MPERG Report 2009-2

Natural Source Contaminants In the Yukon: Focus on Selenium

By

EDI Environmental Dynamics Inc.

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EDI ENVIRONMENTAL DYNAMICS INC.
Natural Resource Consultants

NATURAL SOURCE CONTAMINANTS IN THE YUKON: FOCUS ON SELENIUM

PREPARED FOR:

MINING AND PETROLEUM ENVIRONMENTAL RESEARCH GROUP (MPERG)

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Thanks to Doug Davidge from Environment Canada together with Matt Power from EDI who completed the field sampling portion of the program.

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1 INTRODUCTION

This report is a product of the continuation of a study begun in 2007/08. The 2007/08 report focused on selenium concentrations and pathways in the aquatic ecosystems of various tributaries of the Francis, Finlayson and Pelly rivers, which drain portions of the Yukon Tanana-Terrane and Cassiar Platform between Ross River and Watson Lake. In 2008/09 the sampling program was expanded to another area of the Yukon that is recognized as being highly mineralized: areas within the Selwyn Basin. The 2008/09 study area is located along the North Canol Road, northeast of Ross River.

The Yukon Territory is located on highly mineralized geology, which accounts for naturally elevated concentrations of various elements in terrestrial and aquatic ecosystems. In some locations natural occurring concentrations of certain elements in surface water exceed the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME 2007). Mining for coal, phosphate, uranium, and various other commodities can expedite the release of selenium from rock resulting in elevated background levels (Chapman 2005). The collection of accurate background data would allow for the evaluation of further increases in concentrations of these elements associated with mining operations. In addition to the existing information gap associated with background concentrations, there is also a lack of understanding of the pathways of selenium in aquatic systems and the uptake of potential contaminants in biota in Yukon aquatic ecosystems. Certain elements, hereafter called 'organophilic elements' affiliate more readily with organic matter and are more prone to uptake by biota. These organophilic elements include selenium (Se), arsenic (As), beryllium (Be), mercury (Hg) and vanadium (V). In aquatic ecosystems, organophilic elements are taken up by aquatic plants or animals and may concentrate at subsequently higher levels through the food chain.

The purpose of this study was to investigate natural organophilic element concentrations, with a focus on selenium, and the uptake of these elements in aquatic ecosystems in a number of streams draining the Selwyn Basin. The study had two primary objectives: 1) to examine natural contaminant concentrations in stream sediments, surface water, instream vegetation, benthic invertebrates and fish, and 2) to investigate the uptake of organophilic elements in the aquatic food chain. Concentrations of all organophilic elements will be recorded as part of this project, however, the discussion will be restricted to selenium as this has been the element of most interest in the Selwyn Basin due to local geology.

A secondary objective of the study was to document the community composition of benthic invertebrates in the study streams. Certain species of benthic invertebrates are known to be intolerant to elevated contaminant concentrations associated with mining activity. Characterizing the pre-disturbance benthic invertebrate community composition in the study area may provide a valuable reference for investigation of potential changes resulting from future development in this region.

2 METHODS

2.1 STUDY AREA

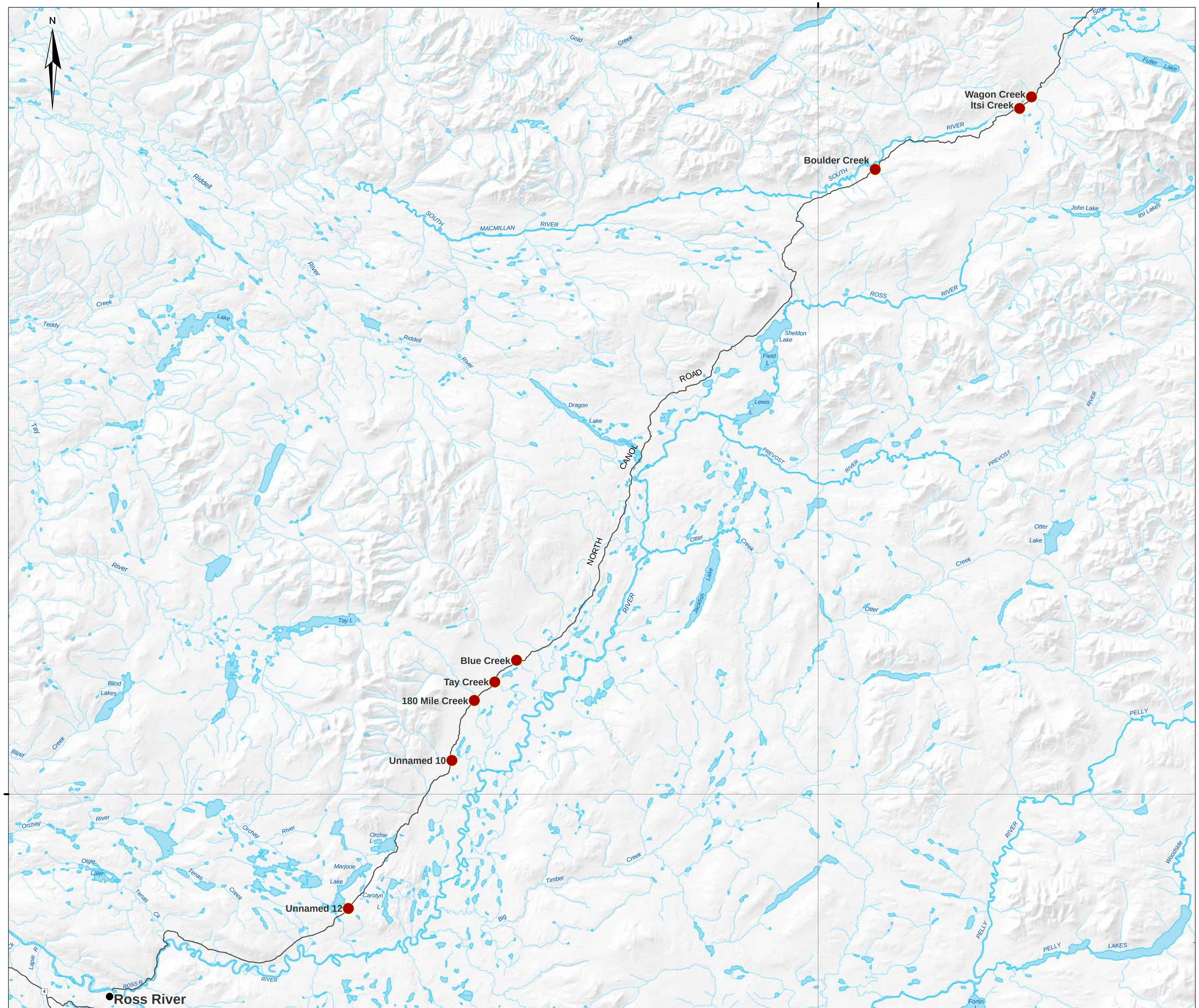
The study area runs along the North Canol Highway from just north of Ross River to within less than 100 km of Macmillan Pass. The area crosses two ecoregions: the Yukon Plateau North to the south, and the Selwyn Mountains towards the north end of the road. The North Yukon-Plateau ecoregion includes rolling uplands and nearly level tablelands dissected by deeply cut, broad, U-shaped valleys (Yukon Ecoregions Working Group 2004). The Selwyn Mountain ecoregion is characterized by rugged, high-elevation mountain ranges, many supporting alpine glaciers. This ecoregion has among the highest peak flows in the Yukon. Many of the first and second order headwater streams are steep and relatively short. Therefore, streamflow response to rainfall events is rapid and extreme. Permafrost is extensive, but discontinuous, in the region (Yukon Ecoregions Working Group 2004). The significant presence of metallic minerals in the MacMillan Pass area is reflected by the naturally elevated metal concentrations in both the soil and water (Soroka and Jack 1983; Kwong and Whitley 1993). The Selwyn Basin is a continental margin basin characterized by the deposition of thick sequences of black carbonaceous shales in euxinic (stagnant, anaerobic) conditions and by development of second order basins through periodic extensional tectonism, subsidence and faulting (YGS 2007). Local area geology can be found in Figure 2.

2.2 STUDY DESIGN

The study was designed to encompass the watercourses draining a portion of the Selwyn Basin known to have naturally high background contaminant concentrations. A total of eight streams were sampled: Wagon Creek, Itsi Creek, Boulder Creek, Blue Creek, Tay Creek, 180 Mile Creek, Unnamed 10 and Unnamed 12 (Figure 1).

The sampling program was designed to enable quantification of natural background concentrations of organophilic elements in aquatic environments, as well as uptake and accumulation of these elements into biota. Sediments and surface water were sampled to capture potential sources, while aquatic vegetation, benthic invertebrates and fish were sampled to assess tissue concentrations as well as uptake and accumulation. Slimy sculpin were chosen as the target fish species because they are present in abundant numbers in freshwater streams throughout the Yukon, and because they have a very high degree of site fidelity. Because the slimy sculpin does not move far during the course of its life, it is an excellent species for investigating site specific environmental quality (Gray et al. 2004).

Selenium in water and sediments is taken up into biota including aquatic vegetation, benthic invertebrates and fish through various pathways (Figure 3). The most common uptake pathway is from sediment to benthic invertebrates, and from benthic invertebrates to fish species. The majority of uptake of organophilic elements is through diet, with lesser uptake directly from the water column (Chapman 2005).



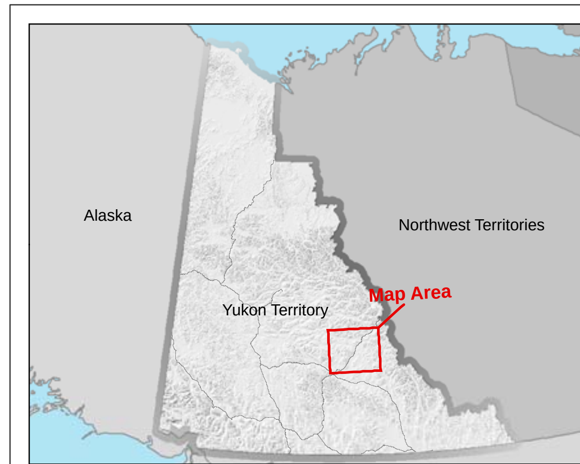


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FIGURE: 1

Sample sites at stream crossings along the North Canol Road in Yukon.

Legend

Sample Sites

..........Stream Crossing Sample Site

Topography

..........Populated Community

..........Road

..........Watercourse

..........Water bodies

0 2.5 5 10 15 20 25

Kilometres

Drawn By: M. Power
Checked By: L. Doetzel
Date: 27 March 2009

Projection: NAD 1983 - UTM Zone 9
EDI Project: 08-YC-0018

Data Sources:

1:250,000 Topographic features provided by National Topographic Database (NTDB) spatial warehouse.

Disclaimer:

This document is not an official land survey and is presented without prejudice. The spatial data presented is subject to change without notice.

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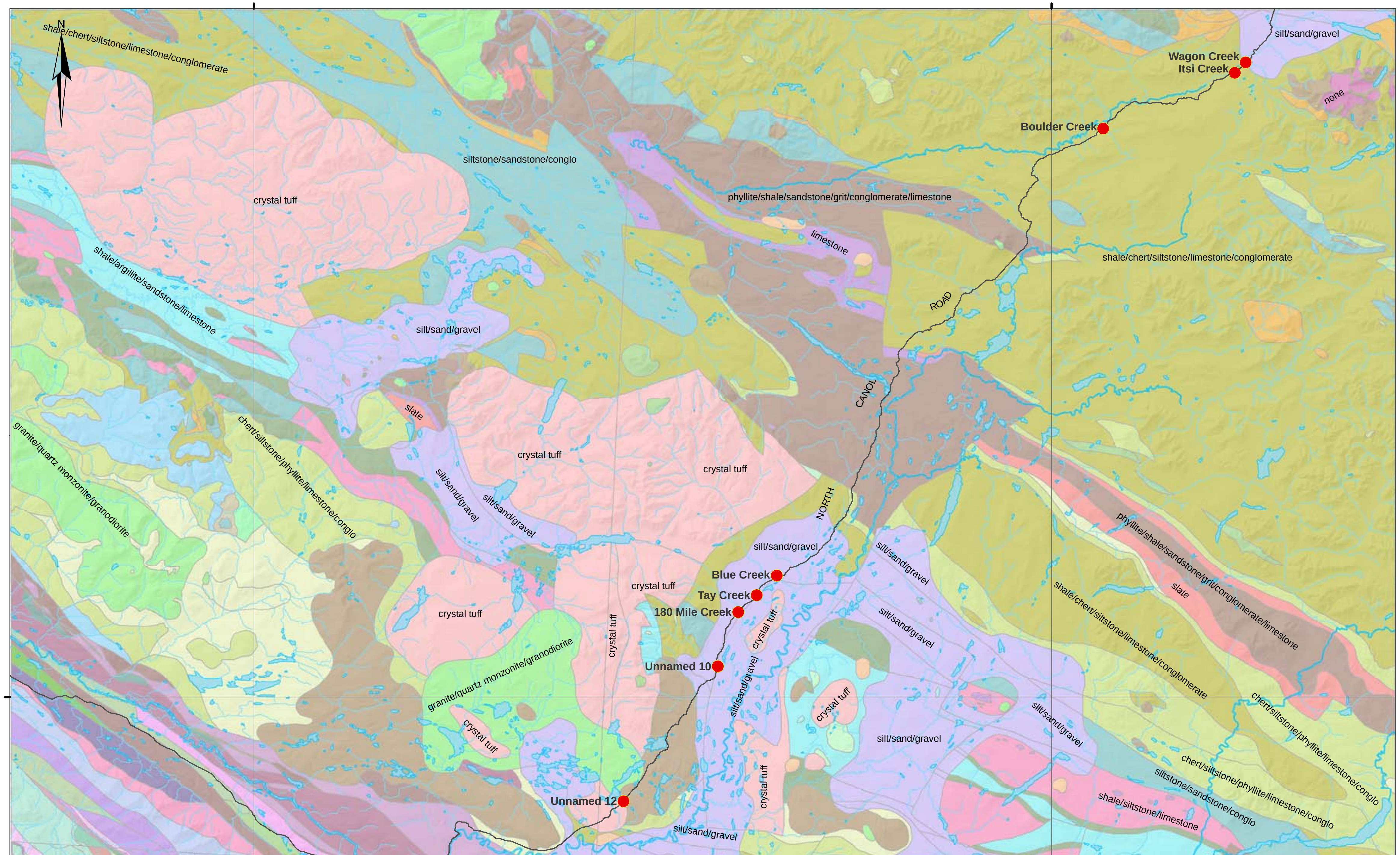

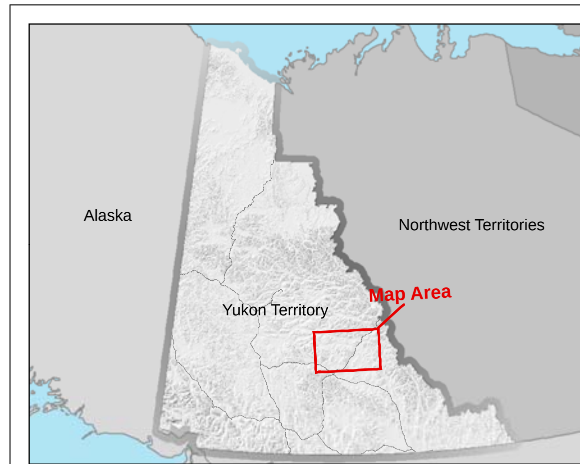

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FIGURE: 2

Overview of study area showing local bedrock geology along the North Canol Road in Yukon

Legend

Sample Sites

..........Stream Crossing Sample Site

Topography

..........Road

..........Watercourse

..........Water bodies

0 3 6 12 18 24 30

Kilometres

Drawn By: M. Power
Checked By: L. Doetzel
Date: 27 March 2009

Projection: NAD 1983 - UTM Zone 9
EDI Project: 08-YC-0018

Data Sources:

1:250,000 Topographic features provided by National Topographic Database (NTDB) spatial warehouse

Bedrock Geology Layer provided by Yukon Geomatics geospatial warehouse.

