FINAL REPORT
ON

HUMAN HEALTH
SCREENING LEVEL RISK ASSESSMENT FOR CLINTON CREEK ABANDONED ASBESTOS MINE

Prepared for:

Department of Industrial Affairs and Northern Development

Prepared by:

SENES Consultants Limited
121 Granton Drive, Unit 12
Richmond Hill, Ontario
L4B 3N4

November 2003

Printed on Recycled Paper Containing Post-Consumer Fibre

TABLE OF CONTENTS

Page No.

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Screening Level Risk Assessments (SLRAs) of the potential impacts on human health from exposure to hazards at eleven mine sites and thirteen former military sites in northern Canada have been carried out to provide Department of Indian Affairs and Northern Development (DIAND) with a basis of ranking the relative risks presented by the sites for input to a process for prioritizing reclamation funding in future years.

This report describes the screening level human health risk assessment for existing conditions at the Clinton Creek site. The human health risk assessment was undertaken for the purpose of determining whether there are contaminant levels present in the aquatic and soil environment that may have an adverse effect on humans that either use, or may potentially use the site. The assessment included the following elements, which are proposed and readily accepted by regulatory agencies such as Environment Canada and the U.S. Environmental Protection Agency:

- receptor characterization;
- exposure assessment;
- hazard assessment; and
- risk characterization.

Measured concentrations of contaminants in water and soil were used in the assessment. A statistical assessment of 1998 field data (Royal Roads University 1999) was carried out to determine the appropriate concentrations to use in the assessment. Other measured site data were available for sediment. Additionally, asbestos in air concentrations measured in 2003 were used in the assessment.

The potential implications to human health from exposure to contaminants was considered for an adult and child resident, at the site for twelve months of the year and consuming drinking water, fish and wild game. The resident was also assumed to be exposed through dermal pathways, inhalation and external gamma. Exposure information, such as drinking water consumption, inhalation rates and body weight, was obtained from data on the general Canadian population. Dietary characteristics, such as consumption of fish, animals and birds, were obtained from a food survey for indigenous populations in the Northwest Territories.

The human health risk assessment was conducted using assumptions that result in an overestimate of exposure. As noted above, the human receptor was assumed to obtain all food and water from the site all year round; however, soil ingestion and dermal contact with exposed soil were limited to the summer months (three months per year). The estimated exposures (or intakes) by the human receptors were compared to intake levels considered to be protective of human health (i.e. reference doses), calculating hazard quotients (HQ) for non-carcinogenic effects, and risk levels for carcinogenic effects. These values are shown in Tables ES-1 and ES-2. Values in **bold** are those exceeding the designated levels for this site (0.5 for HQ, and 1×10^{-5} for risk level).

The assessment of intake showed that the hazard quotients of antimony, barium, chromium, lead, manganese, nickel and selenium exceeded the value of 0.5 selected for this site. Asbestos, arsenic and chromium also exceeded the selected risk level of 1×10^{-5} selected for this site. The main source of contaminants other than asbestos was consumption of fish. For asbestos, the air pathway was only considered.

TABLE ES-1
CALCULATED HAZARD QUOTIENT VALUES

Contaminant	Hazard Quotient	
	Adult	**Child**
Aluminum	0.1	0.2
Antimony	**1.5**	**2.4**
Barium	**1.0**	**1.6**
Chromium	**2.5**	**4.3**
Cobalt	0.04	0.07
Lead	**0.5**	**0.9**
Manganese	**0.8**	**1.2**
Molybdenum	0.2	0.2
Nickel	**1.9**	**2.9**
TOTAL SITE	**8.5**	**13.8**

TABLE ES-2
CALCULATED RISKS OF CARCINOGENIC EFFECTS

Contaminant	Risk Level	
	Adult	**Composite**
Arsenic	**2.6×10^{-2}**	**6.6×10^{-2}**
Asbestos	**4.5×10^{-3}**	**8.9×10^{-3}**
Chromium	4.3×10^{-6}	**1.2×10^{-5}**
Cobalt	9.4×10^{-8}	2.5×10^{-7}
Nickel	1.8×10^{-7}	4.8×10^{-7}
TOTAL SITE	**2.6×10^{-2}**	**7.5×10^{-2}**

There are a number of major physical features at the Clinton Creek Mine site that pose potential risks to the environment and people including, unstable waste rock dumps and a tailing pile, high pit walls, and structures, tanks and other mine equipment and facilities.

