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Natural Resource Consultants

MT. NANSEN TERRESTRIAL AND AQUATIC EFFECTS STUDY 2005-06

VOLUME 1 OF 3 – REPORT

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PREFACE

This report presents the findings of Phase I and II of the Mt. Nansen Terrestrial and Aquatic Effects study as conducted during 2005 and 2006. This follows a Phase 1 report which presented the findings of the 2005 data only. As much of this 2005 data is relevant to this study, it is also included in this report. The data collected from 2005 and 2006 was often combined in order to increase sample sizes and confidence in the result. This 2006 report refines and clarifies findings presented in the 2005 report; therefore, represents a more complete account of the findings of this study.

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1.0 INTRODUCTION

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This study was completed to provide a better understanding of the terrestrial and aquatic effects of the Mt. Nansen mine site.

The terrestrial and aquatic effects of past mining activities associated with the Mt Nansen mine site are not clearly understood. The Little Salmon Carmacks First Nation (LSCFN) and the general Yukon community use the area for subsistence and recreational purposes. As the Yukon Government, Abandoned Mines Branch works towards reclamation of the mine site, a better understanding of the terrestrial and aquatic effects is required to ensure that the works address the issues at the site. In August 2005, EDI Environmental Dynamics Inc. (*Environmental Dynamics*) was retained to design and complete a Terrestrial and Aquatic Effects Study for the Mt. Nansen mine site. The objective of the project was to provide insight into past effects, current levels of contamination and ongoing contamination of various terrestrial and aquatic ecosystem components in the vicinity of the mine site.

1.1 Study Area

Mt. Nansen is located within the LSCFN Traditional Territory, 60 km west of Carmacks, YT.

The Mt. Nansen gold and silver mine site is located approximately 60 kilometres west of Carmacks. A gravel-surface road provides access to the site from Carmacks (Figure 1.1). The site lies within the watershed of Victoria Creek, a tributary stream to the Nisling River, a medium sized river in the Donjek/White Rivers drainage basin. The mine is located in an area of low mountains and rolling hills, composing the western part of what is broadly defined as the Yukon Plateau (central) Ecoregion. It is east of the Ruby Range Mountains, west of the Yukon River, south of the Klondike Plateau, and directly north of the Aishihik Lake area. The region is quite dry and characterized by boreal spruce forest. Immediately west of the site, wide grassland valleys characterize much of the upper Nisling River drainage basin with spruce forests on the hillsides and low mountains. This area was also a part of a glacial refuge that did not undergo the impacts of the last ice age.

Many species of wildlife and fish are found within the general area.

The area is utilized by a variety of wildlife, including woodland caribou (*Rangifer tarandus*), moose (*Alces alces*), wood bison *(Bison bison)*, grizzly bear *(Ursus arctos)*, black bear *(Ursus americanus)*, and a number of furbearers and small game. Low snow packs and the open grassland valleys provide important winter habitat for big game species, particularly to the west of the mine site. The Nisling River is a spawning stream for chinook salmon (*Onchorhynchus tshawytscha)*; however, most spawning activity occurs in the middle and lower portions of the river and not in the upper reaches near the Mt. Nansen area. Fish species utilizing water bodies near (downstream of) the mine site include Arctic grayling *(Thymallus arcticus)*, burbot (*Lota lota*), northern pike *(Esox lucius)*, round whitefish *(Prosopium cylindraceum*) and slimy sculpin *(Cottus cognatus)*.

Local geology affects the soils and the plants.

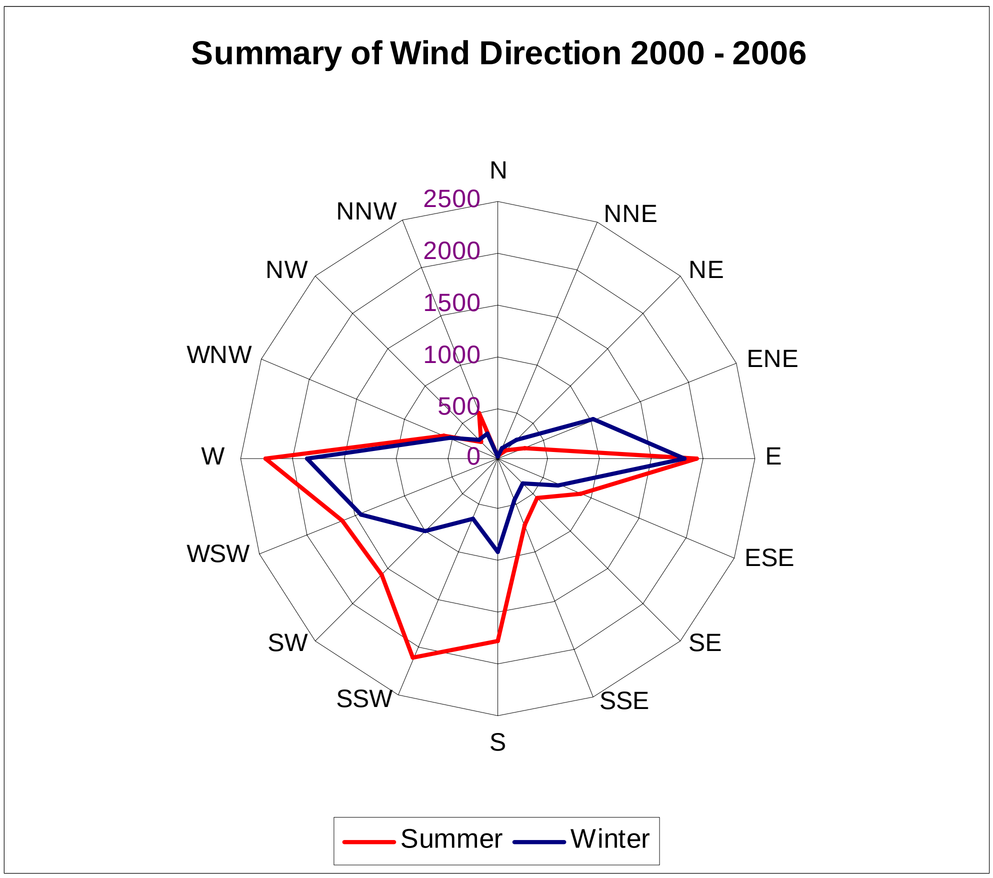
Soil development is generally poor across the property; typically represented by several centimeters of organics overlying a layer of volcanic tephra, which itself overlies decomposed bedrock. Unconsolidated alluvium has been mapped on the property, principally occurring in the Victoria and Nansen Creek Valley bottoms. Loess and volcanic ash have been observed in scattered patches throughout the property. The loess occurs as fine sand mantling some of the lower slopes. White ash appears as a few centimeters of soil exposed in road cuts, and is postulated to be from a recent eruption

Figure 1.1. Study Area map.

(1,230 years ago) in the Wrangell Mountains to the northwest. North facing slopes are typically permafrost-bound, as evidenced by thick moss cover and stunted conifers. The south facing slopes are well-drained and can be grassy to barren of vegetation.

The climate is reflective of the latitude (62^{o} N) and the elevation of the site (approx. 1,200 m). While weather data are incomplete, it is estimated that only May through September have average daily temperatures above freezing. Wind direction data recorded at Mt. Nansen indicate that winds are most prominent from the west, southwest, and east (Figure 1.2). Refer to Appendix A for additional presentation of wind data collected at the site.

A background description of geology is included in Section 1.3.



Wind comes most frequently from the west, southwest and east.

Figure 1.2. Frequency of all wind activity measured hourly per direction at the Mt Nansen site 2000-2006 (data provided by Yukon Government 2006).[1]

[1] Summer data is from May 1 to September 31. Monitoring station is located near the NE edge of the tailings pond in a treed location.

1.2 Site History

Little Salmon Carmacks First Nation has strong ties to the Mt. Nansen area.

The Little Salmon Carmacks First Nation has strong ties to the Mt. Nansen area with numerous accounts of significant use of the area dating back prior to mining or mining exploration. The harvesting of animals and plants in the area was and continues to be an important part of the lifestyle of many members of the Little Salmon Carmacks First Nation.

A detailed site history is presented in this section.

Early reports of placer gold on the Mt. Nansen property date back to the Klondike gold rush, over 100 years ago. Placer mining for gold at the site has continued since that era. The first hard rock gold discovery was made in 1943 by Brown and McDade. To the west of this deposit (on the other side of the hill), the Webber and Huestis hardrock deposits were subsequently identified.

An extensive exploration and sampling program was conducted at Mt. Nansen between 1963 and 1967, including underground development and the construction of a small flotation mill. The small mill treated 10,000 tonnes of material from the Webber and Huestis deposits in 1968 and 1969. However, gold recoveries from this operation proved uneconomical for full production. During 1975 and 1976 an additional 5,000 tonnes of ore from the Huestis zone was processed in a sulphide flotation circuit, however the operation ceased again due to poor gold recovery. It was noted at that time, as in the previous decade, that a cyanide leaching process was required for free gold recovery.

From 1985-1987, a substantial exploration program was conducted by Chevron Minerals in a partnership with BYG Natural Resources Inc. (BYG). This involved surface trenching and diamond drilling. This exploration continued in 1988, but concentrated exclusively on the Brown-McDade deposit. The upper portions of the deposit where the mineralization was oxidized became the focus, as this material can be treated in a cyanide leaching circuit, leading to better gold recoveries than the sulphide flotation process. BYG under new management recommenced exploration in 1994, which led to a feasibility study being initiated later that year. Environmental reviews for the mine were completed and water licensing was granted in early 1996.

Mining of the Brown McDade Pit occurred from 1996 to early 1999.

The BYG mining operation at Mt. Nansen was based on producing ore at a rate of 500 tonnes per day (Denholm, Dumka, and Farquharson 2000) from the Brown-McDade open pit and processing it through a cyanide leaching circuit for a minimum of 4 years. However, unexpected setbacks prevented planned production targets from being achieved, and capital expenditures were considerably higher than planned. The unexpectedly high clay content in the ore, which limited production through the crushing plant, required a significant additional capital investment in the grinding circuit. A further problem then developed. Once the oxide material in the upper levels of the Brown-McDade Pit had been mined, gold recovery decreased as the ore in the lower levels of the pit was increasingly composed of sulphide materials. The cyanide leaching process is only effective for extracting the free gold available in oxide materials. Fine-grained inclusions of gold in pyrite, arsenopyrite, and peripheral infiltrations in sulfide materials found deeper in the pit are not easily recovered, and the processes required a much larger capital expenditure. Therefore extracting gold from sulphide materials is only feasible where the amount of available ore is large enough to justify such expenditure. In this case it appears that the composition of the ore in the Brown-McDade deposit was not well understood by BYG prior to mining. Therefore, once they removed the upper layers of oxide ore and its composition changed to a mix of oxide material and an increasing amount of sulphide material, gold recoveries fell below expected levels. The entire operation subsequently ceased on February 17, 1999 on an order from the Department of Indian and Northern Affairs (DIAND) due to non-compliance with the mine's water license. Cyanide and arsenic levels in the tailings pond had become elevated and proper treatment facilities were not in place. The stability of the tailings pond dam was also in question, and BYG was not able to meet requirements for an environmental liability bond.

Other than possible placer activity in nearby areas, no mining or mineral exploration has taken place since early 1999. DIAND, and subsequently the Yukon Government's Department of Energy, Mines, and Resources (YG-EMR) have assumed responsibility for management of the site.

The history of environmental impacts at the site may go back to the effects of historic placer operations in the area, and therefore the effects of the BYG operation cannot effectively be isolated from other past works at or near the site.

When BYG ceased operations in early 1999, several environmental issues required attention. For example, the tailings containment system of the BYG mine was not functioning properly, resulting in significant volumes of ongoing contaminated seepage flowing through the tailings pond dam. Some contamination of Victoria creek (tributary of Nisling) from tailings pond leakage of the BYG gold mine into Dome Creek (draining into Victoria Creek) was documented in 1998 in association with a fish kill at the mouth of Dome Creek (Environmental Protection, 1999).

Action was subsequently taken by DIAND (and subsequently YG-EMR) managers to address the short-term environmental issues. The tailings pond dam was determined to be stable if water levels in the pond were kept lower (Denholm 2000). A water containment and treatment program was undertaken from 1999 to 2004, to collect and treat tailings water in order to meet water quality standards mandated in the previous water license (BYG)[1]. Containment involved pumping the seepage water from a seepage containment pond (located immediately below the tailings pond dam) back to the tailings pond, from where it was run through the mill and chemically treated to precipitate out metals and destroy cyanide. By 2005, levels of cyanide, bio-available (dissolved) arsenic, ammonia, and heavy metals had decreased to levels where the water could be released to the environment without treatment.

Current management of the tailings water ensures that water is only released into Dome Creek when it meets water license standards.

Further decommissioning of the site is currently being planned. The major outstanding environmental issues include accumulation of metal-contaminated water in the Brown-

[1] During the fall of 1999, untreated water was released until December 1999, due to a short term exemption from toxicity testing requirements.

McDade open pit, as well as the fate of the tailings stored in the tailings pond. Beginning in 2004, studies have been undertaken to evaluate the water balance and potential for existing contamination in the pit to contaminate local ground and surface waters. Levels of metals above CCME water quality guidelines were found in Pony Creek downstream of the Brown-McDade pit; however, these elevated levels are thought to be attributable to an area of waste rock fill where the flow from Pony Creek temporarily disappears to groundwater through the waste rock (Gartner Lee, 2005). Ongoing water balance research is planned for the future to develop a more comprehensive understanding of the geochemistry and hydrology of this site.

There are a number of different options being considered to address the tailings pond area. Several of these options were identified by Denholm et al (2000); however, final decisions on closure will depend first upon the outcome of the water balance and contaminants assessment currently underway for the Brown-McDade pit. Once a clear understanding of the terrestrial and aquatic effects of the mine site has been developed, reclamation activities can be properly planned. Feedback from the community will be instrumental in planning for final reclamation of the site.

1.3 Background Geology

The Mt. Nansen property is situated within the southern part of the Dawson Range, which is part of the Yukon Plateau Physiographic Province in the central Yukon. The area is located within the western boundary of the Yukon Crystalline Terrain, a fault-bounded tectonic terrain package that is dominated by schists and gneisses.

The area is dominated by gently rolling upland that transitions to high standing outcrops at irregular intervals. The area escaped the last major glaciation (Pleistocene) and appears to have avoided significant erosion, since at least the Cretaceous period. Because of the apparent lack of glaciation and erosion, felsenmeer or broken rock on the surface is generally mapped as representative of the underlying bedrock. Surficial weathering (oxidation) has been noted to be deep; measuring up to tens of meters as observed in drill cores (Carlson, 1987).

The geology can be simply divided into three main categories: basement metamorphic schists and gneisses, intruded by early Jurassic foliated plutonic rocks, followed by early Cretaceous to Paleocene plutonic and related volcanic rocks. There are no younger sediments mapped in the area, signifying considerable erosion of the landscape at some point in the Cretaceous time.

1.3.1 Property Geology

The oldest rocks mapped on the property are found to the east of Victoria Creek and throughout the southern one-third of the property, and belong to the Upper Paleozoic or older metamorphic assemblage known as the Basement Metamorphic Complex (Figure 1.3). These rocks regionally are comprised of metamorphosed and deformed sedimentary, volcanic and plutonic rocks. Locally, the unit is represented by quartz-

Specifics of the site geology may help explain some of the results from this study.

feldspar-mica schists of meta-sedimentary affinity that outcrop in the southeast part of the property and are characterized by micaceous quartzite in bands of interlayered coarse mica. Another unit of the basement complex has been identified in an outcrop on the south and western part of the property. These rocks are biotite-quartz-feldspar schists, for which the protolith is unknown but is postulated to be meta-volcanics. These rocks are comprised of a layered succession of quartzofeldspathic schists and plagioclase gneisses that exhibit a strongly developed foliation parallel to metamorphic banding.

The basement rocks are themselves intruded by Early Jurassic meta-plutonic rocks of the Mount Freegold Suite. The suite is dominated in the northeast quadrant of the property by plagioclase-hornblende monzonite and is generally strongly foliated. The emplacement of the suite likely caused the latest metamorphism of the basement crystalline schists.

Early Cretaceous time saw the advent of regionally significant and extensive plutonism marked by the intrusion of the Dawson Range Batholith. In the Mt. Nansen area, the batholith is represented by the Casino granodiorite which is mapped mainly in the central and north central portion of the property. The rocks are comprised of biotite-hornblende granodiorite, are recessive in nature and are generally visible as irregular outcrops.

The northwestern most portion of the property is underlain by the Mount Nansen Volcanics, a suite of mainly andesite to latite flows and feeders. These rocks are Cretaceous or younger in age and have been postulated to be cogenetic with the Casino Granodiorite. The suite at Mt. Nansen is dominated by dark green to black fine-grained andesites with visible feldspar laths up to 2-3 mm in size. The rocks exhibit vertical, possibly columnar jointing in outcrop. Near the western edge of the property a sub-unit of volcanic breccia has been mapped. The origin of this sub-unit could be either intrusive or extrusive.

Cretaceous age porphyry dykes and stocks of the Mt. Nansen Site are found in the center of the property and bordering the northwestern edge of the property. The rocks are mainly porphyritic and show a wide range in composition, from intermediate to felsic. They are typically extensively altered and have a relatively high content of pyrite.

A variety of mineral deposits have been documented on the property, including porphyries, veins and placers. The dominant mineralization found to-date is gold- and silver-bearing quartz veins within the Brown-McDade and Heustis-Webber zones. These zones appear to be structurally associated with localized, northwesterly trending faults and shear zones where the favorable Casino Granodiorites or Mount Nansen volcanics are in contact with the basement rocks. There is also a strong spatial association with the porphyry dykes, suggesting the mineralization may therefore be late Cretaceous in age. At least one age date from the Heustis vein reveals an early Cretaceous date, so the actual timing is uncertain (Carlson, 1987). The porphyry system seems to be the locus for mineralization, and farther from the porphyries, the mesothermal precious metal veins and breccias developed. The mineralizing fluids were low in base metals. The mineralization at Brown-McDade is characterized by pyrite and arsenopyrite with minor chalcopyrite, galena, tetrahedrite, sphalerite and stibnite, in a northwest trending shear zone that cuts the Casino granodiorite. The Webber-Huestis veins occupy northwest trending shear zones which cut schistose rocks of the basement metasedimentary suite. Economic minerals of interest at the Huestis-Webber zone include pyrite and arsenopyrite, with minor galena, chalcopyrite, sphalerite and some sulphosalts.

Figure 1.3. Geology, mineralization and terrestrial site locations.

2.0 METHODS

2

The methods presented in this report were developed by the project team with the assistance of many study advisors (see acknowledgements).

2.1 Community Survey

In late August 2005, a community survey was conducted in association with the Little Salmon Carmacks First Nation (LSCFN). A researcher from the First Nation (Leta Blackjack) assisted *Environmental Dynamics'* staff in identifying, locating and interviewing local people. A total of 15 surveys were completed, targeting community members who used the resources within the study area. Survey participants were questioned in relation to the use of renewable resources within a 15 km radius of the Mt. Nansen mine site to determine the species of plants, animals, and fish that are harvested, or have been traditionally harvested, within this area. The survey also investigated the extent of use, general location, timing, and food parts consumed. In addition, individuals' concerns regarding the mine site and perceived effects were also discussed. The information gathered by the survey was used to determine what species would be collected and analyzed. A summary of survey results is presented in Appendix B.

Community members were surveyed to determine what types of plants and animals are harvested in the vicinity of the mine site so that these could be collected and tested.

2.2 Study Design

The findings of the Community Survey were further built upon through a two day visit to the mine site with LSCFN elder Clive Blackjack. Mr. Blackjack's Traditional Knowledge of current and past use of the area by LSCFN members aided the project team in understanding and fine-tuning the study design. This was of particular relevance in terms of the final selection of species for collection/analysis.

Three potential sources of contamination were identified: the Tailings Pond, the Mill Site, and the Brown McDade Pit.

The mine site has three principle potential sources of contamination; the tailings facility (including tailings pond and seepage pond), the Brown-McDade pit (with associated waste dumps), and the mill site, including stockpiles of low-grade ore material adjacent to the site (photos 2.1 to 2.5). The tailings contain high concentrations of silver, arsenic, barium, copper, iron, manganese, lead, antimony and zinc; however, of these only arsenic and antimony appear readily leached (Conor Pacific 2000). While no analytical results for the waste rock dumps could be located, the Brown-McDade pit walls have high concentrations of silver, arsenic, barium, cadmium, chromium, copper, iron, manganese, lead, antimony and zinc (Conor Pacific 2000). Nicholson (2002) found some elevated arsenic levels in lichens and plants directly adjacent to the potential sources of contamination.

Metals were selected for analysis as they can accumulate in ecosystems.

Pathways for movement of contaminants from the three sources include aerial (from wind) or aquatic (water). Dome Creek, and to a lesser extent, Pony Creek, are potential receivers and transport pathways of contamination. Dome Creek originates from the hill slope adjacent to the mill, flows past the mill and past mill workings and is diverted around the tailings facilities. Pony Creek is a potential receiver due to a waste rock pile adjacent to the creek (Photo 2.5) and a connection via a 200 m (approximate) adit which used to connect to the Brown McDade Pit (Photo 2.6). In 2006, a hydraulic bulkhead was installed in the adit to prevent surface flow from the pit into Pony Creek.

Tailings Pond

Photo 2.1. Northwest view of main tailings pond during low to moderate water levels (late Aug 2005). Waste dumps around the Brown-McDade Pit in background.

Brown-McDade Pit

Photo 2.2. Southeast view of the Brown-McDade Pit and the surrounding area.

Photo 2.3. View of mill site looking north towards bunkhouses (in background).

Mill site

Photo 2.4. Low-grade ore stockpile adjacent to mill site (west view; tailings pond in background).

Low-Grade Ore Stockpile

Pony Creek Waste Rock

Photo 2.5. View of 'Pony Waste Rock Pile' adjacent to Pony Creek, photo taken from road near the Adit location. Pony Creek located in the valley.

Pony Creek Adit

Photo 2.6. View of adit adjacent to Pony Creek (crosses road between truck and adit), prior to installation of hydraulic bulkhead.

The objective of this study was to determine whether or not elevated levels of metals currently exist in the terrestrial and aquatic ecosystems within the vicinity of these sources/pathways of contamination, and also whether or not contamination is ongoing. This has, in-turn, allowed the spatial extent of such contamination as well as any relationship to the mine and/or past mine operations to be evaluated.

"The objective of this study was to determine whether or not elevated levels of metals currently exist in the terrestrial and aquatic ecosystems…"

Another area that was investigated is a prominent zone of blackened (dead) vegetation present on the banks of Dome Creek (see Photos 2.7 & 2.8). On the right (south) bank, this area extends downstream from the seepage pond, with the first 500 m being highly visible, with patchy areas continuing downstream from there. The area of blackened vegetation on the left bank of Dome Creek begins approximately 75 to 100 m downstream from the seepage pond dam, and continues for approximately 150 m to 200 m where it becomes patchy and inconsistent. The width of the visible strips of blackened vegetation extending upward on each bank varies but averages approximately 4-6 m (Photo 2.7).

An area of blackened vegetation adjacent to Dome Creek was investigated.

Photo 2.7. Downstream view of Dome Creek below seepage pond. Note the blackened vegetation on the right bank.

Photo 2.8. Up-close view of blackened vegetation on right bank of Dome Creek.

2.3 Sampling

Members of the Little Salmon Carmacks First Nation worked with the Project Team to collect the samples.

The study included both terrestrial and aquatic components. Each component required the collection of samples that would be later analyzed for metal concentrations. Members of the LSCFN worked with Project Team members to collect the samples during the summer and fall of 2005 and 2006. First Nation workers were trained in proper sampling protocols, and while in the field provided additional insight into the dynamics of plants, animals, and human use relating to the area. The rationale and specifics of each sampling component of the study is presented in the following sections. Figure 2.1 summarizes the sampling components.

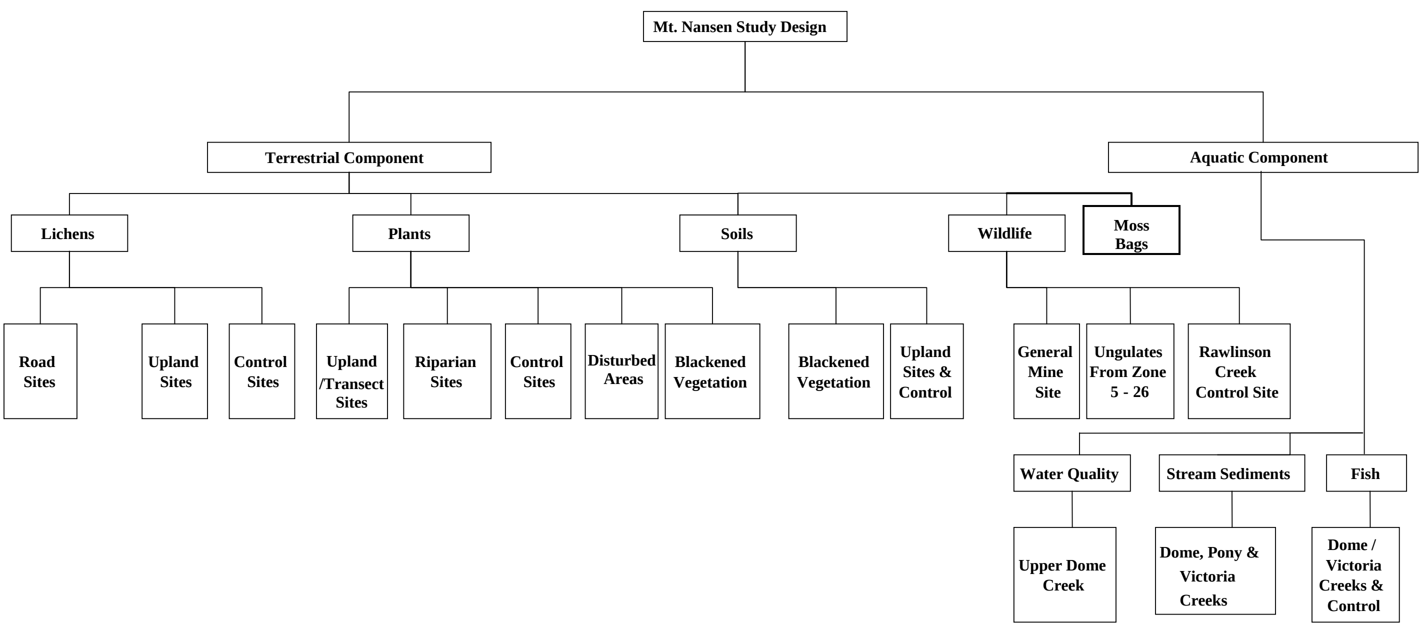


Figure 2.1. Summary of the structure of the Terrestrial and Aquatic Effects study.

2.3.1 Terrestrial Effects

Plants, animals, and soils were sampled to determine terrestrial effects.

The terrestrial ecosystem within the vicinity of Mt. Nansen could potentially be impacted through both aerial and aquatic pathways. Accordingly, both upland sites (subject to aerial contamination) and riparian sites (subject to aquatic contamination[1]) were sampled. In addition, metal uptake could occur as a result of vegetation growing directly on waste materials; therefore, plants growing directly on tailings and waste rock were sampled.

Lichens, vascular plants, soils and animals were investigated to evaluate metal contamination within the terrestrial component. At upland sites, lichens, vascular plants and soils were sampled to assist in the determination of airborne contamination. At riparian sites, vegetation was sampled to determine the presence/absence of contaminants from the aquatic environment (Note: the Aquatic Effects component also evaluated aquatic pathways.) Various small and large animal tissues were collected near the mine site. Animal samples were also collected from a control area situated outside the influence of the mine site (Rowlinson Creek; Figure 1.1).

Transects for sampling lichens, plants and soils were set-up radiating in several directions from each of the potential sources of contamination.

Eighty upland sample plots were established along 18 transects (Figure 2.2). Six transects radiated outwards from each of the three main "point" sources of potential contamination (labeled as A-R). Point sources included the tailings pond, the mill site, and the open pit/waste rock dumps. The first plot (labeled 1) on each transect was located in natural vegetation immediately adjacent to the disturbances. From here, additional plots were established at distances of 50, 200, 450 and 950 meters from the first plot (labeled as 2-5, respectively), and their exact location was recorded by GPS. Some adjustments were made where transects radiating from point sources intersected one-another. This pattern allowed for inspection of the contamination immediately adjacent to the disturbances and for spatial analysis in all directions. The outermost plots on many transects were located outside of the Dome and Pony Creek watersheds and thus provided some additional data for comparative purposes in addition to control plots. Such comparisons are considered relevant, as levels of contaminants at these plots were found to be similar to those found in control plots. All sampling was conducted within a 10 m radius of each plot site.

[1] It should be noted that riparian sites could also be subjected to aerial contamination; however, they were sampled due to the possible effects of aquatic contamination.

Vegetation samples were taken from a variety of other plots (see Figure 2.3). An additional nine upland control plots were sampled, three in each of the following documented areas of mineralization: the Spud, Webber and Flex zones. These sites provided reference samples for comparison within known areas of mineralization that are similar in structural and mineralogical style to the Brown-McDade zone. It should be noted that although these control areas have not been mined, there has been some surface disturbance resulting from exploration in the area.

Control plots were established in areas of mineralization.

In order to evaluate potential road dust impacts, three further upland sample sites were established immediately adjacent to the main access road between the Dome Creek crossing and the mill site.

Four plots sampling riparian vegetation were located on Dome Creek at a 300 m spacing between the tailings seepage impoundment and the Mt. Nansen road (DOME 1 – 4). A further three plots (DOME 5-7) were located on Dome Creek between the tailings pond and the mill site. Three plots were located along Pony Creek (PONY 1-3), downstream of the mine site. Sampling of vegetation (willow, wheatgrass, & foxtail) growing directly on the tailings, the Brown-McDade pit (and associated waste rock piles) and the low grade ore stockpile by the mill site was also conducted. This included random sampling along the "beach" or pond side of the tailings pond dam, as well as sampling from five plots within the pit itself and from three plots in the waste rock piles surrounding the pit.

Several riparian plots were located along Dome and Pony creeks.

Fourteen plots were established to sample the vegetation and soils located in the vicinity of the area of blackened vegetation along Dome Creek below the seepage impoundment (Figure 2.4).

2.3.1.1 Lichens

The potential for airborne dispersal of metals was investigated in detail through sampling of lichens. As lichens mainly receive nutrients from air and rainfall, they are excellent indicators of airborne contamination. A total of 102 lichen samples were collected in 2005 and an additional 26 in 2006. Caribou moss (*Cladina mitis)* was collected from each upland sample site location (see Figure 2.2) where it occurred. This lichen species not only provides an indication of airborne contamination, it is also used by the LSCFN for medicinal purposes and by caribou as a food source. Lichens were collected using unpowdered gloves, which were replaced with new uncontaminated gloves for each sample site. Several lichens at each location were combined into one sample for composite analysis. Non-lichen material was removed from the samples to ensure that only lichen material was analyzed. Replicate and duplicate samples (submitted in a blind manner to the lab) were collected for quality assurance /quality control (QA/QC). Samples were placed in new zip-lock plastic bags, frozen and shipped to the lab for analysis.

"As lichens mainly receive nutrients from air and rainfall, they are excellent indicators of airborne contamination."

Figure 2.2. Map of terrestrial transect vegetation sampling sites.

Figure 2.3. Map of supplemental vegetation sampling sites.

Figure 2.4 Map of plot locations within the zone of blackened vegetation.

2.3.1.2 Berries/Plants

At each upland site, the species listed in Table 2.1 were also collected when they were abundant an the site. These plant species were chosen based upon a review of existing information and as species of importance to the LSCFN. Samples were also collected on an opportunistic basis (when present) at the riparian sites. Composite samples taken from a number of plants within the general vicinity of each sample site were collected (using the same protocol as for the lichens). Replicate samples were taken for 5-10% of the sites. In addition, some duplicate samples (split of the same sample) were submitted in a blind manner to the laboratory. Unwashed Plant samples collected were frozen and stored prior to laboratory analysis. Samples were selected for analysis following the receipt of initial results from the lichen component of this project. At least one sample was sent from each of the 2005 plots with additional samples being sent from areas with high metal levels based on the lichen data.

Plants, lichen, and fungi used by community members were collected from the area.

Table 2.1. Species of vegetation sampled[2].

Species (Code)	Scientific Name	Portion of Plant/Lichen Utilized by Humans
Blueberries (VAUL)	*Vaccinium sp.*	Berry (leaf for medicinal)
Labrador tea (LELA)	*Ledum groenlandicum and/or L. decumbens*	Shoot (used for tea)
Crowberry (EMNI)	*Empetrum nigrum*	Berry
Lowbush cranberry (VAVI)	*Vaccinium vitis-idaea*	Berry
Bolete mushroom (BOSP)	*Leccinum sp.*	Stem
Rose (ROAC)	*Rosa sp.*	Fruit
Caribou horn (Tumble) lichen (MARI and MAHA)[1]	*Masonhalea richardsonii*	Whole plant (used for tea) also food source for caribou.
Willow (SASP)	*Salix spp.*	Leaf, bark, branch (food source for moose.
Spruce, black /white (PIGL)	*Picea spp.*	Fresh pitch/sap
Trembling aspen (POTR)	*Populus tremuloides*	Leaf
Wheatgrass (WHGR)	*Agropyron sp.*	Not used; however, abundant within pit and tailing facility.
Foxtail barley (HOJO)	*Hordeum jubatum*	Not used; however, abundant within pit and tailing facility.
Sphagnum moss	*Sphagnum sp.*	Not used; however, abundant within area of blackened vegetation located downstream of the tailings pond.

A number of other species were identified as important to LSCFN members for subsistence use (as listed in Appendix B); however, these species were not found in the Mt. Nansen area and therefore were not sampled.

[2] Note that the portions of plants sampled generally included those used for human consumption.
[1] The two codes used for caribou horn lichen reflect those used in the field and subsequently in laboratory analysis. They reflect no differences in the samples collected.

2.3.1.3 Soils

To support the lichen and plant analysis data, soil sampling was also conducted at all upland sites and sites within the area with blackened vegetation. Samples were taken from various soil layers, as available at each site. At each upland plot, 125 ml samples were collected from each of the top three horizons (as available). As ash (volcanic) was present at most sample sites (80-90%), it was sampled as one of the respective horizons, usually the second or third. In each case, a sample was taken from the soil layer below the ash. Sampling soil stratification by depth allows for further evaluation of the significance of airborne contamination and provides a thorough understanding of natural levels of metals. Soil samples were collected using stainless steel shovels and trowels. The samples were then placed in glass jars provided by the laboratory. Replicate samples were taken for 5-10% of the sites for QA/QC purposes.

Soils may provide a better understanding of natural and mine related metal levels.

In most cases, the soil horizons were as followings: A Horizon: mineral soil above ash layer; B was the ash layer; and C was the mineral soil below the ash layer.

Laboratory analysis was completed on a subset of the soils collected, based on the lichen results. Soils were analyzed from plots showing high metal (lead and arsenic) levels in lichens in the 2005 data, and from plots located within and adjacent to the area of the blackened vegetation along Dome Creek.

2.3.1.4 Wildlife

Tissue from wildlife may indicate if certain contaminants are being transferred to primary and secondary consumers or bio-magnifying in the food chain. While most of the animals hunted by people in the area are big game species, there was significant value in sampling small mammals and birds that spend most, if not all, of their lives within close proximity to the mine site (Figure 1.1). These animals can provide an important indicator of contamination that may be attributed to the mine site itself. Various small mammal and bird species were targeted due to their importance in the food chain (see Table 2.2).