Disclaimer:

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Bedrock Geology Legend

- basalt/diorite/gabbro/greenstone
- basalt/diorite/gabbro/greenstone/argillite/siltstone/tuff/dunite/peridotite/serpentinite
- basalt/flows/necks/dykes
- basalt/rhyolite/flows/breccia/
- chert/shale/argillite
- chert/shale/argillite/phyllite/breccia
- chert/shale/siltstone
- chert/siltstone/phyllite/limestone/conglo
- chert/tuff
- conglo
- crystal tuff
- dunite/peridotite/harzburgite/diabase/serpentinite
- eclogite
- granite/quartz monzonite/granodiorite
- granodiorite/quartz diorite/quartz monzonite/granite
- limestone
- mudstone/quartzite/limestone/dolostone
- mudstone/shale/siltstone/phyllite/schist
- mudstone/siltstone/shale/sandstone/conglo/flows/tuffs/plugs
- none
- phyllite/shale/sandstone/grit/conglomerate/limestone
- phyllite/siltstone/limestone
- phyllite/siltstone/limestone/conglo
- quartz monzonite/granodiorite/quartz diorite/syenite
- quartzite/gr-quartzite/qt-ms-cl-schist
- quartzite/limestone/dolostone
- rhyolite/flows/tuff/breccia
- sandstone/conglomerate
- shale
- shale/argillite/sandstone/limestone
- shale/chert/siltstone/limestone/conglomerate
- shale/claystone/siltstone/sandstone/conglo/coal
- shale/claystone/siltstone/sandstone/conglo/coal/basalt/flows/porphyry/rhyolite
- shale/quartzite
- shale/siltstone/limestone
- shale/siltstone/quartzite
- shale/siltstone/sandstone/limestone
- shale/slate/quartzite/limestone
- silt/sand/gravel
- siltstone/quartzite/dolostone
- siltstone/sandstone
- siltstone/sandstone/conglo
- siltstone/shale/limestone
- slate
- slate/phyllite/limestone
- slate/sandstone/conglomerate

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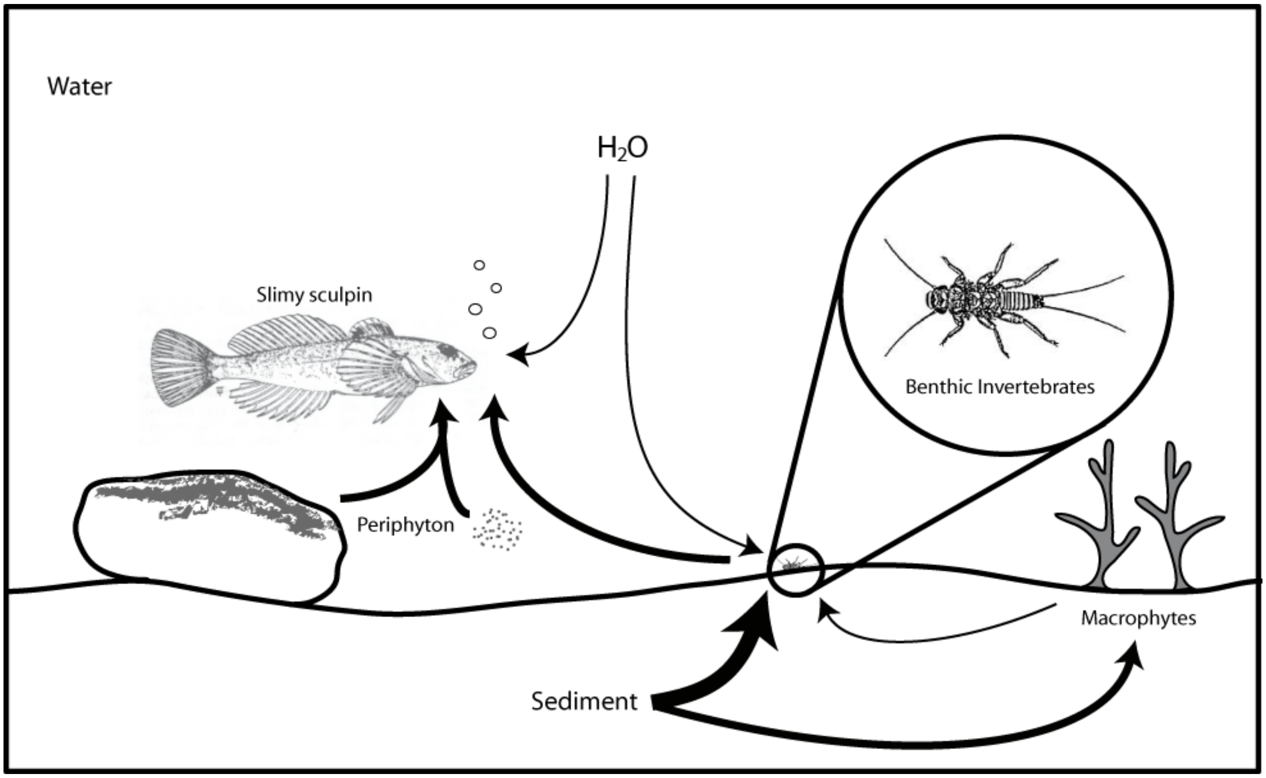

Figure 3. Uptake pathways of organophilic elements in aquatic systems. Heavier arrows indicate the more common pathways.

At each sampling site, stream flow, channel width, wetted width, average channel depth, gradient, temperature, pH, turbidity, and dissolved oxygen measurements were taken, and location coordinates were recorded. Types of stream bed material (substrate), presence and types of aquatic vegetation were documented. Stream sediments, surface water, instream vegetation, benthic invertebrates and fish were collected, where possible. Some biota sampling was not possible at some sampling locations due to local site conditions (i.e. high water velocity, no fish present, etc.; Table 1).

Water quality samples were collected by through 'grab' sampling at a depth of approximately 30 cm (mid water column), using laboratory-prescribed containers. Samples were kept cool and transported to the laboratory for analysis. Stream sediments were sampled using stainless steel instruments and sieved according to laboratory requirements. Samples were stored cold and transported to the laboratory for analysis.

Rooted vegetation was scarce in the study creeks, however, moss was collected from five study sites; Wagon, Itsi, Boulder, Blue and Unnamed 10 creeks. In addition, filamentous algae were collected from Tay Creek and equisetum was collected from Wagon Creek.

Benthic invertebrate samples were collected via kick-net sampling (363 µ mesh size), following the methods outlined by Reynoldson et al. (2003). Specimens were stored in 10% formalin for transport to the office and transferred to 70% ethanol within 72 h. Specimens were identified to genus under microscope and then transported to the Environment Canada laboratory (Pacific and Yukon Region, Surrey, British Columnia) for long term storage.

Fish sampling was conducted by electrofishing at each sampling site. Fish captured were identified to species, and slimy sculpin (*Cottus cognatus*) were retained for analysis. Slimy sculpin samples obtained (of similar sizes) from a sampling site were amalgamated into composite samples to achieve the minimum required weight (5 grams) for laboratory analysis. Samples were stored frozen, and transported to the laboratory for analysis.

Table 1. Summary of sampling locations, and samples collected at each site.

Stream	Date Sampled	Sampling Location		Samples Collected				
		Latitude	Longitude	Water	Stream Sediments	Aquatic Vegetation	Benthic Invertebrates	Fish
Wagon Creek	Sept. 3, 2008	62 56.325	130 29.439	✓	✓	✓	✓	--
Itsi Creek	Sept. 3, 2008	62 55.598	130 30.993	✓	✓	✓	✓	--
Boulder Creek	Sept. 3, 2008	62 51.614	130 50.244	✓	✓	✓	✓	✓
Unnamed 10	Sept. 4, 2008	62 14.381	131 43.805	✓	✓	✓	✓	--
Blue Creek	Sept. 4, 2008	62 20.685	131 35.827	✓	✓	✓	✓	✓
Tay Creek	Sept. 4, 2008	62 19.297	131 38.590	✓	✓	✓	✓	✓
180 Mile Creek	Sept. 4, 2008	62 18.106	131 41.188	✓	✓	--	✓	--
Unnamed 12	Sept. 5, 2008	62 02.770	132 03.339	✓	✓	--	--	--

2.3 LABORATORY ANALYSIS

All laboratory analysis was conducted by Environment Canada (Pacific and Yukon Region, Surrey, British Columbia). Sediment, water, invertebrate and fish analyses were completed for all metals (Table 2). Total metals were analyzed in sediments, invertebrates and fish. Water samples were analyzed for the following water quality parameters:

- pH
- Total dissolved solids (TDS)
- Total suspended solids (TSS)
- Turbidity
- Colour
- Dissolved organic carbon (DOC)
- Sulphate
- Ammonia
- Nitrite
- Nitrate
- Conductivity
- Chloride
- Hardness
- Alkalinity

Table 2. Total and dissolved metals included in analysis of sediment, water, benthic invertebrates and fish.

Element	*Chemical symbol*	**Element**	*Chemical Symbol*
Aluminum	Al	Mercury	Hg
Antimony	Sb	Molybdenum	Mo
Arsenic	As	Nickel	Ni
Barium	Ba	Phosphorus	P
Beryllium	Be	Potassium	K
Bismuth	Bi	Selenium	Se
Boron	B	Silicon	Si
Cadmium	Cd	Silver	Ag
Calcium	Ca	Sodium	Na
Chromium	Cr	Strontium	Sr
Cobalt	Co	Sulfur	S
Copper	Cu	Tin	Sn
Lead	Pb	Thallium	Tl
Lithium	Li	Titanium	Ti
Magnesium	Mg	Vanadium	V
Manganese	Mn	Zinc	Zn

2.4 BIOCONCENTRATION / BIOACCUMULATION FACTORS

Bioconcentration and bioaccumulation are processes that result in biota having higher concentrations of a contaminant than is found in its surround environment. The defining difference between the two processes is that bioconcentration is biologically passive (i.e. movement of contaminants from the water column to sediment), while bioaccumulation occurs through a combination of both active uptake (diet, respiration) and environmental exposure.

Bioconcentration/bioaccumulation factors are useful tools for assessing the uptake of organophilic elements into biota within aquatic ecosystems (See Equation 1). Bioconcentration/bioaccumulation factors illustrate the relationship between contaminant concentrations in animal tissues (i.e. fish tissue, benthic invertebrates) and the concentrations of these same contaminants in possible sources of uptake (i.e. water, stream sediments, benthic invertebrates). Bioconcentration/bioaccumulation factors for the organophilic elements of interest in this study were calculated using the following formula:

Equation 1. Calculation of bioconcentration/bioaccumulation factors.

$$\textit{Bioconcentration/Bioaccumulation Factor (BCF/BAF)} = \frac{\textit{Concentration of Chemical in Tissues}}{\textit{Exposure Concentration}}$$

Bioconcentration and bioaccumulation of arsenic, mercury and selenium through the aquatic ecosystem was investigated; beryllium and vanadium were excluded from uptake investigations because concentrations in many sampled media were below laboratory detection limits.

Bioconcentration of contaminants in aquatic vegetation from water was investigated through calculation of bioconcentration factors. Bioconcentration/bioaccumulation of arsenic, mercury and selenium in benthic invertebrates were investigated, and finally the movement of contaminants into fish from water, sediment, and food sources including benthic invertebrates was investigated in these three creeks.

2.5 BENTHIC INVERTEBRATE COMMUNITY COMPOSITION

Identification and enumeration of benthic invertebrate samples was conducted by Environment Canada (Pacific and Yukon Region, Surrey, British Columbia). Samples were identified to order and family, genus, and where possible, species. Abundance of each order was calculated, and dominant and subdominant orders at each of the sites were determined.

3 RESULTS

3.1 STREAM ATTRIBUTES

The 2008 summer season was a high water one, with large amounts of precipitation, and subsequent surface runoff. This led to flooding in many creeks along the North Canol Road, and likely increased groundwater inputs into these watercourses. Sampling was not conducted until September, rather than in July/August as originally planned, to allow water levels to return to normal. However, water levels continued to be relatively high at the time of sampling due to continued precipitation.

Stream sizes ranged from Tay Creek, which had the largest channel width (16.17 m), to Itsi Creek, which had the smallest (1.75 m). In all sites water was clear, indicating no recent flooding. Water temperatures varied around 5°C, and dissolved oxygen concentrations were high, over 11 mg/L at all sites (Table 3). Substrate was generally composed of a mix of cobble with lesser amounts of gravel, and fines in some locations.

Table 3. Stream attributes, physical parameters, and field water quality, measured at all sites sampled.

Creek Name	Channel Width (m)	Wetted Width (m)	Water Velocity (m/s)	Average Depth (m)	Turbidity	pH	Specific Conductivity (µS/cm)	Temp (°C)	DO (mg/L)	Substrate (D/SD)[1]
Wagon Creek	9.25	7.10	1.08	0.37	clear	7.26	122	5.00	13.89	gravel/cobble
Itsi Creek	1.75	1.59	0.20	0.38	clear	7.01	32	4.45	12.68	cobble/gravel
Boulder Creek	7.77	7.27	0.77	0.23	clear	7.53	103	6.25	13.16	cobble/gravel
Unnamed 10	5.73	5.12	0.75	0.19	clear	7.91	189	4.37	12.46	cobble/gravel
Blue Creek	8.78	5.24	0.43	0.26	clear	7.24	103	3.64	--	cobble/gravel
Tay Creek	16.17	13.79	0.69	0.57	clear	7.58	78	4.88	12.29	cobble/gravel
180 Mile Creek	11.35	10.7	0.42	0.45	clear	7.57	130	5.05	12.47	cobble/fines
Unnamed 12	3.55	1.60	0.23	0.28	clear	7.82	204	6.87	11.75	cobble/gravel

[1] D/SD indicates dominant and subdominant substrate composition components

3.2 CONCENTRATIONS OF ORGANOPHILIC ELEMENTS

Review of the water quality sampling data showed that concentrations of beryllium, vanadium and mercury were below detection in water samples from all streams. However, selenium and arsenic were present in measurable amounts. Selenium concentrations ranged from 0.3 to 4.2 µg/L. Highest concentrations were found in 180 Mile, Unnamed 10, and Wagon creeks, all of which exceeded the CCME (2007) guideline for the protection of freshwater aquatic life (1.0 µg/L; Figure 4). Arsenic concentrations were detectable samples from all creeks; however, concentrations were well below the CCME guideline (2007; Figure 5).