For physical hazards, a site-specific fatality rate was developed by combining an average annual fatality rate (based on United States statistics for abandoned mine sites) with an accessibility factor (which determines how accessible the site is), a hazard factor (which rates the hazards on the site) and a scaling factor (which accounts for the scale (size) of the mining operation). For the Clinton Creek site the annual fatality rate was estimated to equal 5.4×10^{-6}.

1.0 INTRODUCTION

In September 2003, SENES Consultants Limited was retained by the Department of Indian Affairs and Northern Development (DIAND) to undertake Screening Level Risk Assessments (SLRAs) of the potential impacts on human health from exposure to hazards at eleven mine sites and thirteen former military sites in northern Canada, for which DIAND has responsibility. The purpose of the SLRAs is to provide DIAND with a basis to characterize the relative risks presented by the sites for input to a process for prioritizing reclamation funding in future years.

To provide a common basis for comparing human health risks between the sites, a consistent set of conservative assumptions was applied to all sites, with exception of those sites where more detailed assessments have been previously reported. For example, quantitative Tier 2 level risk assessments have previously been completed for the Colomac, Giant and Port Radium mine sites. In these cases, the results of the Tier 2 risk assessment are presented in the current series of reports, where applicable.

To characterize the human health risks, standard approaches were developed for application to mine sites and former military sites, respectively. In both cases, the risk assessments were based on maximum likely exposures to chemical, radiological (where applicable) and physical hazards. In all cases, it was assumed that people would be on the sites for some portion of the year, even though some of the sites are at remote locations.

It should be noted that risk assessment does not provide a precise measure of risk due to the fact that many assumptions must typically be made. To reduce the uncertainty in a risk assessment, measured contaminant data are required. Therefore, sites which have extensive analytical data have less uncertainty in their risk assessments than sites for which less data exist. In cases where only water and soil data exist, assumptions can be made to determine the concentrations of contaminants in other media. If no data exist then quantification of risk associated with that particular contaminant cannot be done.

Many of the former military sites have asbestos containing material (e.g. insulated piping, floor tiles, and asbestos board) on-site. As there are no measured concentrations associated with this material, a quantitative risk assessment was not attempted. However, in general, the asbestos fibres associated with these types of asbestos containing material are not readily released to the environment hence, it can be reasonably concluded that these materials pose a low risk to individuals using the sites.

Similarly, PCB contamination associated with paint and electrical equipment on-site are low in volatility, hence, exposure to PCBs from this material can only come from ingestion of this material, a highly unlikely scenario. Therefore, exposure to PCB in these materials was not considered in the assessment.

For the mine sites, the assessments were carried out for a scenario involving suspension of ongoing care and maintenance activities. A three-pronged approach was undertaken to assess the risks posed by the mine sites:

1. First, the implications of discontinuing care and maintenance activities (e.g. stop treatment of mine water and/or tailings pond water, leave waste areas exposed to weathering conditions, etc.) were assessed to quantify the effects of the release of untreated waters and uncovered contaminated soils on human health;

2. Secondly, the hazards posed by on-site facilities (e.g. open pits, mine openings, waste rock piles, buildings, etc.) were assessed to quantify the potential risks of physical harm (fatality) to people accessing the sites; and

3. Thirdly, an inventory of chemical and fuel containers (e.g. barrels, tanks) and other equipment that pose potential hazards to people were compiled.

For the former military sites, the SLRAs focussed on quantifying the chemical hazards associated with the residual contaminants left on-site (item #1 above) and identifying potential hazards (item #3 above).

This report details the methodology and assumptions and presents the results of the SLRA for the Clinton Creek site.

