty and ecological functioning of nearby streams, and let them know simple ways of protecting the streams. North Shore Streamkeepers events organized or attended in 2008 include:

- four invasive plant removal events on MacKay Creek (ravine near Site 3)
- two invasive plant removal events on Hastings Creek (Lynn Valley)
- planting in lower MacKay Creek (sponsored by Dist of North Vancouver)
- Coho Walk (sponsored by Coho Festival of North Shore, Metro Vancouver
- Rivers Day (on Morten Creek, a tributary of Lynn Creek)
- Gumboots and Goats (on Wagg Creek, Evergreen Foundation)
- distribution of MacKay Creek News (newsletter) to 900 residents in upper MacKay watershed
- annual MacKay Creek cleanup near MacKay Site 1 (sponsored by North Shore Fish and Game Club)