

**SUMMARY OF ENVIRONMENTAL MONITORING  
ACTIVITIES AT THE ABANDONED  
CLINTON CREEK ASBESTOS MINE, 2010**

FOR



**ASSESSMENT AND ABANDONED MINES**

**ENERGY MINES AND RESOURCES**

BY



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## EXECUTIVE SUMMARY

Water and sediment chemistry were assessed over the 2010 season to continue to fill in data gaps. The sampling period encompassed low and high flow conditions. At some point in mid to late August high precipitation events created altered conditions to the Clinton Creek watershed. Coupled with the high rainfall, a log jam which formed at the outlet of Hudgeon Lake caused damage to the gabions, primarily the fourth one. The Clinton Creek access road was washed out at the upper end and landslides covered two sections of the road further down. The landslides were cleared by the September sampling period.

The water quality data continued to show that several parameters exceeded the recommended CCME guidelines for the protection of aquatic freshwater life in the Clinton Creek study area including some of the reference sites. Elevated concentrations of aluminum, chromium and iron were documented throughout the study area and study period.

Asbestos fibres were documented in several water samples at many of the sites and the majority of the fibres were short (<5 um) and all were narrow (diameter < 5 microns). The highest density of asbestos fibres were documented in the July set of samples.

Stream sediment samples from most of the sites were collected in July for the analysis of metals and asbestos fibres. Very high concentrations of chromium were confirmed in the stream sediments from Wolverine Creek downstream of the tailings. The data indicates that the streams, including most of the reference creeks, drain mineralized zones. Asbestos fibres were documented in the stream sediments from Wolverine Creek downstream of the tailings, in Clinton Creek (sites E2, E4 and E7), Eagle Creek and the Forty Mile River upstream of Clinton Creek.

Temperature dataloggers were installed in several groundwater upwelling areas in Clinton Creek near the Porcupine and Wolverine confluences. Water samples were also collected during installation.

Due to historic rainfall and flooding events at the Clinton Creek study area, water and sediment sampling should be conducted in 2011 to monitor any liberation of metals and asbestos fibres to the receiving waters, especially in the Wolverine Creek drainage.

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## **1.0 BACKGROUND**

The former Clinton Creek Asbestos Mine is located approximately 100 km northwest of Dawson City, Yukon, and nine km upstream of the confluence of Clinton Creek and the Forty Mile River. The mine operated from 1967 to 1978. The site encompasses three open pits (Porcupine, Snowshoe and Creek), two waste rock piles (Clinton Creek Dump and Porcupine Creek Dump), and a tailings pile.

In 1974, 60 million tonnes of the Clinton Creek waste rock pile slumped across the Clinton Creek valley creating the formation of Hudgeon Lake. During the 1980s various weirs were constructed to reinforce the Clinton Creek channel in attempts to stabilize and control the outflow from Hudgeon Lake, with limited success. The structures were washed out during a high flow event in 1997. The Federal Government (DIAND) assumed responsibility for the site in 1999; following Devolution in 2003, the Government of Yukon (YG) assumed responsibility for site management. In a series of stages from 2002 to 2004, gabion drop structures were constructed within the channel downstream of the Hudgeon Lake outlet. YG continues to monitor these structures and conducts repairs as necessary. During the summer of 2010, significantly flooding occurred in Clinton Creek due to precipitation events coupled with a log jam at the outlet of Hudgeon Lake. This resulted in some damage to the gabion structures, road washouts and landslides in the immediate vicinity.

### **1.1 Scope of Work**

In the early summer of 2009, Minnow Environmental Inc (Minnow) was contracted by YG to review all existing environmental data pertaining to the Clinton Creek site and make recommendations for any data gaps. This resulted in a monitoring program conducted in late summer 2009 by Laberge Environmental Services (Laberge Environmental Services, 2010).

Laberge Environmental Services (Laberge) was again contracted by YG to conduct various environmental monitoring surveys on Clinton Creek and several of its tributaries

during the 2010 season. In addition to the regular water quality sampling, temperature data loggers were installed in Clinton Creek in the Porcupine Creek beaver pond area to monitor potential fish habitat. Benthic invertebrate sampling was not repeated in 2010 however stream sediment samples were collected from the established water quality sites to compliment the limited sediment sampling conducted in 2009. Methods and the results of the above are summarized in this report.

## 2.0 STUDY AREA

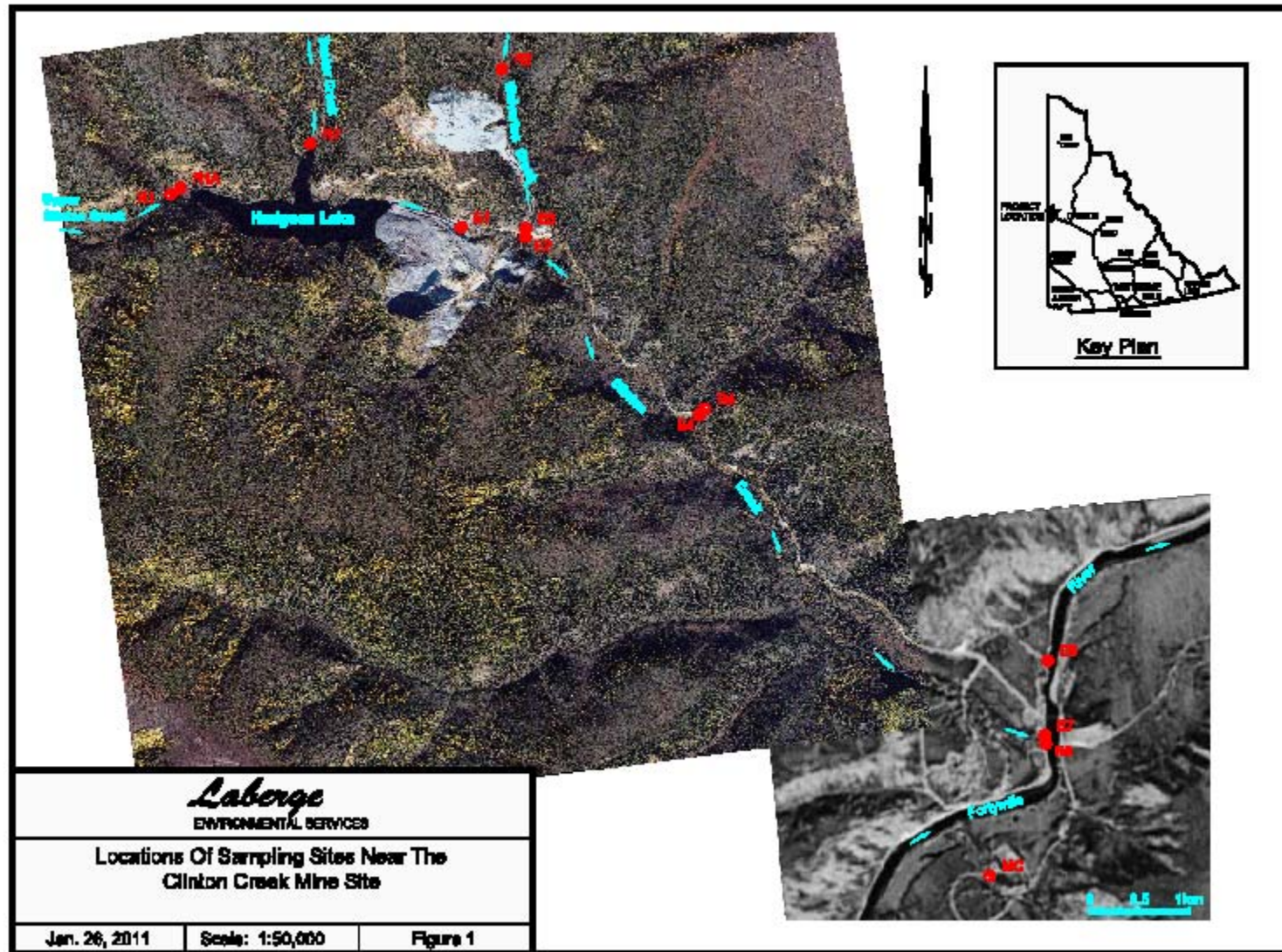
The former Clinton Creek Asbestos Mine is located approximately 100 km northwest of Dawson City, Yukon, and nine km upstream of the confluence of Clinton Creek and the Forty Mile River (Figure 1).