1.1 SLRA APPROACH FOR CHEMICAL AND RADIOLOGICAL EXPOSURES

The SLRA for exposure to chemical (or radiological) hazards undertaken in the assessment evaluated the probability of adverse health consequences to humans caused by the presence of chemical or radiological contaminants in the environment. Receptor characteristics (e.g. proportion of time spent in the study area, source of drinking water, composition of diet) and exposure pathways (e.g. inhalation and ingestion) were taken into consideration.

Very few sites have measured concentrations of contaminants in air. In the absence of these concentrations, representative air concentrations from rural locations were used to calculate exposure from the air pathway. Professional experience suggests that the inhalation exposure pathway related to metals and less volatile organic contaminants such as polychlorinated aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) is insignificant in comparison to the oral pathway. Therefore, the assumption of using representative rural concentrations is not unreasonable.

The receptors selected for the SLRA took into account the proximity of nearby communities as well as the accessibility of the site. The assumptions made for the screening level risk assessment are intended to err on the side of caution and therefore to result in over-estimation of contaminant intakes. The level of caution in these assumptions is consistent with the approach typically adopted at the screening stage.

1.2 SLRA APPROACH FOR PHYSICAL HAZARDS

The SLRA of physical harm evaluated the risk of fatal injury to visitors to the sites due to the presence of unsafe features (e.g. open pits, mine openings, waste rock piles, structures, etc.) remaining at the site. The assessments took into consideration fatality statistics for abandoned mine sites in the United States, accessibility of the sites, proximity of nearby communities, presence/absence of unsafe features and the scale (size) of the mining operation.

An inventory of the number/quantity and condition of all physical features at the mine sites and former military sites (e.g. pits, tailings areas, waste rock piles, chemical storage containers, tank farms, waste dumps, structures) that pose potential hazards to people who may access the sites was prepared using information reported in previous investigations. Only a portion of this information was used in the evaluation of physical risks discussed above. The remaining information is provided to allow comparison of residual issues between the sites.

1.3 REPORT STRUCTURE

The report has been structured into several sections, each of which describes specific aspects of the SLRA. These aspects include:

Section 2 – Site Characterization and Physical Hazards: This section provides a brief description of the site, discusses the accessibility to the site and the proximity of nearby communities. It also summarizes the physical structures and potential hazards that exist on site.

Section 3 – Chemical Hazard Identification: Summarizes the data pertaining to the site for soil and surface water and identifies the Contaminants of Potential Concern (COPC) which are selected by comparing measured concentrations in air and soil with guideline and baseline concentrations. Other available data for sediments, vegetation and air are also summarized.

Section 4 – Receptor Characterization: Identifies the human receptors (i.e. adults) who may spend time in the study area based on the accessibility to the site and the proximity of nearby communities. The pathways of exposure of human receptors and their respective dietary characteristics are described.

Section 5 – Exposure Assessment: Provides a summary of the predicted exposures to human receptors and provides a physical hazard exposure analysis.

Section 6 – Dose Response Assessment: Details the toxicity benchmarks used in the assessment.

Section 7 – Risk Characterization: Presents the results of the pathways modelling and risk assessment.

2.0 SITE CHARACTERIZATION

This section provides a brief description of the Clinton Creek Asbestos Mine site and its physical characteristics.

2.1 CLINTON CREEK ASBESTOS MINE SITE DESCRIPTION

The Clinton Creek Asbestos Mine is located in the Yukon Territory, approximately 100 km northwest of Dawson City (see Figure 2.1). It is adjacent to Clinton Creek, approximately 9 km upstream of its confluence with the Fortymile River. Porcupine and Wolverine creeks are local tributaries of Clinton Creek. The mine site is accessible via a gravel road along the north side of Clinton Creek near the base of the valley. A gravel air strip is located to the north of the mill site. Figure 2.2 is a general site map of the Clinton Creek Mine site.

The mine site is situated within the unglaciated Yukon – Tanana Upland with terrain consisting of a series of ridges. The valley bottoms of the ridges are at an elevation of 400 m with the highest level reaching 610 m above sea level. The site has been described to be in a region of widespread discontinuous permafrost (Stepanek and McAlpine 1992).