It is important to test animal tissue as contaminants can build up in the food chain (bio-magnification).

Table 2.2. Type of wildlife targeted for this study.

Type of Wildlife	Rationale for analysis
Small Mammals (voles, shrews, squirrels, hares)	An important food source of many other animals, and are likely to spend most of their lives in a small area (i.e.: close to the mine site).
Small Predators (mink, weasels, and marten)	Determine if contaminants are accumulating up the food chain.
Small Game Species (grouse / ptarmigan)	An important food source for larger wildlife as well as people.
Large Game Species	Food source for people.

2.3.1.4.1 Trapping Program

Small mammals were trapped within 500 m of the three main potential sources of aerial contamination (the tailings pond, the mill area, and the pit). Small mammals were also trapped in a control area near Rowlinson Creek, approximately 20 km from the mine site (see Figure 1.1). Generally speaking, small mammals have restricted home ranges, making them good indicators of contamination accumulation. As small mammals must be sacrificed for analysis of contaminants, two lethal sampling approaches were used. Snap traps, pit fall (drowning traps) traps and rabbit snares were set at each sampling site.

Small mammals were trapped from the mine site and from a control area.

In addition, a local trapper was hired to trap bigger small mammals such as weasels, mink and marten.

The snap traps were of various sizes (i.e. normal mouse trap and rat trap size) and were baited with various baits to target a variety of species. The traps were set on the ground and in trees within a variety of habitats. In 2005, these traps caught 27 red-backed voles, a red squirrel, a ground squirrel, and 8 gray jays (*Perisoreus canadensis*; as a by-catch). In 2006, an additional 10 red-backed voles (*Falcipennis canadensis*) were collected from the mine site, along with 11 from the control area. While gray jays were not a targeted species, they may also provide some insight into site contaminants. Gray jays are not migratory and Alexander et al. (2003) documented a 23.2 ha breeding territory in a study conducted in the Kluane Lake area. They are omnivores (eat both plants and animals) and thus may also accumulate contaminants.

Voles, shrews, hares, gray jays, grouse and marten were captured.

Pitfall traps, consisting of a bucket dug into a hole on a natural pathway, were filled with distilled water to target shrews. Five masked shrews (*Sorex cinereus*) were captured in this effort. As well, one shrew was trapped at the control site. Shrews, due to their feeding habitats (insectivores with a very high metabolism), are classified as good indicators for monitoring contaminants in terrestrial environments (Hirvi, Henttonen and Suortti 2005).

One marten was trapped at the mine site in 2006. No mink or weasels were captured despite considerable effort by a local trapper. Three snowshoe hares (*Lepus americanus*) were captured at the mine site and three were captured near the Rowlinson Creek control area in 2006.

Significant effort was also expended to obtain small game species (grouse/ptarmigan). The study team obtained seven spruce grouse (*Dendragapus canadensis*) from the mine site and four from the control area. The grouse were shot using a .22 rifle aimed at the head so as to prevent contamination of the tissues to be analyzed.

Shrews were analyzed as whole animals due to their small size, and the individual kidneys and livers of the ground squirrel, gray jays and red-backed vole were analyzed. As well, kidneys, livers and muscle tissue were analyzed from snowshoe hare, martin and spruce grouse. Spruce grouse gizzards were also analyzed.

2.3.1.4.2 Collection of Samples from Hunters

While it was expected that small mammals would provide the most insight into contamination uptake, significant efforts were expended to obtain porcupines and larger mammals that are consumed by humans to address concerns about potential contamination. Animal parts were obtained from species that were harvested in the area for analysis of metals contamination.

Efforts were made to collect samples from hunters.

Attempts were made to obtain any samples available through the Northern Contaminants Program from organs (kidneys and liver) and tissue turned in to Yukon Environment under the current voluntary programs to collect and analyze ungulate parts (as outlined in the hunting regulations). One sample was submitted to this program from the study area in 2006 and no samples were submitted in 2005. In addition, the contaminants program was able to provide the study team with data from some animals collected in the past and did allow access to additional samples that they had in stock. To inform hunters of the Northern Contaminants Program as well as the Terrestrial Effects study, the study team posted signs on the Mt. Nansen Road. This information was also distributed to the community of Carmacks and advertised in the town newsletter (The Hooter). In 2005, the study team obtained samples from two caribou (2 samples) and one moose (3 samples) through the local community. In addition, one moose (2 samples) and three caribou (7 samples) that were in storage were provided by the Northern Contaminants Program. In 2006, the study team obtained two caribou (2 samples) from sub zones 5-22 and 26 (Mt. Nansen) from hunters and one caribou (3 samples) that was turned in to the Northern Contaminants program.

Samples were obtained from eight caribou and two moose.

Data on concentrations of metals in ungulate (caribou and moose) kidneys, livers and muscle tissue were obtained from samples submitted to the Northern Contaminants Program and to the study team.

2.3.1.5 On-going Aerial Contamination

Moss bags are a standard low-technology method for assessing both dry and wet (i.e., airborne and precipitation-based) deposition of airborne contaminants (Temple *et al.*, 1981). Moss bags were assembled following the protocol outlined by Temple *et al.* (1981). Golden fuzzy fen moss (*Tomenthypnum nitens*) was collected from the Rowlinson Creek area. The moss was sent to Cantest's Laboratories for rinsing, drying, homogenization and analysis of pre-exposure metal concentrations. Moss bags were constructed from polypropylene mesh about 2 mm in size secured with nylon zip ties. Each bag contained approximately 3 g dry weight of moss. Moss bags were hung between tree branches with nylon zip ties on October 13, 2005 around the sources of contamination and at the Rowlinson Creek control site. The Rowlinson Creek site was chosen as a control in this case due to the convenience of its location as well as its certain isolation from any possible contamination from the Mt. Nansen Site. These samples were located northeast of the bridge crossing of Rowlinson Creek and were a minimum of 400 m from the road. Three deployments of moss bags were made, one generally covering the winter months, one covering the spring and early summer, and one from summer to early fall (Table 2.3). Figure 2.5 shows the locations of moss bags deployed around the mine site.

Moss bags were deployed to determine the extent of on-going aerial contamination.

Moss bags are small mesh bags filled with moss collect dust from the air.

Table 2.3. Details regarding moss bag deployments.

General Season	Deployment Date	Removal Date	Number Deployed
Winter	October 12, 2005	May 5, 2006	12
Spring and early summer	May 5, 2006	July 27, 2006	30
Summer and early fall	July 27, 2006	October 17, 2006	30

Figure 2.5. Map of moss bag deployment locations.

2.3.2 Aquatic Effects

The aquatic effects component focused on determining levels of contamination in water, sediments and fish. Generally, efforts were focused on fish and sediments, as they provide the most insight into longer-term effects (i.e., compared to water quality sampling).

The aquatic component focused on sediments and fish and to a lesser extent, water quality.

2.3.2.1 Water Quality

The Yukon Government has conducted comprehensive water quality sampling programs since 1999, when BYG ceased operations at the site. Due to the extensive volume of existing water quality data, additional water quality sampling sites were positioned only in areas where past and present sampling information does not exist. The water sampling component of this study focused on 3 sites on Dome Creek upstream of the tailings pond (D1, D2 and D3; Figure 2.6). Water samples were collected using bottles provided by the laboratory (ALS Environmental), including separate bottles for total metals, dissolved metals, ammonium nitrogen (N), and other parameters. The samples for total metals were preserved using nitric acid, and ammonium N was preserved with a sulphuric acid solution, both provided by the lab.

Yukon Government has been and continues to complete regular water sampling around the mine site.

Additional samples were collected from three sites.

2.3.2.2 Sediments

Sediment sampling was completed in many of the same locations as the Conor Pacific (2000) study, similar to previous water license sampling requirements. Sediments were collected from Victoria and Dome creeks in 2005 and 2006 and in Pony Creek in 2006. Temporal comparisons to past sediment sampling results were thought to provide a good indication of the recent effects of the mine. Samples were collected (with stainless steel trowels) from depositional areas, field sieved through a 1 mm plastic screen and placed in lab-provided sampling jars. Once at the laboratory, the samples were dried and screened though a 100-mesh sieve (as outlined in the water license protocol). The sites sampled are presented in Figure 2.6. Samples were analyzed for metal concentrations using a strong acid leachable test which involves drying the sample at 60ºC and digestion using Aqua regia (a mixture of HCl and HNO_3). This is a very strong acid digestion that will dissolve almost all elements.

Sediment samples were collected from Dome, Pony, Back and Victoria creeks.

In addition, for some samples collected in 2005 and all 2006 samples, a partial digestion analysis was completed to determine the metals that were weakly bound to the sediments. The stream sediments samples were subjected to a partial-digestion extraction consisting of warm (50 ºC) 2M HCl-1% H_2O_2 for three hours with continuous agitation. This partial extraction method releases metals associated with hydrous amorphous iron- and manganese-oxide mineral coatings and colloidal particles. This procedure provides a better indication of which metals are more likely to be released from sediments (i.e. bio available).

2.3.2.3 Fish

Slimy sculpin (*Cottus cognatus*) was chosen as the primary species used to monitor metal concentrations within the aquatic environment in the vicinity of the Mt. Nansen Mine because it is less mobile and less migratory than other fish in the region. Small-bodied fish, such as the slimy sculpin, are generally recommended for use as an indicator species, primarily due to the increased probability of longer exposure times as a result of reduced mobility and their non-migratory nature. Sculpin were collected via electrofishing from a number of sites within and outside the influence of the mine site (Figure 2.6). Other species known to occur in the Victoria Creek watershed (Arctic grayling and burbot) are either highly mobile or migratory or are found in lower densities, all of which makes them poor choices for monitoring metal contamination. As the LSCFN and other local community members do harvest Arctic grayling and burbot, some samples in the areas of greatest concern (Victoria Creek near mouth of Dome Creek) were collected. Due to their small size, whole slimy sculpin were analyzed. For Arctic grayling and burbot, liver, kidney and flesh were analyzed, as available. It should be noted that the lower portion of Dome Creek was also sampled for fish; however, none were captured[1].

Slimy sculpin do not migrate long distances and as such are good indicators of point-source contamination.

Grayling were analyzed to determine the safety of eating these species.

[1] There was a small waterfall at the lower end of Dome Creek that would pose a barrier to fish migration, especially during low flows.

Figure 2.6. Map of Aquatic Sampling Sites.

2.4 Analysis Summary

Table 2.4 shows the number of samples analyzed and the type of laboratory analysis completed.

Rationale, types and numbers of samples analyzed.

Table 2.4. Category, objective and number of samples analyzed.

Category	Objective	Laboratory Analysis Parameters	Number of Samples Analyzed 2005	Number of Samples Analyzed 2006	Total Number
Lichens	To determine the presence and extent of airborne contamination.	Metals ICP-MS[1]	102	27	129
Soils	Assist with determining the presence and extent of airborne contamination. Confirm lichen results and determine natural non-mine related sources.	Metals ICP pH	72	0	72
Berries/Plants	Determine whether or not plants and berries are safe to eat.	Metals ICP-MS	221	29	250
Blackened Vegetation	Determine what impacted the blackened vegetation on bank of Dome Creek.	Metals ICP-MS Cyanides & Nutrients	3	11	14
Soils at Blackened Vegetation site	Determine if whatever impacted the blackened vegetation has also impacted the soils.	Metals ICP-MS & Nutrients	10	22	31
Small Mammals	Investigate extent of metal accumulations in the food chain.	Metals ICP-MS	23[a]	30[a]	53
Birds	Investigate extent of metal accumulations in the food chain.	Metals ICP-MS	6[a]	41	47
Ungulates	Investigate extent of metal accumulations in the food chain.	Metals ICP-MS	14	5	19
Fish	Determine impacts on fish and fish consumption.	Metals ICP-MS	32[a]	29[a]	61
Sediment	Determine if metals are accumulating in sediments.	Metals ICP	40	34	74
Water	Answer specific questions pertaining to point sources (2005) and test tea samples made from vegetation from mine site (2006).	Metals ICP-MS Cyanides Nutrients Conductivity / pH / temperature	3	4[b]	7
Moss Bags	Determine whether or not airborne contamination is on-going	Metals ICP-MS	3	47	50

[1] ICP-MS (Inductively Coupled Plasma Metals Scan) was completed for 33 metals.
[a] Some samples included tissue from more than one individual animal.
[b] Tea samples were analyzed as water samples.

Concentrations (ug/g or ppm) of the following 33 metals were analyzed: Aluminum, Antimony, Arsenic, Barium, Beryllium, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Iron, Lead, Magnesium, Manganese, Mercury, Molybdenum, Nickel, Phosphorous, Potassium, Selenium, Silicon, Silver, Sodium, Strontium, Tellurium, Thallium, Tin, Titanium, Uranium, Vanadium, Zinc.

Samples were analyzed for 33 metals.

As outlined in the previous sections, all samples were collected using appropriate field sampling protocols to prevent contamination. Laboratory analysis for most samples was completed by Cantest Ltd. in Burnaby, BC. To allow for consistency of the current water quality-monitoring program, ALS Environmental, in Vancouver, BC completed the water sample analysis. Norwest Labs, in Surrey, BC completed the majority of the sediment analysis. NLET laboratories, from Burlington, ON completed the ungulate analyses in 2005. Cantest's North Vancouver Lab (formerly Elemental Research) completed the analysis of ungulate samples in 2006. Refer to Appendix C to I for detailed laboratory methods.

Replicate samples for QA/QC were taken at approximately 5 to 10% of the total number of sample sites. Duplicate splits (split of one sample; submitted blind to the lab) samples were submitted for many components. In addition, the three accredited laboratories completed the appropriate internal QA/QC requirements. QA / QC can be defined as Quality Assurance and Quality Control and is conducted by collecting duplicate samples at a number of sampling locations. Essentially, QA / QC confirms the accuracy of sampling and laboratory analysis.

Replicate and duplicate samples were submitted for quality control purposes.

2.5 Data Analysis

Data were compared to previous metal analyses conducted in the Yukon (where available) to provide a spatial context to the results. Further comparison to control site data was concentrated on metals that were above Yukon background levels to provide greater site specific context.

Data were compared to Yukon background data and control sites.

In cases where an extensive amount of data was available covering a large spatial area spatial analysis was completed. Specifically, Kriging analyses complemented by non-linear regressions were used to determine spatial patterns of metal levels in lichens.

For other data where spatial analysis was not relevant, data was compared to controls, as well as to subsets of the data in order to detect any notable patterns in the data. When suitable sample sizes existed, patterns were tested using relevant statistical tests. When the data were normally distributed, significance was tested using a two tailed t-test assuming unequal variances or using ANOVA and Tukey's test for multiple comparisons. When the data were not normally distributed, a One-Way ANOVA on Ranks and Dunn's test for multiple comparisons was used. Test specifics are described in the results section for each medium tested.

3.0 RESULTS

3

The results section is divided into the terrestrial and aquatic ecosystem components.

Some variability was found between samples—likely reflective of natural variation.

Quality control included collection of replicate samples and duplicate splits as well as standardized laboratory QA / QC procedures. The data from the replicate samples (two field samples collected from the same site; Appendix J shows some variability; however, most metals exhibit relative percent difference (RPD) less than 20%. For lichens, there were some results between 20% and 71% (RPD), which was attributed to natural variability between plants. For plants, RPD was generally lower than lichens and generally lower than 50% with the exception of samples collected from the tailings pond. This is likely attributable to the low density of plants within the tailings pond requiring the replicate plant samples to be collected over a spread-out area. Replicates of soils had up to 65% RPD while sediments were below 20% for all metals where the results were greater than 5 times the detection limits.

Data from the duplicates in the lichen appear to be quite close, only two occurrences of metals were above a 20% RPD, and these had RPD of 24%. Difference for duplicate samples of plants were mainly within acceptable standards (Appendix K); with a few samples ranging up to 64% RPD. The exception was the samples of tree sap (PIGL-P1) which had commonly high RPD. It should be noted that the duplicates for plants were not homogenized (i.e. blended) as would be completed in a lab setting.

The duplicate fish data shows some variability for specific elements, specifically aluminum, barium and chromium, iron, manganese and strontium.

Two different labs analyzed duplicate sediment data in 2005. The results indicate that there was some variability especially for certain elements. These include potassium, sodium, strontium and nickel which had common RPD ranging from 20-50%. The results from other elements appear to be more consistent.

Laboratory QA/QC included duplicate splits, the analysis of blanks and duplicate blanks, as well as the analysis of unrelated tissues. The variability between replicate samples can be attributed to natural variability at the sampling sites. In all cases the duplicate split samples, and the duplicate blanks were within limits of 20% RPD and unrelated tissues were within acceptable limits. Laboratory QA/QC results are also presented in Appendices C to I.

3.1 Terrestrial Component

Results from the analysis of lichens, plants, soils, mammals and moss bags are described separately in the following sections.

3.1.1 Lichens

Caribou moss (a lichen) was collected and analyzed from most sites.

The lichen species, caribou moss, was present and thus collected from almost all transect sites, control plots and a few riparian sites. The complete laboratory results from the lichen analysis are presented in Appendix C (including lab QA/QC reports).

Comparing the data from the transect sites to known Yukon background/control sites (Gamberg 2006) and control sites (from this study) suggests that there are several metal levels that may be elevated within lichen tissues (Table 3.1). Arsenic, lead, silver, boron, antimony and uranium were present at levels that were more than 5 times above the highest 'control' levels recorded in the Yukon (Gamberg 2006; this 'control' data does not include data from other disturbed sites in the Yukon). Uranium concentrations were 10 times higher than existing Yukon background data, although such available background data is limited. Some lichen samples exceeded the Yukon background data for cadmium, manganese, copper and zinc concentrations (Gamberg 2006). Of these, cadmium and zinc were highest from the control sites and manganese was only slightly higher in the transect sites than the controls (Table 3.1). Of note, all copper samples above Yukon background were located near the tailing facilities. Similarly, all titanium samples above control levels were located to the west of the tailings pond. To provide some perspective on the numbers in the below table, the primary metal that was elevated at Faro in lichens, lead (747.7 ppm), was found to be as high as 109 times greater than Yukon background levels (inferred from Gartner Lee 2006).

Table 3.1. Lichen metal concentrations (ranges) from Mt. Nansen and other sites within the Yukon (only lists metals that were higher at Mt. Nansen than Yukon background data or control data where no Yukon background data existed).

Metal	Known Yukon Range (Gamberg 2006) (ppm)	2005-06 Mt. Nansen Control Site Ranges (ppm; n=10)	2005-06 Mt. Nansen Transect Ranges (ppm; n=110)	Comments
Arsenic (As)	0.0818 - 2.5539	0.3 – 9.9	0.2 – 36.9	Highest level 14 times higher than highest Yukon level.
Lead (Pb)	0.398 – 6.839	0.3 – 5.1	0.2 – 39.4	Highest level 6 times higher than highest Yukon level.
Silver (Ag)	0.0275 - 0.1781	0.08 – 0.33	0.02 - 3.1	Highest level 17 times higher than highest Yukon data.
Boron (B)[3]	1.1 - 1.8	< 2.0	<0.2 – 18	Highest level 10 times higher than highest Yukon level.
Antimony [3]	0.02 - 0.039 (n=6)	<0.1 – 1.0	<0.1-3.5	Highest level 89 times higher than highest Yukon data; however, Yukon data limited to 6 sites. Highest level 3 times that of control data.
Uranium (U)[3]	0.0039 - 0.0109 (n=12)	<0.04	<0.04 - 0.11	Highest level 10 times higher than highest Yukon level; however, Yukon data limited to 12 sites.
Cadmium (Cd)	0.03 – 0.343	0.2 – 1.66	0.07 – 1.49	Highest level is from a control site.
Manganese (Mn)	19 - 382.5	233 – 512	33.7-555	Transect range slightly higher than control and Yukon data.
Copper (Cu)	0.71 - 7.17	1.2 – 4.3	0.7 - 14.6	4 samples above Yukon background data, all by pond
Zinc (Zn)	8.6 - 94	21.8 – 105	9.3 – 99.1	Highest level is from a control site.
Magnesium (Mg)	106 – 1,434	387 – 1640	179-1,880	Transect range slightly higher than control and Yukon data.
Nickel (Ni)	0.187 - 4.37	0.3 – 1.1	0.2-6.5	Only 1 above Yukon background data.
Mercury (Hg)	NA	<0.01 – 0.017	<0.01 – 0.064	Highest transect site 4 times maximum control.
Tin (Sn)	NA	<0.1 – 0.6	<0.1 – 4.0	Only 5 transect values higher than control sites.
Titanium (Ti)	NA	5.0 – 35.7	2.5 – 97.3	Only four sites higher than controls, all west of pond.

NA: Not Available

Metal levels in lichens were compared to existing Yukon data and control sites to determine which metals required further investigation.

Spatial and statistical analyses were used in combination to test if individual metal levels were elevated adjacent to the three potential sources of contamination. Various statistical tests were attempted; however, non-linear regressions were found to be the most useful. Kriging analysis using Vertical Mapper combined with MapInfo (GIS software) was

Spatial and statistical analyses were performed to determine if there was a pattern of higher metal levels around the potential sources of contamination.

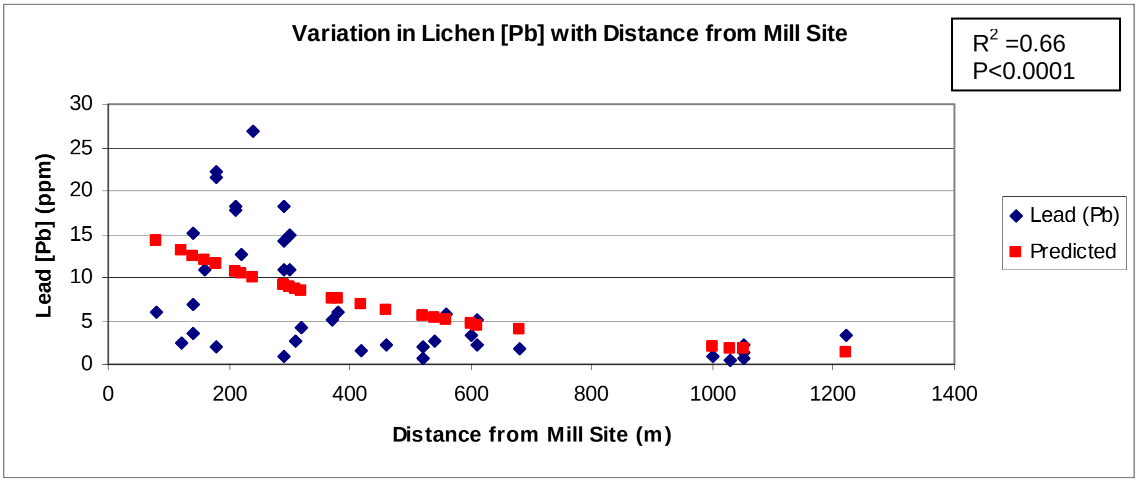
[3] Not that detection limits for these elements were higher than those used for known Yukon background levels.

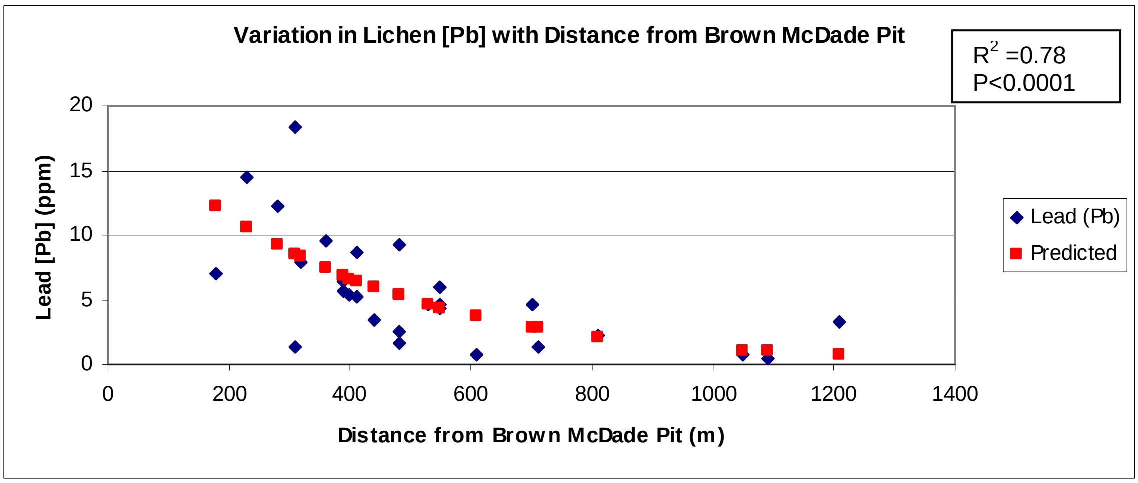
conducted to map noticeable patterns in the data. Kriging is a geostatistical interpolation technique that considers both the distance and the degrees of variation between known data points to estimate values in unknown areas. It provides a means for understanding directional trends in data.

Using non-linear regressions combined with Kriging analysis, clear relationships were found between distance from the sources of contamination and levels of arsenic, lead, copper, silver and antimony. The strongest relationships (with P values <0.05 [95% confidence]) were generally associated with the mill site, followed by the Brown McDade Pit and the tailings pond, respectively. Figures 3.1 – 3.10 show the patterns for the metals showing a significant relationship. Statistical analysis was used to predict metal concentrations from each of the 3 sources of contamination. These predicted values are shown by the red values in figures 3.2 – 3.10. The strength of each of the regression is listed on each figure with R^2 and P-values. Levels of zinc, boron, uranium, manganese, magnesium, cadmium and nickel did not show relevant spatial patterns around the potential sources of contamination. Note that an R^2 value can be defined as a number from 0 to 1 which shows how closely the estimated (i.e.-predicted) values are to the actual values. The predicted values are likely closest to the actual values when the R^2 is at or near 1.

Mapping of the data shows the significant patterns found.

LEAD





Lead levels in lichen were generally higher near the mill site, pit and pond.

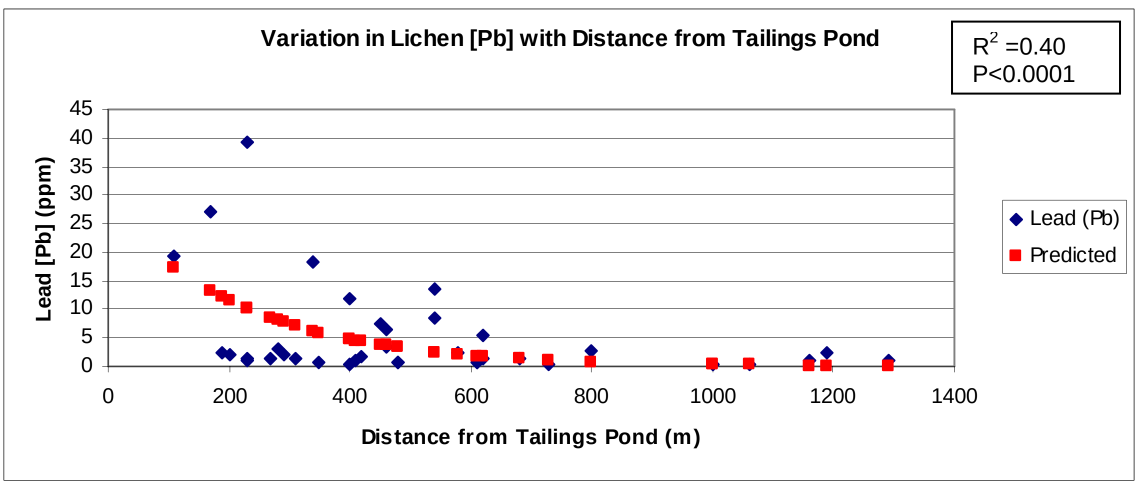
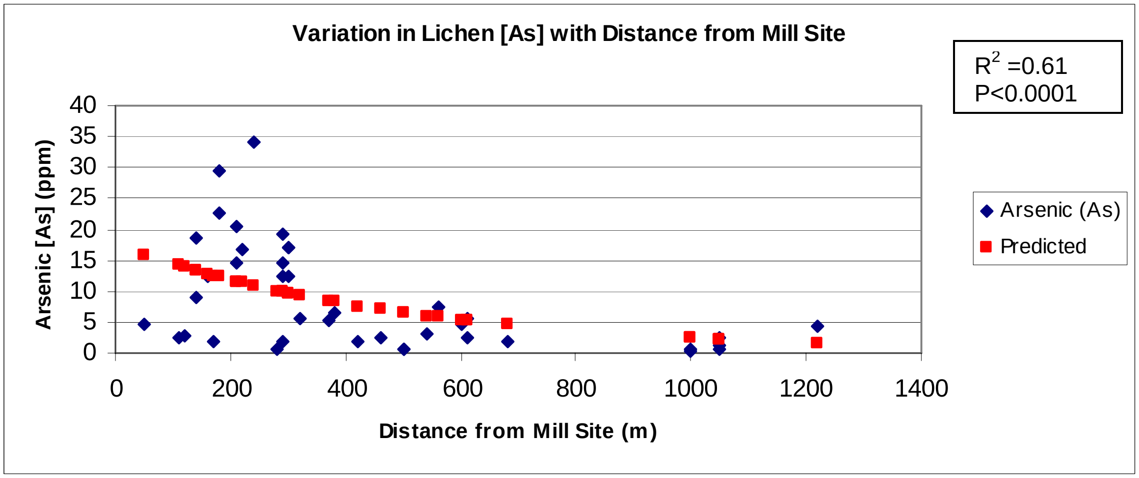
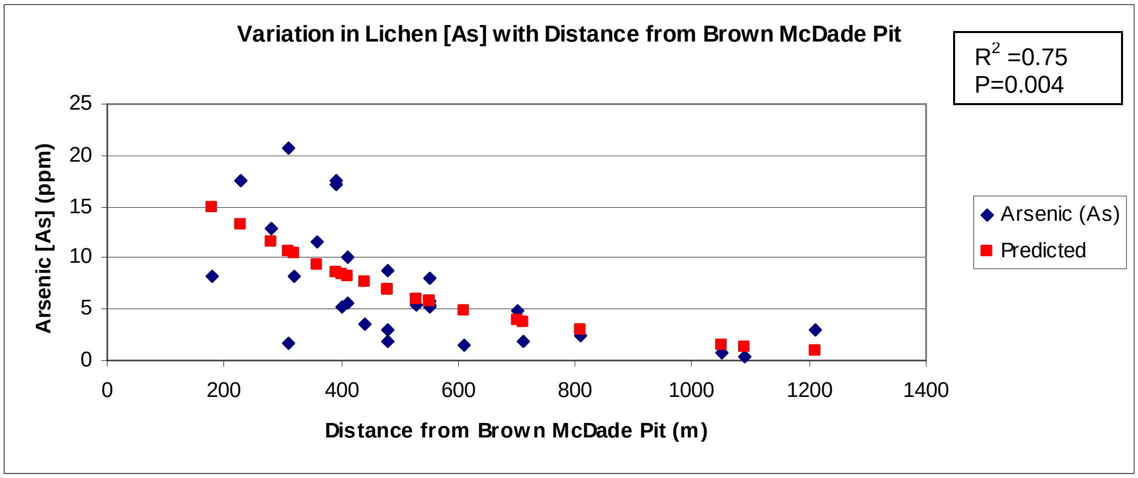


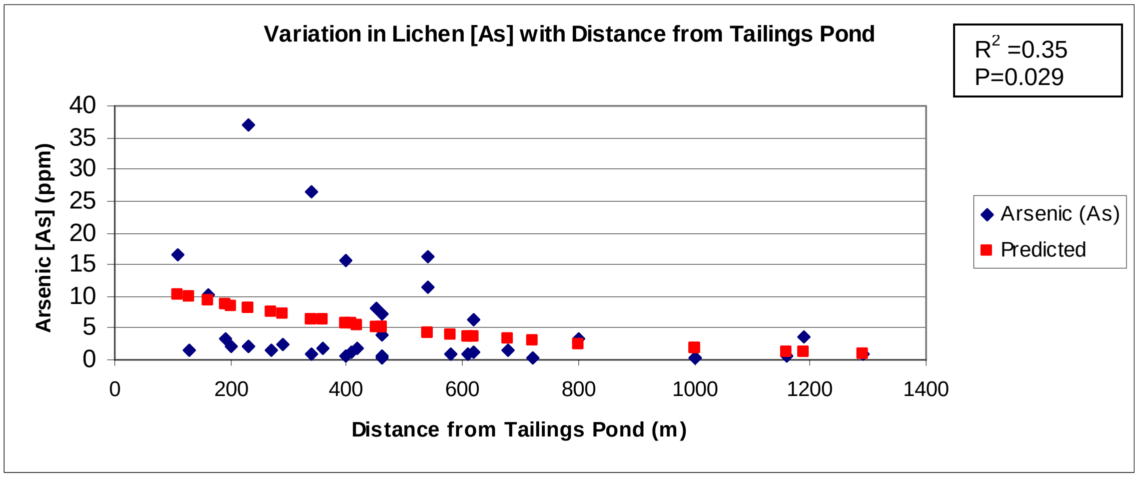
Figure 3.1. Non-linear regressions of lead (Pb) and distance from contamination sources.

Figure 3.2. Map of lead (Pb) concentrations in lichens using the Kriging Analysis.

ARSENIC





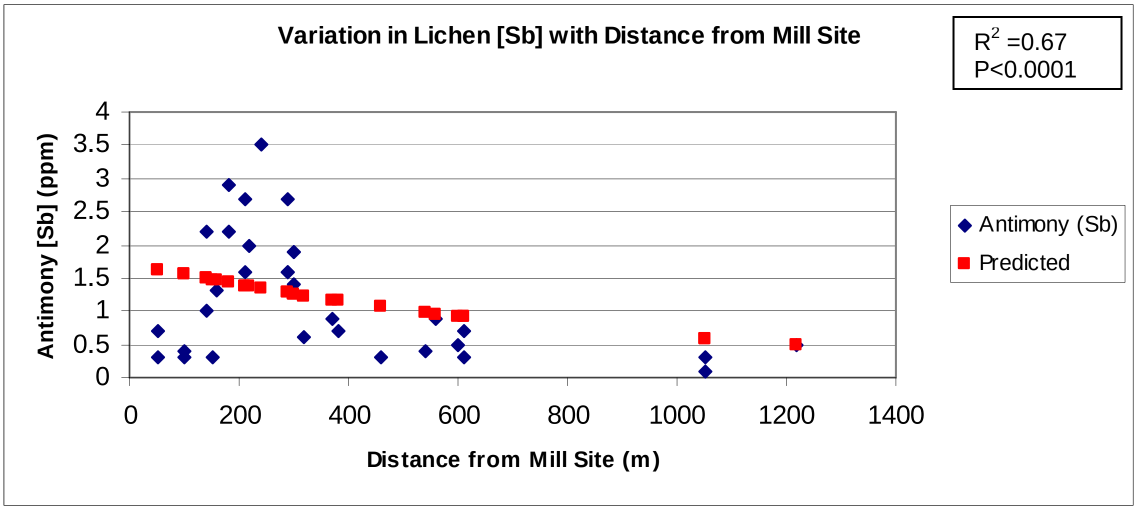


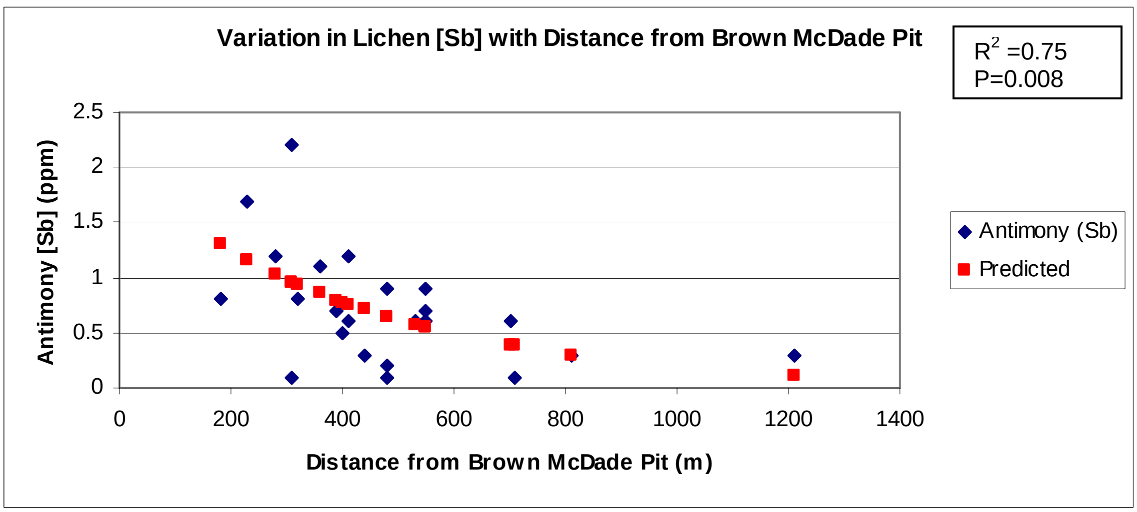
Arsenic levels in lichen were generally higher from locations near the mill site, pit and to a lesser extent, the pond.