The study area lies in the north-west section of the Klondike Plateau Ecoregion. This ecoregion is part of Beringia and due to the lack of glaciation, V-shaped valleys and extensive upland boulder fields are characteristic. Permafrost is discontinuous but widespread (Yukon Ecoregions Working Group, 2004). In the Clinton Creek valley, the south facing slopes are generally well drained and are vegetated with aspen, birch and white spruce. The north facing slopes tend to be underlain with permafrost and contain stands of black spruce.

The study area encompasses tributaries to Hudgeon Lake, Clinton Creek to the Forty Mile River and two sites upstream and downstream on the Forty Mile River. Site descriptions and locations are presented in Table 1 and Figure 1.

Site Type	Site #	Site Description	NAD 83, Zone 07 W	
			Easting	Northing
Reference	R1	Clinton Cr u/s Hudgeon Lake	510600	7147506
	R1A	Creek to the north of Clinton Cr u/s Hudgeon Lake	510695	7147571
	R2	Easter Cr u/s Hudgeon Lake	512006	7148015
	R3	Wolverine Cr u/s tailings	513942	7148771
	R4	Eagle Creek u/s culverts at road crossing	515990	7145340
	R6	Forty Mile River u/s Clinton Creek	519436	7141962
	MC	Mickey Creek	518869	7140633
Exposed	E1	Clinton Cr d/s gabions, u/s Porcupine Cr	513531	7147174
	E2	Clinton Cr d/s Porcupine Cr, u/s Wolverine Cr	514181	7147079
	E3	Wolverine Cr u/s culverts at road crossing	514183	7147163
	E4	Clinton Cr d/s Wolverine Cr, u/s Eagle Cr	515933	7145279
	E7	Clinton Cr near mouth	519421	7142049
	E8	Forty Mile River approx 1 km d/s Clinton Creek	519455	7142803

Tidbit V2 temperature data loggers were also installed in groundwater seeps and upwelling areas in Clinton Creek in the Porcupine beaver pond area. The locations of these are described in Table 2 and displayed on Figure 2.



Seep #	NAD 83	
	Easting	Northing
CCS1	514183	7147086
CCS2	514098	7147085
CCS3	514044	7147053
CCS4	513931	7147027
CSS5	513886	7147033
CSS6	513901	7146975
CSS7	514025	7147044
CCS8	513931	7147026



Figure 2 Locations of the Tid bit temperature data loggers.

### **3.0 METHODS**

Four separate field trips were made to the site in an attempt to capture seasonal variations. Due to limited access the field trips in April and May were conducted via helicopter. The July and September trips were completed using four wheel drive vehicles.

#### **3.1 Water Quality Sampling**

Exova, formerly Bodycote Analytical, supplied Laberge with the necessary sample kits prior to each field trip. Each sample bottle was rinsed three times with the sample waters and then filled and preserved as specified by the laboratory's protocols. Samples were kept cool then shipped as soon as possible to Exova in Surrey, BC. For the analyses Exova used methods as described in Standard Methods for the Examination of Water and Wastewater and the US Environment Protection Agency Methods.

Samples to be analyzed for asbestos were collected in one litre plastic bottles, kept cool and shipped to the Occupational and Environmental Health Laboratory at McMaster University in Hamilton, Ontario. The water samples were analyzed for asbestos by analytical transmission electron microscopy (ATEM). Specifically, the samples were agitated and then filtered through a 0.1 um pore size 47 mm diameter mixed cellulose ester filter. Aliquots ranging from 1 mL to 100 mL were filtered for each sample. The filters were dried at room temperature and then divided into eight equal wedges. One wedge per sample was affixed to a clean glass microscope slide with transparent tape and the filter matrix was collapsed with acetone vapour. The samples were then coated with a 20 to 30 nanometre thick layer of carbon using an Edwards's vacuum evaporator. The filter was dissolved with acetone in a condensation washer depositing the sample onto a 200 mesh nickel finder's grid. Two grids were prepared for each sample.

The grid was placed and inserted in the ATEM and examined at low magnification (300 – 1000X) for acceptability before the analysis was performed using a JEOL TEM, JEM-

1200X equipped with an EDS X-Ray 2004 Microanalysis System used to acquire and analyze x-ray spectra on every fibre providing an elemental analysis.

Several grid openings on each grid were randomly selected and photographed at 10,000 x magnification using an AMT (Advanced Microscope Technology) TEM Imaging System. The fibres were quantified and measured with respect to their length and diameter using a MetaMorph (Image Analysis) computer software. With this method, possible fibre identifications were: chrysotile, amosite, crocidolite, tremolite and other.

In situ measurements of pH, conductivity, water temperature and dissolved oxygen were made using hand held instruments that were calibrated daily.

Discharge measurements were also conducted where possible on each visit. Measurements were made using the salt dilution technique during April, estimated in May, and with a Price velocity meter during July and September.

### **3.2 Groundwater Seeps**

Eight Tidbit V2 temperature data loggers were installed in groundwater seeps and upwelling areas in Clinton Creek within the Porcupine beaver pond area on April 21<sup>st</sup>, 2010 and retrieved on September 21<sup>st</sup>, 2010. In-situ measurements and water samples were collected from each seep during installation. Samples for the analysis of asbestos were collected from CCS1 and CCS4 only.

### **3.3 Stream Sediment Geochemistry**

Duplicate composite stream sediment samples were collected with a steel trowel from the sites during the mid summer field trip in July 2010. Fine grained materials from recently deposited areas were chosen and placed into ziplock bags and kept cool. One set of samples was sent to Exova for metal analysis and the other set was sent to McMaster for asbestos fibre analysis.

At the Exova lab metals were determined using methods as described in the BC Ministry of Environment and McKeague's "Manual on Soil Sampling and Methods of Analysis".

At McMaster, asbestos content was ascertained using Dispersion Staining with Polarized Light Microscopy (PLM), described in U.S. Environmental Protection Agency Test Method EPA/600/R-93/116 "Method for the Determination of Asbestos in Bulk Building Materials", June 1993 as per Ontario Regulation 278/05, November 1, 2005.

## 4.0 RESULTS

The sites established during the 2009 field season were sampled up to four times in 2010. Table 3 outlines when each site was sampled and the type of samples collected.

Site Type	Site #	Site Description	Sampling Event, 2010			
			April 20-21	May 6	July 27-29	Sept 20-22
Reference	R1	Clinton Cr u/s Hudgeon Lake	frozen	WQ	N.S.	N.S.
	R1A	Creek to the north of Clinton Cr u/s Hudgeon Lake	WQ	---	---	---
	R2	Easter Cr u/s Hudgeon Lake	WQ	WQ	N.S.	N.S.
	R3	Wolverine Cr u/s tailings	WQ	WQ	WQ, SS	WQ
	R4	Eagle Creek u/s culverts at road crossing	WQ	WQ	WQ, SS	WQ
	R6	Forty Mile River u/s Clinton Creek	WQ	WQ	N.S.	WQ
	MC	Mickey Creek	---	---	WQ, SS	---
Exposed	E1	Clinton Cr d/s gabions, u/s Porcupine Cr	dry	WQ	WQ	WQ
	E2	Clinton Cr d/s Porcupine Cr, u/s Wolverine Cr	WQ	WQ	WQ, SS	WQ
	E3	Wolverine Cr u/s culverts at road crossing	WQ	WQ	WQ, SS	WQ
	E4	Clinton Cr d/s Wolverine Cr, u/s Eagle Cr	WQ	WQ	WQ, SS	WQ
	E7	Clinton Cr near mouth	WQ	WQ	WQ, SS	WQ
	E8	Forty Mile River d/s Clinton Creek	WQ	WQ	WQ, SS	WQ

WQ = water quality SS = stream sediments N.S. = not sampled due to flooding

During the April sampling event, R1 was frozen solid, so samples were collected instead from R1A, a creek to the north of Clinton Creek which flows into Hudgeon Lake in the same area as Clinton Creek. Due to high water events, the upper sites could not be accessed and R1 and R2 were not sampled after May.

During the July sampling period only, samples were collected from Mickey Creek, which had been suggested as a reference site in 2009, to provide additional background data. Also during the July field trip site E8 was moved approximately one kilometer downstream of the mouth of Clinton Creek to ensure adequate mixing.