Similar to selenium, the highest arsenic concentration was found in Wagon Creek. The dissolved fraction made up nearly 100% of the total concentration for both arsenic and selenium (Appendix G).

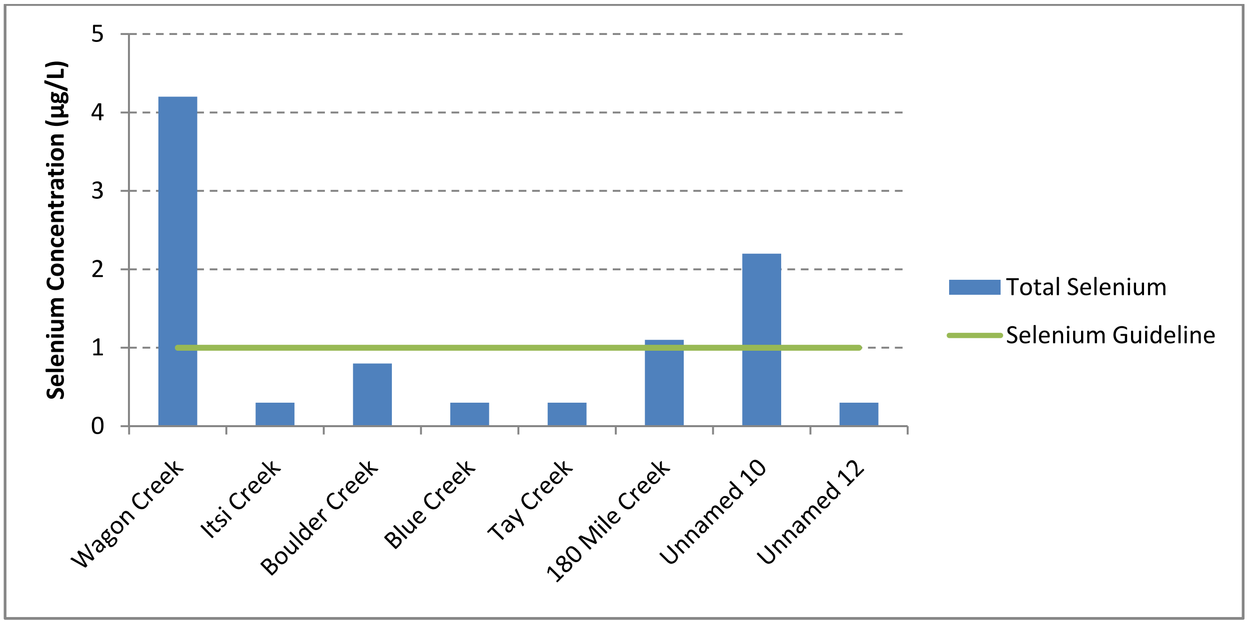

Figure 4. Total selenium concentrations in water samples from all eight study streams. The CCME (2007) guideline for the protection of aquatic life is denoted by the green line.

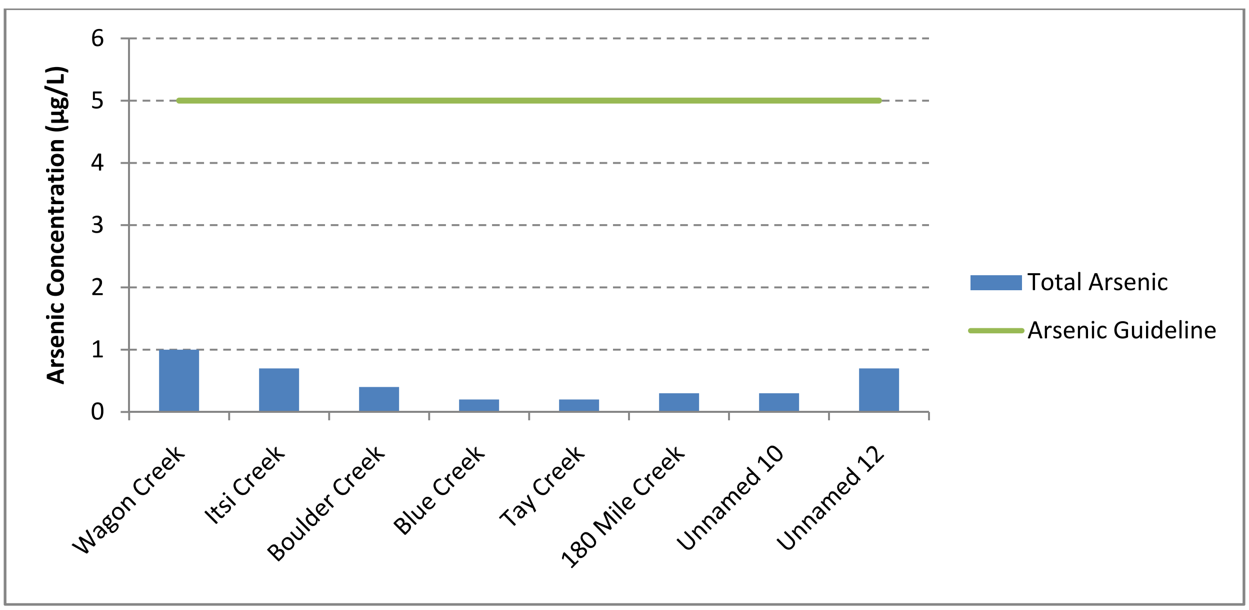

Figure 5. Total arsenic concentrations in water samples from all eight study streams. The CCME (2007) guideline for the protection of aquatic life is denoted by the green line.

Differences in selenium concentrations were apparent between water, sediment, aquatic vegetation (moss), benthic invertebrates and slimy sculpin fish (Figure 6). For purpose of relevant comparison between sites, the only aquatic vegetation included in Figure 6 was moss. Fish were captured in only three creeks; Boulder, Blue and Tay. Selenium concentrations were highest in slimy sculpin from Boulder Creek with a concentrations of 9.3 µg/g dry weight, followed by Tay (9.1 µg/g dw) and Blue creeks (7.8 µg/g dw), respectively (Figure 6). Selenium concentrations in benthic invertebrates were highest in Unnamed 10, followed by Boulder, Itsi, 180 Mile, Tay, Blue and Wagon creeks (Figure 6).

Selenium concentrations in aquatic vegetation (moss) were over twice as high in Wagon Creek as in any other, with a concentration of 10.4 µg/g dry weight. Selenium concentrations moss samples from Itsi, Boulder and Unnamed 10 creeks were comparable with concentrations of 4.6, 4.2 and 4.1 µg/g dry weight. Finally, the moss sample from Blue Creek had the lowest selenium concentration; only 2.5 µg/g dry weight. Selenium concentrations in sediment were highest in Boulder Creek with a concentration of 6.9 µg/g dw, followed by Wagon Creek, with a concentration of 4.2 µg/g dry weight. Unnamed 12, Unnamed 10 and Itsi, Blue, 180 Mile, and Tay creeks, had the lowest concentrations, ranging from 1.1 to 2.5 µg/g (Figure 6).

Concentrations of arsenic were highest in sediment, unlike selenium where the highest concentrations were seen in fish (Figure 7). Fish represent the top of the aquatic food chain. Concentrations of arsenic in fish and benthic invertebrates were more than an order of magnitude lower when compared with concentrations in sediment and aquatic vegetation.

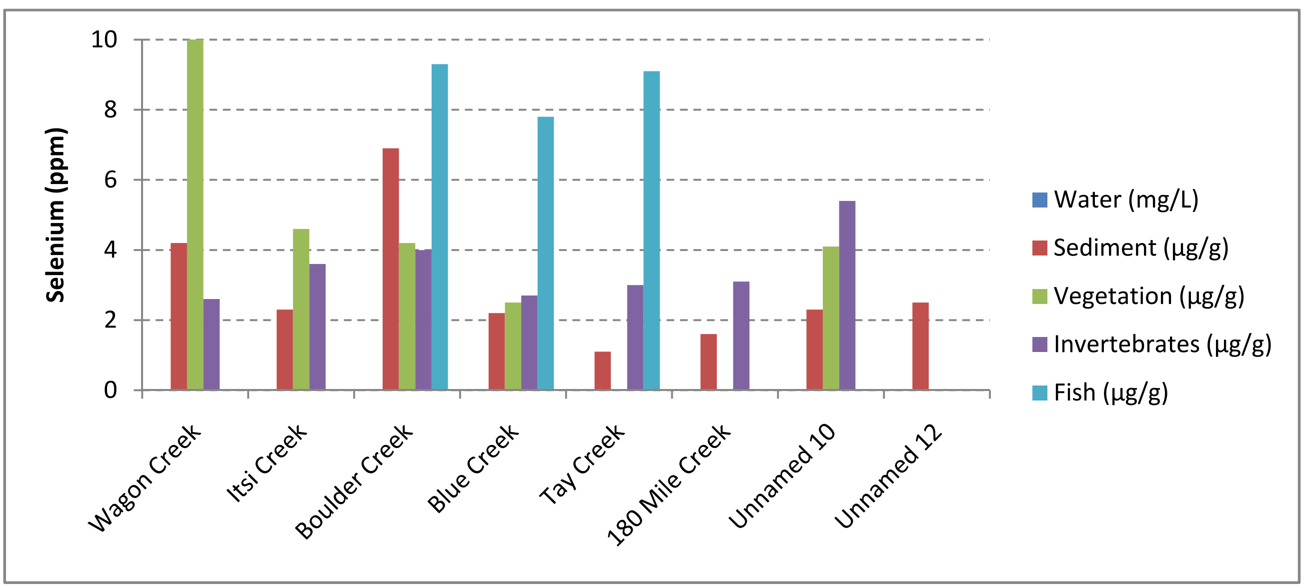

Figure 6. Selenium concentrations in aquatic ecosystem components (waters, sediment, fish, aquatic vegetation (moss), benthic invertebrates) in eight study creeks. All concentrations are in ppm-equivalent units for comparison.

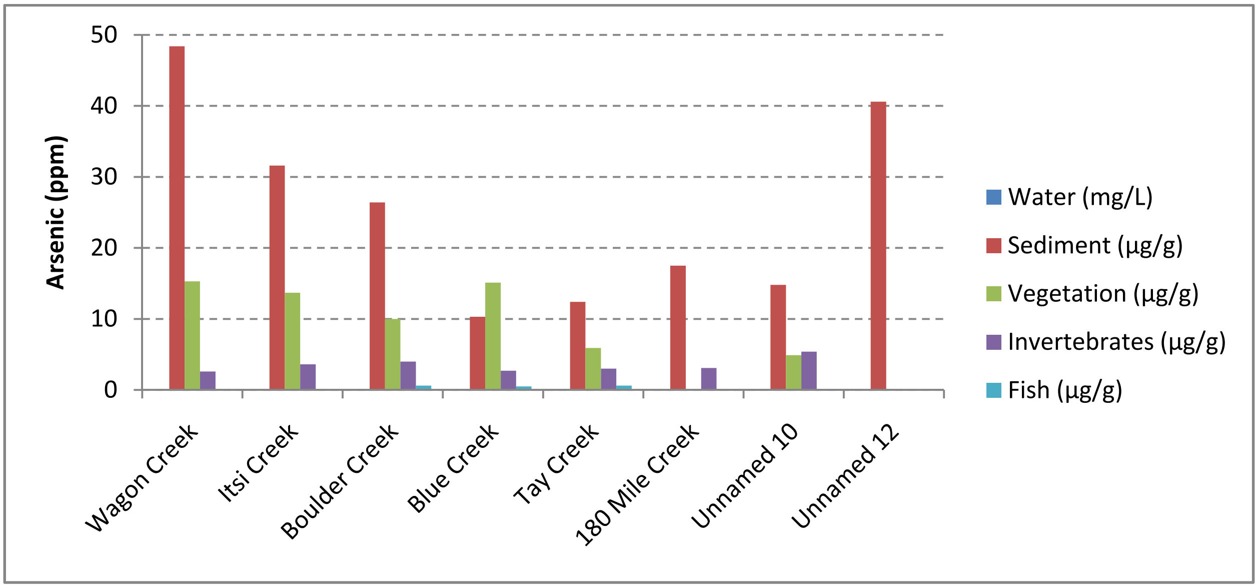

Figure 7. Arsenic concentrations in aquatic ecosystem components (water, sediment, fish, vegetation, benthic invertebrates) in eight study creeks. All concentrations are in ppm-equivalent units for comparison.

3.3 BIOCONCENTRATION AND BIOACCUMULATION

Concentrations of selenium in aquatic vegetation were, on average, nearly 6000 times higher than concentrations seen in the water column. Mercury and arsenic in aquatic plants showed even greater bioaccumulation (Table 4).

Benthic invertebrates take up selenium from water, sediment and aquatic vegetation. However, the bioaccumulation factor measuring selenium concentrations in benthic invertebrates and water is misleading, so care must be taken in data interpretation. Selenium concentration in benthic invertebrates was 6000 times greater than selenium concentrations found in the water column (Table 5); however, the water is not the sole source of selenium to benthic invertebrates. Selenium concentrations in benthic invertebrates were 1.57 times greater than sediment, and 1.20 times greater than in vegetation (Table 5).

The average bioaccumulation factor from sediment to benthic invertebrates was 1.57 (Table 5). The mean bioaccumulation factor from benthic invertebrates to slimy sculpin was 2.75 (Table 6), for a combined bioaccumulation factor of 4.32, just slightly shy of the bioaccumulation factor of 4.39, which is the calculated bioaccumulation factor for movement of selenium from sediment to slimy sculpin (Table 6).

Table 4. Bioconcentration factors of arsenic, mercury and selenium in aquatic vegetation and water.

Creek Name	Arsenic	Mercury	Selenium
Vegetation / Water			
Wagon Creek	50525.0	15200.0	1726.2
Itsi Creek	19571.4	9100.0	15333.3
Boulder Creek	17750.0	8350.0	4250.0
Blue Creek	75500.0	9500.0	8333.3
Tay Creek	29500.0	4900.0	4000.0
Unnamed 10	16333.3	10200.0	1863.6
Mean	**34863.3**	**9541.7**	**5917.7**

Table 5. Bioaccumulation/bioconcentration factors of arsenic, mercury and selenium from water, sediment, and aquatic vegetation into benthic invertebrates.

Creek Name	Arsenic	Mercury	Selenium
Invertebrates / Water			
Wagon Creek	5000.0	10500.0	619.0
Itsi Creek	9428.6	16100.0	12000.0
Boulder Creek	14500.0	10900.0	5000.0
Blue Creek	9500.0	9800.0	9000.0
Tay Creek	4000.0	10100.0	10000.0
180 Mile Creek	19666.7	8200.0	2818.2
Unnamed 10	3666.7	7300.0	2454.5
Mean	**9394.6**	**10414.3**	**5984.5**
Invertebrates / Sediment			
Wagon Creek	0.10	0.50	0.62
Itsi Creek	0.21	1.56	1.57
Boulder Creek	0.22	0.12	0.58
Blue Creek	0.18	0.71	1.23
Tay Creek	0.06	0.86	2.73
180 Mile Creek	0.34	0.79	1.94
Unnamed 10	0.07	0.62	2.35
Mean	**0.17**	**0.74**	**1.57**
Invertebrates / Vegetation			
Wagon Creek	0.10	0.69	0.36
Itsi Creek	0.48	1.77	0.78
Boulder Creek	0.82	1.31	1.18
Blue Creek	0.13	1.03	1.08
Tay Creek	0.14	2.06	2.50
Unnamed 10	0.22	0.72	1.32
Mean	**0.31**	**1.26**	**1.20**

Table 6. Bioaccumulation/bioconcentration factors of arsenic, mercury and selenium from water, sediment, benthic invertebrates and aquatic vegetation into slimy sculpin.