Figure 3.3. Non-linear regressions of arsenic (As) and distance from contamination sources.

Figure 3.4. Map of arsenic (As) concentrations in lichens using the Kriging Analysis.

ANTIMONY





The highest antimony levels in lichen were typically found in locations near the mill site, pit and to a lesser extent, the pond.

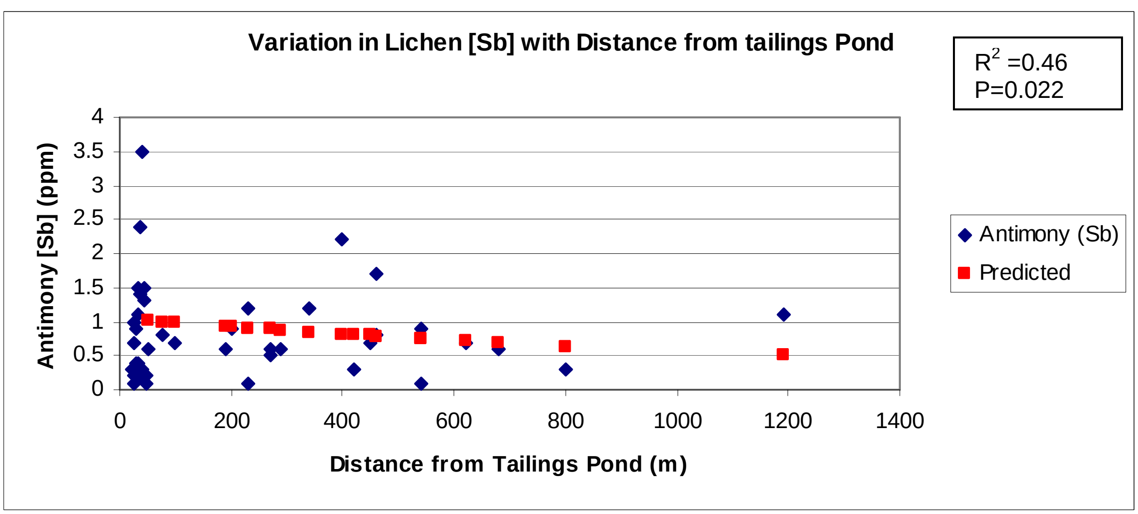
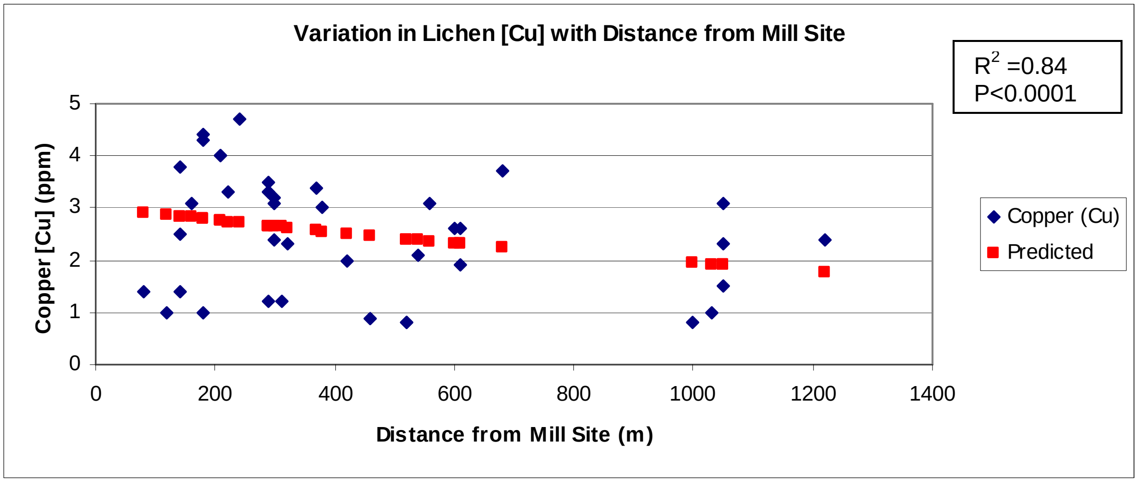
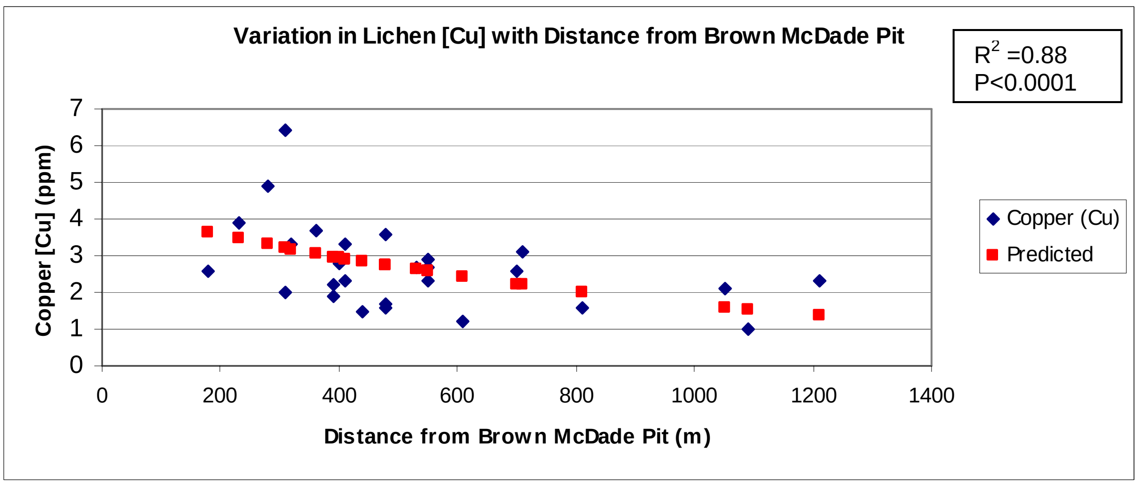


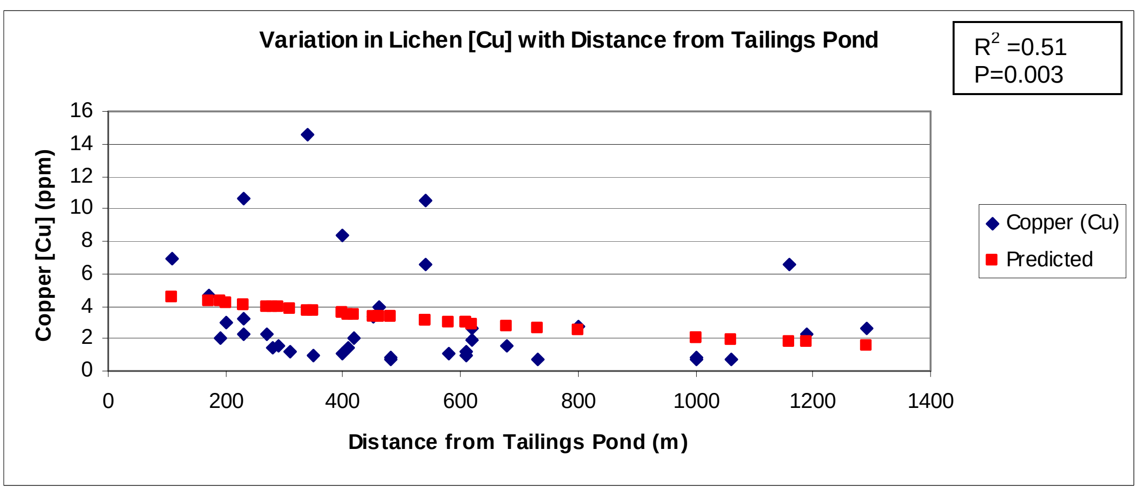
Figure 3.5. Non-linear regressions of antimony (Sb) and distance from contamination sources.

Figure 3.6. Map of antimony (Sb) concentrations in lichens using the Kriging Analysis.

COPPER





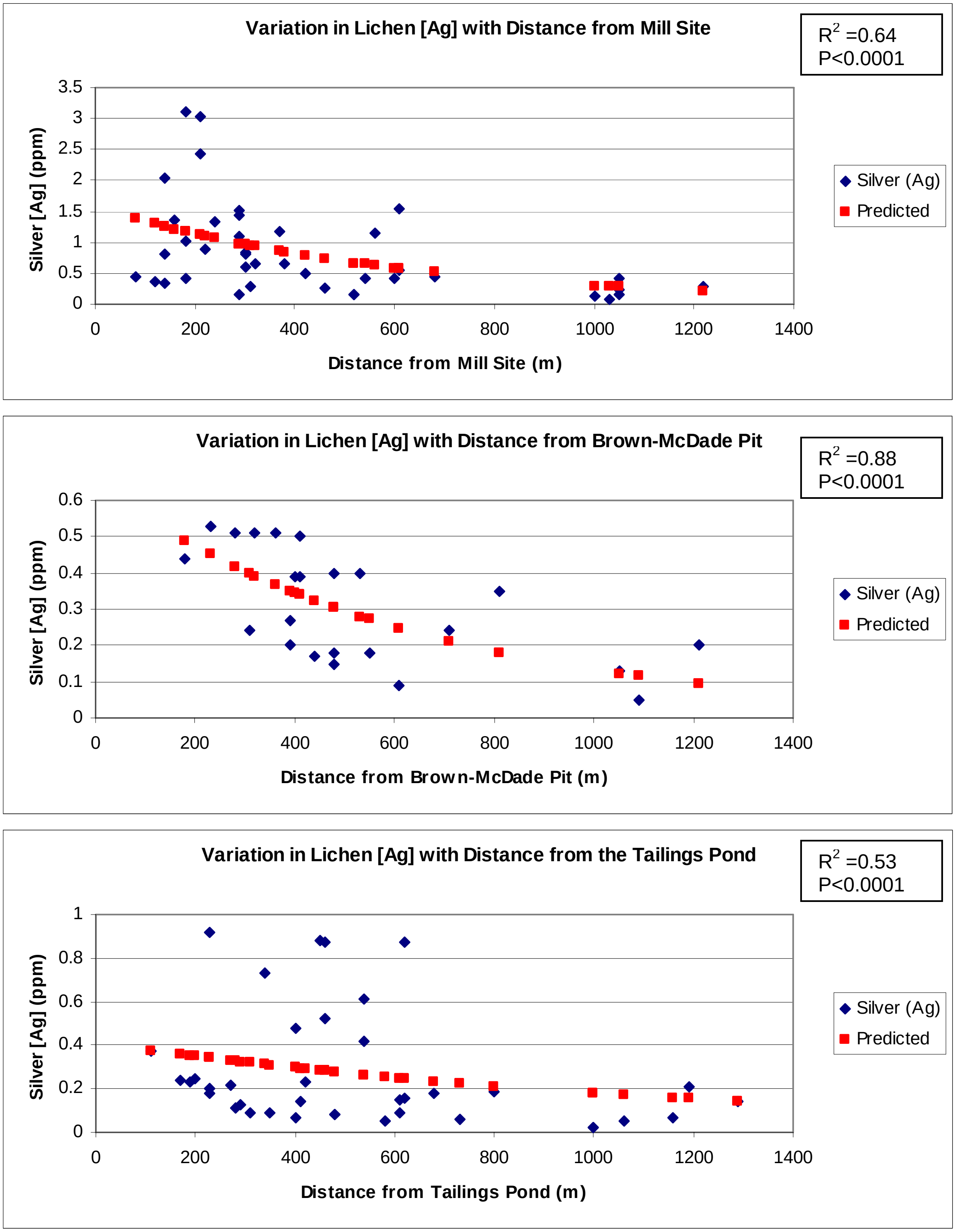


Copper levels in lichen were generally slightly higher in locations near the mill site, pit and the pond.

Figure 3.7. Non-linear regressions of copper (Cu) and distance from contamination sources.

Figure 3.8. Map of copper (Cu) concentrations in lichens using the Kriging Analysis.

SILVER



Silver levels in lichen were typically highest in locations near the mill site, pit and to a lesser extent, the pond.

Figure 3.9 Non-linear regressions of silver (Ag) and distance from contamination sources.

Figure 3.10. Map of silver (Ag) concentrations in lichens using the Kriging Analysis.

Using the Kriging maps, the approximate zones of elevated metal levels in lichen were mapped out (Figure 3.11). These zones were classed as the 'Mill Zone', 'Pit Zone' and the 'Pond Zone'. A comparison of the metal levels of lichens within and outside of these approximate zones of aerial contamination was completed. The mean concentrations of each zone are presented in Table 3.3. As expected, concentrations of the five metals were commonly higher in zones around the sources of contamination compared to the plots outside these zones, including controls. Of interest, mean arsenic, silver and antimony were highest around the 'Mill Zone', while mean copper and lead levels were highest in the 'Pond Zone'.

Table 3.3. Mean values of selected metals in lichens within the predicted zones of aerial contamination in lichens.

Metal	Mean Value				
	Mill Zone (ppm; n=12)	Pit Zone (ppm n=6)	Pond Zone (ppm; n=9)	Transect Plots outside zones (ppm; n=93)	Control Plots (ppm; n=10)
Antimony (Sb)	1.74	1.26	1.32	0.33	0.26
Arsenic (As)	15.6	12.3	13.9	3.38	2.96
Copper (Cu)	3.32	3.87	6.63	1.98	2.49
Lead (Pb)	13.8	10.8	14.2	2.88	1.9
Silver (Ag)	1.43	0.5	0.41	0.34	0.17

When comparing the five metals previously identified as elevated in lichens around the mine site, most statistical comparisons (two tailed t-test assuming unequal variance) between metal levels in the three zones and outside areas were significant, with the exception of copper in the 'Mill Zone' compared to the control samples and silver in the 'Pond Zone' compared to transects (Table 3.4).

Table 3.4. Statistical tests of lichen metal levels that were significant to 95% confidence interval.

Metal	Significance Tests					
	Mill Zone vs Control	Mill Zone vs Transects	Pit Zone vs Control	Pit Zone vs Transects	Pond Zone vs Control	Pond Zone vs Transects
Antimony (Sb)	✓	✓	✓	✓	✓	✓
Arsenic (As)	✓	✓	✓	✓	✓	✓
Copper (Cu)		✓	✓	✓	✓	✓
Lead (Pb)	✓	✓	✓	✓	✓	✓
Silver (Ag)	✓	✓	✓	✓	✓	

Significant tests had p values <0.05, see Appendix L for numbers.

Additional statistics confirm that these metals are often elevated in the predicted zone around mill site, pit and pond.

Figure 3.11. Map of predicted zones of influence (based on Kriging grids of Ag, As, Cu, Pb and Sb).

3.1.2 Plants, fungi, and lichen (other than caribou lichen)

Trace metal concentrations in the plants analyzed as part of this study were compared to background data for plants across the Yukon as well as the control sites. In the analysis of upland plot data, particular emphasis was placed on arsenic, antimony, copper, lead and silver, given the patterns of elevated levels for these metals in lichens around the potential sources of contamination. It should be noted that the background data utilized (Gamberg 2006) has a limited sample size for many of the plant parts analyzed. Some spatial comparison was made between the estimate areas impacted by aerial contamination (as determined by lichen sampling) surrounding the potential sources of contamination (Mill Zone, Pit Zone and Pond Zone refer to Figure 3.11) and the remainder of the terrestrial sampling sites at the mine, as well as the control plots. In addition, samples from potential sources of contamination such as the tailings pond, low grade ore stockpile and waste rock piles were collected and compared to control and transect data. All laboratory results for plants are presented in Appendix C.

Metal levels in plants collected from the study area were evaluated.

3.1.2.1 Berries

Crowberries

Fruit bearing crowberries (*Empetrum nigrum*) were encountered in moderate densities within the study site. A representative number (n=11) of berry samples collected from the terrestrial sites transects were selected for analysis. In addition to these samples, control (n=2), riparian (n=1), replicate (n=1) and duplicate (n=1) samples were analyzed.

The major trace metals of concern (antimony, arsenic, copper, lead and silver) as determined in lichen sampling in this study were not elevated in crowberries when compared to the existing Yukon background data (Gamberg 2006). The results obtained by this study were either below the detection limit or within the range of the background data for the five major elements of concern. Levels of boron, calcium, and manganese were slightly elevated compared to Yukon data; however, this was deemed to be the result of natural conditions (geology and soils) given that many of the higher levels were in areas a significant distance from the mine site (i.e. control sites and at end of transects). The most notable result was found at a riparian site (Pony 3) where tin levels were 1.7 ppm, which is substantially higher than the maximum of 0.14 ppm recorded in the Yukon by Gamberg (2006) and 0.1 ppm found at the control sites (refer to Figure 2.3 for location of Pony 3). The low level of variability in metal concentrations across the landscape did not warrant spatial analysis of this data.

Metal levels in crowberries appeared to be similar to existing Yukon data.

Prickly Rose

Fruit-bearing prickly rose (*Rosa acicularis*) stems were encountered in very low densities within the study site. Two samples made up of several fruits each were collected and analyzed from the terrestrial site transects. In addition, replicate (n=1) and duplicate (n=1) samples were also selected for analysis. Due to the low sample size, no statistical analysis of trace metals was carried out for this species. The results obtained by this

Metal levels in rosehips were compared to background Yukon data.

study were either below the detection limit or within the range of the background data for the five major elements of concern. However, the concentrations of four other metals, calcium, iron, manganese and nickel, were elevated when compared to Yukon background data (Table 3.5). No samples were found at control sites.

Table 3.5. Metal levels in prickly rose fruit for those metals exceeding maximum Yukon background levels (highlighted).

Sample ID[1]	Metal Concentration (ppm)			
	Ca	Fe	Mn	Ni
ROAC-M2-1	14000	63	128	1.5
ROAC-EM3-1B	12000	48	403	0.9
ROAC-EM3-1A	10200	37	365	0.7
ROAC-EM3-2	9940	37	266	0.9
Gamberg (2006) Mean	6501.27	23.36	32.82	0.68
Gamberg (2006) Maximum	9300.00	41.00	64.70	0.98
Gamberg (2006) sample size	11	11	11	8

[1]Sample ID = species code-plot#-sample#.

Blueberry

Fruit bearing blueberries (*Vaccinium uliginosum*) were encountered in low numbers within the study site. A representative number (n=6) of berry samples collected from the terrestrial site transects were chosen for analysis. In addition to these samples, control (n=3) and riparian (n=1) samples were also chosen for analysis. Due to the low number of fruit bearing blueberries at the time of sampling, samples of blueberry leaves as well as leaf / berry composite samples were collected. A low number of composite (n=4) samples were obtained from the transect sites in addition to leaf samples from transect sites (n=5), riparian sites (n=4), control sites (n=1) and a replicate (n=1) sample.

The major trace metals of concern (antimony, copper, lead and silver) in this study were not elevated in comparison to the background data. Due to restrictions with the existing Yukon background data for arsenic, it is not possible to compare the arsenic levels found in blueberries. However, most samples of berries were below the detection limit (0.1 ppm) or slightly above (0.2 ppm). Results for arsenic berries were similar to that found by Nicholson (2002) who found the highest level of arsenic in berries of 0.5 ppm near the old tailings pond by Dome Creek. The composite samples were slightly higher, up to 0.6 ppm and the leaf samples even higher, up to 1.0 ppm. This result is expected, as the leaves would have more opportunity to accumulate metals than would the berries.

Metal levels in blueberries were compared to background Yukon data.

Boron, cadmium and nickel were elevated in comparison to Yukon background data, but of these, only boron and nickel were higher than control sites (Table 3.6). While no spatial analysis was completed, it is apparent that these elevated levels were present throughout the area, including control plots and at the end of a terrestrial transect (A5) far from the potential sources of contamination. It should be noted that an insufficient sample size (in Yukon background data) did not allow for comparison of the metals listed in Table 3.6; however, control site samples were used for comparison with samples from the mine site. Any elements not contained within Table 3.6 were within the normal range for this species when compared to Yukon background data and/or control site concentrations.

Table 3.6. Metal levels in blueberries for sites where at least one metal was above maximum Yukon background levels and control site levels (highlighted).

Sample ID	Plant Part	Metal Concentration (ppm)					
		B	Ni	As	K	Si	Na
VAUL-A5-3	berry	17	0.7	< 0.1	9910	118	6
VAUL-DOMER5-1	berry	25	0.7	< 0.1	7080	97	25
VAUL-F3-1	berry	15	0.7	< 0.1	6140	69	12
VAUL-FG4-1	berry	13	1.2	< 0.1	7950	75	3
VAUL-K3-1	berry	25	0.3	0.2	11500	95	1
VAUL-O1-1	berry	21	0.3	< 0.1	12300	147	3
VAUL-O3-1	berry	17	0.5	< 0.1	8120	63	< 1
Gamberg (2006) Mean	berry	5.4	0.49	NA	NA	NA	NA
Gamberg (2006) Maximum	berry	10.7	0.56	NA	NA	NA	NA
Gamberg (2006) sample size (n)	berry	3	5	0	0	0	0
Control Site Maximum	berry	14	0.7	<0.1	9960	92	9
Control Site Mean (n=3)	berry	10.7	0.53	<0.1	9417	88	4

[1]Sample ID = species code-plot#-sample#.

No patterns of concern were evident in metal levels from blueberries.

Lowbush Cranberry

Fruit bearing lowbush cranberry (*Vaccinium vitis-idaea*) was found throughout the study area and was the most common berry sampled. A representative number (n=28) of berry samples collected from the terrestrial sites transects were chosen for analysis. In addition to these samples, control (n=4), riparian (n=4), replicate (n=1) and duplicate (n=1) samples were also chosen for analysis.

Of the major trace metals of concern (antimony, arsenic, copper, lead and silver) in this study, arsenic was the only element that was above the detection limit (0.1 ppm). This indicates that very low concentrations of most metals were found in lowbush cranberry fruit. Three of the terrestrial transect sites and one of the riparian sites had arsenic concentrations of 0.2 ppm and 0.3 ppm, respectively. A number of other elements were commonly higher than Yukon background data and control data (Table 3.7). Again, the distribution of these somewhat higher levels appears to be random, given that many of the plots that are located a considerable distance from the sources of contamination (I4, D3) showed similar numbers. It should be noted that an insufficient sample size in the background data did not allow for comparison of a number of metals; however, data obtained from the control sites were used as a basis for comparison of these metals. Any elements not presented within Table 3.7 are within the normal range for this species according to Yukon background and/or control plot data.

Table 3.7. Metals in lowbush cranberries showing concentrations above maximum Yukon background and control plot values (highlighted).

Sample ID[1]	Metal Concentration (ppm)														
	Al	As	B	Ca	Co	Fe	K	Mg	Mn	Na	Si	Sn	Sr	Ti	V
VAVI-C1-1	43.5	0.2	9	1750	<0.1	66	8290	641	647	2	123	<0.1	1.5	1.9	0.6
VAVI-C2-1	19.5	<0.1	9	1580	<0.1	18	7580	614	251	2	112	0.2	1.93	0.7	<0.5
VAVI-D2-1	19.5	<0.1	15	1390	<0.1	18	7940	621	361	3	126	<0.1	2.12	0.7	< 0.5
VAVI-D3-1	7.6	<0.1	16	3000	<0.1	19	8230	793	166	1	120	<0.1	7.09	0.8	< 0.5
VAVI-D3-2	6.5	<0.1	18	3270	<0.1	23	9930	968	170	3	130	<0.1	8.45	0.9	< 0.5
VAVI-DOME3-1	18.4	0.3	16	1620	0.2	42	7730	619	92.7	58	128	<0.1	4.84	1.2	< 0.5
VAVI-DOME5-1	11.4	<0.1	12	1420	<0.1	22	8260	730	246	44	113	<0.1	2.14	0.8	< 0.5
VAVI-F1-1	44.8	<0.1	5	896	<0.1	22	6660	492	444	1	106	<0.1	1.78	1	< 0.5
VAVI-F2-1	31.4	<0.1	5	1110	<0.1	13	5530	577	193	3	100	<0.1	2.22	0.5	< 0.5
VAVI-G1-1	15.4	0.2	37	1950	<0.1	19	7100	618	431	11	97	<0.1	2.24	0.8	< 0.5
VAVI-H1-1	14.3	0.2	8	1310	<0.1	17	6210	510	385	2	87	<0.1	1.54	0.7	< 0.5
VAVI-H2-1	14.3	<0.1	8	1880	<0.1	25	8280	633	646	2	113	<0.1	1.32	1	< 0.5
VAVI-H3-1	19.8	<0.1	11	1060	<0.1	11	5980	567	402	6	100	<0.1	0.91	0.4	< 0.5
VAVI-I1-1	16.5	0.1	10	2130	<0.1	25	7840	571	611	7	112	<0.1	2.21	0.9	< 0.5
VAVI-I4-1	20.9	<0.1	10	1690	<0.1	19	7510	565	478	<1	97	<0.1	1.64	0.9	< 0.5
VAVI-K4-1	18	0.2	9	1710	<0.1	25	7890	590	124	1	129	<0.1	2.39	0.8	< 0.5
VAVI-M1-1	13.1	0.2	8	987	<0.1	17	6440	542	193	1	69	<0.1	1.5	0.6	< 0.5
VAVI-N1-1	14.3	<0.1	19	1810	<0.1	15	7660	705	250	3	108	<0.1	2.32	0.6	< 0.5
VAVI-N4-1	15.8	<0.1	14	1840	<0.1	21	8360	606	534	<1	99	<0.1	1.88	0.8	< 0.5
VAVI-O1-1	7.5	<0.1	16	1760	<0.1	21	8990	646	405	1	98	<0.1	2.26	0.8	< 0.5
VAVI-O2-1	4.3	<0.1	20	2340	<0.1	21	7880	657	259	<1	110	<0.1	3.65	0.8	< 0.5
VAVI-PONY3-1	16.8	<0.1	11	1720	<0.1	16	8000	692	475	2	96	<0.1	2.52	0.6	< 0.5
VAVI-R1-1	21.3	0.1	7	1140	<0.1	12	5990	546	270	4	121	<0.1	1.67	0.5	< 0.5
Gamberg (2006) Mean	15.09	NA	5.4	1065	0.03	22.6	NA	553	180	NA	NA	0.02	2.6	NA	0.16
Gamberg (2006) Maximum	30.8	NA	9.1	2341	0.03	39	NA	862	359	NA	NA	0.03	5.7	NA	0.25
Gamberg - Sample size	10	0	5	10	1	8	0	10	10	0	0	2	10	0	4
Control Plot Maximum	24.2	<0.1	12	2160	<0.1	23	9390	815	457	5	127	<0.1	4.35	1.1	< 0.5
Control Plot Mean (n=4)	19.6	<0.1	9	1772	<0.1	19	8445	729	303	3	115	<0.1	3.35	0.9	< 0.5

[1]Sample ID = species code-plot#-sample#.

A few metals in lowbush cranberries were slightly higher than controls. No notable pattern with distance from the mine site was detected.

Given the low level of variability (levels mainly below detection limits) in concentrations of the five elements of concern across the landscape, no spatial analysis was conducted.

3.1.2.2 Shrubs

A high number of shrubs (Labrador tea and willow) were collected throughout the study area. In order to assess whether or not the concentration of the five major elements (antimony, arsenic, copper, lead and silver) varied across the landscape, statistical analysis was carried out based on the 'zones' of aerial contamination as determined by the lichen results (refer to Figure 3.11). Sample sites were grouped into categories for each potential area of contamination ('Mill Zone', 'Pit Zone' and 'Pond Zone'). Results from each area were compared to controls and transect sites outside of areas thought to be contaminated (as determined by the lichen results). Results from riparian sampling sites and disturbed areas (tailings pond, waste rock dump and pit area) were grouped separately and compared to control and transect sites. T-tests (two-tailed assuming unequal variances) were performed to compare mean metal concentrations in the three potential areas of contamination ('Mill Zone', 'Pit Zone' and 'Pond Zone') and the above-mentioned riparian sampling sites and disturbed areas. Refer to Appendix L for the full statistical output of the t-tests (two-sample assuming unequal variances, $\alpha = 0.05$) performed on shrub data.

Labrador Tea

Labrador tea (*Ledum groenlandicum / L. palustre*) was a very common plant within the study area where it was encountered at nearly all samples plots with the exception of some of the riparian, low-grade ore and waste rock sites. A representative number (n=34) of leaf samples collected from the terrestrial site transects were analyzed for metals. In addition to these samples, control (n=8), riparian (n=6), road influence (dust; n=2), duplicate (n=2) and replicate (n=1) samples were analyzed.

Pre-existing Yukon background data for Labrador tea was available for stems and flowers; however, this study focused on the leaves as these are often consumed by humans. As such, values obtained in this study were compared solely to control plot values. Several elements, particularly arsenic, were commonly higher at road, riparian and transect sites than control values. Labrador tea at the Pony 3 site had fourteen metals that were above levels found at the control plots. Pony 3 is the upstream most site on Pony Creek downstream of the waste rock and may be influenced by water quality in Pony Creek. Table 3.8 presents the data for all elements that appeared elevated when compared to control site data; any elements not presented were within the normal range for this species.

Labrador tea from riparian and dust sites (near roads) generally had more metals above the control levels.

Table 3.8. Metals in Labrador tea leaves above maximum control plot values (highlighted).

Sample ID[1]	Metal Concentration (ppm)																					
	Al	Sb	As	Ba	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Ag	Na	Sr	Ti	V	Zn
LELA-PONY3-1	72	1.4	12.5	41	25	0.3	8670	< 0.1	< 0.1	5.1	509	5.2	1850	318	< 0.1	0.3	0.15	13	23	2.7	< 0.5	71.5
LELA-DOMER7-1	21	< 0.1	0.5	3.6	15	1.4	10900	< 0.1	0.9	4.7	101	0.3	3660	606	< 0.1	0.6	0.01	23	19	1.7	< 0.5	202
LELA-DUST1-1	67	< 0.1	0.7	86	24	0.1	6460	< 0.1	< 0.1	3	144	0.3	1200	781	0.1	0.4	0.01	2	13	5.8	< 0.5	30.6
LELA-DUST3-1	92	< 0.1	0.8	104	34	0.1	8520	0.4	< 0.1	3	228	0.3	1670	1240	< 0.1	0.4	< 0.01	2	10	3.7	0.6	37.6
LELA-DOMER7-1B	16	0.1	1.7	34	34	< 0.02	7290	0.1	< 0.1	3.2	106	0.9	2040	83.1	< 0.1	0.2	0.01	7	13	1.4	< 0.5	35.1
LELA-DOMER7-1A	17	0.1	1.7	38	40	0.1	8970	< 0.1	< 0.1	3.3	122	0.7	2360	107	< 0.1	0.3	0.02	6	13	1.8	< 0.5	30.2
LELA-PONY2-1	12	< 0.1	0.3	34	25	0.1	5850	< 0.1	< 0.1	3.8	49	< 0.1	1240	48.4	< 0.1	0.1	0.01	14	13	1.2	< 0.5	39.5
LELA-DOMER6-1	40	< 0.1	0.7	55	39	0.1	9280	< 0.1	< 0.1	2.3	115	0.5	2340	604	< 0.1	0.2	< 0.01	5	15	1.3	< 0.5	29.8
LELA-H2-1	18	< 0.1	0.5	87	18	0.1	5510	0.2	< 0.1	4.5	53	0.2	1320	1760	0.1	0.2	< 0.01	4	6	1	< 0.5	44.3
LELA-P3-1	28	< 0.1	0.2	78	20	0.1	8070	< 0.1	< 0.1	3.2	79	0.1	1100	1740	< 0.1	0.1	0.01	5	12	2.2	< 0.5	31
LELA-G2-1	12	< 0.1	0.3	81	25	0	6170	< 0.1	< 0.1	2.6	38	0.2	1380	688	< 0.1	0.3	< 0.01	15	11	0.8	< 0.5	28.7
LELA-B1-1	35	0.3	4.1	64	10	0	4250	< 0.1	< 0.1	3.8	87	3.8	784	1420	< 0.1	0.4	0.06	7	5.7	0.8	< 0.5	22.4
LELA-G1-1	16	< 0.1	0.6	56	49	0.1	8390	< 0.1	< 0.1	3.4	67	0.3	1340	1310	< 0.1	0.2	0.02	4	7.5	1.6	< 0.5	32.6
LELA-H3-1	24	< 0.1	0.2	60	11	0	5240	0.3	< 0.1	4.1	42	0.1	1020	2080	< 0.1	0.3	< 0.01	9	4.5	0.8	< 0.5	31.3
LELA-PONY2-2	10	< 0.1	0.3	37	18	0.1	6140	< 0.1	< 0.1	3.9	48	0.1	1350	39.6	< 0.1	0.1	0.01	< 1	14	1.1	< 0.5	41.6
LELA-R3-1	43	< 0.1	1.4	75	15	< 0.02	5880	< 0.1	< 0.1	2.5	87	0.5	1330	1660	< 0.1	0.3	< 0.01	4	8.1	1.2	< 0.5	36.2
LELA-I3-1	14	< 0.1	0.5	47	23	< 0.02	5230	< 0.1	< 0.1	4.1	51	0.3	899	1360	< 0.1	0.2	< 0.01	5	7.8	0.8	< 0.5	35.3
LELA-K2-1	14	< 0.1	0.6	74	31	< 0.02	5760	< 0.1	< 0.1	3.6	55	0.5	981	481	< 0.1	0.3	0.01	10	8	1.1	< 0.5	30.5
LELA-J1-1	20	0.1	1.1	51	9	0.2	7900	< 0.1	< 0.1	3.8	83	0.9	1240	862	< 0.1	0.2	0.02	30	9.2	1.8	< 0.5	29.6
LELA-O2-1	12	< 0.1	0.1	86	25	0.1	8340	< 0.1	< 0.1	3.2	58	< 0.1	1280	942	< 0.1	0.1	< 0.01	1	8.6	1.4	< 0.5	28.2
LELA-J2-1	25	0.1	0.7	54	24	< 0.02	5970	< 0.1	< 0.1	3.3	59	0.6	1190	603	< 0.1	0.3	0.01	1	9.2	1.4	< 0.5	20.8
LELA-K4-1	14	< 0.1	0.2	68	16	< 0.02	6070	< 0.1	< 0.1	4.1	54	< 0.1	1240	276	< 0.1	0.7	< 0.01	2	7.2	1.2	< 0.5	29.4
LELA-I1-1	17	< 0.1	0.6	47	24	0	6950	< 0.1	< 0.1	3.9	64	0.3	1060	1200	< 0.1	0.1	0.01	5	7.1	1.7	< 0.5	29.3
LELA-D4-1	28	< 0.1	< 0.1	65	15	< 0.02	5080	< 0.1	< 0.1	2.6	54	< 0.1	1270	644	0.3	0.3	< 0.01	13	9.3	1.1	< 0.5	27.8
LELA-P2-1	25	< 0.1	0.3	38	19	0.1	5920	< 0.1	< 0.1	3.2	69	0.2	1370	572	< 0.1	0.3	< 0.01	2	9.5	1.8	< 0.5	26.1
LELA-J3-1	11	< 0.1	0.7	48	20	< 0.02	8640	< 0.1	< 0.1	3	61	0.4	1630	741	< 0.1	0.1	0.01	2	9.3	1.4	< 0.5	25.4
LELA-C2-1	29	< 0.1	0.4	77	8	0.1	4920	0.1	< 0.1	3.7	44	0.4	847	1170	< 0.1	0.4	< 0.01	4	7	0.9	< 0.5	23.4
LELA-C1-1	52	< 0.1	0.8	70	14	0.1	7540	< 0.1	< 0.1	3.9	68	0.7	1060	2540	< 0.1	0.4	0.01	3	4.6	1.4	< 0.5	21.9
LELA-A2-1	36	< 0.1	< 0.1	60	7	< 0.02	5360	0.4	< 0.1	3.2	84	< 0.1	946	1550	0.2	0.3	< 0.01	4	5	1	< 0.5	18.4
LELA-A1-1	48	< 0.1	< 0.1	66	12	0.1	5640	< 0.1	< 0.1	2.4	45	0.1	1060	921	0.3	0.3	< 0.01	8	7.8	1.3	< 0.5	15.3
LELA-Q4-1	20	< 0.1	< 0.1	66	11	< 0.02	5300	< 0.1	< 0.1	3.6	38	< 0.1	1030	775	< 0.1	0.2	< 0.01	< 1	14	0.8	< 0.5	34
LELA-N1-1	24	< 0.1	0.4	45	30	< 0.02	6050	0.1	< 0.1	2.7	55	0.3	991	558	< 0.1	0.2	0.01	5	8.3	1.2	< 0.5	33.1
LELA-CP7-4	50	< 0.1	0.1	75	10	< 0.02	5790	< 0.1	< 0.1	3.2	64	< 0.1	1550	1250	0.1	0.3	< 0.01	4	7	1.4	< 0.5	31.7
LELA-P1-1	15	< 0.1	0.4	47	18	0.1	7280	< 0.1	< 0.1	3	64	0.2	1180	985	< 0.1	0.1	0.01	4	12	1.4	< 0.5	27
LELA-H5-1	7.9	< 0.1	< 0.1	57	19	0.1	6000	< 0.1	< 0.1	3.6	42	< 0.1	942	733	0.2	0.2	< 0.01	3	8.8	1.1	< 0.5	26.4
LELA-H4-1	44	< 0.1	0.1	43	12	0	4640	< 0.1	< 0.1	2.5	42	< 0.1	875	1070	< 0.1	0.2	< 0.01	6	6	0.9	< 0.5	25.4
LELA-I2-1	17	< 0.1	0.2	46	21	0	6370	< 0.1	< 0.1	3.4	55	< 0.1	1080	1330	< 0.1	0.2	< 0.01	2	6.4	1.3	< 0.5	24.5
LELA-H1-1	25	< 0.1	0.5	55	16	0	6400	< 0.1	< 0.1	4.5	55	0.2	1180	1200	< 0.1	0.4	< 0.01	3	6.1	1.4	< 0.5	24.4
LELA-O1-1	11	< 0.1	0.1	55	21	0	6740	< 0.1	< 0.1	3.1	105	< 0.1	1210	618	< 0.1	0.1	< 0.01	1	11	1.6	< 0.5	23.6
Average 05&06 control	38	< 0.1	< 0.1	60	15	<0.03	5944	< 0.1	< 0.1	3.5	60.7	< 0.154	1352	1240	< 0.1	0.3	<0.01	2.9	7.7	1.5	< 0.5	27.2
Maximum 05&06 control	59	< 0.1	0.1	75	21	0.1	7580	0.2	< 0.1	5.1	87	0.8	1690	2070	< 0.1	0.5	0.01	5	11	2.1	< 0.5	34.4

[1]Sample ID = species code-plot#-sample#.