Due to washouts in August, site E1 was moved upstream for the September sampling. Relevant pictures of some of the sites have been included in Appendix A.

## 4.1 Water Quality

### 4.1.1 Water Chemistry

Water samples were collected from most of the sites on each of the four sampling periods; April 20<sup>th</sup> to 21<sup>st</sup>, May 6<sup>th</sup>, July 27<sup>th</sup> to 29<sup>th</sup> and September 20<sup>th</sup> to 22<sup>nd</sup>, 2010. Table 4 summarizes the data collected from the sites for all occasions. Only metals where the CCME guidelines for the protection of freshwater aquatic life (CCME, 1999) have been exceeded are included in the table. The complete field results and the laboratory analytical reports can be viewed in Appendix B.

The only field data summarized in Table 4 are water temperature and discharge. The water temperature at the sample sites reflected the diurnal and seasonal timing of the sampling.

Discharge varied significantly over the study period. Flows were low in April and late September and considerably higher in May and July. Discharge measurements conducted in April used the salt dilution technique. Due to time restraints as the field trip was helicopter supported, discharge measurements were concentrated at the exposed sites. Flows in May were visually estimated as the field team was lead to believe that freshet would be underway thus the creek waters would be too high to wade, and consequently no discharge instruments were brought along. It appeared that by May 6<sup>th</sup>, 2010, Clinton Creek was actually on the falling limb of the freshet. Rainfall events throughout July created high flows by the late July field trip. Although historic precipitation levels were recorded during the month of August, by late September flows were relatively low. Flows could not be measured on any occasion on the Forty Mile River due to its substantial size.

All sampled waters were slightly alkaline and the pH ranged from 7.25 to 8.2. Conductivity varied at each site over the sampling period with high values reported during periods of low flow (April and September) when the majority of the stream is comprised of base flow. Due to dilution of rain and melt water, conductivity values were lower in May and July. Total alkalinity levels followed the same trend as conductivity.

Summary of Environmental Monitoring Activities at the Abandoned Clinton Creek Asbestos Mine, 2010

Site	Date	Water Temp °C	Discharge (m <sup>3</sup> /s)	pH (lab)	Conductivity (us/cm (lab))	Total Alkalinity as CaCO <sub>3</sub>	Sulfate (mg/L)	T. Organic Carbon (mg/L)	TSS (mg/l)	Aluminum Total (mg/L)	Cadmium Total (mg/L)	Chromium Total (mg/L)	Copper Total (mg/L)	Iron Total (mg/L)	Selenium Total (mg/L)	Zinc Total (mg/L)	Total Hardness as CaCO <sub>3</sub>	* Cd guideline calculation	
E1	5/6/2010	4.7	1.8	7.3	169	39	39.5	35.7	<2	0.194	0.00009	0.0075	0.004	0.446	0.001	0.014	96.6	0.00003	
	7/27/2010	10.1	3.066	7.65	279	72	68.1	23.4	22	0.755	0.00011	0.0034	0.006	1.75	0.001	0.008	155	0.00005	
	9/21/2010	7.4	0.3787	7.87	454	113	114	16.6	<2	0.06	0.00005	0.0011	0.004	0.236	0.0014	0.01	251	0.00007	
E2	4/21/2010	2.7	0.17	7.74	1150	257	439	8.2	3	0.014	0.00006	0.0013	<0.001	1.32	<0.0006	0.002	747	0.00019	
	5/6/2010	5.0	2	7.32	174	42	39.4	36	4	0.191	0.00009	0.0076	0.004	0.464	<0.0006	0.02	98.7	0.00003	
	7/28/2010	9.4	1.2	7.68	309	77	78.5	22.9	28	0.672	0.00011	0.0032	0.005	1.61	0.0008	0.007	175	0.00005	
	9/21/2010	7.9	0.2561	7.88	741	164	220	14	<2	0.039	0.00005	0.0014	0.002	0.476	0.0012	0.006	412	0.00011	
E3	4/21/2010	0.1	0.126	7.94	666	130	220	29.3	12	0.317	0.00005	0.0102	0.002	0.495	<0.0006	0.016	405	0.00011	
	5/6/2010	3.0	0.4	7.67	326	73	92.3	31.3	8	0.191	0.00003	0.01	0.003	0.499	<0.0006	0.016	189	0.00006	
	7/27/2010	6.9	0.267	7.92	376	98	95.3	20.4	28	0.676	0.00006	0.0203	0.004	1.45	<0.0006	0.004	226	0.00007	
E4	9/21/2010	4.2	0.0687	8.1	590	143	160	11.6	10	0.239	0.00003	0.0015	0.002	0.585	<0.0006	0.008	327	0.00009	
	4/20/2010	0.2	0.061	7.74	1090	218	418	13	6	0.032	0.00004	0.0017	0.001	1.62	<0.0006	0.005	680	0.00017	
	5/6/2010	5.8	3	7.45	418	75	128	32	4	0.167	0.00007	0.008	0.004	0.536	0.001	0.011	239	0.00007	
	7/28/2010	11.1	2.84	7.68	416	95	113	20.6	19	0.402	0.00006	0.004	0.004	1.04	0.0008	0.005	237	0.00007	
E7	9/21/2010	4.0	0.6496	7.73	768	175	216	13.3	4	0.074	0.00005	0.0015	0.002	0.466	0.0008	0.005	426	0.00012	
	4/20/2010	0.1	0.967	7.86	999	207	367	13.2	8	0.093	0.00009	0.0012	0.002	0.741	<0.0006	0.005	631	0.00016	
	5/6/2010	4.1	4	7.54	452	88	134	31.5	13	0.198	0.00008	0.0081	0.004	0.675	<0.0006	0.013	261	0.00008	
	7/28/2010	10.1	3.634	7.73	395	93	104	21.4	36	0.737	0.00008	0.005	0.005	1.41	0.0006	0.006	231	0.00007	
E8	9/21/2010	2.8	0.7356	7.87	732	178	202	13.6	10	0.164	0.00006	0.0015	0.003	0.604	<0.0006	0.01	418	0.00011	
	4/20/2010	0.0	---	7.77	859	188	290	10.6	5	0.052	0.00006	0.0011	0.002	0.442	<0.0006	0.005	518	0.00014	
	5/6/2010	4.7	---	7.39	239	52	62.2	31.1	10	0.284	0.00005	0.0066	0.004	0.748	<0.0006	0.005	129	0.00004	
	7/29/2010	10.8	---	7.49	117	40	15.9	19.8	94	3.34	0.00004	0.005	0.007	3.67	<0.0006	0.011	69	0.00002	
R1	9/21/2010	3.3	---	7.61	172	56	26.3	16	10	0.287	0.00002	0.0012	0.003	0.735	<0.0006	0.011	86.1	0.00003	
R-1A	5/6/2010	0.0	0.6	7.38	249	48	72.5	38	<2	0.176	0.00011	0.0067	0.005	0.454	<0.0006	0.008	129	0.00004	
R2	4/20/2010	0.1	---	8.2	540	220	95.6	10.8	<2	0.031	0.00005	0.0006	0.001	0.028	<0.0006	0.004	339	0.00009	
	5/6/2010	0.0	0.2	7.71	336	91	82.2	25	3	0.106	0.00003	0.0079	0.003	0.368	<0.0006	0.006	177	0.00005	
R3	4/20/2010	0.1	---	8.03	590	128	179	21.8	4	0.09	0.00004	0.0022	0.001	0.132	<0.0006	0.006	337	0.00009	
	5/6/2010	0.0	0.3	7.73	466	93	138	30.1	12	0.215	0.00003	0.0081	0.003	0.605	<0.0006	0.005	273	0.00008	
	7/28/2010	5.7	---	7.66	348	81	92.4	21.9	32	1.13	0.00006	0.0036	0.005	1.84	<0.0006	0.015	199	0.00006	
	9/21/2010	0.5	0.0677	7.89	635	133	194	13.6	565	6.18	0.00022	0.0097	0.012	9.28	<0.0006	0.039	375	0.00010	
R4	4/20/2010	0.1	---	7.53	235	56	59.2	30.6	<2	0.085	0.00007	0.001	0.002	0.135	<0.0006	0.008	129	0.00004	
	5/6/2010	0.1	0.6	7.37	208	47	52.7	39.3	89	0.997	0.00019	0.0093	0.006	2.24	<0.0006	0.014	124	0.00004	
	7/28/2010	3.6	0.212	7.81	280	86	57.8	20	18	0.666	0.00007	0.002	0.004	0.849	0.0011	0.006	158	0.00005	
	9/21/2010	0.4	0.0488	7.96	509	156	107	12.1	5	0.101	0.00011	0.0011	0.002	0.283	0.0019	0.016	275	0.00008	
R6	4/20/2010	0.0	---	7.64	510	138	121	6.1	<2	0.04	0.00003	0.0005	0.002	0.06	<0.0006	0.005	275	0.00008	
	5/6/2010	5.0	---	7.25	109	32	15.8	29.5	12	0.321	0.00004	0.0067	0.004	0.84	<0.0006	0.025	57	0.00002	
	9/21/2010	2.3	---	7.62	167	55	25	15.7	6	0.279	0.00002	0.001	0.003	0.653	<0.0006	0.012	82.2	0.00003	
MC	7/29/2010	6.1	---	7.8	254	75	51.9	7.1	18	0.402	0.00004	0.0009	0.002	0.515	<0.0006	0.004	136	0.00004	
Detection Limit:																			
CCME Guideline for the protection of freshwater aquatic life:										0.1		0.001	0.0004	0.001 to 0.004	0.3	0.001	0.030		
* The cadmium guideline for each sample was calculated using the formula 10{0.86[log(hardness)]-3.2}.																			
Note: Values where the CCME guideline for the protection of freshwater aquatic life have been exceeded are highlighted.																			