Creek Name	Arsenic	Mercury	Selenium
Fish / Water			
Boulder Creek	1500.0	11000.0	11625.0
Blue Creek	2500.0	32200.0	26000.0
Tay Creek	3000.0	22100.0	30333.3
Mean	**2333.3**	**21766.7**	**22652.8**
Fish / Sediment			
Boulder Creek	0.02	0.12	1.35
Blue Creek	0.05	2.32	3.55
Tay Creek	0.05	1.89	8.27
Mean	**0.04**	**1.44**	**4.39**
Fish / Invertebrates			
Boulder Creek	0.10	1.01	2.33
Blue Creek	0.26	3.29	2.89
Tay Creek	0.75	2.19	3.03
Mean	**0.37**	**2.16**	**2.75**

3.4 BENTHIC INVERTEBRATE COMMUNITY COMPOSITION

Eleven orders of benthic invertebrates were found in the study area (Appendix B). Within these, a total of 196 taxa were identified to genus. Several orders of benthic invertebrate were abundant in one or two streams but found rarely or not at all in others (Appendix B). Tricoptera were present in Wagon and Boulder Creeks (8.26% and 6.29%, respectively). However, Tricoptera were not abundant in other streams sampled (< 2%; Table 7). In Tay Creek benthic invertebrates of the order Trombiformes comprised 5.72% with lesser amounts in 180 Mile and Unnamed 10 (Table 7). This order seemed to be present in greater amounts in the more southern streams, located in the Yukon Plateau-North. Finally, benthic invertebrates of the order Haplotaxidae were the second most abundant order (23.62%) in 180 Mile Creek; this order was absent or present in low numbers in other creeks.

Table 7. Most abundant orders of benthic invertebrates present in each of the streams sampled.

Stream	Most Abundant Order	Second Most Abundant Order
Wagon Creek	Diptera (43.12%)	Plecoptera (40.37)
Itsi Creek	Diptera (83.63%)	Plecoptera (12.58%)
Boulder Creek	Plecoptera (47.17%)	Ephemeroptera (35.22%)
Blue Creek	Diptera (49.10%)	Ephemeroptera (31.94%)
Tay Creek	Ephemeroptera (41.87%)	Diptera (28.92%)
180 Mile Creek	Plecoptera (64.66%)	Haplotaxida (23.62%)
Unnamed 10	Diptera (57.24%)	Ephemeroptera (21.36%)

4 DISCUSSION

Selenium is an essential nutrient for most organisms; however, it becomes toxic at elevated concentrations. Therefore, CCME (2007) guidelines stipulate the concentration of selenium in water that is considered 'safe' for all aquatic organisms (1.0 μg/L; CCME 2007). Total selenium concentrations in water were above recommended concentrations in three of the creeks sampled, Wagon Creek, Unnamed 10 and 180 Mile Creek. These creeks are not in close proximity, nor do they share stream characteristics that explain the high selenium concentration. Concentrations of selenium in water often exceed CCME guidelines in highly mineralized regions. However, these guidelines were designed with data from aquatic systems very different with respect to stream hydraulics and water quality; it is likely that they are too conservative for most watercourses in Yukon Territory. Proper management of selenium concentration in aquatic systems in Yukon requires site-specific guidelines. Both the Kudz Ze Kayah (KZK) mine site (Cominco Ltd., 1998) and the Viceroy Brewery Creek (Viceroy Minerals Corporation, 2003) were required by the Yukon Water Board to set site-specific guidelines (3.8 μg/L total selenium in water; Cominco Ltd., 1998, Viceroy Minerals Corporation, 2003). When comparing data collected as part of this study to the site specific guideline derived by these mining projects, only Wagon Creek exceeded the site-specific guideline.

In addition, high selenium in water concentrations in the streams sampled as part of the 2008 study may have been affected by high water. The spring and summer of 2008 were marked by very high precipitation, and subsequent surface water runoff throughout Yukon. Flooding increases concentrations of suspended sediments in small streams, and generally leads to increased contaminant concentrations. Effects of flooding may have obscured normal concentrations.

There was a trend toward higher sediment concentrations in the three most northern streams. These drain northwest to the Macmillan River within the Selwyn Mountain Ecozone. Sediment concentrations in Wagon, Itsi and Boulder creeks were twice that of southern creeks, located in the Yukon Plateau North Ecozone draining southeast toward Ross River. The geology in the area of Unnamed 12, Unnamed 10, 180 Mile, Tay and Blue creeks is composed of silt/sand/gravel, while the area surrounding Boulder, Itsi and Wagon creeks is shale/siltstone, limestone conglomerate (Figure 2). The sediment concentrations likely reflect bedrock geology. The more northern streams run through the Selwyn Basin which is naturally rich in selenium (Orberger et al 2003; Loukola-Ruskeeniemi et al. 1999). This geological effect was also seen in 2007 sampling. The highest sediment concentration was in Little Ketza Creek (3.1 μg/g). The Little Ketza Creek is located in a geologic area dominated by shale/claystone/siltstone/sandstone/conglomerate/coal. In addition to being associated with shales, selenium is also found associated with coal deposits, both of which are found in the local geology surrounding Little Ketza Creek (Chapman 2005).

In 2008, vegetation was included in the sampling regime; however, watercourses were fast, clear water mountain streams with little vegetation. Therefore, most samples collected were mosses attached to cobble material, not rooted in-stream vegetation. Selenium concentrations were likely lower in aquatic moss, which takes up nutrients and contaminants from water, than would have been seen in rooted aquatic vegetation, which actively takes up nutrients and contaminants from sediment. As noted with total selenium concentration in the water column, the highest selenium concentration noted in moss samples were from those collected in Wagon Creek, and in general in samples from the northern three creeks. Therefore, the aquatic moss selenium concentrations closely mirror selenium concentrations in water samples.

Benthic invertebrates were collected from all creeks except Unnamed 12. Concentrations were highest in Unnamed 10. A review of dominant and subdominant species at each sampling location aids in interpretation of selenium concentrations in benthic invertebrate samples. Some benthic invertebrate taxa live in closer proximity to sediment, where higher selenium concentrations are found, while others live in cobble/vegetation dominated habitat and had lower exposure to selenium, and therefore lower tissue concentrations. However, in the present study benthic invertebrate samples from Unnamed 10 had the highest selenium concentration, while samples from Blue Creek had the lowest concentrations. The dominant species at both sites was Diptera, which live in close proximity to the sediment. Therefore, review of dominant species did not aid in interpretation of selenium concentrations. A larger sample size may have improved this relationship.

Slimy sculpin were captured in Boulder, Blue and Tay creeks. The highest concentrations came from Boulder and Tay creeks. Though there is no applicable federal tissue guideline for selenium, British Columbia has a tissue guideline of 1.0 μg/g wet weight (BC MOE 2001). When converted to wet weight, the slimy sculpin samples from Boulder, Blue and Tay all exceeded the BC MOE (2001) guideline for selenium. These high concentrations could be due to bioaccumulation of selenium from dietary sources within the aquatic environment.

4.1 BIOCONCENTRATION AND BIOACCUMULATION

When selenium enters an aquatic ecosystem, its fate follows one of three potential pathways: 1) it is absorbed/ingested by aquatic organisms, 2) it binds/complexes with organic material and/or surficial sediments, or 3) remains free in the water column. Eventually, most selenium is either absorbed/ingested by biota or is bound to particulate matter in sediments. Selenium is mobilized from the water column or sediment into aquatic biota through uptake from sediments by rooted aquatic plants, benthic invertebrates and detritus-eating invertebrates (Adams et al. 2000), or the lesser uptake pathway is through absorption from water. Accumulation of selenium at higher trophic levels (i.e. fish) occurs primarily through dietary pathways (Chapman 2005).

Selenium concentration in sediment samples was 1000 to 8000 times higher than the concentration of total selenium in the water column. This is not unexpected as sediment acts as a 'sink' for selenium where it can bind with particulate matter. The 2007, sampling conducted on tributaries of the Francis, Finlayson and Pelly rivers, sediment concentrations were 300 to 4000 times greater than concentrations in water. This decrease in sediment/water ratio was potentially due to the amount of carbon content in the sediment. There is a positive relationship between total organic carbon concentrations in sediment area and to higher total selenium concentrations (Van Derveer and Canton 1997). However, since organic carbon content was not recorded in 2007, this cannot be proven.

Bioaccumulation from the water column into aquatic vegetation was investigated. Although few aquatic species feed directly on living moss, when it dies, it becomes organic detritus and is consumed by benthic invertebrate matter, entering the food chain (Alaimo et al. 1994). Rooted plants were rare in streams within the study area; however, moss patches were noted in many of the streams. Moss does not take up substances via sediment because it is not rooted. Therefore, all selenium is acquired through passive absorption from the water column (Hamilton et al. 2002). The moss sample with the highest selenium concentration was from Wagon Creek, which also had the highest total selenium concentration in water. Alternatively, Blue Creek had both the lowest selenium concentration in both moss and water samples.

Benthic invertebrates are exposed to contaminants through water, sediment (within which they live), and through the consumption of aquatic vegetation. Benthic invertebrates generally accumulate selenium through ingestion of sediment and detritus (Adams et al. 2000). Bioaccumulation factors from sediment into benthic invertebrates in the study streams ranged from 0.6 to 2.7. This was much lower than seen in the results from 2007 sampling in tributaries of the Francis, Finlayson and Pelly rivers where the mean bioaccumulation factor was 7.1. One explanation for this difference is again the high water experienced in the spring/summer 2008. This flooding leads to increased invertebrate drift, moving benthic invertebrates out of an area (Fjellheim et al. 1993). Invertebrates present in streams during sampling were likely in the process of re-colonizing the area, and may not have had sufficient time to accumulate selenium to the same extent as seen in 2007 sampling.

Bioaccumulation of selenium through the food web is best investigated in Boulder, Blue and Tay creeks, where slimy sculpin were captured. Movement of contaminants from water into slimy sculpin can occur via the gills through respiration; also sculpin are carnivorous, generally feeding on benthic invertebrate species. Through feeding, sediment may also be consumed, therefore, both were deemed to be sources of contaminants. Fish from Boulder Creek had the highest concentration of selenium. Sediment and vegetation samples from Boulder Creek also had the highest concentrations. When comparing Blue and Tay Creeks, Tay had higher fish and benthic invertebrate selenium concentrations, but lower concentrations in sediment and vegetation. The difference in additive bioaccumulation and bioaccumulation calculated from laboratory concentrations could be accounted for by trace amounts of uptake from water. These trends suggest that slimy sculpin are taking up more selenium through diet than through exposure, as seen by Chapman (2005).

4.2 BENTHIC INVERTEBRATES COMMUNITY COMPOSITION

A secondary objective of this study was to identify and document the community composition of benthic invertebrates in the study streams effort. Various benthic invertebrate species react differently to changes in water quality and quantity (flow rates), whether due to natural or anthropogenic causes. Creating a database that includes the benthic invertebrate species present and relative percentages of different species in each of the study streams will allow comparisons to be made with future data. Changes in composition allow interpretation of changes in quality of the water and habitat. Currently, Diptera is the most abundant order of benthic invertebrates found in all streams with Plecoptera and Ephemeroptera as subdominant orders.

While Diptera are very common, and can tolerate less than ideal conditions with respect to water quality and contaminants, Ephemeroptera (mayflies) are indicators of excellent stream quality. As stream quality deteriorates, through changes in water quality or stream flow, diversity of mayflies decreases. They are known to be particularly sensitive to mining waste (Maret et al. 2003).

5 CONCLUSIONS

The data collected as part of this study, together with the data collected in 2007, can contribute to the creation of a database of selenium concentrations in aquatic systems in mineralized regions of Yukon. Some conclusions can be made from the data collected as part of this study:

- Total selenium concentrations in fish exceed the BC tissue guideline, and total selenium concentration in water exceeded the CCME guideline for the protection of aquatic life in samples from many sites.
- Sediment and aquatic vegetation concentrations suggest that selenium concentrations are higher in the more northerly reaches of the study area.
- Stream sediments act as a sink for selenium and benthic invertebrates aid in its movement from sediment into food webs;
- Benthic invertebrates appear to take up selenium very efficiently from the sediment, whereas fish take up selenium largely through dietary sources, and lesser amounts directly from water; and
- Valuable data on the community composition and abundance of benthic invertebrates in a series of streams in the Selwyn Basin region of Yukon have been collected and documented. This data will be useful for comparison purposes to track any potential changes should any of this area be affected by future mining or other anthropologic activities.

6 REFERENCES

Adams, W., Toll, J., Brix, K., Tear, L., and D. DeForest. 2000. Site-specific approaches for setting water quality criteria for selenium: differences between lotic and lentic systems. Proceedings of the 24th annual British Columbia Mine Reclamation Symposium, Williams Lake, BC.

Alaimo J., Ogle R.S., and A.W. Knight. 1994. Selenium uptake by larval *Chironomus decorus* from a *Ruppia marintima* based benthic/detrital substrate. Archives of Environmental Contamination and Toxicology 27: 441 - 448.

British Columbia Ministry of Water, Land, and Air Protection (now Ministry of Environment; BC MOE). 2001. British Columbia approved water quality guidelines (criteria): 1998 edition, updated August 24, 2001. Victoria, BC.

Canadian Council of Ministers of the Environment (CCME). 2007. Canadian water quality guidelines for the protection of aquatic life: Summary table. In: Canadian environmental quality guidelines, CCME, Winnipeg, Manitoba. Update 7.0. (http://www2.ec.gc.ca/ceqg-rcge/water.pdf)

Chapman, P. 2005. Selenium monitoring and management – new mines. Golder Associates, North Vancouver, BC.

Cominco Ltd. 1998. Kudz Ze Kayah Water License Application.

Fjellheim A., Håvardstun J., Raddum G.G., and Ø.A. Schnell. 1993. Effects of increased discharge on benthic invertebrates in a regulated river. *Regulated Rivers: Research & Management* 8: 179 – 187.

Gray M.A., Cunjak R.A., and K.R. Munkittrick. 2004. Site fidelity of slimy sculpin (*Cottus cognatus*): insights from stable carbon and nitrogen analysis. *Canadian Journal of Fisheries and Aquatic Sciences* 61: 1717-1722.

Hamilton S.J., Buhl K.J., and P.J. Lamothe. 2002. Selenium and other trace elements in water, sediment, aquatic plants, aquatic invertebrates, and fish from streams in southeastern Idaho near phosphate mining operations: June 2000.Final Report, US Geological Survey, Yankton, SD.

Hart, C. 1999. The Geological Framework of the Yukon Territory. Yukon Geological Survey [online]. Available from http://geology.yk.net/publications/summaries/framework.html.

Kwong, Y.T. and W.G. Whitley. 1992. Natural Acid Rock Drainage at MacMillan Pass, Yukon. National Hydrology Research Institute. A report submitted to the DIAND Committee in partial fulfillment of the requirements of DIAND MEND Project No.11.