In order to determine the spatial distribution of elevated levels of the five elements of concern, a series of t-tests (two tailed, assuming unequal variance) were conducted and are summarized in Table 3.9. The detailed results of the t-tests performed can be found in Appendix L.

Labrador tea leaves at Pony3 had several metals above control values. At many sites arsenic was higher than control sites.

Table 3.9. Summary of t-tests performed on Labrador tea for the five major elements.

		Antimony	Arsenic	Copper	Lead	Silver
Mean Value	Mill Zone (n=9)	0.061	0.522	3.722	0.317	0.009
	Pit Zone (n=4)	0.050	0.225	3.125	0.125	0.006
	Pond Zone (n=3)	0.050	0.433	3.567	0.400	0.007
	Road/Dust (n=2)	0.050	0.750	3.000	0.300	0.008
	Riparian (n=8)	0.231	2.325	3.675	0.633	0.028
	Control (n=10)	0.050	0.065	3.530	0.130	0.006
	Mill, Pit and Pond Zone (n=16)	0.056	0.431	3.544	0.284	0.008
	Transects (n=18)	0.064	0.481	3.283	0.361	0.009
Mill, Pit and Pond Zone vs Control			✓			
Mill, Pit and Pond Zone vs Transects						
Mill Zone vs Control			✓			
Mill Zone vs Transects						
Pit Zone vs Control						
Pit Zone vs Transects						
Pond Zone vs Control						
Road vs Control			✓			
Pond Zone vs Transects						
Riparian vs Control						
Riparian vs Transects						

Transects = plots along transects, outside of Mill, Pit, Pond Zone. / Significant tests had p values <0.05, see Appendix L or numbers.

Arsenic levels were commonly higher around sources of contamination.

Differences between the "Mill, Pit and Pond Zone", 'Mill Zone' and road samples were significant when compared to control samples for arsenic. These patterns (expect the road samples) are similar to the aerial contamination found in the lichens. Other patterns found in lichen data were not apparent in Labrador Tea. It should be noted that the highest concentrations of both arsenic and antimony were observed at the riparian Pony 3 site downstream of the Pony adit and waste rock pile. Results also indicate that concentrations of lead (5.2 ppm), silver (0.15 ppm), iron (509 ppm) and strontium (23 ppm) in Labrador tea were highest at the Pony 3 site. Levels of arsenic, antimony and lead are also noteworthy when looking at riparian sites (Pony and Dome).

Willow

Willow (*Salix spp.*) is a very common plant within the study area and was encountered often along transects, riparian sites and disturbed areas. A representative number (n=31) of branch samples collected from the terrestrial site transects were chosen for analysis. The samples collected were a mixture of new growth and leaves, as these are eaten by both humans and animals. In addition to these samples, control (n=11), riparian (n=9), Pit waste rock (WROCK; n=1), mill low-grade ore (MWR; n=4), Pony waste rock (PWR; n=4), Tailings pond (TAIL; n=2) duplicate (n=1) and replicate (n=1) samples were also chosen for analysis.

The highest metals in willow were associated with samples collected at the low grade ore stockpile and the tailings pond.

A number of metals found in willow, including antimony, arsenic, lead and silver, had elevated metal levels in comparison to Yukon background and control plot data for this species. One sample of willow had seventeen metals exceeding control plot levels in the Low Grade Ore stockpile (MRW) site located adjacent to the mill site. Refer to Table

3.10 to see all elements elevated above control plots levels. It should also be noted that a number of metals had insufficient sample sizes in Yukon background data and were compared solely to control site values.

Table 3.10 Metals in willow shoots above maximum control plot levels (highlighted).

Sample ID[1]	Metal Concentration (ppm)																				
	Al	Sb	As	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mo	K	Si	Ag	Na	Tl	Sn	Ti	V	Zn
SASP-MWR-2	532	5.9	70	12	31.1	18400	2.1	1	10.9	2300	68.8	8850	0.5	9160	473	0.84	6	0.11	0.2	24.1	3	1090
SASP-MWR-3	382	6.4	141	7	4.64	8380	1.5	0.7	8.9	1590	39.3	2150	0.2	11300	281	0.65	4	0.04	0.1	22.2	2.4	272
SASP-MWR-4	77.2	1.3	10.4	11	14.3	15800	0.2	0.3	5.9	418	10.8	4170	0.2	12600	166	0.17	9	0.04	0.2	6.2	0.6	530
SASP-MWR-1	51.8	0.4	3.5	15	19.6	14000	0.4	0.4	5	276	3.7	2800	0.2	12400	200	0.06	6	0.02	< 0.1	3.2	< 0.5	577
SASP-TAIL-2	19.9	0.7	8.3	79	23.7	23200	< 0.1	2	11.2	223	6.3	1880	0.9	11600	97	0.08	5	< 0.02	< 0.1	2.3	< 0.5	372
SASP-L1-1	10.1	0.9	0.7	92	55	12400	< 0.1	< 0.1	6.6	64	0.4	4730	0.2	3110	74	0.02	35	0.03	< 0.1	1	< 0.5	1480
SASP-L2-1	30.2	0.3	3	36	7.21	22700	< 0.1	0.8	3.6	203	1.5	5030	0.3	9190	95	0.05	94	0.02	< 0.1	2.1	< 0.5	633
SASP-PWR-2	56.7	0.7	5.3	27	39.1	8950	0.2	0.3	10.4	276	4.6	6330	0.1	7630	149	0.11	7	< 0.02	< 0.1	2.5	< 0.5	1220
SASP-B1-1	102	0.6	4.7	8	0.81	8250	0.5	1	5.5	209	5.9	2870	< 0.1	6110	166	0.11	13	< 0.02	< 0.1	1.8	< 0.5	147
SASP-PIT1-1	25.4	< 0.1	2.1	21	29.8	14700	0.2	0.8	6.3	147	1.5	3270	0.3	12100	96	0.02	7	< 0.02	< 0.1	1.9	< 0.5	726
SASP-PWR-3	24.5	< 0.1	0.5	28	9.72	6300	< 0.1	1.7	5.8	113	3.4	3420	0.2	8290	110	0.01	8	< 0.02	< 0.1	2.2	< 0.5	502
SASP-DOME1-1	12.6	< 0.1	0.7	46	7.54	14700	< 0.1	0.7	4.6	94	< 0.1	3390	0.5	7050	76	0.01	46	< 0.02	< 0.1	2.3	< 0.5	763
SASP-K1-1	18.8	0.2	1.5	27	5.81	10200	< 0.1	0.3	3.5	91	1.5	2530	0.2	3920	79	0.05	8	< 0.02	< 0.1	1.4	< 0.5	571
SASP-Q1-1	60.4	0.1	2.2	5	3.02	9500	0.4	0.9	3.5	215	1.3	2480	0.1	7430	75	0.02	40	< 0.02	< 0.1	2.9	< 0.5	153
SASP-R2-1	66.2	0.1	2.3	11	9.19	14100	0.2	1.4	4.9	206	1.4	3480	0.2	7160	108	0.02	7	< 0.02	< 0.1	2.6	< 0.5	285
SASP-R3-1	51	0.1	3.5	4	3.87	14700	0.3	0.4	3.2	251	1.2	4370	0.4	7210	85	0.01	41	< 0.02	< 0.1	3.7	0.6	195
SASP-TAIL-1	48.5	0.5	4.5	11	12.2	18700	< 0.1	1.2	4.5	153	6	2480	0.5	7410	74	0.09	4	< 0.02	< 0.1	1	< 0.5	486
SASP-C1-1	81.7	0.1	1.4	10	2.72	17700	< 0.1	1.5	4.3	190	1	3700	0.6	11400	97	0.02	5	< 0.02	< 0.1	2.7	< 0.5	154
SASP-C2-1	38.5	< 0.1	0.5	7	1.46	14100	< 0.1	1.1	4.8	104	0.4	3730	0.2	8260	107	< 0.01	40	< 0.02	< 0.1	1.1	< 0.5	121
SASP-DOME3-1	12.4	< 0.1	0.4	46	1.95	13100	< 0.1	0.8	3.6	96	< 0.1	3980	0.6	6320	72	< 0.01	155	< 0.02	< 0.1	1.7	< 0.5	399
SASP-J1-1	17.5	0.2	1.4	4	5.15	18100	< 0.1	0.4	3.6	140	1	2470	0.2	9270	86	0.03	49	< 0.02	< 0.1	2.1	< 0.5	198
SASP-Q2-1	26.3	< 0.1	0.8	31	17.4	19400	0.1	0.3	4.5	178	0.4	3490	0.3	10800	110	0.03	15	< 0.02	< 0.1	1.8	< 0.5	429
SASP-WROCK2-1	18.2	< 0.1	0.5	33	21.9	19100	< 0.1	0.8	6	111	0.3	2960	0.8	10200	108	0.01	8	< 0.02	< 0.1	2.2	< 0.5	391
SASP-PWR-1	24.4	< 0.1	0.4	28	22.7	9070	0.1	0.6	6.7	104	0.6	2710	< 0.1	7960	127	0.03	7	< 0.02	< 0.1	2.1	< 0.5	1260
SASP-D1-1	17.5	< 0.1	0.2	39	13.8	15200	< 0.1	0.5	5.2	92	< 0.1	2150	0.5	10600	67	< 0.01	2	< 0.02	< 0.1	2.8	< 0.5	356
SASP-DOME2-1	10.4	< 0.1	0.1	33	2.92	11000	< 0.1	0.2	4.7	71	< 0.1	3200	0.3	11600	116	< 0.01	260	< 0.02	< 0.1	1.1	< 0.5	522
SASP-G1-1	16.8	< 0.1	0.6	227	7.39	17900	< 0.1	0.2	5	114	0.4	3540	0.3	7250	110	0.02	12	< 0.02	< 0.1	2	< 0.5	376
SASP-P1-1	24.1	< 0.1	0.6	11	5.89	16600	< 0.1	0.8	3.7	138	0.4	2930	0.2	6050	112	0.01	93	< 0.02	< 0.1	2.2	< 0.5	193
SASP-PONY2-1	10.5	< 0.1	0.2	15	11.5	11300	0.2	0.2	5.2	76	< 0.1	2640	0.3	6080	87	0.02	82	< 0.02	< 0.1	1.1	< 0.5	593
SASP-PONY3-1	18.8	0.1	0.9	9	16	11200	< 0.1	0.4	4.4	139	0.5	2130	< 0.1	3690	59	0.03	180	< 0.02	< 0.1	1.4	< 0.5	457
SASP-PWR-4	19.7	< 0.1	1.1	16	6.58	7360	< 0.1	0.4	3.5	118	1.7	1990	< 0.1	9090	132	0.01	54	< 0.02	0.3	2	< 0.5	281
SASP-C5-1	18.7	< 0.1	< 0.1	14	2.9	16300	< 0.1	0.6	3.1	86	< 0.1	3060	0.9	11100	50	< 0.01	2	< 0.02	< 0.1	1.6	< 0.5	189
SASP-I2-1	22.4	< 0.1	0.2	8	2.53	21500	< 0.1	0.9	3.3	124	0.2	4750	< 0.1	8340	106	0.01	5	< 0.02	< 0.1	2.1	< 0.5	171
SASP-I4-1	32.2	< 0.1	< 0.1	7	1.19	9200	< 0.1	2.3	2.4	82	< 0.1	1890	0.2	7510	95	< 0.01	78	< 0.02	< 0.1	1.5	< 0.5	183
SASP-J2-1	20.4	0.2	1.4	5	1.63	8920	< 0.1	0.3	2	94	1.1	1680	< 0.1	8050	78	0.03	22	< 0.02	< 0.1	1.5	< 0.5	142
SASP-K2-1	10.5	< 0.1	0.3	23	2.88	15700	< 0.1	0.2	3.4	80	0.2	4110	0.2	8730	102	< 0.01	5	< 0.02	< 0.1	1.2	< 0.5	303
SASP-PONY1-1	8.6	< 0.1	< 0.1	15	3.83	9710	< 0.1	0.3	3.2	69	< 0.1	2090	0.3	7280	86	< 0.01	18	< 0.02	< 0.1	1	< 0.5	283
SASP-PONY3-2	13	< 0.1	0.6	10	11.8	11300	< 0.1	0.7	4.3	138	0.3	2110	< 0.1	3570	68	0.03	286	< 0.02	< 0.1	1.1	< 0.5	416
SASP-G2-1	14.9	< 0.1	0.4	12	2.91	13400	0.1	0.3	4.7	85	0.4	2780	< 0.1	6560	97	0.01	17	< 0.02	< 0.1	1.3	< 0.5	373
SASP-H1-1A	21.1	< 0.1	1.8	7	3.55	22700	< 0.1	0.8	3.4	117	0.6	3900	< 0.1	7670	106	0.01	3	< 0.02	< 0.1	1.3	< 0.5	139
SASP-H1-1B	21.4	< 0.1	1.8	7	3.87	21200	< 0.1	0.9	4.3	112	0.6	3710	0.1	8380	75	0.02	3	< 0.02	< 0.1	1.5	< 0.5	204
SASP-H2-1	20.2	< 0.1	0.9	7	6.6	13800	< 0.1	0.6	4	108	0.3	2890	< 0.1	5730	91	0.01	19	< 0.02	< 0.1	1.4	< 0.5	112
SASP-H3-1	45.7	< 0.1	0.3	6	1.15	9180	0.1	1.4	3.8	87	0.2	2770	0.1	7030	116	< 0.01	10	< 0.02	< 0.1	1.1	< 0.5	105
SASP-I1-1	34.2	0.2	1.6	11	3.3	20300	< 0.1	0.8	3.6	155	1.3	4050	< 0.1	7850	98	0.07	4	< 0.02	< 0.1	2.7	< 0.5	175
SASP-J3-1	18.6	< 0.1	0.3	17	4.16	12000	< 0.1	0.2	4.4	78	0.5	2850	0.1	5790	83	0.02	15	< 0.02	< 0.1	1.2	< 0.5	277
SASP-O1-1	10.2	< 0.1	< 0.1	15	10.7	9860	< 0.1	0.2	4.1	73	< 0.1	1450	< 0.1	6770	104	< 0.01	6	< 0.02	< 0.1	1.4	< 0.5	328
Average Control 05&06	51.1	< 0.1	< 0.118	8.18	8.13	13899	< 0.127	1.04	3.75	107	< 0.336	3659	< 0.1	9044	98.7	< 0.0154	10.2	< 0.02	< 0.1	2.4	< 0.5	168
Max 05&06 control	113	< 0.1	0.3	13	27.6	22800	0.3	1.6	4.7	148	2.3	6360	0.1	12500	167	0.04	32	< 0.02	< 0.1	5.4	< 0.5	658
Count (Gamberg 2006)	14	4	8	10	14	15	10	10	15	15	8	15	10	-	-	9	-	1	10	-	3	15
Mean (Gamberg 2006)	15.5	0.14	0.16	14.5	4.43	7098	0.64	0.1	5.08	46.6	0.09	1143	0.29	-	-	0.03	-	0.02	0.05	-	0.12	185
Max (Gamberg 2006)	95	0.5	1	20	22	18100	1.9	0.3	11	173	0.3	1620	0.8	-	-	0.2	-	0	0.1	-	0.2	892

[1]Sample ID = species code-plot#-sample#.

Metals in willow higher than controls are highlighted.

In order to determine the spatial distribution of elevated levels of the five elements of concern, a series of t-test were conducted and are summarized in Table 3.11. The detailed results of the t-tests performed can be found in Appendix L.

Table 3.11. Summary of t-tests performed on willow for the five major elements.

		Antimony	Arsenic	Copper	Lead	Silver
Mean Value	Mill Zone (n=11)	0.105	1.082	3.745	0.691	0.024
	Pit Zone (n=4)	0.063	0.813	4.075	0.513	0.011
	Pond Zone (n=3)	0.067	0.650	3.967	0.483	0.010
	MWR (n=4)	3.5	56.225	7.675	30.650	0.430
	PWR (n=4)	0.213	1.825	6.600	2.575	0.040
	Control (n=11)	0.050	0.095	3.745	0.327	0.014
	Mill, Pit and Pond Zone (n=18)	0.089	0.950	3.856	0.617	0.019
	Transects (n=13)	0.142	0.908	3.656	0.481	0.018
	Riparian (n=10)	0.055	0.435	3.970	0.140	0.039
	Samples from Tailings Pond (n=2)	0.600	6.400	7.850	6.15	0.085
	Samples from Pit (n=1)	0.050	0.500	6.00	0.300	0.010
Mill, Pit and Pond Zone vs Control		✓	✓			
Mill Zone vs Control		✓	✓			
Mill, Pit and Pond Zone vs Transects						
Mill Zone vs Transects						
Pit Zone vs Control						
Pit Zone vs Transects						
Pond Zone vs Control						
Pond Zone vs Transects						
MWR vs Control						
PWR vs Control						
Riparian vs Control			✓			✓
Riparian vs Transects					✓ (transects higher)	✓
Samples from Pit vs Control						
Samples from Tailings Pond vs Control					✓	✓

[1] Transects = plots along transects, outside of Mill, Pit, Pond Zone. Significant tests had p values <0.05, see Appendix L or numbers.

As illustrated through the t-tests (two tailed assuming unequal variances), arsenic and antimony have significantly higher concentrations in all three zones of aerial contamination (when combined) and in the mill zone when compared to controls. Arsenic and antimony also show elevated levels in the mill area when compared to metal concentrations found in willow control samples. Silver was elevated in samples from the riparian sites and from samples taken from the tailings pond.

Some metals around sources of contamination were higher than controls.

While not statistically significant (due to a small sample size and high variance), it should be noted that samples collected from the low-grade ore stockpile (MWR) near the mill site had the highest concentration of arsenic (up to 141 ppm) as well as antimony (up to 6.4 ppm), copper (up to 10.9 ppm), lead (up to 68.8 ppm), and silver (up to 473 ppm). Metals, including aluminium, chromium, iron, potassium, silicon, magnesium, molybdenum, thallium, tin, titanium and vanadium, have their highest observed concentrations at the low-grade ore stockpile as well.

Levels higher than Yukon background data, but lower than those found at the low grade ore stockpile (MWR), were found at the Pony Waste Rock (PWR) and waste rock piles around the Pit (WROCK). Within these areas, samples with notable differences in metal concentrations were found; however, no significant differences were detected, likely due to small sample sizes. Of interest, the sample from the Pony waste rock with the highest metal levels, SASP PWR-2 was taken from middle of the pile, where willows were patchy, likely due to the lack of organic material.

The vegetation growing directly from the tailings pond also had notably high levels of metals. Lead and silver concentrations were significantly higher in the willow from the tailings pond (on dried portion of tailings) than from the control site. In addition, one willow sample from the pond had the highest levels of copper found in willow (11.2 ppm) in this study. This sample also had arsenic and lead levels that were higher than any other site, with the exception of the low grade ore stockpile.

3.1.2.3 Mushrooms

Bolete mushroom

A single sample (n=1) of a bolete mushroom (*Bolete spp.*) was collected (sample included entire mushroom) within the study site and plot I2. The low sample size of this species collected within the study site as well as in the background data makes any comparisons difficult. However, the sample collected within the study site did show moderate levels of both arsenic and lead (Table 3.12).

Table 3.12. Arsenic and lead concentrations in a sample of bolete mushroom.

	Arsenic	Lead
Mt Nansen (2006)	3.6	2.3
Gamberg (2006)	0.07	0.53

3.1.2.4 Spruce Sap

White Spruce

White spruce (*Picea glauca*) was very common in portions the study area; however, amounts of sap significant enough to warrant sample collection were limited to a few trees. Four (n=4) samples were collected, as well as a single (n=1) duplicate sample. The samples collected were of fresh sap; however, the available Yukon background data was for twigs and cones rather than sap. Furthermore, no control samples were obtained for white spruce sap. Due to this discrepancy, it is difficult to make comparisons for this species. It is for this reason that only the five metals of concern (as identified by lichen contamination) are shown below in Table 3.13. In some cases, these metals were elevated in the Pony Creek riparian plot above levels found in other plots (see site P1 in Table 3.12).

Table 3.13. Metal concentrations in samples of white spruce sap for five metals found to be a concern in lichen data.

Sample ID[1]	Metal Concentration (ppm)				
	Antimony	Arsenic	Copper	Lead	Silver
PIGL-E2-1	<0.1	<0.1	0.1	<0.1	<0.01
PIGL-L3-1	<0.1	0.3	0.4	0.2	0.01
PIGL-M2-1	<0.1	0.5	0.2	0.4	<0.01
PIGL-P1-1A	0.3	3.7	1	4	0.06
PIGL-P1-1B	0.2	1.8	0.8	2.1	0.03

[1]Sample ID = species code-plot#-sample#.

Trembling Aspen

Trembling aspen (*Populus tremuloides*) was encountered infrequently within the study site. A single sample was collected in the Pony Creek area (site Q3) and was compared to the Yukon background data for this species. There were no elevated trace metal concentrations found through this comparison.

3.1.2.5 Lichens (other than caribou lichen)

Caribou Horn Lichen / Tumble Lichen

Tumble lichen, also locally known as caribou horn lichen (*Masonhalea richardsonii*) was encountered in moderate amounts within the study site, primarily at the sites at higher elevations. A small number of samples were analyzed (n=3) along with control (n=2) and road influenced (n=1) sites. The small sample size (n=2) of control samples makes a meaningful comparison difficult. However, the levels of metals that appeared elevated when compared to control samples are presented below in Table 3.14.

Table 3.14. Concentrations of metals in caribou horn lichen above maximum control plot levels (highlighted).

Sample ID	Metal Concentration (ppm)													
	Al	Sb	As	Ba	Ca	Co	Cu	Fe	Pb	Si	Ag	Na	Sr	Ti	V
MARI-A4-1	41.2	< 0.1	0.3	5.7	878	< 0.1	0.8	75	1.1	56	0.05	72	2.45	3	< 0.5
MARI-DUST2-1	132	< 0.1	1.8	9.1	4030	0.2	1	280	3.2	80	0.06	64	2.94	5.8	0.6
MARI-F1-1	69.6	< 0.1	0.9	5.7	3110	0.2	0.8	108	3.4	73	0.12	29	6.21	4.8	< 0.5
MARI-R2-1	60.1	0.2	1.8	9.1	2190	0.2	1	141	6	72	0.1	80	4.86	2.3	< 0.5
Control Plot Maximum	51.2	< 0.1	0.5	6.2	3590	0.1	0.8	89	0.9	65	0.03	60	5.86	3.6	< 0.5
Control Plot Average	45.3	< 0.1	0.45	5.7	2905	0.1	0.75	77	0.75	60	0.025	51.5	4.525	3	< 0.5

[1]Sample ID = species code-plot#-sample#.

3.1.2.6 Grasses

Wheat grass

Wheat grass (*Agropyron sp.*) samples (consisting of the above ground portion of the plant) were collected in areas considered to have high contamination potential including the low-grade ore stockpile near the mill (MWR), the pony waste rock pile (PWR), tailings pond (TAIL) and the Brown McDade Pit (PIT). Samples analyzed include: control (n=4); low-grade ore (MWR; n=4); pony waste rock (PWR; n=4); tailings pond (n=2); and pit (n=1).

No data regarding background metal levels for wheat grass in the Yukon were found. As such, samples collected within potential areas of contamination were compared to control data from locations approximately 1-2 kilometres from the Mt. Nansen mine site[4].

In general, metal levels found in wheat grass from both the mine site and control sites were high compared to other plants. Wheat grass from the tailings pond appeared to have slightly elevated levels of some metals, including boron, calcium, and strontium in both of the plants sampled, and arsenic, cadmium, magnesium, sodium and zinc in one plant. The one sample collected from the pit appeared to have elevated levels of arsenic, lead and several other metals. Samples from the pony waste rock pile appeared to have slightly elevated levels of boron, cadmium, magnesium, manganese, and zinc. Samples from the low grade ore stockpile (MWR) had a few metals that appeared to be elevated compared to the control sites. Table 3.15 illustrates the data for all elements exceeding control site data. Any elements not presented were considered within control values for this species.

In general, metal levels found in wheat grass from both the mine site and control sites were high compared to other plants.

Table 3.15. Metals in wheat grass (above ground biomass) above maximum control plot levels (highlighted).

Sample ID[1]	Metal Concentrations (ppm)											
	As	B	Cd	Ca	Pb	Mg	Mn	P	Na	Sr	U	Zn
WHGR-TAIL-1	11.4	11	0.31	3500	9.4	1550	199	850	242	20.6	< 0.04	113
WHGR-TAIL-2	3.5	13	0.07	4890	1.3	393	51.2	968	3	16.9	< 0.04	32.3
WHGR-PIT1-1	16	5	0.66	3840	13.1	788	288	1150	6	11.1	0.06	66.4
WHGR-PWR-1	0.5	10	0.57	2130	0.5	1050	772	2010	7	8.67	< 0.04	272
WHGR-PWR-2	0.4	7	0.83	1760	0.2	2480	814	1920	7	4.13	< 0.04	180
WHGR-PWR-3	0.4	9	0.43	2510	0.3	1220	868	2320	8	9.02	< 0.04	173
WHGR-PWR-4	0.5	5	0.08	2180	1.3	604	299	1420	7	8.22	< 0.04	38.3
WHGR-MWR-4	1.9	5	0.69	3900	2.3	1260	158	1430	1	7.45	< 0.04	61.4
WHGR-MWR-1	4.2	6	0.08	2660	4.1	1110	100	2710	7	7.31	< 0.04	27.2
WHGR-MWR-3	9.5	5	0.12	2470	6.2	972	61	1410	6	7.41	< 0.04	50.1
WHGR-MWR-2	3.8	8	0.22	5400	4.2	1640	105	1240	10	10.3	< 0.04	108
Control Site Average	**1.5**	**3.75**	**0.17**	**2240**	**5.65**	**787**	**109.8**	**1705**	**9.25**	**11.04**	**< 0.04**	**27.85**
Control Site Max	**5.2**	**5**	**0.2**	**2950**	**13**	**1040**	**230**	**2340**	**14**	**14.2**	**< 0.04**	**48.6**

Foxtail Barley

Foxtail barley (*Hordeum jubatum*) samples (above ground biomass) were collected exclusively in potential areas of contamination around the mine site including the tailings pond (TAIL), pit (PIT) and the pit waste rock dumps (WROCK). At this point, no

[4] It should be noted that lichen data indicated that 1-2 kilometres from the site is sufficient for control purposes.

background data regarding metal concentrations within foxtail barley is available for the Yukon. As such, metal concentration results were compared to metal levels within wheat grass from the control areas. Of most interest is the sample collected from the Tailings Pond (HOJU-TAIL-1) which has very high levels of many metals, including the highest recorded levels for copper in any plants in this study (not including blackened vegetation). Metals in foxtail barley collected directly from the pit appeared somewhat elevated, but the sample collected from the waste rock pile around the pit appeared to have levels comparable to the control site (for wheat grass).

Table 3.16. Metals in foxtail barley above maximum control plot levels for wheat grass (highlighted).

	Metal Concentrations (ppm)											
Sample ID	**As**	**B**	**Cd**	**Ca**	**Cu**	**Pb**	**Mn**	**K**	**Ag**	**Na**	**Sr**	**Zn**
HOJU-PIT3-1	1.3	4	0.22	2450	8.8	3.1	1260	13900	0.04	10	7.32	252
HOJU-PIT5-1	5.6	5	0.24	2400	8.3	3.1	1080	11000	0.1	11	8.24	127
HOJU-TAIL-1	50.5	12	1.76	5840	54.2	50.1	1010	18400	0.42	120	17	205
HOJU-WROCK2-1	0.2	5	0.08	1820	3.9	0.2	618	6930	0.03	4	6.03	18.4
Control Plot Average (WHGR)	**1.5**	**3.8**	**0.17**	**2240**	**3.5**	**5.7**	**109.8**	**9622.5**	**N/A**	**9.3**	**11**	**27.9**
Control Plot Maximum (WHGR)	**5.2**	**5**	**0.2**	**2950**	**3.8**	**13**	**230**	**12,300**	**0.12**	**14**	**14.2**	**48.6**

3.1.2.7 Blackened Vegetation

Blackened sphagnum moss and soils were sampled at seven plots, five of which were adjacent to the blackened vegetation plots sampled in 2005 (see map in Figure 2.4). Of the five plots adjacent to those sampled in 2005, three were located just outside of the visibly blackened zone in order to provide comparative results of blackened and unblackened soils/sphagnum.

As well, four sphagnum moss sample plots (06-BVEG1-SPMO-A to D) were located adjacent to each other on the western side of Dome Creek. These four plots were located along a transect ascending up the slope from Dome Creek, with two (06BVEG1-SPMO-A&B) located within the zone of blackened vegetation and two (06BVEG1-SPMO-D&E) above in normal, living, vegetation.

Sphagnum Moss

As presented in Table 3.17, sphagnum moss samples from SPMO-A had the highest levels for the greatest number of metals (19 of 33) amongst all sphagnum samples collected. Plot SPMO-D generally had the lowest concentrations. This is notable for two reasons; i) metal concentrations were highest closer to the creek and substantially lower further up the slope; and ii), the low concentrations from SPMO-D can be considered as a general control sample for comparison of other sphagnum samples within the zone of blackened vegetation. It should be noted that this “control” is still within an area of possible influence of contaminants from the Dome Creek watershed; however, it provides the best available results in this regard.

Table 3.17. Results (2006) from metals from four sphagnum moss sites within and adjacent to the zone of blackened vegetation. 06-BVEG-SPMO-D provides a general control sample.

Sample ID	In Blackened Vegetation?	Al	As	Ba	Be	Co	Cu	Cr	Fe
06-BVEG1-SPMO-A	Yes	2770	113	221	0.15	19.1	512	5.3	25,900
06-BVEG1-SPMO-B2	Yes	1500	30.2	130	0.08	14.5	185	2.4	6790
06-BVEG1-SPMO-C	No	537	6.4	37.5	<0.02	1.8	12.6	0.9	954
06-BVEG1-SPMO-D	No	938	4.8	31.2	<0.02	0.2	4.5	0.8	413
Sample ID	**In Blackened Vegetation?**	**Hg**	**Mo**	**Ni**	**Pb**	**Sb**	**Ti**	**U**	**V**
06-BVEG1-SPMO-A	Yes	0.186	1.9	17.2	31.1	2.9	93.9	4.14	10.4
06-BVEG1-SPMO-B2	Yes	0.129	3.7	13.1	14.5	1.8	42.4	4.58	5.9
06-BVEG1-SPMO-C	No	0.082	0.3	1.8	4.6	0.6	9.9	0.51	1
06-BVEG1-SPMO-D	No	0.058	<0.1	0.6	4.1	0.5	13.1	<0.04	0.9

Metal concentrations in sphagnum moss samples obtained nearest to the creek (SPMO-A) ranged from 3 times greater (for Al) than those taken furthest from the creek/blackened vegetation (SPMO-D), to 114 times greater (for Cu). While all metals in the sphagnum sampled closest to the creek (SPMO-A) were substantially elevated (an average of 32 times higher), the metals showing the greatest differences (and therefore the greatest concentrations) were cobalt (Co) at 95.5 times greater, copper (Cu) at 114 times greater, iron (Fe) at 63 times greater, and uranium (U) at 104 times greater.