Generally waters were clear throughout the study period with greater turbidity experienced during July. The highest total suspended solids concentration occurred at R3 on September 21<sup>st</sup> and Wolverine Creek was visually very turbid (Photo #9). This site was relocated for the September sampling due to changes in the area resulting from the heavy rains in August.

Sulphate enters the aquatic environment through leaching of sedimentary rocks including shales, with natural concentrations ranging from 10 to 80 mg/L (CCREM, 1987). Sulphate concentrations in the Clinton Creek study area ranged from 15.8 mg/L at R6 (May) to 439 mg/L at E2 (April). The highest concentrations were documented during the low flow periods, notably in April, indicating that sulphate is influenced by groundwater. The associated rock in the study area is shale and a contributor of sulphate. There are no recommended national (CCME) guidelines for sulphate for the protection of aquatic life; however British Columbia has set 100 mg/L as a guideline for BC waters. This guideline was exceeded at most sites over the study period and in all samples collected from E4 and E7.

The major sources of organic carbon in water are from organic matter in soils, aquatic vegetation and aquatic organisms. Total organic carbon in natural surface waters may range from non detectable to 30 mg/L (CCREM 1997). Concentrations of TOC in the Clinton Creek study area ranged from 3.8 mg/L at R2 in April to 39.3 at R4 in May. In a database maintained by Environment Canada, TOC concentrations ranged from 0.90 mg/L to 25.5 mg/L in 66 detected samples collected from tributaries to the Yukon River with a mean concentration of 9.86 mg/L (Environment Canada, 2010). In published 2005 water quality data from USGS, total organic carbon ranged from 0.163 mg/L (April) to 13.4 mg/L (July) in monthly samples collected during the open water season from the Yukon River at Eagle Alaska (USGS web site). It would appear that concentrations documented at most of the Clinton Creek stations during high flows in May 2010 were elevated compared to recorded data at other Yukon sites.

Some parameters at several of the sites exceeded the CCME recommended metal guidelines for the protection of freshwater aquatic life. Some of the metals have guidelines that depend upon the hardness of the water. Hardness varied throughout the

study period. The sampled waters were hardest during low flow conditions when the stream flow consisted mostly of groundwater which has been in long term contact with rock and sediment. Waters were considerably softer during high flow events with dilution of rain water and surface runoff playing a large role. The guideline for cadmium is very conservative but since there was such a substantial range of hardness in the study area and over the study period, the calculation using the formula  $10^{0.86[\log(\text{hardness})]-3.2}$  was used to determine the site specific guideline for each location. The guideline for cadmium was exceeded at the reference sites R1, R3, R4 and R6 on at least one occasion. The recommended guideline was also exceeded at the exposed sites E1, E2, E7 and E8. The highest concentrations of cadmium were documented at the reference sites R3 and R4.

The guideline for copper also changes with hardness. For soft waters (0 to 120) the guideline is 0.002 mg/L, for hard waters (120 to 180) the guideline is 0.003 mg/L and for very hard waters (>180) the guideline is 0.004 mg/L. The applicable guideline was exceeded at the reference sites R1, R3, R4 and R6, and at the exposed sites E1, E2, E7 and E8. The highest concentrations of copper were documented at R3 and E8.

The recommended guideline for aluminium is 0.1 mg/L with concentrations greater than the guideline reported at all sites (except R-1A). The greatest concentrations of aluminium were recorded at R3 (6.18 mg/L) and at E8 (3.34 mg/L).

The recommended guideline for chromium (0.001 mg/L) was exceeded at all of the exposed sites on all occasions. It was exceeded on at least one occasion at the reference sites except at R-1A and Mickey Creek. The highest concentration in the study area occurred at E3 on July 27<sup>th</sup> with a value of 0.0203 mg/L.

The recommended guideline for iron was frequently exceeded at all of the sites with the exception of R-1A. The greatest concentrations of iron were recorded at R3 (9.28 mg/L) and at E8 (3.67 mg/L).

The guideline for selenium was slightly exceeded at E1, E2, and R4.

The recommended guideline for zinc was only exceeded once, at R3 on Sept 21<sup>st</sup>.

The recommended guidelines are applicable to total metals only, which includes concentrations contained within the mobilized sediment as well as within the water column. The highest suspended sediment concentrations documented during the study period coincided with the greatest concentrations of many of the metals in Table 4. The toxicity of most metals to aquatic life is highest in the dissolved phase. Dissolved metal analysis was performed on two occasions over the study period, July and September, which also coincided with higher suspended sediment loading (R3 had a very high TSS concentration in September, of 565 mg/L). This dissolved metals data is included in the analytical reports in Appendix B. Upon examination of this data, very few guidelines were exceeded in the dissolved samples. Dissolved aluminium and iron at R3 in September met the guideline whereas the total metals concentrations grossly exceeded the guideline. Conversely, concentrations of chromium also exceeded the recommended guideline in the dissolved metals samples as well as in the total metals samples.

#### 4.1.2 Asbestos

Water samples for the analysis of asbestos were collected on each field trip. This data is presented in Table 5. As well as the total number of fibres/mL calculated per sample, the mass of the fibres that were measured has also been included in Table 5. The majority of all the fibres were small, <5 microns long and all fibres had a diameter of < 0.5 microns. Fibres greater than 5 microns long were documented in a few samples from July and September. The longest fibre measured was 14.94 microns in length collected at E7 in July 2010.

The greatest number of fibres was collected during the July sampling period. Flows were fairly high during and preceding this time due to heavy rainfall, which may have contributed to the mobilization of asbestos fibres in the watersheds. The single sample containing the most asbestos fibres was collected at E7 in July 2010. Of interest to note is the relatively high numbers of fibres found in the Forty Mile River (R6) upstream of the confluence with Clinton Creek, however, curiously none were documented downstream of Clinton Creek (E8) during any of the sampling events. Asbestos fibres are ubiquitous

throughout the Yukon River system with a general concentration of one million fibres/L (Gerry Whitley, pers. comm.).