Loukola-Ruskeeniemi K., Kantola M., Henttonen P., Halonen T., Paukola T., Seppänen K., Kallio E., Ilmasti M., Vanne J., Timonen O., and K. Kollaan. 1999. Migration of potentially harmful elements from black shales to aquatic ecosystems and local residents: Preliminary results in eastern Finland. Geological Survey of Finland, Special Paper (27):107-110.

Maret, T.R., Cain, D.J., MacCoy, D.E., and T.M. Short. 2003. Response of benthic invertebrate assemblages to metal exposure and bioaccumulation associated with hard-rock mining in northwestern streams, USA. *Journal of the North American Benthological Society* 22: 598-620.

Orberger, B., Pasava, J., Gallien, J.-P., Daudin, L., and P. Trocellier. 2003. Se, As, Mo, Ag, Cd, In, Sb, Pt, Au, Tl, Re traces in biogenic and abiogenic sulfides from black shales (Selwyn Basin, Yukon territories, Canada): A nuclear microprobe study: Nuclear Instruments & Methods in Physics Research, Section B, Beam Interactions with Materials and Atoms v. 210: 441–448.

Reynoldson, T., Logan, C., Pascoe, T., and S. Thompson. 2003. Canadian Aquatic Biomonitoring Network (CABIN) Invertebrate Biomonitoring Field and Laboratory Manual. National Water Research Institute, Environment Canada.

Soroka, I.K., and M.E. Jack, 1983: Baseline study of the watersheds near the Tom property, Macmillan Pass, Yukon Territory, Environment Canada Regional Program report No. 83-14.

Van Derveer W.D. and S.P. Canton. 1997. Selenium sediment toxicity thresholds and derivations of water quality criteria for freshwater biota of western streams. Environmental Toxicology and Chemistry 16: 1260–1268.

Viceroy Minerals Corporation. 2003. Viceroy Minerals Corporation; Site Specific Selenium Criteria Report. Addendum to: 2001 Decommissioning and Reclamation Plan. February 2003.

Yukon Ecoregions Working Group. 2004. Yukon Plateau-North. *In*: Ecoregions of the Yukon Territory: Biophysical properties of Yukon landscapes, C.A.S. Smith, J.C. Meikle and C.F. Roots (eds.), Agriculture and Agri-Food Canada, PARC Technical Bulletin No. 04-01, Summerland, British Columbia.

Yukon Geological Survey (YGS). 2007. Selwyn Basin Metallogeny. http://www.geology.gov.yk.ca/pdf/SelwynBasin.pdf, accessed March 2009.

Appendix A. Photo Documentation

Photo 1: Wagon Creek at road crossing, looking upstream.

Photo 2: Itsi Creek, looking upstream.

Photo 3. Boulder Creek, looking upstream from road crossing.

Photo 4. Blue Creek, looking downstream from road crossing.

Photo 5. Tay Creek, looking downstream from road crossing.

Photo 6. 180 Mile Creek, looking upstream toward road crossing.

Photo 7. Unnamed 10 Creek, note surface high water inputs.

Photo 8. Unnamed 12 Creek, looking upstream.

Appendix B. Benthic Invertebrate Community Data

Appendix B. Benthic Invertebrate Community Composition Data.

Stream	Sampler Mesh Size (µm)	Sample Replicate	Individuals per Replicate	Abundance per Replicate (%)	Invertebrate Taxa Identification	Phylum	Class	Order	Family	Genus	Species
Wagon Creek	363	1	6	5.50	Baetis sp	Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis	
Wagon Creek	363	1	1	0.92	Capnia sp	Arthropoda	Insecta	Plecoptera	Capniidae	Capnia	
Wagon Creek	363	1	5	4.59	Podmosta sp	Arthropoda	Insecta	Plecoptera	Nemouridae	Podmosta	
Wagon Creek	363	1	34	31.19	Sweltsa sp	Arthropoda	Insecta	Plecoptera	Chloroperlidae	Sweltsa	
Wagon Creek	363	1	4	3.67	Zapada sp	Arthropoda	Insecta	Plecoptera	Nemouridae	Zapada	
Wagon Creek	363	1	2	1.83	Trichoptera	Arthropoda	Insecta	Trichoptera			
Wagon Creek	363	1	4	3.67	Ecclisomyia sp	Arthropoda	Insecta	Trichoptera	Limnephilidae	Ecclisomyia	
Wagon Creek	363	1	2	1.83	Micrasema sp	Arthropoda	Insecta	Trichoptera	Brachycentridae	Micrasema	
Wagon Creek	363	1	1	0.92	acropedes	Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila acropedes
Wagon Creek	363	1	8	7.34	Chironomidae	Arthropoda	Insecta	Diptera	Chironomidae		
Wagon Creek	363	1	1	0.92	Cardiocladius sp	Arthropoda	Insecta	Diptera	Chironomidae	Cardiocladius	
Wagon Creek	363	1	3	2.75	Cricotopus sp	Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus	
Wagon Creek	363	1	33	30.28	Diamesa sp	Arthropoda	Insecta	Diptera	Chironomidae	Diamesa	
Wagon Creek	363	1	1	0.92	Eukiefferiella sp	Arthropoda	Insecta	Diptera	Chironomidae	Eukiefferiella	
Wagon Creek	363	1	1	0.92	Dicranota sp	Arthropoda	Insecta	Diptera	Tipulidae	Dicranota	
Wagon Creek	363	1	1	0.92	Sperchon sp	Arthropoda	Arachnida	Trombidiformes	Sperchonidae	Sperchon	
Wagon Creek	363	1	1	0.92	Unionicola sp	Arthropoda	Arachnida	Trombidiformes	Unionicolidae	Unionicola	
Wagon Creek	363	1	1	0.92	Nematoda	Nematoda					
Itsi Creek	363	1	8	0.21	Baetis sp	Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis	
Itsi Creek	363	1	1	0.03	Epeorus (Iron) sp	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Epeorus	
Itsi Creek	363	1	9	0.23	Capnia sp	Arthropoda	Insecta	Plecoptera	Capniidae	Capnia	
Itsi Creek	363	1	455	11.88	Podmosta sp	Arthropoda	Insecta	Plecoptera	Nemouridae	Podmosta	
Itsi Creek	363	1	1	0.03	Skwala parallela	Arthropoda	Insecta	Plecoptera	Perlodidae	Skwala	Skwala parallela
Itsi Creek	363	1	17	0.44	Taenionema sp	Arthropoda	Insecta	Plecoptera	Taeniopterygidae	Taenionema	
Itsi Creek	363	1	9	0.23	Diptera	Arthropoda	Insecta	Diptera			
Itsi Creek	363	1	1168	30.50	Chironomidae	Arthropoda	Insecta	Diptera	Chironomidae		
Itsi Creek	363	1	4	0.10	Cardiocladius sp	Arthropoda	Insecta	Diptera	Chironomidae	Cardiocladius	
Itsi Creek	363	1	356	9.30	Cricotopus sp	Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus	
Itsi Creek	363	1	829	21.64	Diamesa sp	Arthropoda	Insecta	Diptera	Chironomidae	Diamesa	
Itsi Creek	363	1	622	16.24	Eukiefferiella sp	Arthropoda	Insecta	Diptera	Chironomidae	Eukiefferiella	
Itsi Creek	363	1	2	0.05	Euryhapsis sp	Arthropoda	Insecta	Diptera	Chironomidae	Euryhapsis	
Itsi Creek	363	1	11	0.29	Micropsectra sp	Arthropoda	Insecta	Diptera	Chironomidae	Micropsectra	
Itsi Creek	363	1	158	4.13	Rheotanytarsus sp	Arthropoda	Insecta	Diptera	Chironomidae	Rheotanytarsus	
Itsi Creek	363	1	9	0.23	Trichotanypus sp	Arthropoda	Insecta	Diptera	Chironomidae	Trichotanypus	
Itsi Creek	363	1	4	0.10	Bezzia sp	Arthropoda	Insecta	Diptera	Ceratopogonidae	Bezzia	
Itsi Creek	363	1	21	0.55	Chelifera sp	Arthropoda	Insecta	Diptera	Empididae	Chelifera	
Itsi Creek	363	1	10	0.26	Dicranota sp	Arthropoda	Insecta	Diptera	Tipulidae	Dicranota	
Itsi Creek	363	1	4	0.10	Isotomurus sp	Arthropoda	Entognatha	Collembola	Isotomidae	Isotomurus	
Itsi Creek	363	1	13	0.34	Hydracarina	Arthropoda	Arachnida	Hydracarina			
Itsi Creek	363	1	1	0.03	Neumania sp	Arthropoda	Arachnida	Trombidiformes	Unionicolidae	Neumania	
Itsi Creek	363	1	10	0.26	Sperchon sp	Arthropoda	Arachnida	Trombidiformes	Sperchonidae	Sperchon	
Itsi Creek	363	1	12	0.31	Harpacticoida	Arthropoda	Crustacea	Harpacticoida			
Itsi Creek	363	1	5	0.13	Candona sp	Arthropoda	Crustacea	Cladocopina	Candoniidae	Candona	
Itsi Creek	363	1	10	0.26	Enchytraeidae	Annelida	Clitellata	Haplotaxida	Enchytraeidae		
Itsi Creek	363	1	45	1.17	Tubificidae	Annelida	Clitellata	Haplotaxida	Tubificidae		
Itsi Creek	363	1	36	0.94	Nematoda	Nematoda					
Boulder Creek	363	1	1	0.63	Ameletus sp	Arthropoda	Insecta	Ephemeroptera	Siphlonuridae	Ameletus	

Appendix B. Benthic Invertebrate Community Composition Data.

Stream	Sampler Mesh Size (µm)	Sample Replicate	Individuals per Replicate	Abundance per Replicate (%)	Invertebrate Taxa Identification	Phylum	Class	Order	Family	Genus	Species
Boulder Creek	363	1	34	21.38	Baetis sp	Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis	
Boulder Creek	363	1	9	5.66	Cinygmula sp	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Cinygmula	
Boulder Creek	363	1	5	3.14	Drunella doddsi	Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Drunella	Drunella doddsi
Boulder Creek	363	1	5	3.14	Epeorus (Iron) sp	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Epeorus	
Boulder Creek	363	1	2	1.26	Heptagenia sp	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Heptagenia	
Boulder Creek	363	1	4	2.52	Capnia sp	Arthropoda	Insecta	Plecoptera	Capniidae	Capnia	
Boulder Creek	363	1	23	14.47	Leuctra sp	Arthropoda	Insecta	Plecoptera	Leuctridae	Leuctra	
Boulder Creek	363	1	1	0.63	Podmosta sp	Arthropoda	Insecta	Plecoptera	Nemouridae	Podmosta	
Boulder Creek	363	1	23	14.47	Sweltsa sp	Arthropoda	Insecta	Plecoptera	Chloroperlidae	Sweltsa	
Boulder Creek	363	1	7	4.40	Taenionema sp	Arthropoda	Insecta	Plecoptera	Taeniopterygidae	Taenionema	
Boulder Creek	363	1	17	10.69	Zapada sp	Arthropoda	Insecta	Plecoptera	Nemouridae	Zapada	
Boulder Creek	363	1	2	1.26	Trichoptera	Arthropoda	Insecta	Trichoptera			
Boulder Creek	363	1	1	0.63	Brachycentrus sp	Arthropoda	Insecta	Trichoptera	Brachycentridae	Brachycentrus	
Boulder Creek	363	1	3	1.89	Glossosoma sp	Arthropoda	Insecta	Trichoptera	Glossosomatidae	Glossosoma	
Boulder Creek	363	1	1	0.63	Rhyacophila sp	Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila	
Boulder Creek	363	1	2	1.26	acropedes	Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila acropedes
Boulder Creek	363	1	1	0.63	vepulsa	Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila vepulsa
Boulder Creek	363	1	1	0.63	Cardiocladius sp	Arthropoda	Insecta	Diptera	Chironomidae	Cardiocladius	
Boulder Creek	363	1	4	2.52	Cricotopus sp	Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus	
Boulder Creek	363	1	3	1.89	Diamesa sp	Arthropoda	Insecta	Diptera	Chironomidae	Diamesa	
Boulder Creek	363	1	1	0.63	Eukiefferiella sp	Arthropoda	Insecta	Diptera	Chironomidae	Eukiefferiella	
Boulder Creek	363	1	3	1.89	Rheotanytarsus sp	Arthropoda	Insecta	Diptera	Chironomidae	Rheotanytarsus	
Boulder Creek	363	1	1	0.63	Simulium sp	Arthropoda	Insecta	Diptera	Simuliidae	Simulium	
Boulder Creek	363	1	1	0.63	Dicranota sp	Arthropoda	Insecta	Diptera	Tipulidae	Dicranota	
Boulder Creek	363	1	1	0.63	Ormosia sp	Arthropoda	Insecta	Diptera	Tipulidae	Ormosia	
Boulder Creek	363	1	2	1.26	Sperchon sp	Arthropoda	Arachnida	Trombidiformes	Sperchonidae	Sperchon	
Boulder Creek	363	1	1	0.63	Nematoda	Nematoda					
Blue Creek	363	1	10	1.49	Ameletus sp	Arthropoda	Insecta	Ephemeroptera	Siphlonuridae	Ameletus	
Blue Creek	363	1	45	6.72	Baetis sp	Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis	
Blue Creek	363	1	109	16.27	Cinygmula sp	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Cinygmula	
Blue Creek	363	1	18	2.69	Drunella doddsi	Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Drunella	Drunella doddsi
Blue Creek	363	1	19	2.84	Epeorus (Iron) sp	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Epeorus	
Blue Creek	363	1	9	1.34	Ephemerellidae	Arthropoda	Insecta	Ephemeroptera	Ephemerellidae		
Blue Creek	363	1	4	0.60	Drunella flavilinea	Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Drunella	Drunella flavilinea
Blue Creek	363	1	27	4.03	Capnia sp	Arthropoda	Insecta	Plecoptera	Capniidae	Capnia	
Blue Creek	363	1	1	0.15	Megarcys sp	Arthropoda	Insecta	Plecoptera	Perlodidae	Megarcys	
Blue Creek	363	1	1	0.15	Skwala curvata	Arthropoda	Insecta	Plecoptera	Perlodidae	Skwala	Skwala curvata
Blue Creek	363	1	2	0.30	Skwala parallela	Arthropoda	Insecta	Plecoptera	Perlodidae	Skwala	Skwala parallela
Blue Creek	363	1	51	7.61	Taenionema sp	Arthropoda	Insecta	Plecoptera	Taeniopterygidae	Taenionema	
Blue Creek	363	1	31	4.63	Zapada sp	Arthropoda	Insecta	Plecoptera	Nemouridae	Zapada	
Blue Creek	363	1	1	0.15	Arctopsyche sp	Arthropoda	Insecta	Trichoptera	Hydropsychidae	Arctopsyche	
Blue Creek	363	1	1	0.15	Ecclisomyia sp	Arthropoda	Insecta	Trichoptera	Limnephilidae	Ecclisomyia	
Blue Creek	363	1	4	0.60	acropedes	Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila acropedes
Blue Creek	363	1	35	5.22	Chironomidae	Arthropoda	Insecta	Diptera	Chironomidae		
Blue Creek	363	1	11	1.64	Brillia sp	Arthropoda	Insecta	Diptera	Chironomidae	Brillia	
Blue Creek	363	1	154	22.99	Cardiocladius sp	Arthropoda	Insecta	Diptera	Chironomidae	Cardiocladius	
Blue Creek	363	1	1	0.15	Corynoneura sp	Arthropoda	Insecta	Diptera	Chironomidae	Corynoneura	
Blue Creek	363	1	22	3.28	Cricotopus sp	Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus	

Appendix B. Benthic Invertebrate Community Composition Data.