While metal concentrations generally decline moving upslope in the zone of blackened vegetation, the differences between SPMO-B2 and C clearly indicate a sharp decline in metal concentrations moving from the zone of blackened vegetation to the adjacent normal vegetation. Metals found in sphagnum moss samples from SPMO-B were, on average, 5.9 times greater than those from SPMO-C.

Tables 3.18, 3.19, 3.20, and 3.21 detail the levels of metals found in sphagnum moss samples taken at other plots within and near the zone of blackened vegetation. Most samples showed higher levels of most metals than the SPMO-D 'control' sample. In terms of sample plots at different elevations on the slope in the same general location, the levels of metals were generally higher (not always higher) at the lower elevations. The only exception is that 06-BVEGE-SPMO had consistently lower levels of metals than 06-BVEGD-SPMO, despite being at a lower elevation closer to Dome Creek.

In general, metal levels in sphagnum were highest near the creek and decreased further up slope.

Table 3.18. Sphagnum moss collected just below the seepage pond. BVEG3 was collected within blackened vegetation and BVEG3-1 was collected in green vegetation.

Sample ID	In Blackened Vegetation?	Al	As	Ba	Be	Co	Cu	Cr	Fe
BVEG3 (2005)	Yes	976	64.4	171	0.04	3.4	332	1.2	32,400
SPMO-BVEG3-1	No	552	21.2	47.7	<0.02	0.3	16.7	1.6	1020
06-BVEG-SPMO-D ('control')	No	938	4.8	31.2	<0.02	0.2	4.5	0.8	413
Sample ID	**In Blackened Vegetation?**	**Hg**	**Mo**	**Ni**	**Pb**	**Sb**	**Ti**	**U**	**V**
BVEG3 (2005)	Yes	0.151	1.8	4.5	15.2	1.3	37.3	1.87	2.9
SPMO-BVEG3-1	No	0.073	0.1	1.3	19	2.1	22.9	<0.04	1.5
06-BVEG-SPMO-D ('control')	No	0.058	<0.1	0.6	4.1	0.5	13.1	<0.04	0.9

These tables show the general pattern of higher metal levels in moss from the area of blackened vegetation compared to moss collected from areas outside of the blackened vegetation.

Table 3.19. Sphagnum moss collected opposite the confluence of the bypass channel and Dome Creek. BVEG2 and BVEGH-1 were located within blackened vegetation.

Sample ID	In Blackened Vegetation?	Al	As	Ba	Be	Co	Cu	Cr	Fe
BVEG2 (2005)	Yes	1000	141	252	0.06	5.7	613	2.1	26,400
SPMO-BVEGH-1	Yes	552	11.8	35.8	<0.02	0.4	10.4	2.3	987
SPMO-BVEGG-1	No	407	13.3	73	<0.02	0.4	11.7	1.2	866
06-BVEG-SPMO-D ('control')	No	938	4.8	31.2	<0.02	0.2	4.5	0.8	413
Sample ID	**In Blackened Vegetation?**	**Hg**	**Mo**	**Ni**	**Pb**	**Sb**	**Ti**	**U**	**V**
BVEG2 (2005)	Yes	0.561	0.9	21.8	62.6	1.7	39.1	1.99	9.3
SPMO-BVEGH-1	Yes	0.096	0.2	1.8	11.7	1.2	21.8	0.04	1.7
SPMO-BVEGG-1	No	0.081	<0.1	2.4	12.5	1.4	19.3	0.07	1.4
06-BVEG-SPMO-D ('control')	No	0.058	<0.1	0.6	4.1	0.5	13.1	<0.04	0.9

Table 3.20. Sphagnum moss collected approximately 80 m downstream of the bypass confluence (left bank). BVEG-1 and BVEGD-1 were located within blackened vegetation.

Sample ID	In Blackened Vegetation?	Al	As	Ba	Be	Co	Cu	Cr	Fe
BVEG1 (2005)	Yes	5000	219	179	0.25	7.3	195	9.7	42,000
SPMO-BVEGE-1	No	405	7.8	25.7	<0.02	0.3	6.8	1.8	679
SPMO-BVEGD-1	Yes	629	23.5	68.3	<0.02	0.5	9.7	2	1190
06-BVEG-SPMO-D (control)	No	938	4.8	31.2	<0.02	0.2	4.5	0.8	413
Sample ID	**In Blackened Vegetation?**	**Hg**	**Mo**	**Ni**	**Pb**	**Sb**	**Ti**	**U**	**V**
BVEG1 (2005)	Yes	0.076	1.50	12.8	48.3	1.6	195	2.54	22.4
SPMO-BVEGE-1	No	0.057	<0.1	2.3	6.9	0.8	19	<0.04	1.3
SPMO-BVEGD-1	Yes	0.088	0.1	1.8	24.9	2.6	30.9	0.05	1.9
06-BVEG-SPMO-D (control)	No	0.058	<0.1	0.6	4.1	0.5	13.1	<0.04	0.9

Table 3.21. Sphagnum moss collected approximately 300 m downstream of the bypass confluence (outside the blackened vegetation).

Sample ID	In Blackened Vegetation?	Al	As	Ba	Be	Co	Cu	Cr	Fe
SPMO-BVEGA-1	No	2020	64.6	77.8	0.1	2.4	21.4	6.4	12,700
SPMO-BVEGB-1	No	190	2.5	2.5	0.02	0.7	3.3	0.9	1760
06-BVEG-SPMO-D (control)	No	938	4.8	31.2	<0.02	0.2	4.5	0.8	413
Sample ID	**In Blackened Vegetation?**	**Hg**	**Mo**	**Ni**	**Pb**	**Sb**	**Ti**	**U**	**V**
SPMO-BVEGA-1	No	0.05	0.3	5.6	23.5	2.4	89	.87	9.1
SPMO-BVEGB-1	No	0.039	1.5	1.3	1.2	0.2	7.9	8.6	1.5
06-BVEG-SPMO-D (control)	No	0.058	<0.1	0.6	4.1	0.5	13.1	<0.04	0.9

While elevation appeared to generally have a bearing on metal levels in SPMO, this appeared to be especially the case in the lower sections of the blackened vegetation. All the lowest elevation samples had the highest metal levels in their relevant area. Interestingly, the samples collected from the upper portion of the blackened vegetation were often similar to the samples collected from the adjacent green vegetation, just above the blackened vegetation. Metal levels from these areas were generally in between the 'control' and the lowest elevation sample. Examples of this include BVEGH and G (Table 3.19) and BVEG E and D (Table 3.21). In addition, samples BVEGA-1 downstream of a patch of blackened vegetation had high levels of metals. This data indicates that the zone of elevated metal levels appears to be more widespread than the visible blackened vegetation (both in elevation and extent downstream).

Live Labrador Tea and Willow Growing in Area of Blackened Vegetation.

A small number of living shrubs were present within the area of blackened vegetation. Samples of live Labrador tea (n=2) and willow (n=3) were collected from this location. Table 3.22 outlines the comparison made between live samples collected from the blackened vegetation area and control samples. Several samples had metal levels that were higher than the highest levels at the control sites; however, in most cases the difference was not more than an order of magnitude. Interestingly, the highest levels of Ba, B, Cu, Fe, Na, and Sr found in Labrador tea were from the area of blackened vegetation. However, the levels of most metals found in willow from the area of blackened vegetation were much lower than willow in the disturbed areas around the mine site (low grade ore and tailings). It should be noted that the blackened vegetation area is adjacent to Dome Creek and somewhat near the tailings ponds and as such may be influenced by many factors compared to the control samples.

Some metals appeared elevated in live vegetation growing within the area of blackened vegetation.

Table 3.22. Metal levels that were higher than the control samples for live vegetation collected within the area of blackened vegetation (BVEG). Yellow highlighted values have at least one sample above the range of control sites while orange highlighted values were all above control samples.

Metal	Labrador Tea (n=2)		Willow (n=3)	
	Green Samples from BVEG area	Control Samples	Green Samples from BVEG area	Control Samples
Al	20.2 - 22.4	24.6 – 59.3	18 -142	19.3 - 113
As	0.5 - 3.2	<0.1 - 0.1	0.4 - 1.4	<0.1 - 0.3
Ba	98.6 - 110	41 – 74.8	21.3 - 55.7	25.1 - 130
B	27 - 81	10.0 - 21.0	25 - 29	5.0 - 13.0
Ca	8000 - 10000	4980 - 7580	13000 - 15300	8560 - 22800
Co	<0.1 - 0.1	<0.1	0.2 - 1.8	0.5 - 1.6
Cu	3.2 - 5.8	2.8 – 5.1	4.3 - 5.1	3.4 - 4.7
Fe	68 - 753	40 - 87	104 - 141	77 - 148
Mg	1440 - 2150	1130 - 1690	3350 - 4210	1890 - 6360
Mo	<0.1	<0.1 - 0.1	<0.1 - 0.2	<0.1 - 0.1
Ni	0.5 - 0.7	0.2 - 0.5	0.8 - 6.2	0.7 - 4.4
Si	180 - 182	83 - 214	145 - 179	57 – 137
Ag	0.01 - 0.09	<0.01 - 0.01	<0.01 - 0.03	<0.01 - 0.04
Na	8 - 160	1.0 - 5.0	13 - 38	5.0 – 32
Sr	24.6 - 27.1	5.97 - 11.0	49.8 - 54.6	52.2 – 146
Tl	0.11 - 0.28	0.03 - 0.15	<0.02	<0.02
Sn	0.1 - 0.3	<0.1 – 0.2	<0.1 - 0.2	<0.1-0.1

This table provides a comparison between the green vegetation growing in the area of blackened vegetation compared to control sites.

3.1.3 Soils

The soils component of the project was undertaken with the view that soils are one of the environmental components that, in context with other parameters, may provide insight into the natural and human induced geochemical processes occurring in this area.

Soil samples were analyzed from sites located within areas found to contain elevated levels for metals (arsenic and lead) in lichen samples. As well, soil samples from three sites located within the zone of dead/blackened vegetation located along the bank of Dome Creek were analyzed. In addition, for reference purposes, 5 samples from the mineralized control area (Spud, Webber and Flex zones) located approximately 1-2 km northwest from the mine site were analyzed. These samples should provide insight into the background levels of metals present in the Mt. Nansen area which are believed to be not directly impacted by mining activities (please note there was some surface exploration activity in this area). In all cases, these included samples from the A and B soil horizons. It also included samples from the C soil horizon where sampling was not restricted by permafrost conditions. Refer to Appendix E for the results of all soil samples analyzed.

Soil samples were analyzed from sites around the mill, pit, and pond as well as the area of blackened vegetation and from control plots.

Laboratory analyses of the control site samples showed noticeable patterns between the sampled horizons (Table 3.23). Mean metal levels in the C-horizon were often higher compared to the other horizons, perhaps as a result of the underlying geology (mineralized zone). The B-horizon, which mostly consisted of a volcanic ash layer, appeared to be relatively depleted of several elements (As, Ba, Cu, Fe, Mg, Mn), indicating that vertical transport between the existing horizons in this area may be limited. The A-horizon was relatively acidic (pH ~ 4.5) most likely due to the well-developed organic layer, which typically contains humic and fluvic acids. The slightly elevated levels of As, Cd, Hg are likely the result of higher organic matter content of this horizon. These metals are known to be readily adsorbed by organic substances.

Metal levels from the control sites were typically highest in the lowest soil (C) horizon.

Table 3.23. Mean levels of metals in soils at the control sites.

Soil Horizon	Mean Metal Levels (ppm)[1]														
	Sb	**As**	**Ba**	**Be**	**Cd**	**Cr**	**Co**	**Cu**	**Pb**	**Hg**	**Mo**	**Ni**	**Se**	**Ag**	**Sn**
A	<DL	29.2	133	<DL	2.22	8.2	2.8	14	11	0.142	<DL	5.4	<DL	1.4	<DL
B	<DL	11.2	46	<DL	0.30	8	3.2	12	8.9	0.021	<DL	7.5	0.14	<DL	<DL
C	<DL	85.2	125	<DL	1.34	21	8.2	30	28	0.042	<DL	12	0.11	<DL	<DL
	V	**Zn**	**Al**	**B**	**Ca**	**Fe**	**Mg**	**Mn**	**P**	**K**	**Na**	**Sr**	**Ti**	**Zr**	
A	15	62	5882	0.9	2984	7932	1223	121	981	664	83	30	108	.6	
B	24	31	4200	<DL	997	8890	1225	134	245	344	132	8	254	.6	
C	43	111	17120	<DL	2156	19980	3956	356	450	691	92	18	347	1.8	

[1] To calculate average levels, detection limits estimated at ½ of detection limit. DL = below detection limit.

Table 3.24 details the mean levels of metals found in the soil samples from each horizon taken at transect plots with high levels of lead and arsenic (in the lichens). Of interest, unlike the control plots the mean levels for many metals were highest in the A-horizon. Of the five metals of primary concern (determined by the lichen sampling) arsenic, lead, antimony and copper all show this pattern (this pattern was not evident in silver where all values were below the detection limit).

In areas around the mill, pit and pond, the mean levels for many metals were highest in the A-horizon.

Table 3.24. Mean levels of metals in soil samples from transect sites with high lead and arsenic levels in lichens.[a]

Soil Horizon	Mean Metal Levels (ppm)[1]														
	Sb	**As**	**Ba**	**Be**	**Cd**	**Cr**	**Co**	**Cu**	**Pb**	**Hg**	**Mo**	**Ni**	**Se**	**Ag**	**Sn**
A	6	59	239	DL	2	6.3	6	27	10	0.09	DL	7	0.3	DL	DL
B	DL	35	118	DL	1	6.5	6	8.1	9	0.03	DL	4	0.2	DL	DL
C	DL	30	130	DL	1	13	7	20	7	0.03	DL	7	0.1	DL	DL
	V	**Zn**	**Al**	**B**	**Ca**	**Fe**	**Mg**	**Mn**	**P**	**K**	**Na**	**Sr**	**Ti**	**Zr**	
A	19	56	6098.5	1	9272	11017	1510	1079	977	478	101	58	140	1	
B	31	40	4653.4	DL	2566	11864	1418	1253	514	324	158	16	367	1	
C	43	44.4	10089	DL	3210	16650	3450	290.3	624	814	112	19	483	1	

[1] To calculate average levels, detection limits estimated at ½ of detection limit. DL = below detection limit.
[a] Plots where lichen lead levels were 9.3 ppm and/or arsenic levels over 11.5 ppm

Soils were collected in order to provide further insight into the levels of metals currently in the soils in the area of blackened vegetation. For analysis purposes, the results were grouped into year of collection, given that all 2005 soil plots were located in highest impacted, low elevation areas within the blackened vegetation, and that sphagnum moss from these areas all had high metal levels. Samples from 2006 were located in the upslope portions of the blackened vegetation as well as adjacent areas outside of the blackened vegetation. Table 3.25 details the mean levels of metals found in soils within and near the zone of blackened vegetation along Dome Creek in 2006 samples and Table 3.26 provides the mean concentrations for the 2005 samples at lower elevations than 2006 plots.

Table 3.25. Mean levels of metals in soils from lower elevation areas within the blackened zone along Dome Creek (2006 data).

Soil Horizon	Mean Metal Levels (ppm)[1]														
	Sb	**As**	**Ba**	**Be**	**Cd**	**Cr**	**Co**	**Cu**	**Pb**	**Hg**	**Mo**	**Ni**	**Se**	**Ag**	**Sn**
A	<DL	38.5	217	1	2.3	5.6	4.6	47.6	7.5	0.23	<DL	6.9	0.3	29	<DL
B	<DL	93.7	145	<DL	1.3	11.5	8.1	14.4	19	0.06	<DL	8.7	0.85	<DL	<DL
C	<DL	117	82.5	1	1.3	8.3	2.8	7.5	15	0.09	<DL	4.6	1.1	<DL	<DL
	V	**Zn**	**Al**	**B**	**Ca**	**Fe**	**Mg**	**Mn**	**P**	**K**	**Na**	**Sr**	**Ti**	**Zr**	
A	10	51.3	4040	9.3	7492.8	8840	1005	966.9	804	427.7	175.5	61.3	63.1	1	
B	30.9	32.4	6086.6	30.9	2655.1	29947.1	1290.1	240.9	526.4	248.1	83.2	28.1	247.4	5	
C	29.5	19.7	6570	13.7	1918.2	16375	1609.8	224	404	289.7	150	16.8	219.7	7	

In the blackened vegetation, the mean levels for many metals appeared elevated in the A and B horizons (especially the B horizon).

Table 3.26. Mean levels of metals in soils from the upslope area of the blackened vegetation and adjacent to the blackened vegetation along Dome Creek (2005 data).

Soil Horizon	Mean Metal Levels (ppm)[1]														
	Sb	**As**	**Ba**	**Be**	**Cd**	**Cr**	**Co**	**Cu**	**Pb**	**Hg**	**Mo**	**Ni**	**Se**	**Ag**	**Sn**
A	DL	104	162	DL	2.5	6	12.3	160.7	7.3	0.1	DL	9.3	0.4	2.7	4.5
B	6.7	320	342.6	DL	4.2	4.2	28.6	92.7	27.3	0.1	3.7	17.3	0.9	DL	5.9
C	DL	9	44.3	DL	DL	7.3	3.5	7	DL	0.01	DL	5.3	DL	DL	DL
	V	**Zn**	**Al**	**B**	**Ca**	**Fe**	**Mg**	**Mn**	**P**	**K**	**Na**	**Sr**	**Ti**	**Zr**	
A	16.3	90	4846.7	6	8776	24966	1747.3	3921	746.3	388	81.7	38.3	102.3	1	
B	83	131	27766	DL	4650	86933	2673	6103	973.7	510.7	115	39	251	5.3	
C	19.5	27	4737.5	DL	1945	6660	1806	71.8	423.8	433	163	12	292	1	

The mean metal levels in the area upslope of the blackened vegetation (in the A and B horizon) indicates this area has been subject to contamination as well.

Soil data from within the blackened zone show that concentrations of metals are generally elevated in the A and B horizons (Tables 3.25 and 3.26), more specifically the B horizon. This is in contrast to results found in other areas of the mine site where the C horizon generally had the highest metal concentrations. An exception to this is 06-BVEGA where significantly elevated concentrations of most metals were found in all three soil horizons. Soil plots located outside of the zone of blackened vegetation, including 06-BVEGA and BVEG1-1-T, had levels of metals elevated in the A and B horizons when compared to the C-horizon and control samples. This indicates that the zone of influence from contaminants associated with the zone of blackened vegetation extends beyond the obvious area of dead organic matter.

Soil sampling results for all sites by major element types are presented below.

Antimony

Summaries of specific metals in soils are presented below.

The levels of antimony were found to be at very low levels (below the detection limit of 10 ug/g) at all sites except J-1 in the upper horizon where the concentration was 25 ug/g. All levels were within CCME (2002) guidelines and Yukon Contaminated Sites Regulations (2002) for industrial sites (40 ug/g). Antimony levels were below or near detection limits for all other sites (including control sites and blackened vegetation sites).

Arsenic

Arsenic appears to be the most noteworthy metal found in the soils in this study.

Arsenic appears to be the most noteworthy metal found in the soils in this study. High levels of arsenic were found at several sampling sites, mostly within the upper horizon.

Many sites, including controls, have levels that exceed the CCME (2002) guideline for industrial sites (12 ug/g) for arsenic. The Yukon Contaminated Sites Regulations (2002) limit for industrial sites (toxicity to soil invertebrates and plants) is 100 ug/g. Only 2 control samples, both in the C-horizon (CP8 and CP5) had levels over the 100 ug/g (141 and 106 ug/g respectively).

High arsenic levels in soils may be the results of natural variation, and/ or mine site development.

The area of highest arsenic concentrations was around the mill site (J1, J2, K2) where the highest levels (209-485 ug/g) were detected within the upper soil horizon. In this area, horizon B (ash layer) and even the C horizon showed relatively high levels of arsenic (70 – 247 ug/g). The levels of arsenic in the mill area exceeded the Yukon Contaminated Sites Regulations (2002) for industrial sites (100 ug/g) in the A horizon at site J2 and in both the A and B horizons at J1 and K2. Levels were also high in the B-horizon beneath the blackened vegetation (212-400 ug/g) and in the A-horizon at one site (201 ug/g). Archer, Cathro & Associates Limited (1987) completed extensive soil sampling around the Mt. Nansen area (in the B and C-horizons) prior to mine development and found many areas with levels of arsenic (up to 4,010 ug/g).

Notable levels of arsenic were also found in some sample plots in the vicinity of the blackened vegetation. Five samples from 3 plots exhibited levels above CCME (2002) guidelines (12 ppm for all types of sites). Plot 06-BVEGA had elevated levels in the two top soil horizons (horizon A – 60 ppm & horizon B – 18 ppm). These values, however, were not as high as that found in the C horizon at BVEG2-1, for which the level of arsenic was found to be 223 ppm, 18.6 times greater than the CCME guideline of 12 ppm. Another sample with an arsenic level above the CCME guideline was 06-BVEGD-2 (B horizon) (156 ppm).

Cadmium

For all sites, cadmium levels were variable and ranged from less than the detection limit (0.5 ug/g) to 7 ug/g. All samples fell below the CCME limits for industrial sites (22 ug/g) and Yukon Contaminated Sites Regulations (2002; 500 ug/g).

Copper

For transect and control sites, the concentration of copper was below the CCME guidelines (2002) and Yukon Contaminated Sites Regulations (2002) for industrial sites at all sampling sites (91 ug/g and 250 ug/g respectively). The levels were generally highest in A and C-horizon.

The highest copper levels were found within the blackened vegetation plots, with levels up to 340 ug/g in the A-horizon and 94 ug/g in the B-horizon. Conversely, the lowest copper concentrations were found in the C-horizon (2-11 ug/g).

Lead

Although there was an increase in lead levels in the A-horizon at several sites near the Mill site (129 ug/g at J1/ 13 ug/g at J2 / 28 ug/g at K2), the numbers were still within the CCME (2002) guidelines (600 ug/g) and Yukon Contaminated Sites Regulations (2,000 ug/g) for industrial sites. There were relatively low lead levels detected within B and C-horizons (up to 35 ug/g). Lead levels were relatively low in the soil samples under the blackened vegetation (highest level recorded was 31 ug/g in the B-horizon). Levels at the control sites were generally low with the highest levels found in the C-horizon (maximum of 32 ug/g).

Lead levels were higher near the mill site but lower than relevant guidelines.

Manganese

The most notable manganese (Mn) was found in the B horizon in the 2005 blackened vegetation plots at 6,103 ppm. This is in contrast to the mean manganese values in the B-Horizon at control sites of 134 ppm.

Mercury

Concentrations of mercury were detected at very low levels at all sampling sites (well below all CCME guidelines (50 ug/g; 2002)[1]. The highest mercury levels were found in the A-horizon.

Silver

Concentrations of silver were below the detection limit (2 ug/g) at all sites, with the exception of a levels of 6 ug/g and 3 ug/g found in the A-horizon at one site under the blackened vegetation and one control site, respectively. These levels are well below CCME (2002) guidelines and Yukon Contaminated Sites Regulations for soils (industrial sites; 40 ug/g).

[1] No Yukon Contaminated Sites Regulations limits for Mercury were found.

Zinc

The highest concentration of zinc was detected at J1 near the Mill site (253 ug/g for A horizon and 222 ug/g for B horizon) and was likely due to a natural anomaly. The samples from other sites showed relatively uniform concentrations and all were below CCME (2002) guidelines and Yukon Contaminated Sites Regulations for industrial sites (360 ug/g and 600 ug/g respectively).

3.1.4 Wildlife

Wildlife species collected and subsequently analyzed for levels of metals included the red-backed vole (*Clethrionomys glareolus*), gray jay (*Perisoreus canadensis*), masked shrew (*Sorex cinareus*), arctic ground squirrel (*Spermophilus parryii*), snowshoe hare (*Lepus americanus*), pine marten (*Martes martes*) and spruce grouse (*Falcipennis canadensis*). Specimens were collected from within the mine site as well as within a control area near Rowlinson Creek. No control samples were obtained for ground squirrel or pine marten; however, Yukon background data was found for marten. No control samples of the masked shrew were obtained in 2005, but one was obtained in 2006. Spruce grouse specimens were obtained in both the mine and control sites, but only in 2006. Gray jay samples were obtained in 2005 only from both the mine and control sites. Moose (2 samples in 2005) and caribou (9 samples in 2005; 5 samples in 2006) were also obtained and analyzed for levels of metals.

Wildlife tissue collected from the mine site was compared to control (Rowlinson Creek area) and Yukon background data.

Results are presented for each tissue type of each wildlife species sampled for all metals for which there is a notable difference between the mine and control areas. The complete laboratory results for concentrations of all metals analyzed are included in Appendix F.

3.1.4.1 Small Mammals/Birds

Shrew and Ground Squirrel

Only one shrew control sample was obtained from the Rowlinson Creek area; however, additional control data (5 samples) was gained from a ‘control’ site near Faro (Gartner Lee 2007). On average many metals were higher from control areas including copper, lead and zinc Of note phosphorous, silicon and titanium were statistically lower from shrews at Mt. Nansen (mine site) compared to the control values (via t-test; see Appendix L). The only metals that were on average higher at Mt. Nansen were arsenic, cadmium and silver (Table 3.27). When control samples were combined (Rowlinson and Faro) and compared to the Mt. Nansen samples, none of these differences were statistically significant (using a two tailed t-test).

Metals in shrews collected at the mine site were generally similar or lower than metal levels in shrews from controls.

Table 3.27 Concentrations (ppm) of metals in shrews in control and mine sites (2005 and 2006 pooled data).

	Arsenic		Cadmium		Silver	
	Average*	Range	Average	Range	Average*	Range
Mine Site (n= 7)	0.41	0.1 - 1.9	0.93	0.23 - 1.81	0.026	0.01-0.04
Rowlinson Control Site (n=1)	<0.1	NA	0.14	NA	0.03	N/A
Faro Control (Gartner Lee 2007; n=5)	0.12	0.1 - <0.4	0.7	0.2-1.84	0.015	<0.01-0.06

*For averages and statistical purposes, concentrations below laboratory detection limits were estimated at ½ of detection limits.

For the single ground squirrel specimen obtained in 2005, levels of arsenic (As) were slightly higher (5.4 ppm dry weight or 1.63 ppm wet weight; taken very close to the mill) than maximum levels from samples collected throughout northern Alaska (wet weight – 1.02 ppm; Allen-Gill, 1997).

Red-backed vole

Data for concentrations of metals in kidneys and livers of red-backed voles caught in 2005 and 2006 were pooled. Mean and maximum concentrations of arsenic (As), cadmium (Cd), chromium (Cr), and silver (Ag) were notably higher in liver samples obtained at the mine site, as was the maximum concentration of lead (Pb). These differences were significant for mean concentrations of cadmium, chromium and silver (Table 3.28). Detailed results of the statistical analyses are presented in Appendix L.

A few metals were somewhat higher in livers of red-backed voles captured at the mine site.

Table 3.28. Concentrations (ppm) of metals in livers of red-backed voles in control and mine sites (2005 and 2006 pooled data).

		Arsenic		Cadmium		Chromium		Lead		Silver	
		Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
Location	Mine Site (n= 9)	0.24	<0.1 - 0.8	10.8	3.24 - 36.6	0.3	<0.1 - 0.5	0.1	<0.1 - .4	0.03	<0.01 - 0.05
	Control Site (n=5)	0.07	<0.2	1	0.7 - 2.15	0.1	<0.05 - 0.2	0.07	<0.2	0.007	<0.01-<0.02
Mine Site vs Control Site				✓		✓				✓	

*For averages and statistical purposes, concentrations below laboratory detection limits were estimated at ½ of detection limits.

Metal levels displayed great variation in samples collected from the mine site. While the minimum concentrations of these metals were similar at both the mine and control sites (and below detection limits for arsenic, lead and silver), maximum concentrations of each of these metals were several to many times higher at the mine site.

It should be noted that two metals showed higher concentrations at the control site than at the mine site. Iron (Fe) concentrations in red-backed vole livers were significantly higher at the control site (651±103 ppm) than at the mine site (463±74 ppm) ($t=-3.563$, $p<0.05$). Mercury (Hg) levels were also slightly higher at the control site (0.19±0.16) than at the mine site (0.084±0.030), but this difference was not significant.

In red-backed vole kidneys, maximum concentrations of arsenic (As), cadmium (Cd), lead (Pb) and silver (Ag) were notably higher at the mine site than the control area, and mean concentrations were slightly higher as well (Table 3.29). However, the sample size of red-backed vole kidneys was too small to analyze statistically. Similar to red-backed vole livers, the variation in metal levels was greater for samples collected at the mine site than at the control site. Again, while minimum levels of these metals were similar (for arsenic, lead and silver) between the mine and control sites, maximum levels were several times higher at the mine site.

A few metals appeared to be higher in red-backed vole kidneys from the mine site; however, the sample size of control data was small.

Table 3.29. Concentrations (ppm) of metals in kidneys of red-backed voles in control and mine sites (2005 and 2006 pooled data).

	Arsenic		Cadmium		Lead		Silver	
	Average	Range	Average	Range	Average	Range	Average	Range
Mine Site (n= 5)	0.2	<0.3-0.40	13.4	7.7-24.3	0.6	0.2-1.0	0.03	<0.03-.04
Control Site (n=2)	0.1	<0.1-<0.3	3.1	1.1-5.1	0.1	0.1-<0.3	0.01	<0.01-<0.03

*For averages and statistical purposes, concentrations below laboratory detection limits were estimated at ½ of detection limits.

Spruce Grouse

Concentrations of metals in spruce grouse kidney, liver, gizzard and muscle tissue samples obtained in 2006 were analyzed. Unpublished data on metal concentrations in spruce grouse livers, kidneys and muscle tissue samples collected throughout the Yukon were also obtained (pers. comm. Gamberg, 2006).

In spruce grouse kidneys, mean concentrations of aluminum (Al), arsenic (As), cadmium (Cd) and lead (Pb) were higher at the mine site than the control area. This difference was significant only for arsenic. Mine site arsenic levels were also significantly higher than levels recorded in the Yukon data set. As well, the maximum concentrations of aluminum at the mine site were higher than levels recorded in the Yukon data set, but this difference was not significant. In contrast, cadmium and lead levels at the mine site were lower than the highest levels of these metals recorded in the Yukon data set (Table 3.30). The wide range in values for all four of these metals in the larger Yukon data set (n=27) points to a high degree of variability in aluminum, arsenic, lead and cadmium concentrations in spruce grouse that may not be captured by the smaller sample sizes in the mine and control sites.

Average levels of Al, As, Cd, Cr, Pb, were higher in spruce grouse kidney from the mine site; however, only arsenic was significantly higher compared to the control site and Yukon background data.

Table 3.30. Concentrations (ppm) of metals in spruce grouse kidneys in control and mine sites (2006), as well as specimens collected throughout the Yukon.

		Aluminum		Arsenic		Cadmium		Lead	
		Average	Range	Average	Range	Average	Range	Average	Range
Location	Mine Site (n= 7)	10.8	3.1-42.3	0.4	0.2-0.6	15.5	1.2-72.9	4.4	0.6-10.3
	Control Site (n=4)	5.4	3.6-7.1	0.1	0.1-0.1	4.6	2.7-5.9	0.9	0.3-2.6
	Yukon (n=27)	3.6	0.03-20.8	0.08	0.01-0.5	40.3	0.88-760	10.7	0.10-285
Mine Site vs Control Site				✓					
Mine Site vs Yukon				✓					

It should also be noted that mean molybdenum (Mo) concentrations were significantly higher at the control site (4.1±0.4) than at the mine site (5.6±0.3) ($t=-6.828$, $p<0.05$).

For spruce grouse livers, maximum concentrations of cadmium (Cd) and lead (Pb) were higher at the mine site than the control site. However, the highest concentrations of cadmium and lead in samples obtained at the mine site were lower than the highest levels of these metals recorded in the Yukon data set (Table 3.31). No significant differences were detected in mean concentrations of these metals.

Table 3.31. Concentrations (ppm) of metals in spruce grouse livers in control and mine sites (2005 and 2006 pooled data), as well as specimens collected throughout the Yukon.

	Cadmium		Lead	
	Average	Range	Average	Range
Mine Site (n= 7)	3.4	0.47-10.1	1	0.2-2.3
Control Site (n=4)	2.4	1.8-2.8	0.3	0.05-0.9
Yukon (n=23)	4.5	0.36-14.8	0.46	0.014-2.4

It should also be noted that mean concentrations of aluminum (Al), manganese (Mn) and arsenic (As) in spruce grouse livers were higher at the control site than the mine site, but these differences were not significant. There were no notable differences in mine site and control metal concentrations in spruce grouse muscle tissue. For spruce grouse gizzards, levels of arsenic and cadmium were higher at the mine site than the control site, but this difference was not significant (Table 3.32). Again, while minimum concentrations of these two metals were similar between the control and mine sites, maximum concentrations of both were several times higher at the mine site.

There were no notable differences in mine site and control metal concentrations in spruce grouse muscle tissue.

Table 3.32. Concentrations (ppm) of metals in spruce grouse gizzards in control and mine sites (2005 and 2006 pooled data).

	Arsenic		Cadmium	
	Average	Range	Average	Range
Mine Site (n= 6)	0.78	0.1-1.2	0.15	0.1-0.2
Control Site (n=4)	0.35	0.13-0.91	0.21	0.13-0.29

Gray Jays

Gray jay samples were obtained only in 2005. Tables 3.33 and 3.34 show metal concentrations in the mine and control sites for gray jay kidneys and livers. In gray jay kidneys, the mine site sample shows slightly higher levels of chromium, manganese, cadmium and magnesium. In gray jay livers, concentrations of arsenic, lead, silver and manganese are higher at the mine site, and this difference is significant for arsenic and manganese. Please note that the sample size is extremely small.

Table 3.33. Concentrations (ppm) of metals in gray jay kidneys in control and mine sites (2005 data).

	Cadmium	Chromium	Manganese	Magnesium
Mine Site (n= 1)	13.7	0.6	12.4	734
Control Site (n=1)	7.35	0.5	10.9	686

In gray jay liver and kidneys from the mine site, some metals appeared higher

Table 3.34. Concentrations of metals (ppm) in gray jay livers in control and mine sites (2005 data).

	Arsenic		Lead		Manganese		Silver	
	Average	Range	Average	Range	Average	Range	Average	Range
Mine Site (n= 2)	0.75	0.7-0.8	0.25	0.2-0.3	9.6	8.8=10.3	0.08	0.04-0.11
Control Site (n=2)	<0.05	<0.05	<0.1	<0.1	5.1	4.6-5.5	<0.01	<0.01
Mine Site vs Control Site	✓				✓			

*For averages and statistical purposes, concentrations below laboratory detection limits were estimated at ½ of detection limits.

Snowshoe Hare

Snowshoe hare snared at the mine showed higher levels of a number of metals than the Rowlinson Creek control area. In kidneys, the highest concentrations of aluminum, arsenic, barium, cadmium, and lead were 4 to 21 times higher from hares from the mine than the control area (Table 3.35). The level of zinc was slightly higher in the mine site than in the control area. Lead was the only metal that was higher in snowshoe hare kidneys at the mine site than levels recorded in Yukon background data (Gamberg 2007). It should also be noted that molybdenum levels were higher in snowshoe hare kidneys in the control area (0.8-1.4 ppm) than at the mill site (0.6 ppm). None of these differences (between the mine site and controls) were statistically significant.