Site Type	Site #	Date 2010	Fibres/L	# of fibres measured	Asbestos Mass of fibres (pg/mL)
<b>Exposed</b>	E1	May 6	203,000	1	1.54
	E1	July 27	1,055,400	13	104.2
	E1	Sept 21	0	0	0
	E2	April 21	243,000	3	40.6
	E2	May 6	4,383,700	54	28.2
	E2	July 28	0	0	0
	E2	Sept 21	0	0	0
	E3	April 21	0	0	0
	E3	May 6	3,815,700	47	50.2
	Duplicate	May 6	0	0	0
	E3	July 27	8,362,000	103	214.3
	E3	Sept 21	0	0	0
	E4	April 21	0	0	0
	E4	May 6	406,000	2	0.918
	E4	July 28	6,900,700	85	473.6
	E4	Sept 21	0	0	0
	E7	April 21	243,500	3	1.47
	Duplicate	April 21	4,221,600	52	44.6
	E7	May 6	0	0	0
	E7	July 28	11,449,500	141	482.1
	E7	Sept 21	852,400	21	40.8
	E8	May 6	0	0	0
	E8	July 29	0	0	0
	E8	Sept 21	0	0	0
<b>Reference</b>	R1A	April 21	0	0	0
	R1	May 6	0	0	0
	R2	April 21	0	0	0
	R2	May 6	0	0	0
	R3	April 21	0	0	0
	R3	May 6	162,000	2	1.45
	R3	July 28	1,217,800	16	195.1
	R3	Sept 21	0	0	0
	R4	April 21	0	0	0
	R4	May 6	0	0	0
	R4	July 28	0	0	0
	R4	Sept 21	730,600	18	56.1
	R6	April 21	811,800	10	628.4
R6	May 6	609,000	3	5.51	
R6	Sept 21	0	0	0	
Mickey Creek	July 28	0	0	0	

Asbestos appears to be a difficult parameter to sample and analyze judging by the significant discrepancies recorded for the blind duplicate samples. In April, a blind duplicate sample was collected from E7.  $2.4 \times 10^5$  fibres/L were recorded in the sample at E7 yet  $4.2 \times 10^6$  fibres/L were counted in the blind duplicate collected from the same site at the same time. In May a duplicate sample was collected at E3. There were  $3.8 \times 10^6$  fibres/L in the sample yet the blind duplicate yielded none.

There are no Canadian guidelines for asbestos in drinking water or surface waters. The US Environment Protection Agency has set a maximum concentration level of 7 million fibres/L in drinking water (US EPA website), but has no standard for aquatic life. Although there is no intention on using the study area's water for drinking purposes, this standard was met for most of the samples. The only samples that exceeded this criteria were the E3 and E7 July samples.

Chrysotile asbestos fibres mined at Clinton Creek are found associated with serpentine minerals. Chrysotile fibres contain high levels of nickel, chromium, cobalt and manganese (Schreier et al, 1987). Chrysotile asbestos is a magnesium silicate mineral ( $Mg_3(Si_2O_5)(OH)_4$ ) that is only stable at very high pH. When exposed to pH less than 8.0, the Mg is leached from the fibre structure and during this process trace metals are released. The pH of the waters of Wolverine Creek frequently were less than 8 and leaching may be a contributing source of chromium concentrations recorded in the study area. Wolverine Creek downstream of the tailings, E3, had the greatest concentrations of chromium in the study area (see Section 4.1.1)

Little work has been conducted on the potential effects of asbestos on fish and other aquatic biota, but Schreier et al speculate that detrimental effects may be caused from the associated trace metals that are released into the stream from the leaching of the chrysotile fibres (Schreier et al, 1987). Since it is difficult to quantify asbestos fibres in tissues, performing metal analysis on tissues could provide information in asbestos contaminated areas. DFO conducted a sculpin survey in 2010 but no tissue analyses for trace metals were conducted.

#### 4.1.3 *Quality Assurance / Quality Control*

A set of blind duplicate water chemistry samples was collected at a selected site during each sampling period; E7 in April, E3 in May, E8 in July and E7 in September. A review of the data in Appendix B shows good correlation between the duplicates and site data. Exova performed their own QA/QC on each data set and the results of these are also included in Appendix B.

As mentioned in Section 4.1.2, blind duplicate samples were also collected from E3 (May) and E7 (April) for the analysis of asbestos fibres. No blind duplicates were collected in July or September. There was a significant discrepancy between each duplicate and its representative sample as analyzed by McMaster University. The reason for this is unknown, but a possible explanation could be that since such a small aliquot of sample is filtered and then the filter is subsampled, consistency in acquiring a representative sample may be challenging. McMaster also ran a blank sample using 500 mL of double deionized distilled water for each batch of samples, which showed no asbestos fibres present.

## **4.2 Groundwater Seeps**

### *4.2.1 Temperature Data Loggers*

Eight Tid bit temperature loggers were installed on April 21<sup>st</sup>, 2010 in seeps and groundwater upwelling areas in Clinton Creek in the general area of the Porcupine and Wolverine Creek confluences. On July 28<sup>th</sup>, CCS1 was located and downloaded, then replaced. On September 21<sup>st</sup>, the loggers were retrieved however due to flooding in August and the resultant damage and alterations to the creek, CCS4, CCS7 and CCS8 could not be located. The temperature data from all retrieved loggers are graphically represented in Figures 3 through 7. The original objective was to leave the loggers in place throughout the winter but due to the changed state of the area a decision was made to remove them.

Based on the temperature data it appears that CCS1, CCS6 and possibly CCS5, were located at sites that were likely groundwater sources. The high gradient of temperatures recorded at CCS2 and CCS3 suggest that these loggers were installed in seeps influenced by surface water.

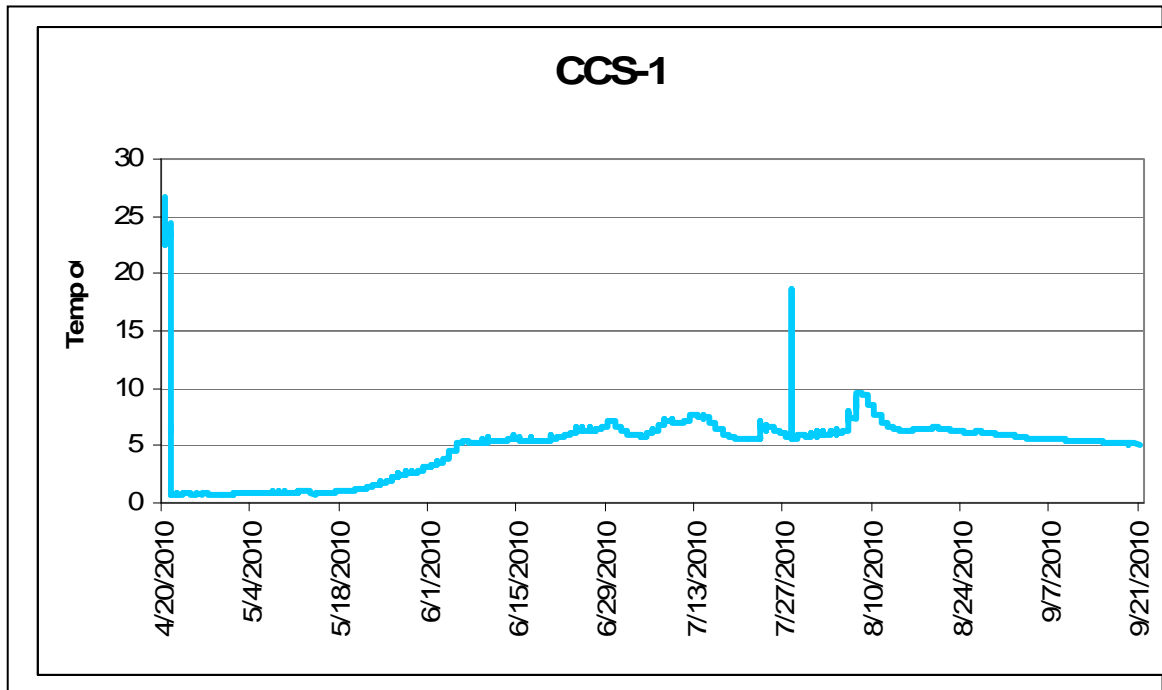


Figure 3: Chart of ground water temperature data April 21 to September 21, 2010 at CCS-1. Logger was removed, downloaded and replaced on July 28<sup>th</sup>, 2010.