Stream	Sampler Mesh Size (µm)	Sample Replicate	Individuals per Replicate	Abundance per Replicate (%)	Invertebrate Taxa Identification	Phylum	Class	Order	Family	Genus	Species
Blue Creek	363	1	6	0.90	Diamesa sp	Arthropoda	Insecta	Diptera	Chironomidae	Diamesa	
Blue Creek	363	1	8	1.19	Eukiefferiella sp	Arthropoda	Insecta	Diptera	Chironomidae	Eukiefferiella	
Blue Creek	363	1	2	0.30	Euryhapsis sp	Arthropoda	Insecta	Diptera	Chironomidae	Euryhapsis	
Blue Creek	363	1	18	2.69	Rheotanytarsus sp	Arthropoda	Insecta	Diptera	Chironomidae	Rheotanytarsus	
Blue Creek	363	1	4	0.60	sp	Arthropoda	Insecta	Diptera	Chironomidae	Thienemannimyia	
Blue Creek	363	1	28	4.18	Pericoma sp	Arthropoda	Insecta	Diptera	Psychodidae	Pericoma	
Blue Creek	363	1	33	4.93	Simulium sp	Arthropoda	Insecta	Diptera	Simuliidae	Simulium	
Blue Creek	363	1	7	1.04	Dicranota sp	Arthropoda	Insecta	Diptera	Tipulidae	Dicranota	
Blue Creek	363	1	2	0.30	Hydracarina	Arthropoda	Arachnida	Hydracarina			
Blue Creek	363	1	2	0.30	Neumania sp	Arthropoda	Arachnida	Trombidiformes	Unionicolidae	Neumania	
Blue Creek	363	1	2	0.30	Sperchon sp	Arthropoda	Arachnida	Trombidiformes	Sperchonidae	Sperchon	
Blue Creek	363	1	2	0.30	Unionicola sp	Arthropoda	Arachnida	Trombidiformes	Unionicolidae	Unionicola	
Tay Creek	363	1	9	2.71	Ameletus sp	Arthropoda	Insecta	Ephemeroptera	Siphlonuridae	Ameletus	
Tay Creek	363	1	12	3.61	Baetis sp	Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis	
Tay Creek	363	1	27	8.13	Cinygmula sp	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Cinygmula	
Tay Creek	363	1	58	17.47	Drunella doddsi	Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Drunella	Drunella doddsi
Tay Creek	363	1	19	5.72	Epeorus (Iron) sp	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Epeorus	
Tay Creek	363	1	12	3.61	Ephemerellidae	Arthropoda	Insecta	Ephemeroptera	Ephemerellidae		
Tay Creek	363	1	1	0.30	Drunella flavilinea	Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Drunella	Drunella flavilinea
Tay Creek	363	1	1	0.30	Rhithrogena sp	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Rhithrogena	
Tay Creek	363	1	30	9.04	Capnia sp	Arthropoda	Insecta	Plecoptera	Capniidae	Capnia	
Tay Creek	363	1	7	2.11	Leuctra sp	Arthropoda	Insecta	Plecoptera	Leuctridae	Leuctra	
Tay Creek	363	1	13	3.92	Podmosta sp	Arthropoda	Insecta	Plecoptera	Nemouridae	Podmosta	
Tay Creek	363	1	3	0.90	Skwala parallela	Arthropoda	Insecta	Plecoptera	Perlodidae	Skwala	Skwala parallela
Tay Creek	363	1	15	4.52	Zapada sp	Arthropoda	Insecta	Plecoptera	Nemouridae	Zapada	
Tay Creek	363	1	1	0.30	Trichoptera	Arthropoda	Insecta	Trichoptera			
Tay Creek	363	1	1	0.30	Arctopsyche sp	Arthropoda	Insecta	Trichoptera	Hydropsychidae	Arctopsyche	
Tay Creek	363	1	3	0.90	angelita	Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila angelita
Tay Creek	363	1	13	3.92	Chironomidae	Arthropoda	Insecta	Diptera	Chironomidae		
Tay Creek	363	1	22	6.63	Cardiocladius sp	Arthropoda	Insecta	Diptera	Chironomidae	Cardiocladius	
Tay Creek	363	1	14	4.22	Cricotopus sp	Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus	
Tay Creek	363	1	3	0.90	Diamesa sp	Arthropoda	Insecta	Diptera	Chironomidae	Diamesa	
Tay Creek	363	1	1	0.30	Eukiefferiella sp	Arthropoda	Insecta	Diptera	Chironomidae	Eukiefferiella	
Tay Creek	363	1	5	1.51	Rheotanytarsus sp	Arthropoda	Insecta	Diptera	Chironomidae	Rheotanytarsus	
Tay Creek	363	1	12	3.61	Bezzia sp	Arthropoda	Insecta	Diptera	Ceratopogonidae	Bezzia	
Tay Creek	363	1	24	7.23	Pericoma sp	Arthropoda	Insecta	Diptera	Psychodidae	Pericoma	
Tay Creek	363	1	2	0.60	Simulium sp	Arthropoda	Insecta	Diptera	Simuliidae	Simulium	
Tay Creek	363	1	2	0.60	Hydracarina	Arthropoda	Arachnida	Hydracarina			
Tay Creek	363	1	15	4.52	Sperchon sp	Arthropoda	Arachnida	Trombidiformes	Sperchonidae	Sperchon	
Tay Creek	363	1	4	1.20	Unionicola sp	Arthropoda	Arachnida	Trombidiformes	Unionicolidae	Unionicola	
Tay Creek	363	1	1	0.30	Enchytraeidae	Annelida	Clitellata	Haplotaxida	Enchytraeidae		
Tay Creek	363	1	2	0.60	Nematoda	Nematoda					
180 Mile Creek	363	1	9	0.37	Baetis sp	Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis	
180 Mile Creek	363	1	3	0.12	Cinygmula sp	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Cinygmula	
180 Mile Creek	363	1	1	0.04	Drunella doddsi	Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Drunella	Drunella doddsi
180 Mile Creek	363	1	13	0.54	Epeorus (Iron) sp	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Epeorus	
180 Mile Creek	363	1	5	0.21	Ephemerellidae	Arthropoda	Insecta	Ephemeroptera	Ephemerellidae		

Appendix B. Benthic Invertebrate Community Composition Data.

Stream	Sampler Mesh Size (µm)	Sample Replicate	Individuals per Replicate	Abundance per Replicate (%)	Invertebrate Taxa Identification	Phylum	Class	Order	Family	Genus	Species
180 Mile Creek	363	1	17	0.70	Capnia sp	Arthropoda	Insecta	Plecoptera	Capniidae	Capnia	
180 Mile Creek	363	1	1536	63.42	Podmosta sp	Arthropoda	Insecta	Plecoptera	Nemouridae	Podmosta	
180 Mile Creek	363	1	12	0.50	Sweltsa sp	Arthropoda	Insecta	Plecoptera	Chloroperlidae	Sweltsa	
180 Mile Creek	363	1	1	0.04	Taenionema sp	Arthropoda	Insecta	Plecoptera	Taeniopterygidae	Taenionema	
180 Mile Creek	363	1	5	0.21	Trichoptera	Arthropoda	Insecta	Trichoptera			
180 Mile Creek	363	1	2	0.08	Brachycentrus sp	Arthropoda	Insecta	Trichoptera	Brachycentridae	Brachycentrus	
180 Mile Creek	363	1	1	0.04	Ecclisomyia sp	Arthropoda	Insecta	Trichoptera	Limnephilidae	Ecclisomyia	
180 Mile Creek	363	1	2	0.08	Glossosoma sp	Arthropoda	Insecta	Trichoptera	Glossosomatidae	Glossosoma	
180 Mile Creek	363	1	7	0.29	Micrasema sp	Arthropoda	Insecta	Trichoptera	Brachycentridae	Micrasema	
180 Mile Creek	363	1	2	0.08	acropedes	Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila acropedes
180 Mile Creek	363	1	4	0.17	Diptera	Arthropoda	Insecta	Diptera			
180 Mile Creek	363	1	11	0.45	Chironomidae	Arthropoda	Insecta	Diptera	Chironomidae		
180 Mile Creek	363	1	54	2.23	Abiskomyia sp	Arthropoda	Insecta	Diptera	Chironomidae	Abiskomyia	
180 Mile Creek	363	1	9	0.37	Cardiocladius sp	Arthropoda	Insecta	Diptera	Chironomidae	Cardiocladius	
180 Mile Creek	363	1	5	0.21	Cricotopus sp	Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus	
180 Mile Creek	363	1	4	0.17	Diamesa sp	Arthropoda	Insecta	Diptera	Chironomidae	Diamesa	
180 Mile Creek	363	1	1	0.04	Eukiefferiella sp	Arthropoda	Insecta	Diptera	Chironomidae	Eukiefferiella	
180 Mile Creek	363	1	1	0.04	Micropsectra sp	Arthropoda	Insecta	Diptera	Chironomidae	Micropsectra	
180 Mile Creek	363	1	14	0.58	Rheotanytarsus sp	Arthropoda	Insecta	Diptera	Chironomidae	Rheotanytarsus	
180 Mile Creek	363	1	20	0.83	Chelifera sp	Arthropoda	Insecta	Diptera	Empididae	Chelifera	
180 Mile Creek	363	1	1	0.04	Pericoma sp	Arthropoda	Insecta	Diptera	Psychodidae	Pericoma	
180 Mile Creek	363	1	14	0.58	Simulium sp	Arthropoda	Insecta	Diptera	Simuliidae	Simulium	
180 Mile Creek	363	1	5	0.21	Dicranota sp	Arthropoda	Insecta	Diptera	Tipulidae	Dicranota	
180 Mile Creek	363	1	7	0.29	Tipula sp	Arthropoda	Insecta	Diptera	Tipulidae	Tipula	
180 Mile Creek	363	1	48	1.98	Lebertia sp	Arthropoda	Arachnida	Trombidiformes	Lebertiidae	Lebertia	
180 Mile Creek	363	1	8	0.33	Neumania sp	Arthropoda	Arachnida	Trombidiformes	Unionicolidae	Neumania	
180 Mile Creek	363	1	7	0.29	Sperchon sp	Arthropoda	Arachnida	Trombidiformes	Sperchonidae	Sperchon	
180 Mile Creek	363	1	4	0.17	Wandesia sp	Arthropoda	Arachnida	Trombidiformes	Protziidae	Wandesia	
180 Mile Creek	363	1	16	0.66	Candona sp	Arthropoda	Crustacea	Cladocopina	Candoniidae	Candona	
180 Mile Creek	363	1	567	23.41	Enchytraeidae	Annelida	Clitellata	Haplotaxida	Enchytraeidae		
180 Mile Creek	363	1	5	0.21	Tubificidae	Annelida	Clitellata	Haplotaxida	Tubificidae		
180 Mile Creek	363	1	1	0.04	Nematoda	Nematoda					
Unnamed 10	363	1	16	0.58	Ameletus sp	Arthropoda	Insecta	Ephemeroptera	Siphlonuridae	Ameletus	
Unnamed 10	363	1	12	0.44	Baetis sp	Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis	
Unnamed 10	363	1	250	9.07	Cinygmula sp	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Cinygmula	
Unnamed 10	363	1	118	4.28	Epeorus (Iron) sp	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Epeorus	
Unnamed 10	363	1	70	2.54	Capnia sp	Arthropoda	Insecta	Plecoptera	Capniidae	Capnia	
Unnamed 10	363	1	4	0.15	Megarcys sp	Arthropoda	Insecta	Plecoptera	Perlodidae	Megarcys	
Unnamed 10	363	1	1	0.04	Podmosta sp	Arthropoda	Insecta	Plecoptera	Nemouridae	Podmosta	
Unnamed 10	363	1	5	0.18	Skwala parallela	Arthropoda	Insecta	Plecoptera	Perlodidae	Skwala	Skwala parallela
Unnamed 10	363	1	6	0.22	Sweltsa sp	Arthropoda	Insecta	Plecoptera	Chloroperlidae	Sweltsa	
Unnamed 10	363	1	10	0.36	Taenionema sp	Arthropoda	Insecta	Plecoptera	Taeniopterygidae	Taenionema	
Unnamed 10	363	1	229	8.31	Zapada sp	Arthropoda	Insecta	Plecoptera	Nemouridae	Zapada	
Unnamed 10	363	1	16	0.58	Trichoptera	Arthropoda	Insecta	Trichoptera			
Unnamed 10	363	1	8	0.29	Ecclisomyia sp	Arthropoda	Insecta	Trichoptera	Limnephilidae	Ecclisomyia	
Unnamed 10	363	1	22	0.80	acropedes	Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila acropedes
Unnamed 10	363	1	8	0.29	Diptera	Arthropoda	Insecta	Diptera			
Unnamed 10	363	1	177	6.42	Chironomidae	Arthropoda	Insecta	Diptera	Chironomidae		

Appendix B. Benthic Invertebrate Community Composition Data.