Table 3.35. Concentrations of metals in snowshoe hare kidneys near the mine site, control site (2006 data) and Yukon background data.

	Aluminum		Arsenic		Barium		Cadmium		Lead		Zinc	
	Average*	Range	Average*	Range	Average*	Range	Average*	Range	Average*	Range	Average*	Range
Mine Site (n= 3)	7.63	0.7-20.1	0.32	<0.1-0.5	2.3	0.8-4.1	49.8	40.9-58.3	1.03	0.2-2.1	115	89.4-151
Control Site (n=3)	1.57	0.9-2.4	0.07	<0.1-0.1	0.8	.6-1.1	8.79	8.3-9.6	0.07	<0.1-0.1	78.7	54.2-104
Yukon Background Data (n=28)	2.03	<0.05-24	0.36	<0.01-0.8	1.18	0.15-11.01	23.78	6.2-166	0.21	<0.014-0.67	69.2	46-197

*For averages and statistical purposes, concentrations below laboratory detection limits were estimated at ½ of detection limits.

In snowshoe hare livers, the highest concentrations of arsenic, barium, cadmium and lead were higher at the mine site than in the control area. However, comparisons to Yukon background data (Gamberg 2007) show that all metal concentrations for snowshoe hare livers from the zone of influence are within the range of Yukon wide data for this species (Table 3.36). It should also be noted that molybdenum concentrations were higher in snowshoe hare livers in the control site (0.8-1.4 ppm) than the mill site (0.4 ppm) or the tailings pond (0.1-0.4 ppm).

Some metals were notable in snowshoe hare kidneys from the mine site.

Table 3.36. Concentrations of metals in snowshoe hare livers near the mine site, control site (2006 data) and Yukon background data.

	Arsenic		Barium		Cadmium		Lead	
	Average*	Range	Average*	Range	Average*	Range	Average*	Range
Mine Site (n= 3)	0.18	<0.1-0.3	0.4	0.2-0.6	2.7	1.83-3.0	0.7	0.2-1.3
Control Site (n=3)	<0.1	<0.1	0.2	0.1-0.3	0.46	0.41-0.49	<0.1	<0.1
Yukon Background Data (n=27)	0.59	<0.01-0.81	0.42	<0.005-1.56	1.83	0.1-4.9	0.35	<0.01- 1.57

*For averages and statistical purposes, concentrations below laboratory detection limits were estimated at ½ of detection limits.

In showshoe hare muscle tissue, the highest concentrations of aluminum and arsenic were 2 to 3 times higher at the mine site than in the control area. As well, arsenic levels in the mill site sample were 4 times higher than in the control area. However, aluminum levels from Yukon background data (Gamberg 2007) were higher than the data from the mine site. Arsenic levels appeared to be only slightly elevated in comparison to Yukon background data (Table 3.37).

Several metals were found to be higher in snowshoe hare muscle (flesh) from the mine site when compared to controls.

Table 3.37. Concentrations of metals in snowshoe hare muscle tissue at the mine site, control site (2006 data) and Yukon background data.

	Aluminum		Arsenic	
	Average*	Range	Average*	Range
Mine Site (n= 3)	2.73	1.3-4.2	0.25	<0.1-0.4
Control Site (n=3)	1.93	1.6-2.1	<0.1	<0.1
Yukon Background Data (n=12)	3.20	<0.05-5.58	n/a	<0.01-0.10

*For averages and statistical purposes, concentrations below laboratory detection limits were estimated at ½ of detection limits.

Marten

One marten was trapped at the mine site in 2006. This sample showed levels of aluminum in kidney that were 6 times higher than the highest concentration of aluminum found in marten samples collected from throughout the Yukon. There were no notable differences in concentrations of metals between the marten liver sample collected at the mine site and livers collected throughout the Yukon (n=7). It should be noted that no data were available for levels of silver or mercury in the Yukon data set; thus, comparison with the mine site sample was not possible for these metals.

Table 3.38. Concentrations of metals in marten kidneys in the mine site and Yukon.

	Aluminum	
	Average	Range
Mine Site (n= 1)	10.1	10.1
Yukon Background Data Gamberg (2006) (n=7)	0.838	<0.55-1.78

3.1.4.2 Ungulates

Element concentrations in moose and caribou tissues from the Mt. Nansen mine site were compared to concentrations in moose and caribou from other parts of the Yukon. Data from the Yukon Contaminants Database was utilized for comparisons, and all data from Game Management Zone 5 (near the Mt. Nansen mine site) were removed before comparisons were made. Caribou were compared only to other woodland caribou from the territory, and not to barren-ground caribou (*Rangifer tarandus granti*; Porcupine herd) because of the differences in diet that could contribute to differential body burdens of some elements.

Metal levels in moose and caribou tissues from the Mt. Nansen mine site were compared to concentrations in moose and caribou from other parts of the Yukon

Some elements can vary with age in moose and caribou (Gamberg 2000), and should be considered as a factor when comparing element concentrations among sites or herds. Because the data were not normally distributed, the effect of age was investigated for each element in each tissue in each species using Spearman's Rank Correlation. When age was a significant factor (α=0.05), the element concentration was normalized for age (age/year) before proceeding further with the analysis.

Element concentrations were compared between the Mt. Nansen site and the rest of the Yukon for each moose tissue (kidney, liver, muscle) using a t-test where the data were normally distributed, and a Mann-Whitney Rank Sum test when the data were not normally distributed, and using age-normalized data where appropriate. The effect of herd on element concentration was tested for woodland caribou tissue (kidney, liver, muscle) was tested using an ANOVA and Tukey's test for multiple comparisons when the data were normally distributed, and using a One-Way ANOVA on Ranks and Dunn's test for multiple comparisons when the data were not normally distributed. In all cases α=0.05. In the multiple comparison tests, all other herds were compared against the Klaza herd (from the Mt. Nansen site). It should be noted that sample numbers from the Mt. Nansen site were very low, and caution should be taken when drawing conclusions from the analyses of so few data.

Mean concentrations of elements are compared in tissues from Mt. Nansen and other areas of the Yukon for woodland caribou in Table 3.39, and for moose in Table 3.40. Each element of concern will be discussed individually. Note that boron and magnesium were not measured by the analytical laboratory.

Concentrations of some elements, such as zinc, were fairly consistent for each organ, even between species, with the exception of one individual moose, that had anomalous levels of several elements. This individual moose was shot near the Mt. Nansen tailings pond and was sampled because there was a concern about contamination from a human consumption standpoint. This individual (ID# 99-774) had relatively high concentrations of liver aluminium, copper, iron and tin, and very low concentrations of renal zinc (kidney).

Antimony

Antimony levels in ungulates harvested near the mine site were similar to ungulates from other areas.

Antimony is not an essential element for animals and although it can be toxic, mobility in food chains is low (Ainsworth et al., 1990). Little antimony occurs free in nature, most being found as the ore stibnite. Industrial uses of antimony include the manufacture of dyes, rubber, paint and enamel vessels. Antimony-tin alloys have also been used in battery grids, lead shot, cable coverings, printer type, foil and solder (Puls, 1994).

Age did not significantly affect antimony concentrations in any tissues measured in moose or caribou measured in this study. In this study, most samples were near or below the detection limit for antimony (Tables 3.39 and 3.40) and no significant differences were observed between the Mt. Nansen mine site and other areas of the Yukon for any tissue in moose or caribou. These data show no evidence of elevated antimony concentrations in moose or caribou from the Mt. Nansen area.

Table 3.39. Mean concentrations (mg/kg dry weight) of elements in woodland caribou tissues from the Mt. Nansen mine site (Klaza herd) and from other areas of the Yukon, and a statistical comparison of element concentrations between the two areas.

	Kidney			Liver			Muscle		
	Mt. Nansen	Yukon	Difference	Mt. Nansen	Yukon	Difference	Mt. Nansen	Yukon	Difference
N	5	169		7	107	-	3	50	-
Antimony	0.009	0.047	-	0.003	0.003	-	0.003	0.004	-
Arsenic	0.10	0.22	✓ ($p<0.001$)	0.01	0.08	✓ ($p=0.006$)	0.03	0.25	-
Cadmium	51.0	95.7	-	7.1	8.4	✓ ($p<0.001$)	0.1	0.1	-
Chromium	1.395	0.697	✓ ($p=0.002$)	0.765	0.583	-	1.390	0.502	-
Copper	25.2	24.3	✓ ($p<0.001$)	88.0	73.0	-	10.4	10.4	-
Lead	0.143	0.566	✓ ($p<0.001$)	0.053	0.709	✓ ($p<0.001$)	0.014	0.054	-
Manganese	7.1	8.2	✓ ($p<0.001$)	9.9	10.4	✓ ($p=0.041$)	1.3	1.1	-
Mercury	0.86	2.51	✓ ($p=0.001$)	0.13	0.54	✓ ($p=0.001$)	0.01	0.02	N/A
Nickel	0.005	0.235	✓ ($p=0.005$)	0.041	0.084	✓ ($p<0.001$)	1.047	0.150	-
Selenium	3.80	5.56	✓ ($p<0.001$)	0.86	1.44	✓ ($p<0.001$)	0.46	1.55	-
Silver	0.018	0.023	-	0.961	1.996	-	0.088	0.007	-
Zinc	114.6	124.5	✓ ($p<0.001$)	71.5	81.0	✓ ($p=0.009$)	107.9	164.1	-

- indicates no significant difference at $\alpha=0.05$; N/A indicates too few data to compare.

In general, most metal levels were similar or in caribou tissue from the mine site area compared to caribou in other areas in the Yukon.

Table 3.40. Mean concentrations (mg/kg dry weight) of elements in moose tissues from the Mt. Nansen mine site and other areas of the Yukon, and a statistical comparison of element concentrations between the two areas.

	Kidney			Liver			Muscle		
	Mt. Nansen	Yukon	Difference	Mt. Nansen	Yukon	Difference	Mt. Nansen	Yukon	Difference
N	4	365		4	55		3	36	-
Antimony	0.001	0.016	-	0.003	0.010	-	0.003	0.061	-
Arsenic	0.07	0.33	✓ ($p=0.008$)	0.04	0.08	-	0.06	0.09	-
Cadmium	125.5	144.3	-	16.9	15.6	-	0.1	0.1	-
Copper	17.5	17.0	-	351.0	107.7	✓ ($p=0.029$)	4.8	5.8	-
Chromium	0.233	1.068	✓ ($p=0.007$)	0.190	1.526	✓ ($p=0.006$)	0.290	0.997	✓ ($p=0.008$)
Lead	0.060	0.451	-	0.028	0.300	-	0.013	5.068	-
Manganese	15.2	8.7	-	11.2	7.3	-	0.7	0.8	-
Mercury	0.06	0.08	-	0.03	0.03	-	<0.002	0.07	-
Nickel	0.325	0.470	-	0.179	0.093	-	0.125	0.092	-
Selenium	2.87	4.99	✓ ($p=0.017$)	1.21	4.89	✓ ($p=0.045$)	0.41	0.93	-
Silver	<0.0001	0.0151	-	0.3683	0.3514	-	<0.0001	0.0911	-
Zinc	128.4	143.9	-	65.5	100.7	-	178.4	208.9	-

- indicates no significant difference at $\alpha=0.05$.

In general, most metal levels were similar or in moose tissue from the mine site area compared to moose in other areas in the Yukon.

Arsenic

Although arsenic is a generally considered a non-essential element, it has recently been identified as an essential trace element for domestic goats (Puls, 1994). It can be absorbed by ingestion, inhalation and permeation of skin or mucous membranes and accumulates in the liver, kidney, spleen, muscle, skin and hair. Toxic effects include respiratory cancer, peripheral nervous system disorders and dermatitis (Jaworski, 1980). Toxicity depends on the concentration and form, trivalent arsenic (arsenite) being 5 to 10 times more toxic than pentavalent (arsenate). Elemental arsenic is non-toxic. Since the use of arsenic in herbicides, insecticides, fungicides and rodenticides has been largely discontinued, the main sources of arsenic to the environment are mine tailings, smelter waste and natural mineralizations (Jaworski 1980).

Arsenic levels in ungulates harvested near the mine site were often lower than ungulates from other areas.

Age did not significantly affect arsenic concentrations in any tissues measured for moose or caribou from this study. Arsenic levels in caribou and moose from this study were consistently low (Tables 3.26 and 3.27) and were significantly lower in moose and caribou kidneys and caribou liver from the Mt. Nansen mine site than from other areas of the Yukon. No significant differences were seen between the two areas in any other tissues for moose or caribou. As such, these data show no evidence of elevated arsenic concentrations in moose or caribou from the Mt. Nansen area.

Cadmium

Cadmium is a toxic element that accumulates in animals over time (and therefore with age), primarily in the kidneys and liver. Chronic exposure may lead to anemia, enteropathy, renal damage, osteoporosis and osteomalacia. Long-range transport distributes cadmium widely over the environment, and natural mineralization may serve as point sources. Lichens absorb cadmium directly from the air, eventually passing it on to caribou who feed on the lichen. Plants differ in their ability to absorb cadmium from soil and water, some species, such as willow (*Salix* spp.), accumulating relatively high concentrations if they grow in cadmium-rich soil. Cadmium accumulates in long-lived herbivores, generally not in high enough levels to impair their health. Industrial uses of cadmium include production of cadmium-plated metal, nickel-cadmium batteries, pigments and plastic stabilizers, mining and refining of copper, lead and zinc (Jaworski, 1980).

Cadmium levels in ungulates harvested near the mine site were normal.

Age significantly affected cadmium concentrations in moose and caribou kidneys, but not in liver and muscle. Age-normalized data for cadmium in moose and caribou kidneys were used to test for differences between the Mt. Nansen area and other areas of the Yukon. Cadmium concentrations were significantly lower in caribou liver from the Mt. Nansen mine site than from other areas of the Yukon. No significant differences were found in kidney or muscle in moose or caribou or in moose liver (Tables 3.26 and 3.27). Renal tubule dysfunction has been shown to occur at kidney cadmium levels of 400-800 ppm dry wt for most birds and mammals studied (Elliot et al., 1992; Kjellstrom, 1986). Concentrations measured in this study do not approach these concentrations, and should not be cause for concern in terms of the health of the animals. These data show no evidence of elevated cadmium concentrations in moose or caribou from the Mt. Nansen area.

Chromium

Chromium is an essential trace element in animals, and is closely associated with the functioning of insulin. Toxicity may cause scouring, dehydration, dermatitis and skin allergies. Chromate is used in oil fields as a drilling aid, production of pigments for ink, paint, etc., as a wood preservative and in the tanning industry (Puls, 1994).

Age significantly affected chromium concentrations in moose kidneys, but not in liver or muscle, or in any of the tissues measured in caribou. Age-normalized data for chromium in moose kidneys were used to test for differences between the Mt. Nansen area and other areas of the Yukon. Chromium concentrations in moose kidney, liver and muscle were significantly lower in animals collected from the Mt. Nansen area as compared with other areas of the Yukon (Tables 3.26 and 3.27). Concentrations in caribou kidneys were higher in Klaza caribou from the Mt. Nansen area than in herds from other areas of the Yukon. However, all concentrations of chromium measured in this study, even the highest concentrations seen in Klaza caribou kidneys, fall within the range considered normal for domestic cattle (Puls, 1994) and should not be a toxicological concern for the animals.

Chromium levels in moose harvested near the mine site were lower than in other areas.

Copper

Copper is an essential element. Since it is homeostatically controlled, excess Cu is excreted in the urine, and toxicity is rare under normal conditions. Toxic effects may occur, however, and can include dermatitis, anemia, gastric ulcers, renal damage and hemolysis (Aaseth and Norseth, 1986). Copper deficiency has been noted in Alaskan moose with faulty hoof keratinization and reduced reproductive rates (Flynn et al., 1977). Industrial uses include production of electrical equipment and alloys, plating, plumbing, heating, and uses in mining and smelting.

Age significantly affected copper concentrations in moose kidneys and caribou liver, but not in other tissues measured. Age-normalized data for copper in moose kidneys and caribou liver were used to test for differences between the Mt. Nansen area and other areas of the Yukon. Significantly higher concentrations of copper were found in moose liver and caribou kidneys from Mt. Nansen when compared with the same species collected from other areas of the Yukon (Tables 3.26 and 3.27). Copper concentrations were also higher in moose kidney and caribou liver from the Mt. Nansen area, but the differences were not statistically significant. Although most of the copper concentrations measured in this study fall within the range considered normal for domestic cattle, one individual moose (sampled from near the tailings pond) had a high concentration of copper in the liver (564 mg/kg dry weight) which would fall into the category of ‘high’ for domestic cattle (however below ‘toxic’; Puls, 1994). It should be further noted that liver copper appears to be the most informative regarding copper status of the animal.

Most ungulates from the areas near the mine site had normal copper levels.

Lead

Lead is a toxic element that is stored for the long term in bone tissue, and in the short-term, in liver and kidney. Toxic signs include anemia, anorexia, fatigue and blindness. Common sources of lead include mining, smelting and refining of lead and other ores, burning petroleum fuels containing lead additives, burning coal and oil and use in shotgun pellets. Lead may also be found in paint (even 'lead-free paint may contain up to 1% lead), waste engine oil, lead batteries, putty, roofing tiles, linoleum, solder and golf balls. Some pipe joint or thread compounds (used on drilling sites) can contain up to 40% lead powder (Puls, 1994).

Lead levels in ungulates harvested near the mine site were lower than in other areas.

Age significantly affects lead concentrations in caribou muscle, but not in other tissues measured. Age-normalized data for lead in caribou muscle were used to test for differences between the Mt. Nansen area and other areas of the Yukon. Lead concentrations in all tissues measured in moose and caribou were lower in animals from the Mt. Nansen mine area when compared with other areas of the Yukon, but only differences seen in caribou kidney and liver were significantly lower (Tables 3.26 and 3.27). All lead concentrations measured in the study were low, and did not approach the threshold value of 20 ppm wet weight (≅ 80 ppm dry weight) indicative of lead poisoning (Scheuhammer, 1991). These data show no evidence of elevated lead concentrations in moose or caribou from the Mt. Nansen area.

Manganese

Manganese is an essential element for normal thyroid function, cartilage and bone formation, lipid and carbohydrate metabolism, maintaining normal central nervous system function and for reproductive processes. Calcium, cadmium, cobalt, iron, phosphorus and zinc are antagonistic to manganese. Deficiency of manganese is rare, but may lead to reduced reproductive success and skeletal deformities in newborns. Toxic signs include reduced appetite and growth rate, anemia and abdominal discomfort. Manganese is used in gasoline in Canada to raise the octane level (Puls, 1994).

Concentrations of manganese in caribou liver and kidney were significantly lower at Mt. Nansen than in other areas.

Age significantly affects manganese concentrations in moose kidney and liver, but not in moose muscle or caribou kidney, liver or muscle. Age-normalized data for manganese in moose liver and kidney were used to test for differences between the Mt. Nansen area and other areas of the Yukon. No significant differences were found between manganese concentrations in kidney, liver or muscle from moose between the two areas (Table 3.26). However, manganese concentrations in moose liver and kidney appear somewhat higher in moose from the Mt. Nansen area. Concentrations of manganese were significantly lower in caribou kidney and liver from the Klaza herd from the Mt. Nansen area than in caribou herds from other areas of the Yukon (Table 1, and although they fall into the high range for domestic sheep, they do not approach toxic concentrations (Puls, 1994).

Mercury

Mercury is a toxic element that accumulates in brain and kidney tissue, affects neurological functions and may cause gastrointestinal disturbance, reduction of food intake, poor growth, renal damage or death. Prenatal exposure may lead to cerebral palsy (Berlin, 1986). Inorganic mercury may be transformed to methylmercury (a more toxic form of mercury) by natural microbial action in lakes. This process may be promoted by excess sulphides from atmospheric deposition or nutrification of lakes. Aquatic life is generally more sensitive to methylmercury than terrestrial species. Environmental sources of mercury include mining, milling and smelting of mercury-containing ores, chlor-alkali plants, coal-burning plants, municipal wastewater treatment plants, pulp and paper mills and fungicides. Natural mercury occurs as volcanic gases, natural mineralization and evaporation from oceans (World Health Organization, 1989).

Age did not have a significant effect on mercury concentrations of kidney, liver or muscle from moose or caribou from this study. Mercury concentrations in all tissues measured in moose and caribou were lower in animals from the Mt. Nansen area as compared to other areas of the Yukon, but the only differences that were statistically significant were for caribou kidney and liver (Tables 3.26 and 3.27). There were too few samples to statistically analyze the difference in mercury concentrations between areas in caribou muscle. Mercury concentrations found in this study were uniformly low and should not pose a health hazard to the animals.

Mercury levels in ungulates harvested near the mine site were similar or less than in other areas of the Yukon.

These data show no evidence of elevated mercury concentrations in moose or caribou from the Mt. Nansen area.

Nickel

Nickel is an essential micronutrient accumulating mainly in the kidney, and appears to be under homeostatic control in mammals but not birds. Deficiency may cause decreased weight gain and increased mortality, while toxic effects include decreased immune system function, growth, insulin function, bone density, organ weights and reproductive performance. Acute poisoning affects the central nervous system and may be lethal. Nickel is not biomagnified in mammalian or avian food chains. The groups most at risk are those depending on freshwater plants, fish or invertebrates as food. Terrestrial plant herbivores are least susceptible (Outridge, 1991).

Age significantly affects nickel concentrations in moose kidney and muscle, but not in moose liver or caribou kidney, liver or muscle. Age-normalized data for nickel in moose kidney and muscle were used to test for differences between the Mt. Nansen area and other areas of the Yukon. Although nickel concentrations in caribou liver and kidneys were significantly lower in caribou from the Mt. Nansen area when compared to other areas of the Yukon (Tables 3.26 and 3.27), the absolute difference between means was low. Nickel concentrations measured in moose and caribou in this study were uniformly low and should not pose a toxicological threat to the animals.

There was no evidence of elevated nickel in ungulates harvested near the mine site.

These data show no evidence of elevated nickel concentrations in moose or caribou from the Mt. Nansen area.

Selenium

Selenium is an essential element which interacts with vitamin E to ensure optimum functioning of the immune and reproductive systems. Because some geographical areas are naturally low in selenium, deficiencies can occur, causing white muscle disease, reduced growth and reproductive rates, and reduced immune response. Signs of toxicity may include emaciation, lameness, cracked or deformed hooves and loss of hair. It has been thought that excess selenium also causes 'blind staggers', but this may be due to other compounds in the selenium-accumulating plants (*Astralagus* sp.) responsible for this disease (Puls, 1994). Industrial uses of selenium include electronics, photography, glass production, fungicides, insecticides and pigments in plastics, paints, enamels, inks and rubber.

Age significantly affects selenium concentrations in moose kidney, but not in moose liver or muscle or caribou kidney, liver or muscle. Age-normalized data for moose kidney were used to test for differences between the Mt. Nansen area and other areas of the Yukon. Selenium concentrations in moose and caribou kidney and liver were significantly lower in animals collected from the Mt. Nansen area when compared to other areas of the Yukon (Tables 3.26 and 3.27). The same trend was seen in selenium concentrations in moose and caribou muscle, but the differences were not statistically significant. Although some moose and caribou from the Yukon have concentrations of selenium that fall into the high to toxic range for domestic cattle (Puls, 1994), this is not the case for those animals from the Mt. Nansen mine which were measured in this study; those moose and caribou fall into the marginal to adequate range.

The data from this study show no evidence of elevated selenium in ungulates harvested near the mine site.

These data show no evidence of elevated selenium concentrations in moose or caribou from the Mt. Nansen area.

Silver

No essential function of silver has been demonstrated in animals, and most ingested silver is eliminated in the feces. Toxic signs include those of induced selenium/vitamin E or copper deficiency, reduced weight gain and increased mortality (Puls, 1994).

Age did not significantly affect silver concentrations in kidney, liver or muscle from moose or caribou measured in this study. No significant differences were seen in silver concentrations between the Mt. Nansen area and other areas of the Yukon for moose or caribou kidney, liver or muscle tissue. Silver concentrations measured in this study were low in tissues of both moose and caribou and should not be of toxicological concern.

This study found no evidence of elevated silver in ungulates harvested near the mine site.

These data show no evidence of elevated silver concentrations in moose or caribou from the Mt. Nansen area.

Zinc

Zinc is an essential, homeostatically controlled element, and is an important component of many proteins and enzymes. Zinc deficiency may result in reduced conception rate, reduced feed intake and growth rate, and thickening and shortening of bones. Toxic effects include anemia, poor bone mineralization, arthritis, general osteochondrosis and lameness (Sileo and Beyer, 1985). Zinc is released into the environment through mining, smelting and residential and industrial effluents and is used industrially in electroplating, the combustion of fossil fuels, petroleum by-products and solid wastes.

Zinc levels in ungulates harvested near the mine site were often lower than in other areas in the Yukon.

Age did not significantly affect zinc concentrations in moose or caribou kidney, liver or muscle tissue from this study. Zinc concentrations in caribou liver and kidneys were significantly lower in caribou collected from the Mt. Nansen area when compared with other areas of the Yukon. The same trend was seen in moose kidney, liver and muscle, and caribou muscle. Zinc concentrations found in moose and caribou in this study ranged from marginal (liver) to adequate to high (kidney) as compared with domestic cattle (Puls, 1994).

These data show no evidence of elevated zinc concentrations in moose or caribou from the Mt. Nansen area.

3.1.5 Moss Bags

Moss bags were deployed three times over the course of one year.

Results for moss bags can be split into three time periods, 'winter' (October 12, 2005 and May 5, 2006), 'spring – early summer' (May 5 to July 27, 2006) and 'late summer early fall' (July 27 to October 17, 2006) which when combined cover slightly more than a calendar year. Complete laboratory data from moss bags are in Appendix G.

3.1.5.1 Winter Deployment

For the 'winter' deployment period, metal levels from the mine site were found to be similar or only slightly higher than levels at the control site (Rowlinson Creek; Figure 3.12 and 3.13, Table 3.41). Of note, one pit sample, Pit 2, located northeast of the Brown McDade Pit, had the highest levels of arsenic and lead. In fact, this sample raised the average for lead and arsenic for the pit substantially. On average, lead and arsenic concentrations were found to be highest at the pit site followed by the pond and mill. Other metals appeared to be relatively similar at all sites, including copper (Figure 3.14). These results indicate that only some metals are being spread by aerial dispersion.

Table 3.41. Mean metal levels (ug/g) in moss bags for the winter deployment period.

Metal	Sampling Location					
	Lab Control	Office Control	Rowlinson Control	Pit	Tailings Pond	Mill Site
Arsenic (As)	0.30	0.25	0.20	0.78	0.45	0.38
Antimony (Sb)	0.01	0.10	0.10	0.13	0.10	0.10
Copper (Cu)	16.67	12.15	13.37	14.4	13.8	13.15
Lead (Pb)	0.83	0.60	1.08	1.73	1.60	1.30
Silver (Ag)	0.01	0.02	0.03	0.03	0.03	0.03

During the 'winter' deployment metal levels in moss bags were comparable to control data; however, slightly higher around the pit.

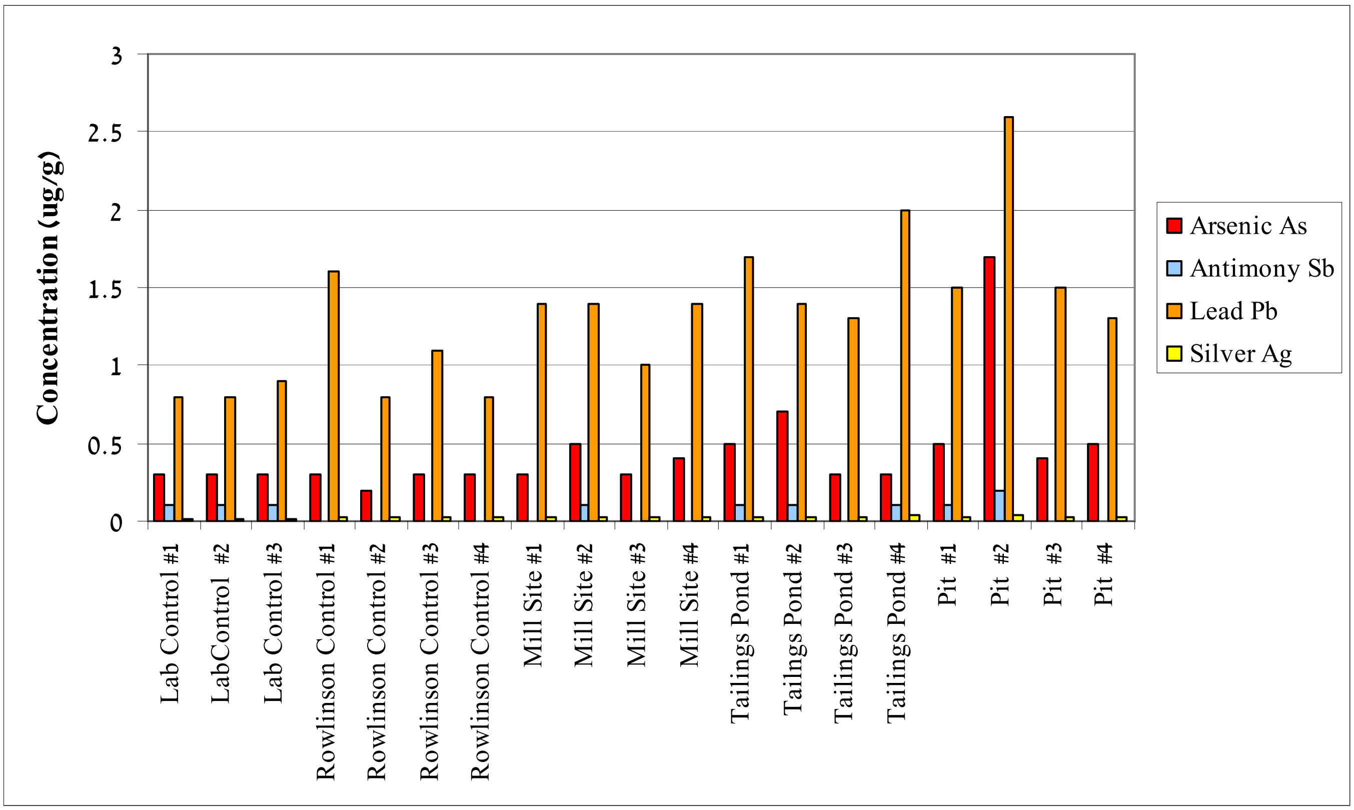


Figure 3.12. Metal concentration (ug/g) of arsenic, antimony, lead and silver at each sample location (October 2005 – May 2006).

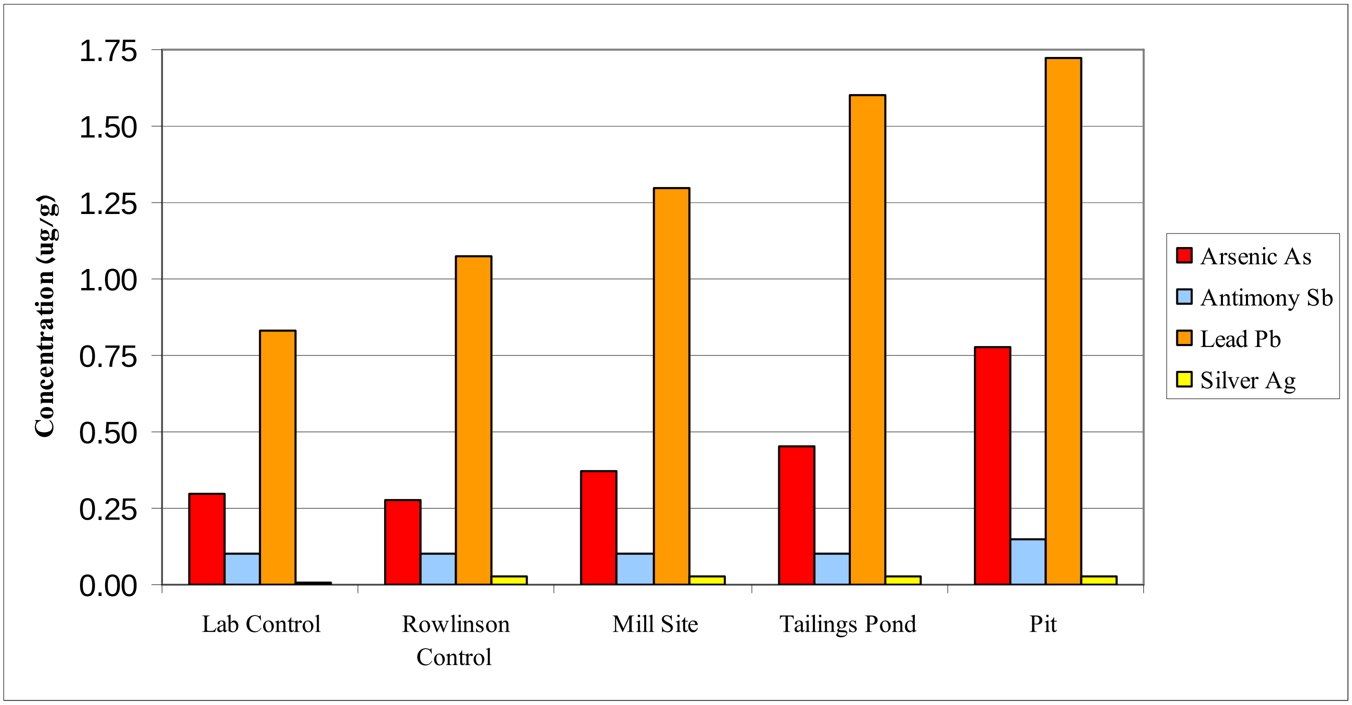
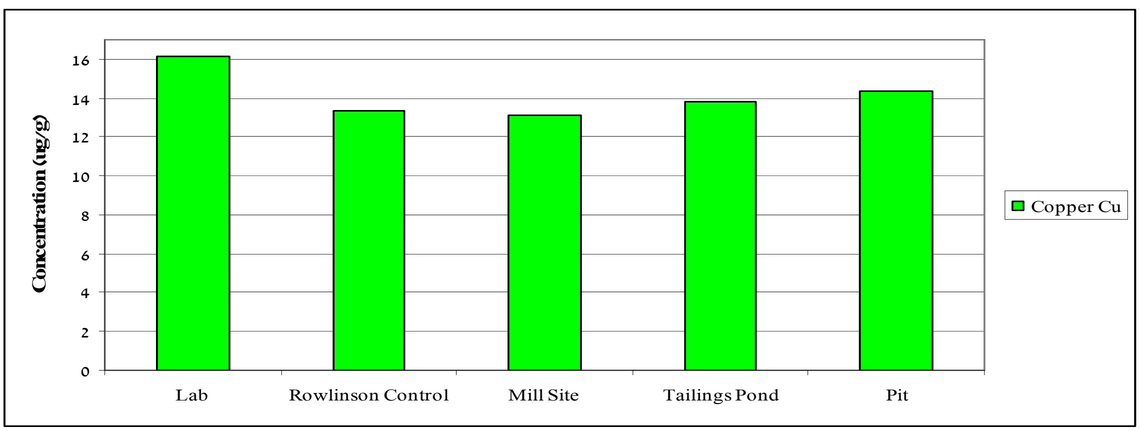


Figure 3.13. Average arsenic, antimony, lead, and silver concentrations (ug/g) around each site (October 2005 – May 2006).



These results indicate that copper does not appear to be transported by dust around the mine site during the winter.