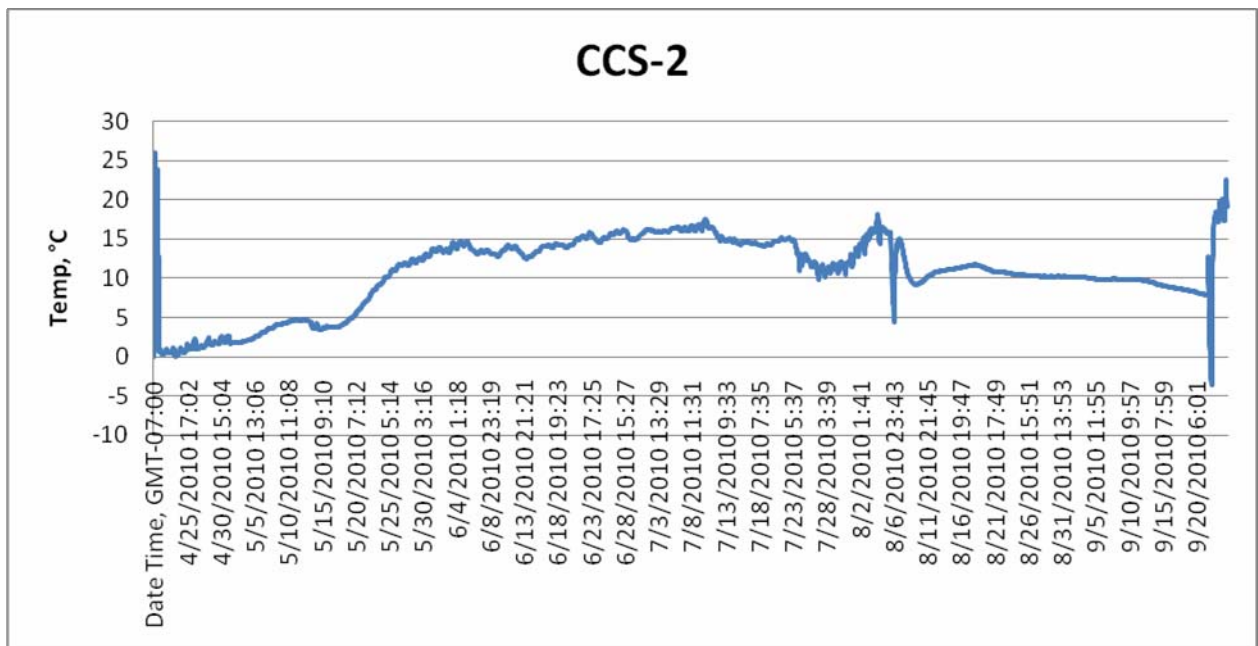


Figure 4: Chart of ground water temperature data April 21 to September 21, 2010 at CCS-2.

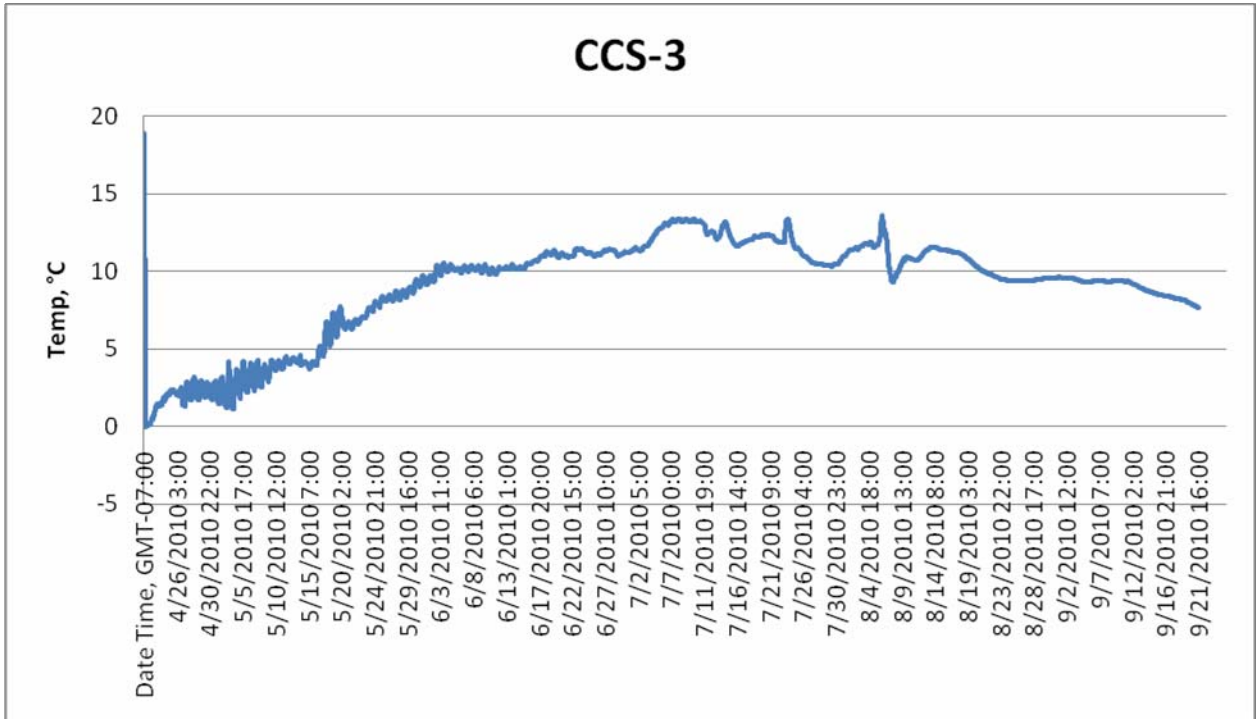


Figure 5: Chart of ground water temperature data April 21 to September 21, 2010 at CCS-3.

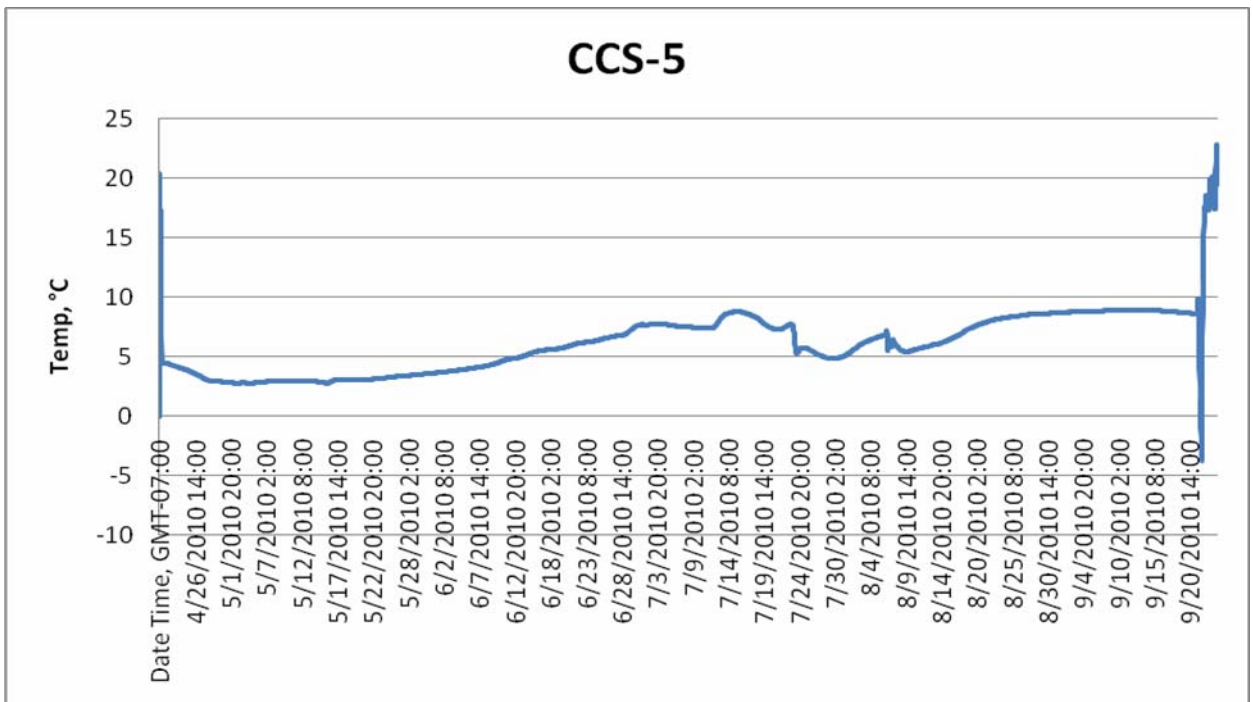
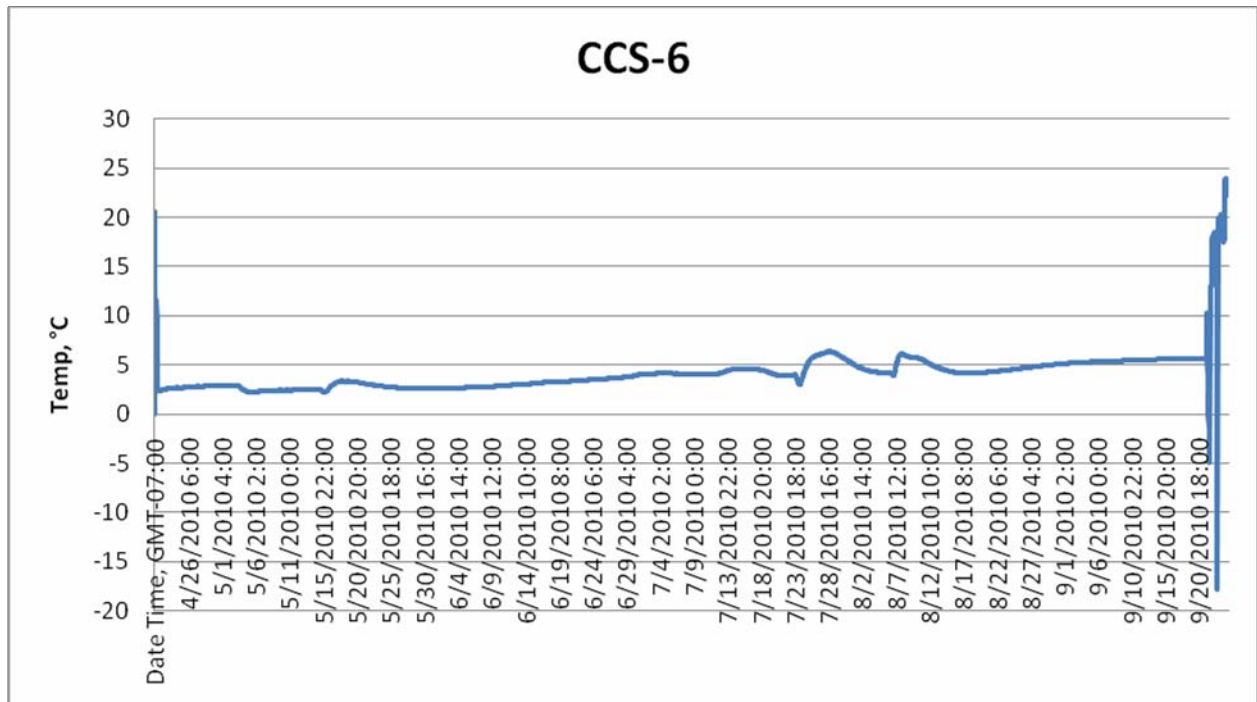