Stream	Sampler Mesh Size (µm)	Sample Replicate	Individuals per Replicate	Abundance per Replicate (%)	Invertebrate Taxa Identification	Phylum	Class	Order	Family	Genus	Species
Unnamed 10	363	1	127	4.61	Cardiocladius sp	Arthropoda	Insecta	Diptera	Chironomidae	Cardiocladius	
Unnamed 10	363	1	100	3.63	Cricotopus sp	Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus	
Unnamed 10	363	1	393	14.26	Diamesa sp	Arthropoda	Insecta	Diptera	Chironomidae	Diamesa	
Unnamed 10	363	1	17	0.62	Eukiefferiella sp	Arthropoda	Insecta	Diptera	Chironomidae	Eukiefferiella	
Unnamed 10	363	1	29	1.05	Euryhapsis sp	Arthropoda	Insecta	Diptera	Chironomidae	Euryhapsis	
Unnamed 10	363	1	1	0.04	Micropsectra sp	Arthropoda	Insecta	Diptera	Chironomidae	Micropsectra	
Unnamed 10	363	1	876	31.80	Rheotanytarsus sp	Arthropoda	Insecta	Diptera	Chironomidae	Rheotanytarsus	
Unnamed 10	363	1	10	0.36	sp	Arthropoda	Insecta	Diptera	Chironomidae	Synorthocladius	
Unnamed 10	363	1	7	0.25	Chelifera sp	Arthropoda	Insecta	Diptera	Empididae	Chelifera	
Unnamed 10	363	1	2	0.07	Hemerodromia sp	Arthropoda	Insecta	Diptera	Empididae	Hemerodromia	
Unnamed 10	363	1	2	0.07	Pericoma sp	Arthropoda	Insecta	Diptera	Psychodidae	Pericoma	
Unnamed 10	363	1	1	0.04	Prosimulium sp	Arthropoda	Insecta	Diptera	Simuliidae	Prosimulium	
Unnamed 10	363	1	1	0.04	Simulium sp	Arthropoda	Insecta	Diptera	Simuliidae	Simulium	
Unnamed 10	363	1	14	0.51	Dicranota sp	Arthropoda	Insecta	Diptera	Tipulidae	Dicranota	
Unnamed 10	363	1	2	0.07	Ormosia sp	Arthropoda	Insecta	Diptera	Tipulidae	Ormosia	
Unnamed 10	363	1	8	0.29	Hydracarina	Arthropoda	Arachnida	Hydracarina			
Unnamed 10	363	1	3	0.11	Sperchon sp	Arthropoda	Arachnida	Trombidiformes	Sperchonidae	Sperchon	
Unnamed 10	363	1	66	2.40	Unionicola sp	Arthropoda	Arachnida	Trombidiformes	Unionicolidae	Unionicola	
Unnamed 10	363	1	8	0.29	Cyclopoida	Arthropoda	Crustacea	Cyclopoida			
Unnamed 10	363	1	65	2.36	Candona sp	Arthropoda	Crustacea	Cladocopina	Candoniidae	Candona	
Unnamed 10	363	1	31	1.13	Enchytraeidae	Annelida	Clitellata	Haplotaxida	Enchytraeidae		
Unnamed 10	363	1	8	0.29	Tubificidae	Annelida	Clitellata	Haplotaxida	Tubificidae		
Unnamed 10	363	1	32	1.16	Nematoda	Nematoda					
Unnamed 10	363	2	16	4.20	Ameletus sp	Arthropoda	Insecta	Ephemeroptera	Siphlonuridae	Ameletus	
Unnamed 10	363	2	2	0.52	Baetis sp	Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetis	
Unnamed 10	363	2	5	1.31	Cinygmula sp	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Cinygmula	
Unnamed 10	363	2	250	65.62	Epeorus (Iron) sp	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Epeorus	
Unnamed 10	363	2	1	0.26	Rhithrogena sp	Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Rhithrogena	
Unnamed 10	363	2	17	4.46	Capnia sp	Arthropoda	Insecta	Plecoptera	Capniidae	Capnia	
Unnamed 10	363	2	1	0.26	Podmosta sp	Arthropoda	Insecta	Plecoptera	Nemouridae	Podmosta	
Unnamed 10	363	2	3	0.79	Skwala parallela	Arthropoda	Insecta	Plecoptera	Perlodidae	Skwala	Skwala parallela
Unnamed 10	363	2	26	6.82	Sweltsa sp	Arthropoda	Insecta	Plecoptera	Chloroperlidae	Sweltsa	
Unnamed 10	363	2	7	1.84	Taenionema sp	Arthropoda	Insecta	Plecoptera	Taeniopterygidae	Taenionema	
Unnamed 10	363	2	20	5.25	Zapada sp	Arthropoda	Insecta	Plecoptera	Nemouridae	Zapada	
Unnamed 10	363	2	2	0.52	Trichoptera	Arthropoda	Insecta	Trichoptera			
Unnamed 10	363	2	1	0.26	Glossosoma sp	Arthropoda	Insecta	Trichoptera	Glossosomatidae	Glossosoma	
Unnamed 10	363	2	10	2.62	Chironomidae	Arthropoda	Insecta	Diptera	Chironomidae		
Unnamed 10	363	2	1	0.26	Brillia sp	Arthropoda	Insecta	Diptera	Chironomidae	Brillia	
Unnamed 10	363	2	1	0.26	Cardiocladius sp	Arthropoda	Insecta	Diptera	Chironomidae	Cardiocladius	
Unnamed 10	363	2	6	1.57	Cricotopus sp	Arthropoda	Insecta	Diptera	Chironomidae	Cricotopus	
Unnamed 10	363	2	5	1.31	Diamesa sp	Arthropoda	Insecta	Diptera	Chironomidae	Diamesa	
Unnamed 10	363	2	2	0.52	Eukiefferiella sp	Arthropoda	Insecta	Diptera	Chironomidae	Eukiefferiella	
Unnamed 10	363	2	2	0.52	Euryhapsis sp	Arthropoda	Insecta	Diptera	Chironomidae	Euryhapsis	
Unnamed 10	363	2	1	0.26	sp	Arthropoda	Insecta	Diptera	Chironomidae	Synorthocladius	
Unnamed 10	363	2	1	0.26	Hydracarina	Arthropoda	Arachnida	Hydracarina			
Unnamed 10	363	2	1	0.26	Unionicola sp	Arthropoda	Arachnida	Trombidiformes	Unionicolidae	Unionicola	

Appendix C. Fish Capture Data

Appendix C. Fish capture data.

Creek Name	Sampling Date	Northing	Easting	Sampling Method	Sampling Effort (seconds)	Species Captured	Number Captured	Mortalities
Wagon Creek	3-Sep-08	62 56.325	130 29.439	Electrofishing	303	NFC[1]	0	--
Itsi Creek	3-Sep-08	62 55.598	130 30.993	Electrofishing	258	NFC[1]	0	--
Boulder Creek	3-Sep-08	62 51.614	130 50.244	Electrofishing	945	CCG[2]	6	6
Unnamed Creek 10	4-Sep-08	62 14.381	131 43.805	Electrofishing	335	NFC[1]	0	--
Blue Creek	4-Sep-08	62 20.685	131 35.827	Electrofishing	498	CCG[2]	15	15
Tay Creek	4-Sep-08	62 19.297	131 38.590	Electrofishing	1096	CCG[2]	12	12
				Electrofishing		GR[3]	1	released
				Electrofishing		CH[4]	4	released
180 Mile Creek	4-Sep-08	62 18.106	131 41.188	Electrofishing	371	NFC[1]	0	--
Unnamed Creek 12 (Marjorie Cr)	5-Sep-08	62 02.770	132 03.339	Electrofishing	474	NFC[1]	0	--

[1]NFC - No fish captured

[2]CGC - *Cottus cognatus* , slimy sculpin

[3]GR - *Thymallus arcticus* , Arctic grayling,

[4]CH - *Oncorhynchus tshawytscha* , Chinook salmon

Appendix D. Water Quality Laboratory Results

Appendix D. Water Quality Laboratory Results

Routine Parameters

Creek Name	Sampling Date	pH	Specific Conductance	AlkalinityTot-pH4.5	Hardness Total extr.	Color True	DOC	Chloride (Cl)	Sulphate (SO4)	Solids, Total Dissolved	Solids, Total Suspended	Turbidity
		pH Units	µS/cm	mg CaCO3 / L	mg CaCO3 / L	Col. unit	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
Wagon Creek	3-Sep-08	7.51	196	21.1	131	<2.5	1.8	0.1	69	129	<5	2.17
Itsi Creek	3-Sep-08	7.48	54	17.4	26.1	25	7.7	<0.1	7	55	<5	0.67
Boulder Creek	3-Sep-08	7.81	158	37.6	123	25	7.2	<0.1	38	121	<5	1.55
Blue Creek	4-Sep-08	7.84	171	64.7	128	5	3.4	<0.1	22.6	115	<5	0.38
Tay Creek	4-Sep-08	7.94	125	50	57.4	5	2.8	<0.1	13.1	86	<5	0.55
180 Mile Creek	4-Sep-08	8.07	203	72.1	161	15	4.6	<0.1	32	141	<5	2.11
Unnamed 10	4-Sep-08	8.19	307	128	268	15	4	0.1	36	193	<5	0.71
Unnamed 12	5-Sep-08	8.12	320	91.3	243	90	21.9	0.5	70	255	<5	1.64
CCME Protection of Freshwater Life		6.5 - 9	--	--	--	--	--	--	--	--	--	--

Nutrients

Creek Name	Sampling Date	Ammonia as N	Nitrogen, Nitrite as N	Nitrogen, Nitrate as N	Nitrate + Nitrite as N	Total Phosphorus
		mg/L	mg/L	mg/L	mg/L	mg/L
Wagon Creek	3-Sep-08	<0.002	0.004	0.155	0.159	0.007
Itsi Creek	3-Sep-08	<0.002	<0.002	0.009	0.009	0.008
Boulder Creek	3-Sep-08	<0.002	0.002	0.007	0.009	0.01
Blue Creek	4-Sep-08	<0.002	0.004	0.005	0.009	<0.002
Tay Creek	4-Sep-08	<0.002	0.004	0.015	0.019	<0.002
180 Mile Creek	4-Sep-08	<0.002	0.003	0.008	0.011	0.008
Unnamed 10	4-Sep-08	<0.002	<0.002	0.018	0.018	0.004
Unnamed 12	5-Sep-08	<0.002	0.003	0.007	0.01	0.011
CCME Protection of Freshwater Life		0.019	0.06	13	--	--

Total Metals

Creek Name	Sampling Date	ICP Total Aluminum (Al)	ICP Total Antimony (Sb)	ICPMS Total Arsenic (As)	ICP Total Barium (Ba)	ICP Total Berylium (Be)	ICP Total Boron (B)	ICPMS Total Cadmium (Cd)	ICP Total Calcium (Ca)	ICP Total Chromium (Cr)	ICP Total Cobalt (Co)	ICPMS Total Copper (Cu)	ICP Total Iron (Fe)	ICPMS Total Lead (Pb)	ICP Total Magnesium (Mg)	ICP Total Manganese (Mn)
		mg/L	mg/L	µg/L	mg/L	mg/L	mg/L	µg/L	mg/L	mg/L	mg/L	µg/L	mg/L	µg/L	mg/L	mg/L
Wagon Creek	3-Sep-08	0.49	<0.06	1	0.07	<0.001	<0.01	10.5	21.9	<0.006	<0.006	5.71	0.1	0.03	8.6	0.267
Itsi Creek	3-Sep-08	0.11	<0.06	0.7	0.074	<0.001	<0.01	0.04	6.6	<0.006	<0.006	1.31	0.13	0.04	2.3	0.005
Boulder Creek	3-Sep-08	0.08	<0.06	0.4	0.05	<0.001	<0.01	0.07	18.9	<0.006	<0.006	1.36	0.26	0.04	7.4	0.022
Blue Creek	4-Sep-08	<0.06	<0.06	0.2	0.068	<0.001	<0.01	0.02	21.8	<0.006	<0.006	0.89	0.1	0.04	4.9	0.038
Tay Creek	4-Sep-08	<0.06	<0.06	0.2	0.038	<0.001	<0.01	0.02	18.6	<0.006	<0.006	0.65	0.11	0.04	2.9	0.006
180 Mile Creek	4-Sep-08	0.16	<0.06	0.3	0.071	<0.001	<0.01	0.07	28.8	<0.006	<0.006	1.2	0.27	0.12	6.1	0.023
Unnamed 10	4-Sep-08	<0.06	<0.06	0.3	0.086	<0.001	<0.01	0.05	54.7	<0.006	<0.006	0.91	0.71	0.03	7.1	0.008
Unnamed 12	5-Sep-08	0.1	<0.06	0.7	0.05	<0.001	<0.01	0.07	37.6	<0.006	<0.006	2.13	0.47	0.14	15.6	0.022
CCME Protection of Freshwater Life		0.1	--	5	--	--	--	0.017	--	0.0089	--	2-4	0.3	1-7	--	--

Creek Name	Sampling Date	ICP Total Molybdenum (Mo)	ICP Total Nickel (Ni)	ICP Total Phosphorus (P)	ICP Total Potassium (K)	ICPMS Total Selenium (Se)	ICP Total Silicon (Si)	ICP Total Silver (Ag)	ICP Total Sodium (Na)	ICP Total Strontium (Sr)	ICP Total Sulfur (S)	ICP Total Tin (Sn)	ICP Total Titanium (Ti)	ICP Total Vanadium (V)	ICPMS Total Zinc (Zn)	Mercury -total Mercury (Hg)
		mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L
Wagon Creek	3-Sep-08	<0.01	0.13	1.7	0.4	4.2	3.8	<0.01	0.8	0.095	26	<0.06	<0.002	<0.01	1330	<0.02
Itsi Creek	3-Sep-08	<0.01	<0.02	0.9	0.3	0.3	4.92	<0.01	1.2	0.035	2.92	<0.06	<0.002	<0.01	6.4	<0.02
Boulder Creek	3-Sep-08	<0.01	<0.02	1.6	0.3	0.8	4.88	<0.01	1.1	0.057	14.3	<0.06	0.002	<0.01	12.3	<0.02
Blue Creek	4-Sep-08	<0.01	<0.02	1.8	0.7	0.3	3.74	<0.01	2.7	0.112	8.62	<0.06	<0.002	<0.01	5.4	<0.02
Tay Creek	4-Sep-08	<0.01	<0.02	1.6	0.4	0.3	3.7	<0.01	1.9	0.085	5.07	<0.06	<0.002	<0.01	4.7	<0.02
180 Mile Creek	4-Sep-08	<0.01	<0.02	2.6	0.5	1.1	4.1	<0.01	1.8	0.126	11.9	<0.06	0.003	<0.01	8.4	<0.02
Unnamed 10	4-Sep-08	<0.01	<0.02	3.2	0.4	2.2	3.44	<0.01	1.1	0.152	13.7	<0.06	<0.002	<0.01	3.5	<0.02
Unnamed 12	5-Sep-08	<0.01	<0.02	2.7	1.1	0.3	3.74	<0.01	4.5	0.163	26.7	<0.06	0.002	<0.01	12.1	<0.02
CCME Protection of Freshwater Life		--	0.025	--	--	1	--	0.0001	--	--	--	--	--	--	30	0.026

Appendix D. Water Quality Laboratory Results

Dissolved Metals

Creek Name	Sampling Date	ICP Dissolved	ICP Dissolved	ICPMS Dissolved	ICP Dissolved	ICP Dissolved	ICP Dissolved	ICPMS Dissolved	ICP Dissolved	ICP Dissolved	ICP Dissolved	ICPMS Dissolved	ICP Dissolved	ICPMS Dissolved	ICP Dissolved	ICP Dissolved
		Aluminum (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Berylium (Be)	Boron (B)	Cadmium (Cd)	Calcium (Ca)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Magnesium (Mg)	Manganese (Mn)
		mg/L	mg/L	µg/L	mg/L	mg/L	mg/L	µg/L	mg/L	mg/L	mg/L	µg/L	mg/L	µg/L	mg/L	mg/L
Wagon Creek	3-Sep-08	0.12	<0.05	0.7	0.067	<0.001	<0.01	12	18.7	<0.005	0.007	3.76	0.023	0.03	8.5	0.263
Itsi Creek	3-Sep-08	0.07	<0.05	0.7	0.069	<0.001	<0.01	0.03	6.5	<0.005	<0.005	1.38	0.082	0.02	2.3	0.001
Boulder Creek	3-Sep-08	<0.05	<0.05	0.4	0.047	<0.001	<0.01	0.07	18.3	<0.005	<0.005	1.3	0.159	0.02	7.4	0.018
Blue Creek	4-Sep-08	<0.05	<0.05	0.3	0.068	<0.001	<0.01	<0.01	22.2	<0.005	<0.005	0.78	0.057	<0.01	4.9	0.036
Tay Creek	4-Sep-08	<0.05	<0.05	0.2	0.037	<0.001	<0.01	0.01	18.7	<0.005	<0.005	0.54	0.025	0.04	3	0.005
180 Mile Creek	4-Sep-08	<0.05	<0.05	0.4	0.067	<0.001	<0.01	0.05	28	<0.005	<0.005	1.02	0.111	0.03	6.1	0.016
Unnamed 10	4-Sep-08	<0.05	<0.05	0.5	0.084	<0.001	<0.01	0.04	48.6	<0.005	<0.005	0.76	0.032	0.02	7	0.004
Unnamed 12	5-Sep-08	<0.05	<0.05	0.8	0.05	<0.001	<0.01	0.06	35.5	<0.005	<0.005	1.35	0.337	0.04	16.2	0.017