Figure 3.14. Average copper concentrations (ug/g) around each site (October 2005 – May 2006).

3.1.5.2 Spring, Early Summer Deployment

For the spring period, moss bags were deployed from May 5, 2006 to July 27, 2006 and were returned to the lab for analysis; unfortunately, the lab combined moss bags from all of the sites in each sampling location. As a result, four composite samples were tested - one each for Rowlinson, the mill site, the pit and the pond. Despite this, the results during this period revealed some interesting trends. Arsenic, lead and, to a lesser extent, antimony, silver and cadmium were considerably higher from the moss bags deployed around the tailings pond than the other sites (Table 3.42; Figure 3.15 and 3.16). Arsenic and lead levels were somewhat higher at the pit and mill site than control locations. It is suspected that the low water levels in the pond in the early summer made some of the tailings susceptible to movement by wind. Of note, wind data from this time period indicates the prevailing wind was from the south-west (see Appendix A). The wind monitoring station is located in a timbered area near the tailings pond, approximately 100 metres up the slope on its northern side.

During the 'spring, early summer' deployment, arsenic, antimony, cadmium, lead and silver levels were highest in moss bags around the tailings pond.

Table 3.42. Metal levels (ug/g) in moss bags for the spring, early summer deployment period (mean levels from lab and office control).

	Sampling Location					
Metal	**Lab Control (n=3)**	**Office Control (n=2)**	**Rowlinson Control (n=1)**	**Pit (n=1)**	**Tailings Pond (n=1)**	**Mill Site (n=1)**
Arsenic (As)	0.30	0.25	0.30	1.10	13.30	1.80
Antimony (Sb)	0.01	0.10	0.70	0.70	2.00	1.20
Copper (Cu)	16.67	12.15	13.4	15.3	17.8	22.2
Lead (Pb)	0.83	0.60	0.70	1.20	11.10	1.60
Silver (Ag)	0.01	0.02	0.02	0.03	0.30	0.05

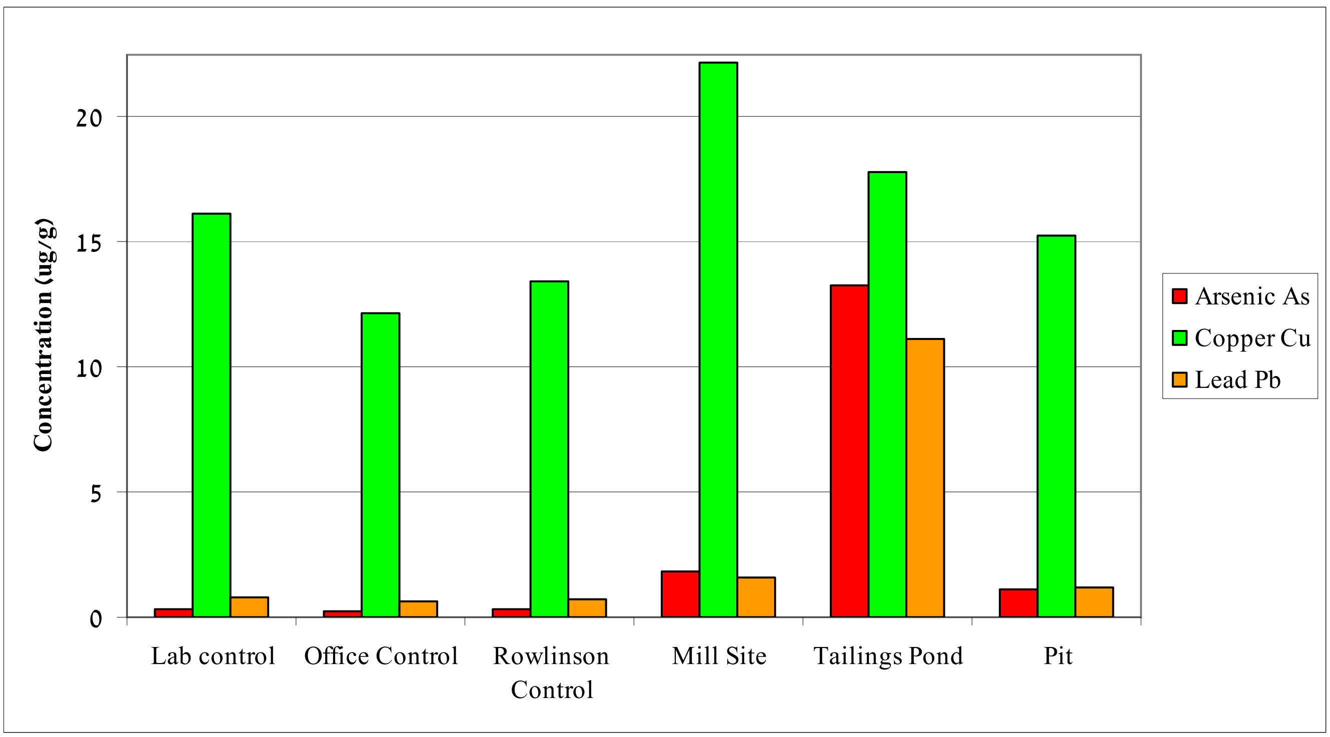


Figure 3.15. Average arsenic, copper and lead concentrations (ug/g) in moss bags around each site (May – July 2006).

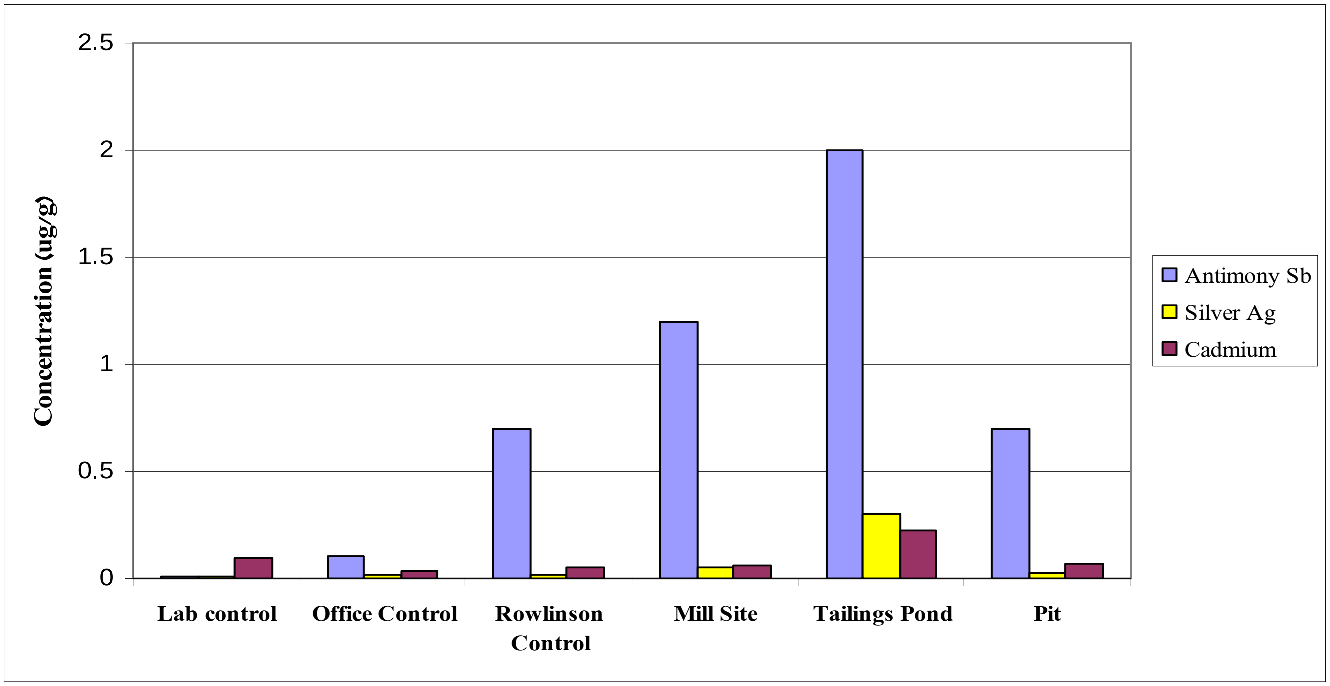


Figure 3.16. Antimony, silver and cadmium concentrations (ug/g) in moss bags around each site (May 2006 – July 2006).

3.1.5.3 Summer, Early Fall Deployment

Moss bags that were deployed from July 27, 2006 to October 17, 2006 showed some interesting results. Unlike the spring, early summer deployment, the samples for each site were tested separately. However, the mean metal concentrations for each area reveal a similar trend to the spring, early summer deployment (Table 3.43). Although not as high as the spring, early summer deployment, lead, antimony, arsenic and silver levels were highest around the tailings pond.

Table 3.43. Mean metal levels (ug/g) in moss bags for the summer, early fall deployment period.

	Sampling Location					
Metal	**Background Moss (n=3)**	**Office Control (n=2)**	**Rowlinson Control (n=6)**	**Pit (n=8)**	**Tailings Pond (n=8)**	**Mill Site (n=7)**
Arsenic As	0.3	0.3	0.3	0.7	3.4	0.8
Antimony Sb	<0.1	<0.1	0.8	0.8	1.4	1.0
Copper Cu	3.6	2.8	2.6	2.9	3.7	2.8
Lead Pb	1.4	0.7	0.7	1.0	3.4	1.0
Silver Ag	0.02	0.02	0.02	0.03	0.06	0.02

During the 'Summer, early fall' deployment, arsenic, antimony, lead, and to a lesser extent copper, and silver levels were highest in moss bags around the tailings pond.

In terms of direction, the results reveal a number of patterns. The highest levels of arsenic, lead, silver and copper were generally located to the east or southeast of the tailings pond (Figures 3.17 to 3.21). Antimony appeared slightly elevated to the west of the tailings pond; however, moderate concentrations were also found at one point near the mill site and to the southeast of the tailings pond.

Figure 3.17. Lead (Pb) concentrations in summer / fall moss bags.

Figure 3.18. Arsenic (As) concentrations in summer / fall moss bags.

Figure 3.19. Copper (Cu) concentrations in summer / fall moss bags.

Figure 3.20. Silver (Ag) concentrations in summer / fall moss bags.

Figure 3.21. Antimony (Sb) concentrations in summer / fall moss bags.

3.2 Aquatic Component

The results for water, sediment and fish are presented in the following sections.

3.2.1 Water Quality

Water sampling was conducted in the upper part of Dome Creek above the tailings pond in order to gain a better understanding of the water chemistry and processes occurring in this area, which was not part of the routine water quality sampling program. Sampling was conducted on the 29th of September, 2005, simultaneously with water samples taken for the weekly monitoring program[1]. The water was analyzed for physical parameters (conductivity, pH), alkalinity, nutrients, cyanides and total and dissolved metals. These results were compared with existing data from the regular weekly monitoring program.

Complete water sampling results are presented in Appendix H. Table 3.44 lists the parameters of most interest[5]. It should be noted that the sites located downstream of the tailings pond (Upper Dome / Dome at Road / Victoria at Road) were influenced by the active discharging of water from the seepage pond into Dome Creek (Figure 3.22).

Table 3.44. Selected results from the water quality sampling program.

Parameter	Dome 1	Dome 2	Dome 3	Upper Dome – (D4)	Dome at Road - (D5)	Victoria at Road -(V4)
Total Zinc (mg/L)	0.496	<0.010	0.024	0.0114	0.0103	<0.0050
Dissolved Zinc (mg/L)	0.343	<0.010	<0.010	0.0054	0.0058	<0.0050
Dissolved Arsenic (mg/L)	0.00420	0.00530	0.00212	0.00269	0.00624	0.00102
Thiocyanate (mg/L)	1.24	1.16	1.07	1.99	1.83	<0.50
Alkalinity-Total CaCO3 (mg/L)	259	190	153	153	140	65.8
Sulphate SO4 (mg/L)	561	460	378	461	376	24.1

Flow direction →

In general, the results revealed elevated levels for metals and dissolved anions upstream from the tailings pond but downstream from the mill site (DOME 1 and DOME 2). The most significant elevated metal was zinc. Levels of zinc at the upper site were above the CCME (2002) Guidelines for Protection of Aquatic Life (0.03 mg/L); however, 600 m downstream (at Dome 2) concentrations dropped below the detection limit (Table 3.44).

Water quality data indicates that some parameters were highest directly downstream of the mill site.

Alkalinity was the only parameter that showed the highest levels at the site furthest upstream, and decreased consistently with distance downstream. Sulphate and thiocyanate showed a similar pattern; however, these levels were higher downstream of the seepage discharge than levels at the site furthest upstream.

[1] DIAND (since 1999) and then the YG Abandoned Mine Branch (since 2003) had been testing water quality at a number of sites within the Dome and Victoria Creek watersheds on a regular basis.
[5] Parameters of most interest were determined based upon relevance to toxicity concerns and elevated results (Zn).

Figure 3.22. Map of aquatic sampling sites, including sites sampled by Yukon Abandoned Mines.

3.2.2 Sediments

Results from the sediment analysis are presented below for the most notable metals, while complete results are presented in Appendix E (Cantest, 2005), Appendix I (Norwest 2005 and 2006) and Appendix M (which includes comparisons to previous studies). Initial 2005 results from the laboratory (Cantest) were dramatically lower for most metals at all sample sites (including controls) than previous studies using the same sites and procedure (Conor Pacific 2000; Yukon Geological Survey 2003; Environment Canada 1988 and 1997). Accordingly, the same samples were sent to a second lab (Norwest), which produced similar results to those of Cantest. In 2005, Norwest also completed a partial digestion procedure to determine weakly bounded metals. In 2006, all samples were processed by Norwest for both strong acid leachable and partial digestion analysis. Figure 2.6 shows the stream sediment sampling sites. A summary of results for notable metals are presented below.

Stream sediments were analyzed in various methods and compared to past data.

Antimony (Sb)

Antimony concentrations were near or below detections limits at most sites, including all sites on Victoria Creek and most sites on Dome Creek. The exception to this includes D1 on Dome Creek and P2 and P3 on Pony Creek. The levels detected by strong acid extraction at D1 ranged from 49 to 57 ug/g[1] in 2005 and 99.6 ug/g in 2006. The sites furthest downstream, P2 and P3 on Pony Creek, had levels of 88.8 to 91.7 ug/g, respectively. Results from the partial digestion revealed that a very small amount of antimony is weakly bound or releasable in to the aquatic environment (D1 4.6 ug/g in 2005 and 13.4 ug/g in 2006; P2, 3.4 ug/g; P3, 1.7 ug/g).

Antimony levels were highest in Dome Creek near the mill and Pony Creek downstream of the adit.

Arsenic

Highest concentrations of arsenic were found in the upstream portions of the Dome Creek drainage, followed by Pony Creek. The concentrations of arsenic in Victoria Creek were generally very low, at or slightly above the detection limit (10 ug/g).

Arsenic levels were higher in 2006 than 2005 within Dome Creek at all but one sampling site, D5. The highest levels of arsenic were found at near the mill site at D1 with levels more than twice the amount in 2006 compared to 2005 (1,180 ug/g, 1,080 ug/g in 2005 and 2,500 ug/g in 2006). Bioavailable levels of arsenic were also considerably higher at this site in 2006 (partial digestion analysis 182 ug/g in 2005; 506 ug/g in 2006). Sites further downstream from D1 generally have lower arsenic levels. In 2006, concentrations at D-2 to D-5 were 153 ug/g, 61.7 ug/g, 128ug/g and 74.8ug/g, respectively. At these sites, most of the arsenic seems to be weakly bound and thus bioavailable (partial digestion ranging from 52-81% in 2006).

Arsenic levels were highest in Dome Creek near the mill and Pony Creek downstream of the adit.

The two downstream sites on Pony Creek had high levels of arsenic (P2, 945 ug/g and P3, 1050 ug/g), with about 40% being weakly bound. Interestingly, these elevated levels in

[1] When referring to specific results for 2005 strong acid extraction, those provided by Cantest are provided first followed by those provided by NorWest Labs.

Pony Creek were not apparent in samples from Back Creek. Although slightly elevated (compared to Victoria Creek), the strongly bound arsenic levels in sediments from Back Creek were found to be higher upstream of the mouth of Pony Creek (40.6 ug/g) than downstream (34 ug/g). Bioavailable arsenic levels were similar at both Back Creek sites (10.8 ug/g upstream and 11 ug/g downstream of Pony Creek).

Barium

Barium concentrations were generally very uniform (mostly between 40-100 ug/g) throughout the whole study area in 2005 and 2006. There is a notable but very modest amount of barium in sediments from Back creek and Pony creek drainages where concentrations were detected in the range of 120 - 150 ug/g with strong acid leachable analysis, and 78 to 102 ug/g via partial digestion. This may be a result of geochemical changes in the underlying geology in the vicinity of these two drainages.

Barium concentrations were quite uniform throughout the study area.

The highest concentration of barium in Dome Creek was found at D1 (88 ug/g, 94 ug/g in 2005 and 97 ug/g in 2006) which was only slightly higher than the upstream control areas on Victoria Creek (V1; 67-72 ug/g). In addition, the results from the partial digestion indicate similar levels of barium bioavailable in Dome Creek (28.6-63.9 ug/g) and Victoria Creek (36-68 ug/g).

Cadmium

Except for sites D1 and P3, cadmium concentrations in sediment were usually at or slightly above the detection limit (0.05 ug/g in 2006). In 2005, high cadmium levels were detected at D1 (13.1 ug/g, 14.8 ug/g; partial digestion 2.6 ug/g). In 2006, the cadmium levels found at D-1 were almost 4 times higher (48 ug/g) with 13.7 ug/g being bioavailable.

Cadmium levels were slightly higher in Dome and Pony creeks compared to other sites.

The high levels of cadmium at P-3 (22.8 ug/g with 16.2 ug/g partial digestion) has not yet translated into increased levels in Back Creek (levels downstream of Pony Creek were < 1 ug/g).

Chromium

The levels of chromium are very uniform throughout the study area and it is very likely they represent the natural background levels of this element. The strong acid extractable results were in the very narrow range of 8-18 ug/g in both 2005 and 2006. There seems to be very similar pattern of concentrations within a narrow range for cobalt and nickel as well. These two elements have a similar geochemical behaviour to that of chromium; based on their low and uniform concentrations it appears that these metals are within natural background levels.

Chromium concentrations were relatively uniform throughout the study area.

Copper

The Dome Creek site closest to the mill, D1, and the two sites furthest downstream on Pony Creek, had the highest concentrations of copper in sediments. At D1, 2006 strong acid extractable analysis levels (157 ug/g) were considerably higher than 2005 samples (40 and 43.6 ug/g), with the majority being bioavailable in both years. However, downstream Dome Creek sites had levels of copper in sediments similar to Victoria Creek upstream of mine site (VIC1).

Dome Creek near the mill and the two sites furthest downstream on Pony Creek, had the highest concentrations of copper in sediments.

Samples collected from the study area show that sites P3 (214 ug/g) and P2 (95ug/g) had elevated concentrations of copper. Back Creek had similar levels upstream and downstream of the mouth of Pony Creek, which were comparable to Victoria upstream of the mine site (VIC1).

Victoria Creek sites downstream of Dome Creek had similar levels to the upstream control site. Conor Pacific (2000) found that elevated concentrations of copper were recorded at both reference and exposure stations in 1999, suggesting that the increases are not related to point source discharges. Partial digestion revealed a relatively high proportion of the copper in most sites to be weakly bound.

Lead

Concentrations of lead in sediments samples appear to have a similar pattern to arsenic. The highest levels were recorded at site D1 in the vicinity of the Mill site and Pony creek sites P3 and P2. At D1, levels were also higher in 2006 (507 ug/g, partial digestion of 447 ug/g) than 2005 (295 ug/g, 324 ug/g; partial digestion 283 ug/g). Lead levels at D5 were somewhat higher (15.9 - 24 ug/g) than the samples from the middle portions of Dome Creek and Victoria Creek. Levels within Victoria Creek are consistently below 10 ug/g, which is lower than the CCME (2002) interim sediment quality guideline of 30 ug/g. Generally, lower levels of lead were found in stream sediments in this study in comparison to assessment studies done in the past. Potentially bioavailable lead levels in Victoria Creek sediments were similar throughout.

Lead levels were highest in sediments near the mill site; however, all levels found in this study were within guidelines.

The high lead levels in Pony Creek were most apparent at the sites furthest downstream (P3 409ug/g; P2 345ug/g). These high levels were not apparent in Back Creek upstream or downstream of Pony Creek (28-32ug/g).

Mercury

Concentrations of mercury were around or below the detection limit (0.01 ug/g) at all sampling sites in 2005. In 2006, mercury levels were notable at D-1 (0.207ug/g) and P-3 (0.136ug/g), the two most affected sites in the study area. The level at D1 was slightly above CCME (2002) interim sediment quality guidelines (0.170 ug/g). Concentrations of mercury at other sites were recorded at very low levels.

The highest levels of mercury, silver and zinc were found in Dome Creek downstream of the mill and the furthest downstream site on Pony Creek.

Silver

The highest levels of silver were detected at the most notable sites, P3 and D1. Sites D1 (8.6 ug/g), P3 (12.7 ug/g) and P2 (9.5 ug/g) were found to contain the highest levels of silver. All other samples had very low levels of silver, often below the detection limit (0.2 ug/g). A partial digestion analysis indicates some bioavailability of silver, with a questionable result at D1 (13.3 ug/g which was higher than the strong acid digestion value of 8.6 ug/g).

Zinc

The highest concentration of zinc (2,030 ug/g) was detected at the mill site (D1) in 2006. This represents a notable increase over the range of zinc levels in the previous year's samples (662 - 744 ug/g). Other relatively high zinc levels in sediments were detected in the downstream samples of Pony Creek P3 (948 ug/g) and P2 (582 ug/g). There also appeared to be slightly higher than normal levels in Back Creek samples, but these levels were consistent with samples upstream and downstream of the mouth of Pony Creek. Generally, the samples from other sites showed very uniform concentrations; even those from the Dome Creek drainage (with the exception of D1) did not reveal notably high levels of zinc. Relatively high potential for bioavailability was detected from sampling site D1 (85%) and P3 (80%).

In summary, many metals were highest just downstream of the mill site and Pony Creek downstream of the adit.

Summary

In summary, many metals were highest (from both strong acid extractable and partial digestion) in Dome Creek, just downstream of the mill site (D1) and in Pony Creek downstream of the adit and waste rock pile (P2 and P3). Also, results from some sites, especially D1, were generally higher in 2006 than 2005.

3.2.3 Fish

Slimy sculpin, Arctic grayling and burbot were sampled within the study area.

Three species of fish were sampled from Victoria Creek, the outlet of Victoria Lake, the Nisling River and Rowlinson Creek. Slimy sculpin were the focal point of sampling and were sampled at six sites, three of which were within the possible zone of influence from past / present activities at the Mt Nansen Mine site (downstream of Back and Dome creeks; VIC 3, VIC 4 and VIC 6; Figure 2.6 and 3.22). Of these, VIC 3 and 4 are within 2.5 km of Dome Creek, while VIC 6 is on the Nisling River approximately 7.5 km downstream from Dome Creek.

Due to their small size, slimy sculpin were analyzed whole, while Arctic grayling and burbot were dissected to test specific body parts (including liver, kidneys and tissue; Table 3.45). In cases where the sample size did not meet the minimum sample weight required for analysis, samples were pooled to form a composite sample (Table 3.45).

Table 3.45. Details regarding fish collected during this study.

Location	Sample ID	Year Collected	Species	Body Part	Sample Weights (g) [1]	Length of fish (mm)
Victoria Ck, ~500m above Back Ck	VIC1-CCG-1 to 5	2005	Slimy Sculpin	whole	12.9, 13.4, 11.4, 6.3, 3.1	110, 105, 100, 82, 64
Victoria Ck, between Dome Ck & road crossing	VIC3-CCG-1A, 1B, 2 and 3	2005	Slimy Sculpin	whole	3.1, 3, 12.7, 20.5	70, 70, 100, 110
	VIC3-CCG- 2 and 4	2006	Slimy Sculpin	whole	6.5, 7.3	78, 84
	VIC3-GR-K-1	2005	Arctic Grayling	kidney	2.2	170, 160, 155, 160, 175, 170, 150
	VIC3-GR-L-1	2005	Arctic Grayling	liver	3.9	
	VIC3-GR-T-1	2005	Arctic Grayling	muscle	8.8	170, 150
	VIC3-GR-T-2	2005	Arctic Grayling	muscle	18.0	160, 175
	VIC3-GR-T-3A	2005	Arctic Grayling	muscle	18.3	155, 160, 170
	VIC3-GR-T-3B	2005	Arctic Grayling	muscle	15.9	155, 160, 170
	VIC3-BB-L-1	2005	Burbot	liver	3.6	174, 180, 193
	VIC3-BB-T-1	2005	Burbot	muscle	8.3	
	06-VIC3-BB-T-1	2006	Burbot	Tissue		205
	06-VIC3-BB-L-1	2006	Burbot	Liver	2.5	205
Victoria Ck, ~400m downstream of road crossing	VIC4-CCG-1-4	2005	Slimy Sculpin	whole	16.6, 7.3, 15.1, 28.2	115, 90, 110, 30
	VIC4-CCG-5	2005	Slimy Sculpin	whole	2.2, 1.5	60, 55
	VIC4-CCG-1, 2, 4, 10	2006	Slimy Sculpin	whole	98, 82, 77, 99, 91	12.5, 7.5, 6.3, 15.6, 9.8
	06-VIC4-BB-T-1 and 2	2006	Burbot	Tissue	11.5, 8.7	265, 163
	06-VIC4-BB-L-1 and 2	2006	Burbot	Liver	2.6, 2.5	265, 163
	VIC4-GR-K-1	2005	Arctic Grayling	kidney	3.1	190, 190, 220
	VIC4-GR-L-1	2005	Arctic Grayling	liver	2.6	
	VIC4-GR-T-1	2005	Arctic Grayling	muscle	34.2	
Victoria Lake outlet stream	VIC5-CCG-1, 2 and 4	2005	Slimy Sculpin	whole	6.2, 7.2, 0.9	83, 89, 40
	VIC5-CCG-3A & 3B	2005	Slimy Sculpin	whole	6.4	70, 70
	VIC5-BB-L-1	2005	Burbot	liver	2.0	250
	ViIC5-BB-T-1	2005	Burbot	muscle	11.4	250
	06-VIC5-BB-T-1, 2 and 3	2006	Burbot	Tissue	5.9, 13.6, 9.8	192, 258, 310
	06-VIC5-BB-L-1, 2 and 3	2006	Burbot	Liver	1.7, 2.8, 2.6	192, 258, 310
Nisling River, below Victoria Ck	VIC6-CCG-1 and 2	2005	Slimy Sculpin	whole	14.5, 0.8	95, 42
Rowlinson Ck	ROW1-CCG-1, 4, 6, 7, 8, 9, 11, 12, 14, 15	2006	Slimy Sculpin	whole	5.3, 8.1, 8.3, 15.6, 7, 6.8, 4.7, 3.7, 9.6	74, 61, 78, 81, 98, 76, 81, 71, 67, 87

[1] Weight refers to weight of sample submitted. Only slimy sculpin were submitted whole.

3.2.3.1 Sculpin

In order to determine if trace metals were elevated in sculpin from the zone of influence, sculpin from sites VIC 3 and VIC 4 (zone of influence) were compared to samples from Rowlinson Creek (ROW) and control areas within the Victoria Creek watershed (VIC 1, located upstream of Dome and Back Creeks and VIC 5, the outlet to Victoria Lake). In general, metal levels in sculpin were relatively close between sites, with some metals (silicon, copper) found in slightly higher concentrations in samples from the Rowlinson Creek control area. Five metals were significantly higher in sculpin captured in the zone of influence than sculpin from Rowlinson Creek; these included arsenic, cadmium, lead, selenium, and silver (Table 3.46, Appendix L). A similar pattern was found when comparing zone of influence samples to those from Control A, the outlet to Victoria Lake (VIC 5). Sculpin from the upstream Victoria Creek control area (VIC 1) typically showed lower levels than the zone of influence but higher than those from the Victoria Lake outlet (VIC 5). However, only arsenic was significantly lower in sculpin at the upstream control B (VIC 1) compared to the zone of influence. Although, this may be a reflection of fish migrating between areas, it may also be related to natural background water quality.

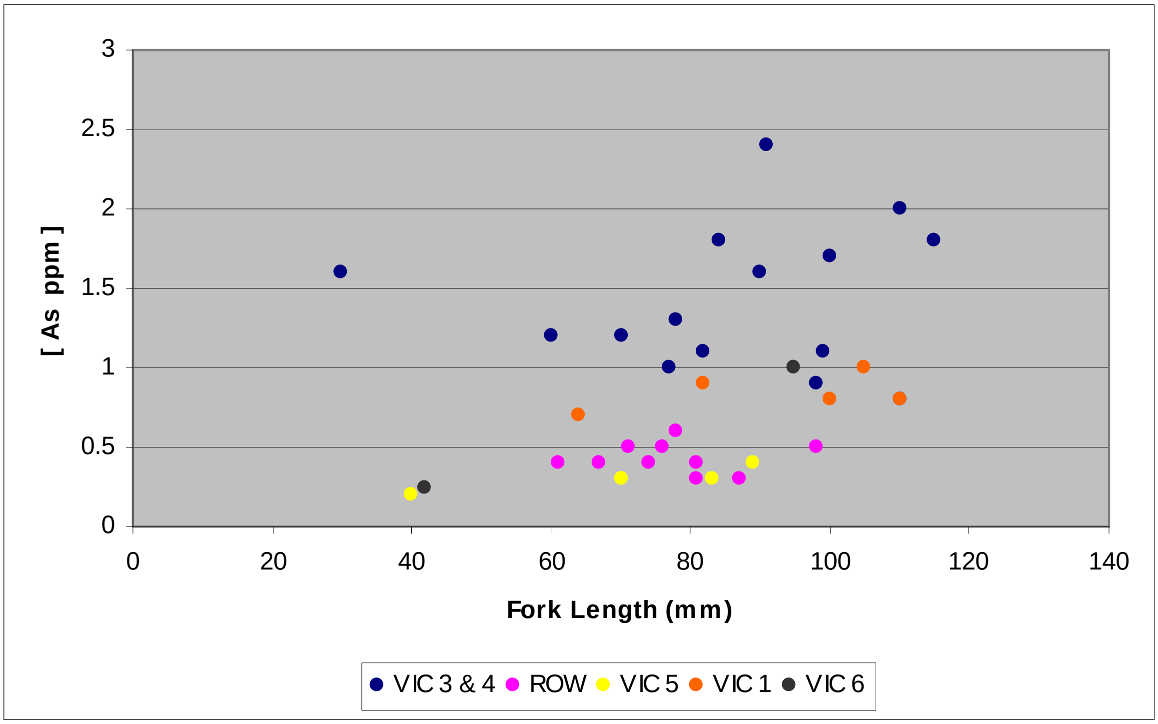
Some metal levels in sculpin were somewhat elevated in areas close to the mine site.

Table 3.46. Results of significance tests for slimy sculpin in zone of influence and control sites.

Trace Metal	Mean value (ppm)				Significant Difference[1]		
	Zone of Influence (VIC 3 & 4)	Rowlinson (ROW)	Victoria Lake Outlet Control A (VIC 5)	Victoria U/S Control B (VIC 1)	Zone of Influence vs Rowlinson	Influence vs Victoria Lake Outlet Control A	Influence vs Victoria U/S Control B
Arsenic (As)	1.43	0.43	0.30	0.84	✓	✓	✓
Cadmium (Cd)	0.20	0.03	0.03	0.25	✓	✓	
Cobalt (Co)	0.34	0.30	0.09	0.34		✓	
Copper (Cu)	3.86	4.10	3.46	3.76			
Lead (Pb)	0.25	0.05	0.08	0.14	✓	✓	
Selenium (Se)	3.26	1.22	0.86	4.66	✓	✓	
Silver (Ag)	0.012	0.005	0.008	0.006	✓		✓
Zinc (Zn)	84.04	75.24	83.33	80.88			

[1] $p < 0.05$ / if value was below detection limit, the detection limit was split in half to assist with statistical analysis.

Review of the above-noted metals at all sites provides some insight into the variability between sites. Levels of arsenic (Figure 3.23) were generally lowest in sculpin at the outlet of Victoria Lake (VIC 5), followed by Rowlinson. Sculpin captured upstream of Victoria Creek (VIC 1) appeared to have arsenic levels in between the levels found at the control sites and the 'zone of influence'. Given the closeness of this upstream control site, migration between areas cannot be ruled out.



Arsenic concentrations in slimy sculpin were generally highest in fish from Victoria Creek downstream of Dome and Pony creeks (Vic 3 & 4).

Figure 3.23. Arsenic (As) concentrations in slimy sculpin collected at all sites.

Aside from location, another variable that appeared to affect arsenic concentration was the size of the sculpin captured. Figure 3.23 shows the relationship between arsenic concentration and total length for sculpin from all sites. This figure generally shows that larger sculpin had higher arsenic concentrations in comparison to smaller individuals. This general pattern was observed at all sampling sites, including the control areas.

3.2.3.2 Arctic Grayling

Trace metal levels in grayling appeared generally low – especially in flesh.

Arctic grayling tissue, kidney and liver samples were analyzed only from sites downstream and close to the mouth of Dome Creek (VIC3 and VIC4). Trace metal concentrations were very low in grayling muscle tissue (flesh) collected from the zone of impact. The average mercury concentration in grayling muscle/flesh within the zone of influence was 0.136 ppm. This is well below the average found in grayling by Matz et al. (2005) in a pristine spring-fed stream in the Tetlin National Wildlife Refuge in Alaska. Results from this study were also comparable to mean mercury concentrations found in lake whitefish tissue from Kloo Lake, near Haines Junction, YT (0.11 ppm wet weight; Northern Contaminants Program 1997).

Metal concentrations from kidneys and livers sampled from grayling in this location were higher than that in the muscle tissue, which is to be expected due to the role of these organs within the body. Within kidney samples, the following metal concentrations appeared to be slightly elevated; arsenic (0.8 ppm), cadmium (1.36 ppm) and silver (0.14 ppm). Within livers analyzed, levels of copper appeared to be slightly elevated (18 ppm at VIC 4) in comparison to Matz et al. (2005), who found a maximum copper concentration of 11.5 ppm for grayling livers. Mercury concentrations within the kidneys and livers averaged 0.242 ppm and 0.323 ppm, respectively, which are well within the range of values found by Matz et al. (2005).

3.2.3.3 Burbot

Extensive effort was put into collecting burbot from the 'zone of influence' and control areas. Burbot were only captured within the zone of influence (VIC 3 and 4) and from the outlet of Victoria Lake. Four samples of liver and tissue from each area were analyzed. Efforts to capture burbot in Rowlinson Creek were unsuccessful and other Yukon data from juvenile burbot was not found. Mean arsenic levels were slightly higher in both liver and muscle tissue samples from the 'zone of influence' than the control, but these differences were not statistically significant (using a two tailed t-test, see, tables 3.47 and 3.48, Appendix L). The mean arsenic concentrations in liver and tissue (muscle) from the zone of influence were 8.8 and 2.1 ppm, respectively, as compared to 6.7 and 1.0 ppm from the control area. Other metal levels appeared to be relatively similar between sites, with many being slightly higher at the control site (i.e. zinc and cadmium in livers).

Some metal levels in burbot muscle were somewhat higher in areas close to the mine site than the control.

Table 3.47. Metal concentrations in burbot tissue at the control sites and in the zone of influence (highlighted values represent higher mean levels).