The mine was operated from October 1967 to August 1978 by Cassiar Asbestos Corporation Ltd. The mill buildings and associated town site, located 10 km southeast of the mine were auctioned off in 1978. Cassiar Asbestos Corporation Ltd., later Princeton Mining Corporation still owns the mine site (Royal Roads University 1999). The mine site is accessible via a gravel road from the former town site along the north side of Clinton Creek near the base of the valley (UMA 2000).

During operation, ore was extracted from three open pits (Porcupine, Snowshoe and Creek pits) along the south side of Clinton Creek. The Porcupine and Snowshoe pits are located on a hilltop. The Creek pit is located on the original alignment of Porcupine Creek. The ore body comprised chrysotile asbestos veinlets embedded in jade green serpentine (Royal Roads University 1999).

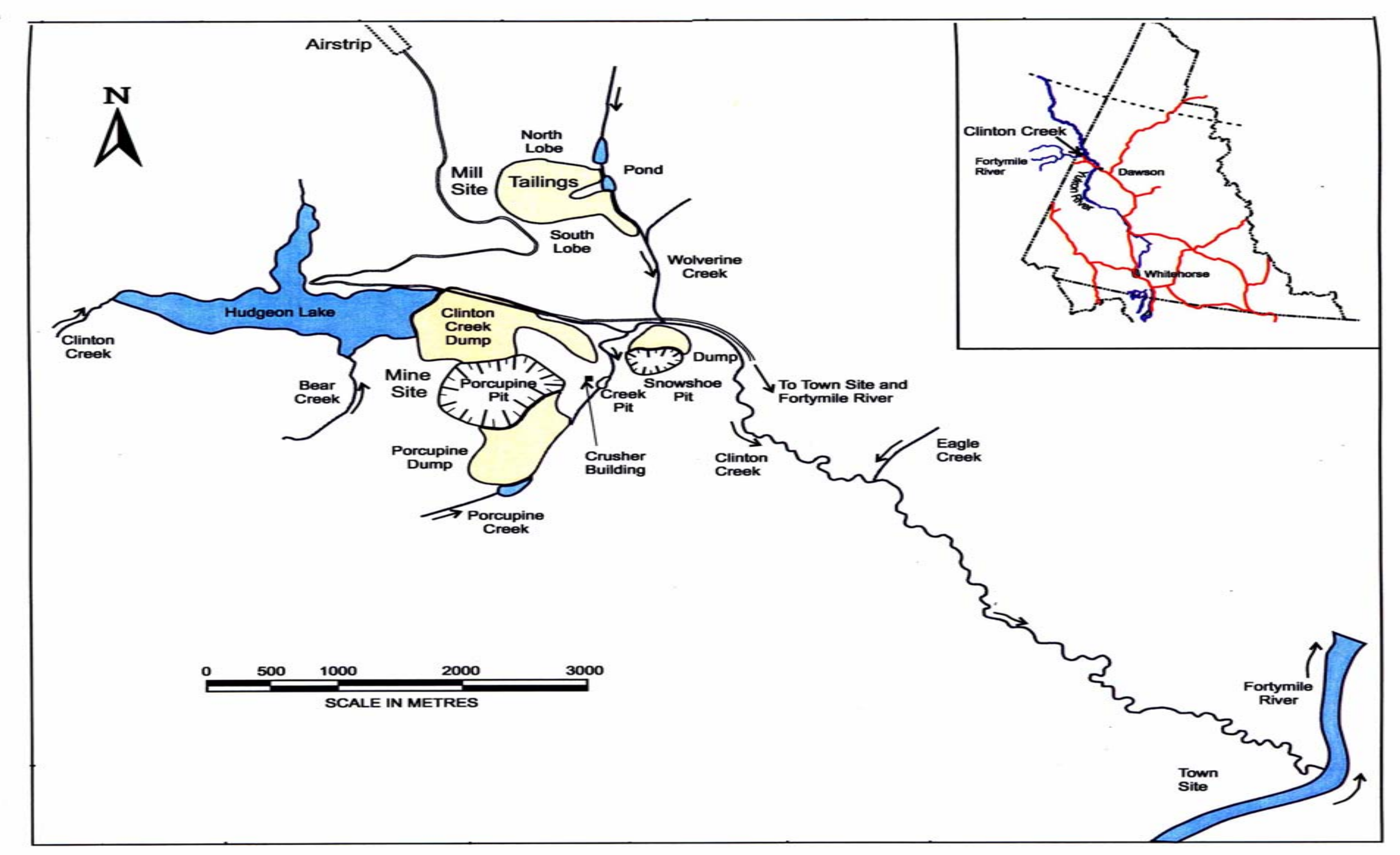
From 1978 to 1987, the Cassiar Asbestos Corporation undertook a series of decommissioning activities which included the removal of structures from the town site, removal of the main segments of the concentrator, removal of most mining equipment and facilities (except the primary crusher), re-vegetation through hydro-seeding of the town site, waste dumps and tailings piles, and the installation of erosion control measures (Royal Roads University 1999).