Creek Name	Sampling Date	ICP Dissolved	ICP Dissolved	ICP Dissolved	ICP Dissolved	ICPMS Dissolved	ICP Dissolved	ICP Dissolved	ICP Dissolved	ICP Dissolved	ICP Dissolved	ICP Dissolved	ICP Dissolved	ICP Dissolved	ICPMS Dissolved	Mercury -dissolved
		Molybdenum (Mo)	Nickel (Ni)	Phosphorus (P)	Potassium (K)	Selenium (Se)	Silicon (Si)	Silver (Ag)	Sodium (Na)	Strontium (Sr)	Sulfur (S)	Tin (Sn)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)	Mercury (Hg)
		mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L
Wagon Creek	3-Sep-08	<0.01	0.13	<0.1	0.4	4.9	3.68	<0.01	0.7	0.095	22.1	<0.05	<0.002	<0.01	1220	<0.02
Itsi Creek	3-Sep-08	<0.01	<0.02	<0.1	0.2	0.4	4.84	<0.01	1.1	0.034	2.4	<0.05	<0.002	<0.01	6.8	<0.02
Boulder Creek	3-Sep-08	<0.01	<0.02	<0.1	0.2	1	4.84	<0.01	1	0.059	12.2	<0.05	<0.002	<0.01	12.1	<0.02
Blue Creek	4-Sep-08	<0.01	<0.02	<0.1	0.5	0.3	3.71	<0.01	2.5	0.114	7.23	<0.05	<0.002	<0.01	4.5	<0.02
Tay Creek	4-Sep-08	<0.01	<0.02	<0.1	0.3	0.3	3.66	<0.01	1.9	0.086	4.37	<0.05	<0.002	<0.01	3.6	<0.02
180 Mile Creek	4-Sep-08	<0.01	<0.02	<0.1	0.3	1.3	3.94	<0.01	1.7	0.129	10.2	<0.05	<0.002	<0.01	5.4	<0.02
Unnamed 10	4-Sep-08	<0.01	<0.02	<0.1	0.3	2.8	3.34	<0.01	1	0.153	11.4	<0.05	<0.002	<0.01	3	<0.02
Unnamed 12	5-Sep-08	<0.01	<0.02	<0.1	1	0.3	3.74	<0.01	4.4	0.173	23.7	<0.05	<0.002	<0.01	10.2	<0.02

Appendix E. Stream Sediment Laboratory Results

Appendix E. Stream Sediment Laboratory Results

Creek Name	Sampling Date	Carbon Total Organic	ICP Total Aluminum (Al)	ICP Total Antimony (Sb)	ICPMS Total Arsenic (As)	ICP Total Barium (Ba)	ICP Total Berylium (Be)	ICP Total Boron (B)	ICPMS Total Cadmium (Cd)	ICP Total Calcium (Ca)	ICP Total Chromium (Cr)
		% dry wt.	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)
Wagon Creek	3-Sep-08	1.12	13300	<5	48.4	3260	1.2	14	44.1	4490	18.4
Itsi Creek	3-Sep-08	0.8	12800	<5	31.6	1490	0.8	11	4.23	3170	15.4
Boulder Creek	3-Sep-08	0.87	7940	<5	26.4	1260	0.5	18	5.23	15500	19.8
Blue Creek	4-Sep-08	2.01	12600	<5	10.3	432	0.6	11	1.93	4850	13
Tay Creek	4-Sep-08	<0.5	10600	<5	12.4	508	0.7	11	0.92	4550	12.6
180 Mile Creek	4-Sep-08	1.35	12000	<5	17.5	912	0.5	13	1.95	4020	19.1
Unnamed 10	4-Sep-08	1.62	11000	<5	14.8	630	0.6	11	2.72	7760	17.1
Unnamed 12	5-Sep-08	<0.5	7370	<5	40.6	388	<0.1	13	2.47	17300	11.8
CCME Protection for Aquatic Life		--	--	--	**5.9**	--	--	--	**0.6**	--	**37.3**

Creek Name	Sampling Date	ICP Total Cobalt (Co)	ICPMS Total Copper (Cu)	ICP Total Iron (Fe)	ICPMS Total Lead (Pb)	ICP Total Magnesium (Mg)	ICP Total Manganese (Mn)	ICP Total Molybdenum (Mo)	ICP Total Nickel (Ni)	ICP Total Phosphorus (P)	ICP Total Potassium (K)
		µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)
Wagon Creek	3-Sep-08	76	110	24700	17	2760	3650	8	369	1550	1450
Itsi Creek	3-Sep-08	13.6	32.9	22500	10.8	2790	1550	4	42	822	1250
Boulder Creek	3-Sep-08	13.8	106	34200	14.8	7740	1590	12	105	1850	1690
Blue Creek	4-Sep-08	11.7	27.9	25900	11.2	4250	488	1	34	815	1260
Tay Creek	4-Sep-08	8.4	25.1	25200	11	4440	453	2	26	845	1180
180 Mile Creek	4-Sep-08	13.7	40.5	34300	20.4	5700	1100	3	50	1090	1320
Unnamed 10	4-Sep-08	9.2	39.4	24100	19.1	5710	616	3	42	1240	1330
Unnamed 12	5-Sep-08	12.2	49.6	30200	21.8	9330	654	5	58	1400	1010
CCME Protection for Aquatic Life		--	**35.7**	--	**35**	--	--	--	--	--	--

Creek Name	Sampling Date	ICPMS Total Selenium (Se)	ICP Total Silicon (Si)	ICP Total Silver (Ag)	ICP Total Sodium (Na)	ICP Total Strontium (Sr)	ICP Total Sulfur (S)	ICP Total Tin (Sn)	ICP Total Titanium (Ti)	ICP Total Vanadium (V)	ICPMS Total Zinc (Zn)	Mercury -total Mercury (Hg)
		µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)
Wagon Creek	3-Sep-08	4.2	831	<1	217	57.1	1030	5	154	82	1.2	0.208
Itsi Creek	3-Sep-08	2.3	995	<1	142	31.6	590	<5	148	51	341	0.103
Boulder Creek	3-Sep-08	6.9	879	<1	145	123	2600	<5	75.4	97	541	0.936
Blue Creek	4-Sep-08	2.2	1040	<1	190	37.1	1220	<5	124	44	171	0.139
Tay Creek	4-Sep-08	1.1	908	<1	164	38.1	535	<5	115	40	144	0.117
180 Mile Creek	4-Sep-08	1.6	1000	<1	99	51.7	508	<5	22.8	50	217	0.104
Unnamed 10	4-Sep-08	2.3	1080	<1	195	52	468	<5	82.7	42	227	0.118
Unnamed 12	5-Sep-08	2.5	871	<1	102	67.8	1490	<5	24.5	42	276	0.097
CCME Protection for Aquatic Life		--	--	--	--	--	--	--	--	--	**123**	**0.17**

Appendix F. Metals Concentrations in Aquatic Vegetation

Appendix F. Metals Concentrations in Aquatic Vegetation.

Creek Name	Vegetation Type	Moisture Content	Aluminum (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Berylium (Be)	Boron (B)	Cadmium (Cd)	Calcium (Ca)	Chromium (Cr)
		% (W/W)	ug/g(dry)	ug/g(dry)	µg/g (dry)	ug/g(dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)
Blue - Moss	Moss species	11.2	8370	5	15.1	548	1.6	21	3.77	9210	23
Boulder - Grass	Grass	19.6	982	5	4.2	142	0.2	9	9.48	7490	28.1
Boulder - Moss	Moss species	13.3	4580	5	10	702	0.8	29	8.86	11400	20.7
Itsi - Moss	Moss species	14.1	7040	5	13.7	962	0.7	19	5.85	9220	91.9
Tay-Filamentous Algae	Filamentous Algae	92.2	2670	5	5.9	182	0.3	17	3.85	6060	4.9
Unnamed 10 - Moss	Moss species	15.9	2210	5	4.9	171	0.5	36	3.91	14000	15.4
Wagon-Equistetum	Equistem	16.8	5630	5	15.3	235	1	27	36.2	16800	5
Wagon - Moss	Moss species	13.3	23200	5	85.75	2750	4.4	27	498.5	8270	19.6

Creek Name	Vegetation Type	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Magnesium (Mg)	Manganese (Mn)	Molybdenum (Mo)	Nickel (Ni)	Phosphorus (P)	Potassium (K)
		µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)
Blue - Moss	Moss species	14.5	31.4	19800	6.28	3500	6300	3	125	857	4590
Boulder - Grass	Grass	2.6	44.9	3490	0.63	3450	512	4	92	2820	23600
Boulder - Moss	Moss species	20.8	41.1	15800	2.82	4250	5400	4	185	2090	6050
Itsi - Moss	Moss species	17.9	27.5	11600	3.26	2930	2900	3	2730	1690	5610
Tay-Filamentous Algae	Filamentous Algae	12.9	12.4	6340	1.92	1350	3780	1	31	752	1510
Unnamed 10 - Moss	Moss species	5.1	17.5	9000	3.48	2510	1060	2	280	2330	11900
Wagon-Equistetum	Equistem	29	84.6	3380	2.44	7630	1290	3	399	2480	36000
Wagon - Moss	Moss species	1490	642	16600	10.7	2250	83900	33	2890	1150	2480

Creek Name	Vegetation Type	Selenium (Se)	Silicon (Si)	Silver (Ag)	Sodium (Na)	Strontium (Sr)	Sulfur (S)	Tin (Sn)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)	Mercury (Hg)
		µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)
Blue - Moss	Moss species	2.5	1340	1	276	54	1030	39	284	46	161	0.095
Boulder - Grass	Grass	2.6	997	1	536	26.9	5180	32	16.8	19	229	0.058
Boulder - Moss	Moss species	4.2	935	1	172	52.8	1720	22	46.1	44	653	0.109
Itsi - Moss	Moss species	4.6	920	1	182	54.3	1590	16	53.2	26	183	0.091
Tay-Filamentous Algae	Filamentous Algae	1.2	504	1	1440	25	2520	21	57.8	12	155	0.049
Unnamed 10 - Moss	Moss species	4.1	450	1	239	41	1950	28	32.2	12	116	0.102
Wagon-Equistetum	Equistem	4.1	2060	1	408	78.1	20200	23	26.9	16	4737	0.064
Wagon - Moss	Moss species	10.4	1380	1	186	58.9	1740	26	102	92	30885	0.24

Appendix G. Metals Concentrations in Benthic Invertebrate

Appendix G. Metals Concentrations in Benthic Invertebrates.

Creek Name	Moisture Content	Aluminum (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Berylium (Be)	Boron (B)	Cadmium (Cd)	Calcium (Ca)	Chromium (Cr)
	% (W/W)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)
Wagon	89	896	<4	5	75.2	0.16	47.3	19.3	8700	1.7
Itsi	87.3	1300	<4	6.6	170	< 0.08	6.4	2.34	3690	1.8
Boulder	87.6	380	5	5.8	69.3	< 0.08	25.8	3.08	6240	2.4
Blue	84.5	356	<4	1.9	44.6	< 0.08	7.5	1.7	2640	0.7
Tay	88.4	388	4	0.8	39.7	< 0.08	33.1	4.12	9270	1
180 Mile	86.8	756	<4	5.9	94.7	< 0.08	13	4.99	6590	1.7
Unnamed 10	84.3	611	<4	1.1	40.5	< 0.08	6.8	5.23	6200	1.7

Creek Name	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Magnesium (Mg)	Manganese (Mn)	Molybdenum (Mo)	Nickel (Ni)	Phosphorus (P)	Potassium (K)
	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)
Wagon	11.3	103	1160	< 0.01	1210	780	6.4	129	4080	1600
Itsi	3.1	93.6	2440	3.55	793	303	5.3	5	4980	756
Boulder	3.5	127	1630	1.31	771	479	6.8	31	5560	910
Blue	1.7	54.1	1560	1.54	515	587	1.7	6	4530	481
Tay	2.8	80.9	1120	1.15	1170	415	3.6	11	6460	1230
180 Mile	4.9	93.5	4220	4.38	1570	581	3.9	39	6890	564
Unnamed 10	1.4	47.9	1690	4	1120	211	2.9	7	6910	549

Creek Name	Selenium (Se)	Silicon (Si)	Silver (Ag)	Sodium (Na)	Strontium (Sr)	Sulfur (S)	Tin (Sn)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)	Mercury (Hg)
	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)	µg/g(dry)
Wagon	2.6	807	< 0.8	2680	54.5	3290	33	36.7	7.3	866	0.105
Itsi	3.6	249	< 0.8	1060	25	4820	14	29.4	5.9	116	0.161
Boulder	4	674	< 0.8	1740	35.4	4940	35	10.5	10.8	368	0.109
Blue	2.7	139	< 0.8	1030	16.4	3210	8	6.6	2.1	131	0.098
Tay	3	502	< 0.8	2210	52.5	4410	23	6.9	3.3	341	0.101
180 Mile	3.1	272	< 0.8	1800	35.9	4690	15	8.8	7.7	426	0.082
Unnamed 10	5.4	213	< 0.8	926	22.6	4680	14	10.9	3.4	219	0.073

Appendix H. Metals Concentrations in Fish

Appendix H. Metals Concentrations in Slimy Sculpin.

Creek Name	Moisture Content	Aluminum (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Berylium (Be)	Boron (B)	Cadmium (Cd)	Calcium (Ca)	Chromium (Cr)
	% (W/W)	ug/g(dry)	ug/g(dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)
BLUE	83.7	40	4	0.5	14.9	<0.08	1.7	0.36	46200	<0.4
BOULDER	76.5	51	4	0.6	12.3	<0.08	1.8	1.06	53100	0.5
TAY	82.2	89	4	0.6	20	<0.08	1.4	0.56	53900	0.9

Creek Name	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Magnesium (Mg)	Manganese (Mn)	Molybdenum (Mo)	Nickel (Ni)	Phosphorus (P)	Potassium (K)
	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)
BLUE	1.1	4.16	131	<0.01	1510	85.2	2	3	36000	12500
BOULDER	2.1	5.35	117	<0.01	1890	113	1.8	8	39300	11100
TAY	1.7	5.92	187	<0.01	1720	70.1	1.9	4	41500	12300

Creek Name	Selenium (Se)	Silicon (Si)	Silver (Ag)	Sodium (Na)	Strontium (Sr)	Sulfur (S)	Tin (Sn)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)	Mercury (Hg)
	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)
BLUE	7.8	62	0.8	4770	48.2	10200	35	1	<0.8	109	0.322
BOULDER	9.3	49	0.8	4140	33.6	9020	38	0.8	0.8	163	0.11
TAY	9.1	72	0.8	4520	57.8	10600	36	3.1	<0.8	140	0.221