Sample ID	Year	Fork Length (mm)	Body Weight (g)	As	Se	Sr
06-VIC5-BB-T-1	2006	192	41.3	0.9	0.5	2.95
06-VIC5-BB-T-2	2006	258	67.6	1.2	0.9	1.59
06-VIC5-BB-T-3	2006	310	158.2	1.3	1.4	1.86
VIC5-BB-T-1	2005	250	NA	0.7	0.4	3.94
Mean Control				**1.025**	**0.8**	**2.585**
Maximum Control				**1.3**	**1.4**	**3.94**
06-VIC3-BB-T-1	2006	205	40.9	1.3	10.3	4.41
06-VIC4-BB-T-1	2006	265	65.7	1.5	8	1.72
06-VIC4-BB-T-2	2006	163	38.2	2.7	0.8	3.83
VIC3-BB-T-1	2005	182	NA	2.8	1	5.1
Mean Zone of Influence				**2.075**	**5.025**	**3.765**
Max Zone of Influence				**2.8**	**10.3**	**5.1**

Table 3.48. Metal concentrations in burbot liver in the control sites and in the zone of influence (highlighted values represent higher mean levels).

Sample ID	Fork Length (mm)	Total Body Weight (g)	Year	As	Cd	Cu	Hg	Se	Ag	Sr	Sn
06-VIC5-BB-L-1	192	41.3	2006	4.9	0.25	20.1	0.128	0.9	0.03	0.48	0.1
06-VIC5-BB-L-2	258	67.6	2006	9.1	1.01	13.4	< 0.05	1.7	0.03	0.48	0.2
06-VIC5-BB-L-3	310	158.2	2006	10.5	1.32	22.5	0.432	4.5	0.1	0.83	0.2
VIC5-BB-L-1	250	NA	2005	2.1	0.05	20.6	0.035	0.6	0.01	0.86	< 0.2
Mean Control				**6.65**	**0.658**	**19.150**	**0.198**	**1.925**	**0.0425**	**0.6625**	**0.167**
Max Control				**10.5**	**1.32**	**22.5**	**0.432**	**4.5**	**0.1**	**0.86**	**0.2**
06-VIC3-BB-L-1	205	40.9	2006	2.7	0.01	7.1	0.037	3.1	0.02	0.38	< 0.1
06-VIC4-BB-L-1	265	65.7	2006	5.4	0.01	17.8	0.164	5.3	0.06	0.48	0.3
06-VIC4-BB-L-2	163	38.2	2006	13	0.01	17.5	0.108	1.1	0.005	1.13	1.1
VIC3-BB-L-1	182	NA	2005	14.1	0.92	21.3	0.049	2.2	0.08	0.88	< 0.2
Mean Zone of Influence				**8.8**	**0.2378**	**15.925**	**0.090**	**2.925**	**0.041**	**0.718**	**0.7**
Max Zone of Influence				**14.1**	**0.92**	**21.3**	**0.164**	**5.3**	**0.08**	**1.13**	**1.1**

Some metal levels in burbot liver were somewhat higher in areas close the mine and others were somewhat higher in the control area.

4.0 DISCUSSION

4

The aim of this study was to provide insight into past effects, current levels of contamination and ongoing contamination in various terrestrial and aquatic ecosystem components in the vicinity of the mine. The results provide significant insight in this regard and are discussed for the terrestrial and aquatic components.

4.1 Terrestrial Effects

The terrestrial ecosystem can be impacted by mining in different ways. There is the obvious footprint of the mine (cleared areas etc.) that is clearly visible and there are the things that are not clearly visible such as the impact that the mine and/or mining operations may be having on the health of the surrounding plants and animals. The results of this study has provided considerable insight into the ecosystem health.

The results from this study provide a window into the health of the ecosystem (the things we cannot see).

Aerial Contamination

The elevated levels of arsenic, lead, antimony, silver and copper in lichens demonstrate past aerial contamination around the mine site. This effect has been most apparent around the mill site, followed by the Brown McDade pit, and to a lesser extent, the tailings pond. The element copper is an exception to this, for which the increase was most pronounced in association with the tailings pond.

The lichen results combined with the moss bag results provide insight into the timing of aerial dispersion of metals. In general, the moss bags around the tailing pond displayed the highest levels of arsenic, lead, silver, and antimony, especially in the spring and summer months, indicating that aerial dispersion of dust is most prominent in this location. The pattern of dispersion from the summer and early fall in an eastern to south-eastern direction is somewhat consistent with the most prominent wind direction (from the southwest), especially given the location of the wind measuring instrument and the likely swirling of winds due to the local topography. The on-going contamination at the tailings pond indicates that the contamination detected in the lichens around the pond has likely occurred over a long time period. Conversely, the limited amount of on-going aerial contamination at the mill site indicates that the dispersion of metals likely is related to the past mining activities at the site. This pattern is best demonstrated in Figure 4.1 which shows the moss bag data for silver displayed over the modeled data from the lichens. During the operation of the mill there are accounts of significant dust being generated in this area (Wheeler pers. comm. 2006). Not only was there a crusher that created significant dust as it broke down the ore, but also truck traffic and activity (i.e. dumping) was common in this area. The apparent aerial dispersion around the mill appeared to be evident in all directions, covering approximately 100-150 meters from the edge of the mill site and associated disturbed ground.

Evidence of past aerial dispersion (i.e. from mining) of metals was most prominent around the mill site.

Current aerial dispersion was most prominent around the tailings pond.

The results from the plants (especially willow) indicate that this aerial contamination may be starting to show up in plants (at much lower levels than the lichens). In willow and

Some plants showed somewhat elevated metal levels.

Figure 4.1 Moss bag data (points) displayed over Kriging data from lichen data (shaded) for silver.

Labrador tea, levels of arsenic (and antimony in willow only) appeared to be higher near the sources of contamination compared to controls. As the plants were not washed it is possible that these higher levels could be a result of dust on the plant surface, rather than root uptake from the soils.

It appears that some soils immediately adjacent to the sources of contamination (especially the mill) may have been influenced by aerial contamination. However, as soils are influenced by many variables including geology, weathering and plant uptake it is difficult to confirm this. The strongest evidence for this includes the high arsenic levels near the mill site in the A-horizon and the different horizon patterns between the control plots and transect plots taken within the apparent zone of aerial contamination. The highest levels of antimony, arsenic, copper and lead were found in the A-horizon for the transect plots and in the C-horizon for the control plots.

Although some soils immediately adjacent to the point sources had some higher metal levels, it is unclear if this is related to the mine or mining activities.

It is possible that the bedrock geology and local zones of higher mineralization are responsible for enriching the lowest C-horizon. This pattern is obvious from the sampling site I1 where the highest levels of arsenic were recorded at the bottom (100 ug/g) and low readings were obtained in the B horizon (<10 ug/g) and A horizon (17 ug/g). Similar patterns were also noticed at the control sites. Further evidence that arsenic levels may be naturally high in this area (i.e. due to geology), was that many plants collected from many areas around the study had arsenic levels that were higher than Yukon background data.

From the background information gained from the control sites and low levels under the blackened vegetation it appears that the C-horizon in the studied area is not likely impacted by aerial contamination. This can be demonstrated from the results under the blackened vegetation where the upper horizons (A and B) appeared impacted by contamination while the C-horizon was not. Rather, the concentrations of the metals in the C-horizon are predominately determined by the composition of the underlying rocks and proximity of the mineralized zones.

Uptake of arsenic by plants is generally low, depending on plant species, composition of the soil and form of the arsenic. It is not rare to see the soil contaminated at extreme levels and plants still containing levels of arsenic near background. When evaluating the potential phytotoxicity of the arsenic it is very important to evaluate the content of clay minerals, Fe, Al oxy-hydroxides and organic matter in the soil. The pH and Eh values are decisive factors for the arsenic form and the As^{3+} is considered a more mobile form and more phytotoxic as the As^{5+}. Three sites with highest As levels (J1, J2 and K2) are also those with highest pH levels (7.2-7.6) which is likely a beneficial factor limiting arsenic mobility and phytotoxicity. Arsenic levels in willow from J1 and J2 were only slightly higher than natural maximum Yukon background levels (1.4 ppm compared to 1.02 ppm) and levels in K2 were low (0.3 ppm).

4.1.1 Blackened Vegetation

The results of this study indicate that a significant source of metals contamination killed the vegetation along the banks of Dome Creek. According to a local source, a perforated drainpipe was laid out along the slope of the right bank during active mining, where it was used to discharge contaminated water from the mining operation. No knowledge of similar activities that may explain the dead vegetation on the left bank was found. However, any number of factors such as flow across the ice surface during the winter months may have influenced the left bank. Dome Creek typically experiences significant ice build-up in the winter months and overflow of contaminants may explain elevated metals in the soils surrounding Dome Creek, in and outside of the blackened vegetation.

Blackened vegetation area appears to be a physical barrier to plant growth.

The levels of many metals in the dead, blackened plant material were extremely high; however, metals only appeared to be somewhat elevated in the soils (relative to the plants) and only in the A and B-horizons. The fact that both A and B horizons show elevated levels of some metals is consistent with aquatic contaminant transport, whereas contaminant transport by wind would generally only show impacts to the A horizon. A further indication of an aquatic pathway is that the lead levels were not as elevated as other metals, as lead is generally not mobile in water. While there is minimal green vegetation in the area, this is likely the result of the physical barrier created by blackened vegetation. The blackened vegetation (moss-lichen base) is quite thick and likely prevents seed from reaching the soil surface. The live vegetation (Labrador tea and willow) growing in the area of blackened vegetation had some high metal levels compared to control sites. Of interest, metal levels in Labrador tea were more commonly higher than control levels as compared to metal levels in willows in the mine site and control area. It is speculated that this pattern is likely related to rooting depth. Generally speaking, willow has a deeper root system than Labrador tea and, as such, likely penetrates into the less impacted C-horizon.

Plants with deeper roots (i.e. willows) may not uptake as many metals as smaller plants growing in this area.

Removal or modification of this blackened vegetation would likely help promote plant growth in this area. However, disturbance of this area could facilitate a more rapid mobilization of metals into Dome Creek. A better option may be to plant through the blackened vegetation area with live willow stakes (i.e. bioengineering). This method involves driving willow stakes into the ground approximately 1 m and, as such, would likely promote root growth in the C-horizon.

4.1.2 Vegetation – Non Aerial Pathways

Many of the vegetation samples collected within the potential contamination sources (low grade ore stockpile, Brown McDade pit and tailings pond) were among the highest for several metals, including arsenic, lead and copper. This is consistent with past data indicating these areas had high levels of certain metals (Conor Pacific 2000). One willow sample taken from the pond had the highest levels of copper found in willow (11.2 ppm) in this study. In addition, this sample had arsenic and lead levels that were higher than any other site, with the exception of the low grade ore stockpile. Many of the grasses collected from the tailings pond revealed high metal levels as well.

Reclamation plans should consider the higher metal levels found in plants collected within the tailings and the low-grade ore stockpile.

The levels of metals recorded from plants growing in the low-grade ore stockpile were some of the highest recorded in plants. Levels of arsenic, and to a lesser extent lead, silver, zinc and antimony, were drastically higher than any found in transect and riparian sites. For example, one willow collected from the ore had an arsenic level (141 ppm) that was 470 times that of the maximum control value (0.3 ppm).

The samples taken from the waste rock piles around the pit and at Pony Creek showed highly variable metal levels, generally higher than controls, but lower than the low grade ore stockpile and tailings pond. When comparing metal levels in willow, most metals were not notably elevated compared to the highest levels found in willows in the transect plots.

The influence of past water quality at Pony and Dome creeks has likely impacted the plants within these riparian areas. Of these, vegetation from PONY3, located directly downstream of the adit, as well as Pony waste rock pile and DOME7, located just downstream of the mill site, appeared to be most impacted (this pattern is consistent with the sediment results). Vegetation from other riparian sites appeared less impacted, which is roughly consistent with other transect sites.

Wildlife

Analysis of small mammals and birds indicate that slightly elevated levels of some metals may be present in the local wildlife around the mine site. Metals that were generally higher from the mine site include arsenic, cadmium, chromium, lead, and silver; however, only the results for cadmium, chromium and silver in were statistically significant in red-backed vole livers, arsenic in gray jay livers and spruce grouse kidneys and manganese in gray jay livers. These differences may be related to the mine site and/or natural differences in geology between the control site and mine site. Of the metals found to have elevated levels in small mammal samples from the mine site most were within levels found in other areas and/or in other wildlife or domestic livestock, and as such likely do not posed a significant threat of toxicity to wildlife.

Some metals were slightly higher in small mammals at the mine site; however, differences were not drastic.

Although considerable effort went into trapping animals from higher trophic levels, only one martin was captured. With the exception of aluminum, the metal levels in this martin were within Yukon background levels. Considering the indication of slightly elevated levels in the results obtained in this study, it is possible that some bioaccumulation (up the food chain) is occurring; however, the small sample size prevents confirmation of this.

The metal levels within caribou and moose from within the Game Management subzones 5-22 and 5-26 (near the Mt. Nansen site) were generally similar to that of Yukon background data with some exceptions. Interestingly many metals were lower in caribou kidneys and livers from animals harvested near the mine site. Of all the elements tested, copper and chromium were the only element that was significantly higher at the Mt Nansen area compared to the Yukon background data. Copper was higher in moose liver and caribou kidney and chromium was higher in caribou kidney. While copper is one of

In general, moose and caribou from the Mt. Nansen area had similar (or lower) metal levels to other areas of the Yukon.

the metals of concern, specifically around the tailings pond (in lichens), there is limited evidence to suggest the mine site is responsible for this. While caribou eat lichen they are a migratory species that cover large ranges and would be unlikely to spend considerable amount of time in the area of the pond. The copper levels within willow (primary moose forage) were all below background Yukon levels. In addition, the copper levels in the tailings pond water have not been identified as a concern. For example, weekly to monthly water sampling of the tailings pond from April, 2005 to December, 2006 found a highest level of total copper was 0.109 mg/l. This level is well below the CCME (2002) guidelines for Aquatic life (2-4 mg/l) or for livestock (500-5,000 mg/l).

4.2 Aquatic Effects

Generally, aquatic systems can be important indicators, often showing pathways of contamination leading to point or even diffuse sources. In this case, the results indicate that present contamination of the affected aquatic systems may not be particularly significant, particularly in comparison with the results of studies conducted during or shortly after BYG's operation of the mine.

4.2.1 Water Quality

The results indicate that headwaters of Dome Creek are negatively impacted.

The results indicate that the headwaters of Dome Creek are negatively impacted by nearby sources of contamination, including the mill site, low grade ore stockpile, former tailings facility (pre-BYG era), roads, and past exploration activity.

Surface water quality improves moving downstream.

Generally, the surface water in the upper parts of the Dome Creek has a higher mineralization level (sulfates, calcium, magnesium are most notable parameters). The water quality is predominantly affected by high amounts of zinc, which was found at a level approximately 16 times higher than CCME guidelines for aquatic life. Other than invertebrates, aquatic life is likely quite limited in this part of Dome Creek, and no fish have been documented in Dome Creek. Generally, the water quality improves moving downstream due to the processes of natural attenuation occurring within the stream and its riparian zone. In this regard, zinc is being effectively attenuated moving downstream from the ponds, which is likely due to dilution and an abundance of organic matter in the riparian zone.

4.2.2 Sediments

Patterns for sediments were similar to surface water quality.

With a few exceptions, the levels of metals identified in sediments during this study are generally lower than those obtained in past studies (Conor Pacific 2000, Yukon Geological Survey 2003; Environment Canada 1988 and 1997). Almost every natural system has a tendency to attenuate contamination once it is introduced into the system. It appears that the natural attenuation process may be occurring in this area as well, which would correspond with the overall decrease in levels of several metals when compared to past data. The drop in levels of metals and semi-metals composing a significant part of the surrounding geological materials (i.e. Fe, Al, Ca, Mg) remains unexplained. Possible causes include highly variable composition of stream sediments within a small spatial scale, and/or subtle changes in laboratory digestion or analyzing processes, and/or variations of sampling procedures. Another possibility is that some flux in contaminant levels can occur over time between water and sediments. That is, when water contains high levels of contaminants, it can over time lead to increased levels in sediments, and conversely, when levels are low in water, contaminant loads in sediment can be released into the water.

Nevertheless, the analysis of metal levels in stream sediments in key areas within and around the mine site did confirm the presence of some above-normal levels which may be attributable to past mining activities. The stream sediments with highest concentrations of contaminants were found at the sample site closest to the mill, as well as Pony Creek below the waste rock pile. The results obtained in this study indicate that the mill site and surrounding disturbed areas has been a major source of contamination of the area. In addition, generally higher levels of metals found in 2006 compared to 2005 directly downstream of the mill site may be an indication that contamination is on-going. Such contamination could be related to high water events which mobilize contaminated sediments. The low-grade ore stockpile, storage and frequent handling of chemicals in the past, and heavy use of the road may all be, or have been, factors contributing to contamination of the area. During heavy rainfall and snowmelt events, surface runoff from the disturbed areas including the low grade ore flows into Dome Creek. Further investigation of this area may be warranted.

Highest metal levels in sediments were found in Dome Creek directly downstream of the mill and in Pony Creek downstream of the waste rock pile.

Downstream of the mill site metal levels are mildly elevated in Dome Creek; however, this has not translated into obvious elevated levels in Victoria Creek. In fact, most metal levels in Victoria Creek downstream of the mine site (Dome and Back Creeks) have similar metal levels as the upstream control site (V1). In addition, while there are problems with comparisons to past data, as noted above, comparing arsenic levels in Victoria Creek with Conor Pacific's (2000) data indicate levels are declining in Victoria Creek. Conor Pacific found arsenic to be lowest (11 ug/g) in the control site (V1) compared to the other Victoria site (52-97 ug/g) in 1999. Conversely, the 2005 and 2006 results show relatively similar levels in all Victoria sites (<17 ug/g).

The high metal levels in Dome Creek sediments were not apparent in Victoria Creek.

The high metal levels found in Pony Creek downstream of the adit and waste rock pile may be a result of past and current influence of the waste rock pile. Gartner Lee (2005) found some metals in Pony Creek water samples to be above CCME guidelines. Water flows through and along side the waste rock pile and as such may mobilize metals downstream. Even though the metal levels in Back Creek were slightly higher than those from Victoria Creek, it does not appear that Pony Creek is negatively affecting Back Creek. Reasons for this may include significant dilution by Back Creek and/or immobilization and attenuation processes occurring within Pony Creek drainage. Slightly higher levels of metals in Back Creek, upstream and downstream of Pony Creek, could be a result of different geology and/or placer mining activities in this watershed.

There are significant limitations of using stream sediments as indicators of potential environmental impact. It is important to note that elevated levels of certain metals in stream sediments do not necessarily translate into a threat to the surrounding environment. The key factor in this regard is the form in which the metals are present in the aquatic environment. If they are primarily in a stable form, this limits their bioavailability and thus any potentially adverse environmental effect. Using the partial digestion method of analysis, further insight can be obtained regarding the chemical form and distribution of metals between various phases of stream sediments. Detecting metals that are weakly bound and thus easily released from these phases into the aquatic environment is an important component of quantifying the potential impact of contaminants. The lack of such information from the past studies represents a current disadvantage in terms of comparison and changes of metals levels over time. Such data provided by this study may serve as a starting point for comparison in future assessments of the Mt. Nansen area (i.e. after reclamation has taken place).

4.2.3 Fish

Slimy sculpin appeared to have some slightly elevated levels of metals in Victoria Creek downstream of Dome Creek. These levels could be a result of background water quality, the Mt. Nansen mine site and/or a placer operation on Back Creek. In order to provide insight into the magnitude of trace metal concentrations, comparisons to a study done on contaminants in slimy sculpin which took place near Cook Inlet, Alaska were completed. This study (Frenzel 2000) found similar metal concentrations as the means found in VIC3 and VIC4 for arsenic (1.5 ppm) and lead (0.3 ppm) in an undeveloped watershed (Deshka River) and similar or higher metal levels for selenium (8.5 ppm), cadmium (0.4 ppm) and copper (4.6 ppm) levels in a creek within Denali National Park (Costello Creek).

A few metals were higher in slimy sculpin captured from the 'zone of influence' compared to sculpin from control sites.

The slight differences in metal levels between burbot from the zone of influence and the control site do not provide strong evidence that metals are biomagnifying up the food chain. Levels within grayling appeared to be within normal ranges for this species and are not a concern in terms of toxicity to the species. Provided that metal levels within the water remain within CCME standards for protection of aquatic life, metal levels for fish within the zone of influence is not expected to be a concern in the future.

4.3 Tolerable Intake Analysis

In order to put the results into perspective, it was deemed important to determine if the levels of metals found in the plants and animals were a concern in terms of human health. To accomplish this, the results were compared to the tolerable daily or weekly intakes as presented in Table 4.1. A tolerable daily/weekly intake is an estimate of the amount of a substance in air, food or drinking water that can be taken in daily/weekly over a lifetime without appreciable health risk. It should be noted that this is not a comprehensive human health risk assessment; rather, provides some insight to the daily intakes for several metals[6]. For more comprehensive information on human health at the Mt. Nansen mine site refer to SENES Consultants Limited (2003).

Tolerable intake limits were calculated to put the results in perspective.

[6] Note that tolerable daily intake is intended for all sources of a particular substance, and therefore the numbers detailed in this study do not provide for any other sources of the substances in question. A risk based analysis would provide more comprehensive information in this regard.

Table 4.1. Tolerable daily or weekly intakes as listed by Joint FAO/WHO Expert Committee on Food Additives (2006)[1].

Metal	Tolerable Intake mg/kg of body weight	Tolerable Intake for a 50 kg person (*ug*)
Antimony (Sb)[2]	0.003 daily	150 daily
Arsenic (As)	0.015 weekly	750 weekly
Cadmium (Cd)	0.007 weekly	350 weekly
Copper (Cu)	0.5 daily	25,000 daily
Iron	0.8 daily	40,000 daily
Lead	0.025 weekly	1,250 weekly
Mercury (Hg)	0.005 weekly	250 weekly
Silver (Ag)[2]	0.005 daily	250 daily
Zinc (Zn)	1 daily	50,000 daily

[1] Lists only metals that had a tolerable intake listed.
[2] TDI for antimony and silver as provided by Hilts, Pers. comm. (2006).

Tolerable intake limits for metals are listed in this table.

Using the above values, maximum amounts of tissue that could be consumed for each plant or animal were calculated based on the maximum metal concentrations found in this study (Appendix N). It should be noted that this approach tests the unlikely event that a person will collect a particular tissue only in the location of most concern. As many metals are present in each tissue, it was deemed important to identify the metal which limited consumption to the greatest degree for each tissue type (Tables 4.2). For example, if berries were consumed, a person could eat 2,101 grams (approximately 16.7 cups) per day before reaching the tolerable daily intake for arsenic; however, at 372 grams (approximately 3.0 cups) per day the limit for cadmium would be reached. Table 4.2 lists the metal that would limit daily in-take the most for each tissue type.

Table 4.2. Tolerable daily intakes for tissue from the mine site as determined by the metal that would limit consumption the most (see Appendix N for complete list).

Tissue Type	Species	Limiting Factor			Amount (wet weight) that could be consumed by a 50 kg person (g/ day)
		Metal	Site	Concentration (ug/g) (based on dry weight)	
Lichens	Caribou Moss	Arsenic (As)	B1	36.9	5
Shrubs	Labrador Tea	Arsenic (As)	PONY3	12.5	14
	Willow	Cadmium (Cd)	MWR	141	2
Mushrooms	*Bolete* Mushroom	Arsenic (As)	I2	3.6	119
Berries	Blueberry	Cadmium (Cd)	CP1	0.79	372
Liver	Arctic grayling	Cadmium (Cd)	VIC3	1.36	177
Flesh	Arctic grayling	Mercury (Hg)	VIC3	0.155	1,047
Liver	Burbot	Arsenic (As)	VIC3	14.1	22
Flesh	Burbot	Arsenic (As)	VIC 4	2.7	194
Liver	Ground squirrel	Cadmium (Cd)	MILL	12.1	14
Kidney	Ground squirrel	Cadmium (Cd)	MILL	44.8	4
Liver	Red squirrel	Iron (Fe)	MILL	870	163
Kidney	Red squirrel	Cadmium (Cd)	MILL	1.86	109
Liver	Spruce grouse	Cadmium (Cd)	POND	2.05	85
Kidney	Spruce grouse	Cadmium (Cd)	POND	72.9	3
Flesh	Spruce grouse	Lead (Pb)	POND	3.7	181
Gizzard	Spruce grouse	Arsenic (As)	POND	2.3	203
Liver	Snowshoe Hare	Cadmium (Cd)	TAIL	3.26	53
Kidney	Snowshoe Hare	Cadmium (Cd)	MILL	58.3	3
Flesh	Snowshoe Hare	Cadmium (Cd)	TAIL	0.56	339
Liver	Caribou	Cadmium (Cd)	NA	14.7	11
Kidney	Caribou	Cadmium (Cd)	NA	75.5	3
Flesh	Caribou	Iron (Fe)	NA	99.6	1673
Liver	Moose	Cadmium (Cd)	NA	5.87	29
Kidney	Moose	Cadmium (Cd)	NA	23.9	10
Flesh	Moose	Zinc (Zn)	NA	50.7	4,197

Please note there was no moisture content for some plant samples; however, this was estimated using data from other samples: Willow (50%), Labrador tea (45%) and mushrooms (50%).
[a] It should be noted that Nicholson 2002 found arsenic levels in bolete mushroom a considerable distance from the mine site to be 34.8 *u*g/g with a TDI of 1.6 g dry weight for a 57 kg person.

Calculations were made to determine how much of each tissue (from the most effected sites) could be consumed per day.

Please note this does not take into consideration other food types that may be consumed in the same day.

Tolerable intake of the tissue types is limited mainly by elements that do not appear to have elevated patterns around the sources of contamination (iron, mercury). These elements likely occur at levels that are reflective of natural conditions at the site. In a few cases, arsenic, which is elevated around the sources of contamination, appears to be of most concern. Arsenic is also a carcinogen, and therefore is of further concern.

Of the plant tissue types, willow and caribou moss (reindeer lichen) collected near the mill and tailings pond, respectively, have the lowest tolerable daily intakes. Willow is used by the LSCFN members for medicinal purposes and is likely not ingested fully. Caribou moss is also used for medicinal purposes in the form of tea. Unless the metals are on the lichen surface (i.e. dust) and/or a considerable amount of tea is consumed, it is unlikely that consumption of tea would result in consumption over the weekly intake. To provide additional reference, samples were collected from the most affected sites to test whether local preparation methods affected levels that may be consumed. Local LSCFN citizens prepared tea from caribou moss (collected from B1) and Labrador Tea (collected from PONY3) and using traditional/local methods, the resulting tea had metal levels that were below CCME (2002) guidelines for drinking water (full description of methods and results presented in Appendix O).

Tea made in the community by elders from caribou moss and Labrador tea from impacted sites (Pony3) did not have high metal levels.

In terms of small game species, in snowshoe hare and grouse again the organs appear to be most restrictive mainly due to cadmium levels. Perhaps most notable is lead restricting the intake of spruce grouse flesh to 181g per day (1,267g per week) in one spruce grouse sample. In other small mammals, not surprisingly, kidneys and livers appear the most restrictive. Given the small size of these organs, it is unlikely that someone would consume above the tolerable limits. The ground squirrel kidney collected was 1.7 grams; therefore, 3.7 kidneys of the similar concentration would have to be consumed to meet the daily limit for cadmium. It must be considered that a sample of ground squirrel flesh was not analyzed, and that only one ground squirrel was captured. Therefore, these results may not be representative regarding any implications for human health.

For moose and caribou organs, the limiting element was cadmium. Cadmium levels were not significantly different in ungulate organs from the site than other areas in the Yukon. In fact the Tolerable Daily Intake, averaged out over a yearly basis, appears less restrictive than Yukon Health standards that recommend yearly consumption levels for ungulate organs (Table 4.3). In addition, cadmium is the element which restricts the Yukon Health consumption levels for organs (Gamberg pers. comm. 2006) which is consistent with the finding of this project. It does not appear that moose and caribou flesh contain metals that would be concern from a human consumption point of view. It appears metal levels in moose and caribou taken on or near the Mt. Nansen mine site are not a concern for human consumption beyond those already identified for the Yukon as a whole.

It appears metal levels in moose and caribou are not a concern for human consumption beyond those already identified for the Yukon as a whole.

Table 4.3. Maximum consumption of organs / person / year (Yukon Government 2007).

	Kidneys	Livers
Caribou	7-32	4-16
Moose	1	1

Yukon standards for moose and caribou organ consumption.

In fish, the livers from Victoria Creek were also the most restrictive. However, considering the size of the fish captured in Victoria Creek, Arctic grayling are the only species likely to be consumed by humans. Grayling livers could be consumed up to 177 grams (approximately 1 cup) per week to meet the weekly limit for cadmium. However, over a kilogram of grayling flesh could be consumed per day before exceeding any of the tolerable daily intakes. Considering the size of the grayling in Victoria Creek, several could be consumed per day. It should be noted that SENES Consultants Limited (2003) found the risk level for arsenic exceeded the accepted risk level and the ingestion of fish was of most concern. It should be noted that this data was calculated via water transfer to fish calculations and was not based on sampling of fish. In this regard, generic water to fish transfer factors from other sources were utilized.

It should be noted again that the levels above are for the most extreme cases found in this study. However, given the above results, perhaps some caution and some moderation should be used when consuming plants and animals at the site. Collection of plants/small animals should be limited at or immediately around the three sources of contamination (the mill site/pit/pond). In addition, rinsing plant parts prior to consumption or preparation is recommended. Avoiding collection of plants/small animals in the immediate vicinity of the mine site would likely eliminate any concern regarding the consumption of contaminants.

As a precautionary step, collection of plants/small animals should be limited at or immediately around the three sources of contamination (the mill site/pit/pond).

5.0 CONCLUSIONS

Contaminants can be introduced into the terrestrial ecosystem via aerial dispersion and through direct uptake by plants and animals. The data from the lichens provide strong evidence that that aerial dispersion of metals has occurred in the past around the three sources of contamination (the mill, pit and pond). The high levels of metals found in vegetation growing on the low grade ore stockpile and on the tailings indicate that contaminants are starting to mobilize within the terrestrial ecosystem via uptake by plants.

There is evidence that metals have been mobilizing via dust and plant uptake.

At present, there is some indication that a few metal levels in some plants (other than lichens), soils and animals around the mine site may be slightly higher than normal; however, not at levels that would pose significant concern for the health of the ecosystem components. As such, reclamation efforts should focus ensuring that existing sources of contamination are prevented from being introduced into the ecosystem.

Metal levels are not currently posing a threat to the health of the plants and animals.

Reclamation efforts can reduce future concerns.

As indicated by the lichen and moss bag results, it appears the majority of such aerial dispersion around the mill and Brown McDade pit occurred during the active mining period. In contrast, the aerial dispersion of metals around the tailings pond appears to be ongoing and will continue to enter the surrounding environment if not addressed.

As vegetation is starting to regenerate on the low grade ore stockpile and tailings, metals are being uptaken by these plants at notable rates. Currently vegetation is sparse in these areas. Significant natural revegetation may pose concerns as animals (and perhaps people) use these plants for food. Bio magnification in the ecosystem is possible if these areas were to provide a significant food source for animals with small ranges.

Metals have also entered into the aquatic ecosystems at higher than normal rates. The most influenced areas include the upper portion of Dome Creek near the mill site and the lower part of Pony Creek. The source of the Pony Creek contaminants may be related to some waste rock located in and beside the stream near the Pony Creek adit. While no flow from the adit has been observed, the recent (2006) construction of hydraulic bulkhead in the adit is intended prevent any pit surface water or other flows from entering Pony Creek in the future. The introduction of metals into Dome Creek may be related to many different developments around the mill site including the low-grade ore stockpile, extensive waste in the stream channel (metal and debris from old vehicles and equipment), erosion around the mill site and the old tailings facilities in this area. In the longer term, continued aerial dispersion from the tailings could affect other waterways as contaminants in areas prone to deposition through wind build up and mobilize into aquatic systems.

Upper Dome and Pony creeks have been impacted by mining developments.

6.0 RECOMMENDATIONS

The following things must be addressed by reclamation:

Limit aerial movement of tailings.

The observed dispersion of metals around the tailings pond in 2006 indicates that the tailings are an on-going source of contamination. Reclamation plans should include methods to eliminate continued aerial contamination at the pond site. The tailings could be moved and/or covered with a suitable growing medium, thick enough to prevent the rooting of plants in the tailings. Such a cover will require a capillary break in order to prevent uptake of contaminants by capillary action. Movement of the tailings would also aid in addressing water quality concerns in this area.

Relocate or cap the low grade ore stockpile.

The low grade ore stockpile should be moved and/or capped. While it does not appear to be a notable source of aerial contamination, the high metal levels found in plants growing in this area are a concern. As vegetation becomes more prominent, there is more opportunity for the metals to accumulate in the natural ecosystem. In addition, these materials may be impacting sediments and likely water quality in the upper portion of Dome Creek. Lastly, as the low grade ore breaks down there may be more potential for aerial contamination.

The waste rock and the road crossing associated with Pony Creek should be removed.

The Pony Creek stream crossing adjacent to the adit should be should be deactivated. Associated with this, waste rock directly in the Pony Creek stream channel should be removed. The vegetation growing on the waste rock adjacent to the Pony Creek did not have similar metal levels to the vegetation growing on the low grade ore stockpile or tailings and as such this area likely can be re-vegetated without being moved. Revegetation in this area may also be enhanced by the introduction of topsoil to the area.

Planting the area of blackened vegetation with willows may help with the recovery of this area.

To accelerate vegetation growth in the area of blackened vegetation, the area should be planted with live willow stakes (i.e. bioengineering). This method involves driving willow stakes into the ground approximately 1 m and as such would promote root growth in the C-horizon. Willow growth in this area will allow for additional organic matter to establish which in turn may allow for other plants to establish. Prior to such planting, further sampling of willows currently growing in the BVEG zone would confirm that the uptake of metals will not be a concern in this regard.

In all areas considered for revegetation, the uptake of metals by plants must be prevented through the use of appropriate measures. Otherwise, such vegetation can act as a vector to further mobilize contaminants into the ecosystem.

Investigate and prevent contaminants from entering Dome Creek near the mill site.

The on-going contamination into the aquatic pathway (Dome Creek) at the mill site should be investigated and addressed. The sediment and the water quality data indicate that contamination may be on going and will likely continue without intervention. Possible contributors to contamination in the area include the low-grade ore stockpile, extensive waste in the stream channel (metal and debris from old vehicles and equipment), erosion around the mill site and the old tailings facilities in this area. Reclamation of the area to prevent further contamination would benefit not only the aquatic ecosystem, but also the terrestrial ecosystem (i.e. plants in the riparian as well higher levels of the food chain). There may be value in conducting investigations of surface water sources feeding Dome Creek in the vicinity of the mill site to more clearly identify specific sources of contaminant mobilization. Such sampling would best be conducted immediately following a heavy rain event, and could provide information that would assist in appropriately targeting remediation efforts to address sources of contamination in this area. Possible solutions include deactivating the stream crossing, removing debris from the stream channel, recontouring (and/or capping), revegetating all disturbed areas.

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Project Geochemist: Roman Krska
Project Technologist: Matt Power
Project Advisor: John Errington, C.E. Jones and Associates.
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DETAILED PRESENTATION OF WIND DATA

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SUMMARY OF COMMUNITY SURVEY

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RESULTS FROM TRADITIONAL PREPARATION OF TEA FROM CONTAMINATED VEGETATION