Figure 6: Chart of ground water temperature data April 26 to September 20, 2010 at CCS-5.



**Figure 7: Chart of ground water temperature data April 26 to September 20, 2010 at CCS-6.**

#### 4.2.2 Water Chemistry

Water samples were collected from each of the seeps during installation of the temperature loggers in April. Table 6 summarizes the data. Only metals where the CCME guidelines for the protection of freshwater aquatic life have been exceeded are included in the table. The only field data in Table 6 are water temperature, dissolved oxygen and conductivity. The complete field results and the laboratory analytical reports can be viewed in Appendix B.

The water temperatures were low reflecting the time of year sampled. The warmest water (4.2°C) at CCS-5 indicates that this could be a groundwater source. Dissolved oxygen was very low at all of the sites, which is to be expected of groundwater sources. The data suggests that CCS6 and CCS8 may be influenced by surface water. The CCME guideline of 9.5 mg/L is the lowest acceptable dissolved oxygen concentration for the protection of early life stages of cold water biota. None of the sites met this criterion.

Conductivity was very high at all sites and ranged from 997 at CCS-1 to 2780 mg/L as CaCO<sub>3</sub> at CCS-8. All waters were generally clear and slightly alkaline with pH ranging from 7.53 to 8.46.

**TABLE 6 WATER QUALITY SUMMARY OF THE SEEPS, APRIL 21, 2010**

Parameter	Units	CCS1	CCS2	CCS3	CCS4	CCS5	CCS6	CCS7	CCS8	CCME Guideline
Water Temperature	°C	0.7	0.7	0.1	2.1	4.2	2.1	0.5	2.8	
Dissolved Oxygen	%	48.5	9.1	41.7	29	42.5	53.9	29.4	54.9	
Dissolved Oxygen	mg/L	6.57	1.22	5.76	3.81	5.23	6.93	4.03	7.04	9.5
Conductivity - field	µS/cm	1006	1123	1016	2210	1906	2390	1455	2350	
Total Suspended Solids	mg/L	<2	<2	12	8	9	13	<2	3	
pH		8.46	7.59	7.62	7.7	7.73	7.53	7.71	7.8	6.5 - 9
T-Alkalinity	mg/L	256	207	181	294	314	235	246	338	
Sulfate (SO4)	mg/L	325	392	395	958	1120	5.18	941	1520	
<b>Trace Total Metals</b>										
Arsenic	mg/L	0.0044	0.0004	0.0018	0.0086	0.0008	0.0016	0.0013	0.0021	0.005
Cadmium	mg/L	0.00001	0.00046	0.00004	0.00092	0.00013	0.00017	0.00017	0.00022	*
Chromium	mg/L	0.0026	0.001	0.0009	0.0026	0.0013	0.0011	0.001	0.0021	0.001
Iron	mg/L	0.094	0.033	3.85	14.4	0.028	2.03	0.024	0.013	0.3
Selenium	mg/L	<0.0006	<0.0006	<0.0006	0.0044	0.0038	<0.0006	0.0027	0.0044	0.001
Hardness	mg CaCO <sub>3</sub>	651	648	643	1610	1750	952	1340	2190	
Calculated guideline for Cadmium:		0.00017	0.00017	0.00016	0.00036	0.00039	0.00023	0.00031	0.00047	
* The cadmium guideline for each sample was calculated using the formula $10\{0.86[\log(\text{hardness})]-3.2\}$ .										
Data that exceeds the recommended guideline are highlighted.										

Total alkalinity, the water's ability to neutralize acid, was also very high throughout ranging from 181 at CCS-3 to 338 mg/L at CCS-8.

Sulphate concentrations ranged considerably from 5.18 at CCS-6 to 1520 mg/L at CCS-8. Sulphate was very high at CCS-4, CCS-6 and CCS-7 with concentrations near 1000 mg/L. Although there currently are no recommended national (CCME) guidelines for sulphate for the protection of aquatic life, British Columbia has set 100 mg/L as a guideline for BC waters. Based on this, all sites grossly exceeded the guideline with the exception of CCS-6.

All of the seeps were fairly mineralized and the CCME guideline was exceeded at each site for at least one metal. Concentrations of arsenic, cadmium, chromium, iron and selenium exceeded the recommended guidelines at CCS-4, and were the highest levels recorded for the seeps.

All of the seeps had extremely hard water ranging from 643 at CCS-3 to 2190 mg/L as CaCO<sub>3</sub> at CCS-8.

Samples were also collected for asbestos analysis from CCS-1 and CCS-4 only and this data is presented in Table 7.

Site	Fibres/L	Asbestos mass, pg/mL
CCS-1	Non detected	0
CCS-4	1,055,400	40.3

### 4.3 Stream Sediment Geochemistry

#### 4.3.1 Metals

Composite stream sediment samples were collected from each site except E1, during the July sample period and analyzed for metal content by Exova. Due to the high velocities at E1, there were no depositional areas and hence stream sediment samples could not be collected. Table 8 shows the geochemistry data for selected parameters compared to the CCME sediment quality guidelines. The laboratory analytical reports containing results for all of the parameters can be examined in Appendix C.

Site Type	Site Description	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Zinc	pH
Reference	R3 - Wolverine Cr u/s tailings	5.3	<b>0.96</b>	<b>40.1</b>	<b>101</b>	12.3	0.101	116	7
	R4 - Eagle Cr u/s culverts	<b>6.2</b>	0.4	24	<b>42.8</b>	7.4	0.08	68.1	7.8
	Mickey Creek	<b>7.4</b>	0.3	24.3	30.3	8	0.053	69.4	7.8
Exposed	E2 - Clinton Cr d/s Porcupine u/s Wolverine	<b>25.4</b>	<b>2</b>	<b>283</b>	<b>176</b>	9.8	<b>0.215</b>	<b>125</b>	8.3
	E3 - Wolverine Cr u/s culverts	5.5	<0.05	<b>1160</b>	<b>68.4</b>	4.5	0.035	42.3	9
	E4 - Clinton Cr d/s Wolverine u/s Eagle	<b>13.2</b>	<b>0.7</b>	<b>222</b>	<b>128</b>	8.7	<b>0.736</b>	111	8.6
	E7 - Clinton Cr near mouth	<b>9.1</b>	0.5	<b>82.6</b>	<b>71.4</b>	8.3	0.072	86.1	8
	E8 - Forty Mile River d/s Clinton Creek	3.9	0.08	21.7	24.4	4.4	0.051	45.1	7.8
	<b>ISQG</b>	5.9	0.6	37.3	35.7	35	0.17	123	
	<b>PEL</b>	17	3.5	90.0	197	91.3	0.486	315	

Note: ISQG = Interim freshwater Sediment Quality Guidelines, in **bold** where exceeded.  
 PEL = Probable Effects Level (>50% of adverse effects occur above this level), highlighted and in **bold** where exceeded.

The concentration for arsenic exceeded the interim freshwater sediment quality guidelines (ISQG) at R4, Mickey Creek, E2, E4, and E7, and the probable effects levels (PEL) at E2. Generally, concentrations greater than the PEL have a 50% incidence of creating adverse biological effects. The ISQG for cadmium was exceeded R3, E2 and E4.

Concentrations of chromium were very high at some of the sites with E3, Wolverine Creek u/s of Clinton Creek, displaying the greatest concentration of 1160 ppm that considerably exceeded the PEL of 90 ppm. Stream sediment analysis was completed at this site in 2009 (Laberge, 2010). An extremely high concentration of chromium was documented on that occasion as well, with a reported value of 1180 ppm. In 2009, another stream sediment sample was collected from depositional areas just downstream of the confluence with Wolverine Creek and Clinton Creek. The concentration here was 1170 ppm. To put these high chromium concentrations into perspective, the Yukon stream sediment database maintained by Environment Canada (Environment Canada, 2009) was reviewed. Of the 2,614 stream sediment samples where chromium was detected, the concentrations ranged from 0.2 ppm to 363 ppm. The highest concentrations were documented from stream sediments in the South MacMillan River, part of the Pelly River drainage. The concentrations recorded in the stream sediments at Wolverine (1,180 ppm and 1160 ppm) and Clinton (1,170 ppm) Creeks are the highest yet recorded.

The chromium PEL was also exceeded in Clinton Creek in 2010, at sites E2 and E4 with concentrations of 283 ppm and 222 ppm respectively. The concentration in the sediment upstream on Wolverine Creek, R3, which is located above the tailings, slightly exceeded the ISQG, but at 40.1 ppm was significantly lower than at E3. It is plausible that Wolverine Creek is picking up chromium as it flows through and over the slumped tailings in the Wolverine Creek valley. The ISQG was exceeded downstream at E7, Clinton Creek near the mouth but the concentration was below the PEL.

The high concentrations of chromium documented in the study area are likely due to the fact that the mineral chromite (iron chromium oxide) is associated with the serpentine minerals in this area (Htoon, 1979).

The ISQG for copper was exceeded in the sediments at all sites except for the Forty Mile River, E8, and Mickey Creek. Concentrations of lead were very low and were well below the ISQG. The PEL for mercury was exceeded at E4 and the ISQG was exceeded at E2. The ISQG for zinc was exceeded at E2 only.

#### 4.3.2 Asbestos

The results for the composite samples sent to McMaster for the analysis of asbestos are presented in Table 9. No asbestos fibres were found in the stream sediments collected from R3 (Wolverine Creek upstream of the tailings) and from Mickey Creek. As these are reference sites, the lack of asbestos fibres is not surprising. However, asbestos fibres were documented at the reference site R4, Eagle Creek upstream of Clinton Creek.

The stream sediments at E2 and E3 contained the highest percentage (10 to 25) of asbestos fibres. Smaller amounts of asbestos were documented at E4, E7 and E8. Other fibres that were present in the sample were also reported. They were either cellulose or man-made mineral fibres (mmmf) which may include fibreglass, mineral wool, slag wool, rock wool and ceramic fibres.

<b>TABLE 9 ASBESTOS FIBRES IN STREAM SEDIMENTS, JULY 2010</b>				
<i>Laboratory Sample No.</i>	<i>Sample Identification</i>	<i>Type of Asbestos</i>	<i>Non Asbestos Fibres</i>	<i>% (area)</i>
10080030	E-2 Clinton Cr d/s Porcupine Cr u/s - dark grey	chrysotile	hair cell }	10-25 0.5-10
10080031	E3- Wolverine Cr u/s Culverts - light grey	chrysotile		10-25
10080032	E4- Clinton Cr d/s Wolverine Cr u/s -light grey	chrysotile	cellulose	0.5-10 0.5-10
10080033	E7- Clinton Cr near mouth - dark grey	chrysotile	cellulose	0.5-10 0.5-10

<b>TABLE 9 ASBESTOS FIBRES IN STREAM SEDIMENTS, JULY 2010</b>				
10080034	E8- Forty Mile River d/s Clinton Cr -light grey	chrysotile	cellulose	< 0.5 < 0.5
10080035	R3- Wolverine Cr u/s tailings -dark grey	nd	cellulose mmmf }	10-25
10080036	R4- Eagle Cr u/s culverts - light grey	chrysotile	cellulose	< 0.5 10-25
10080037	Mickey Creek -light grey	nd	cellulose	10-25

## 5.0 RECOMMENDATIONS

Due to historic rainfall and flooding events at the Clinton Creek study area during the summer of 2010, water and sediment sampling should be conducted in 2011 to monitor any liberation of metals and asbestos fibres to the receiving waters, especially from the Wolverine Creek drainage. The study area should be expanded to include two sites on the Yukon River (upstream and downstream of the Forty Mile River confluence) to determine any effects on ambient asbestos concentrations.

Since the instability of chrysotile asbestos minerals can release associated trace metals (chromium, cobalt, nickel and manganese) at pH less than 8, it may be beneficial to sample slimy sculpin in the Clinton Creek drainage for whole body metal analysis. Chromium is currently documented in very high concentrations in the stream sediments at several of the sites within the drainage. Slimy sculpin, a benthic organism, live their life on stream bottoms and thus live in close proximity to the contaminated sediments. A fairly extensive database of metals in slimy sculpin tissues exists and it could be worthwhile to determine the range of concentrations found in the sculpins from the Clinton Creek drainage and compare them regionally.

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**APPENDIX A**

**CLINTON CREEK SITE PHOTOGRAPHS, 2010**



Photo #1: CCS2, April 21<sup>st</sup>, 2010.



Photo #2: E1 is dry on April 21<sup>st</sup>, 2010.



Photo #3: Locations of R1 on upper Clinton Creek and the tributary R1A, which was sampled in April since R1 was frozen at that time. Photo taken on May 6<sup>th</sup>, 2010.



Photo #4: R3 is located on Wolverine Creek upstream of the tailings, May 6<sup>th</sup>, 2010.



Photo #5: The mouth of Clinton Creek, E7, is flooded during the July sampling period, July 29<sup>th</sup>, 2010.



Photo #6: Looking upstream to the bridge crossing the 40 Mile River from the newly established site of E8, July 29<sup>th</sup>, 2010.



Photo #7: Late August rains washed out the Clinton Creek access road and E1 has been relocated upstream of the original location for the September sampling.



Photo #8: Further upstream, undercutting has occurred at the fourth gabion structure leaving the lower portion of the baskets hanging. Photo taken on September 21, 2010.



Photo #9: Waters were extremely turbid at R3, Wolverine Creek u/s of the tailings, September 21<sup>st</sup>, 2010.



Photo #10: Asbestos fibres are ensnared on the vegetation near E3, Wolverine Creek, after the recent flooding. Photo taken on September 21<sup>st</sup>, 2010.