Waste rock from the three open pits was deposited on the valley slopes adjacent to the pits and hence, created three waste rock dumps (Clinton, Porcupine and Snowshoe). The waste rock consists mainly of argillite, phyllite, platy limestone and micaceous quartzite (Stepanek and McAlpine 1992) and the volume has been estimated at 60 million tonnes (Roach 1998). The ore was transported by an aerial cable tramway to the mill site. A dry hammer mill process was used

FIGURE 2.1
LOCATION OF CLINTON CREEK MINE SITE

Source: National Geographic (1999).

FIGURE 2.2
CLINTON CREEK ASBESTOS MINE SITE MAP



Source: Royal Roads University (1999).

to extract asbestos fibre from the ore. The tailings were then deposited in two lobes over the slopes of the mill site.

Waste rock deposited on the north-facing slope of the Clinton Creek valley failed and subsequent downslope movement of waste rock resulted in the blockage of Clinton Creek and the creation of Hudgeon Lake in 1974. In 1999, the surface area of Hudgeon Lake was approximately 115 ha with a maximum depth of 27 m (Royal Roads University 1999). A discharge channel from Hudgeon Lake developed at the northern perimeter of the dump and discharge from the outflow flows across the north side of the waste dump. A channel was also excavated along the eastern extremity of the toe of the waste rock mass to maintain drainage from the lake.

Waste rock placed along the Porcupine Creek valley also formed an impoundment across the creek. The downslope movement of the tailings deposits along the two lobes resulted in the partial blockage of Wolverine Creek, a tributary to Clinton Creek.

The waste rock and tailings continue to move and the long-term stability of the three blockages is not known. The probability of a breach failure in any of the blockages is considered high (Stepanek and McAlpine 1992). A breach of an existing blockage may increase the potential for the chronic or massive downstream movement of asbestos-containing sediments into the creek (Royal Roads University 1999).

The drainage area of Wolverine and Porcupine Creeks, the two main tributaries of Clinton Creek, are approximately 28.6 and 4.7 km^2 respectively. Clinton Creek drains approximately 116.6 km^2 upstream of the confluence with Wolverine Creek, increasing to 203.8 km^2 at the junction with Fortymile River. Fortymile River flows into the Yukon River 2 km downstream of the Clinton Creek confluence; which enters Alaska approximately 70 km downstream from the abandoned mine site (UMA 2000).

2.2 PHYSICAL FEATURES

2.2.1 Physical Hazards at Mine Sites

Typically, there are numerous physical hazards associated with abandoned mine site. The nature of these physical hazards depends on whether the mine was an open pit or underground mining operation. The following paragraphs describe the most important hazardous features of the abandoned mine sites.

Shaft Openings

An open shaft is a vertical opening that may be hundreds of feet deep. A shaft may be visible or it may be hidden by debris or vegetation. Internal seepage and periodic storms or flashfloods may create deep water at the base of such shafts. In addition to the direct risk from drowning, the presence of water can accelerate the decay of support structures, leading to cave-ins and collapses.

Adits

Adits are horizontal openings that lead to underground mine workings. Adits provide a variety of dangers, including unstable rock ceilings and walls and decayed structures that may collapse, causing a rock fall.

Open Pits

Not all mines are underground. Often large areas of the surface have been disturbed to access the minerals near the surface, altering the original contours and creating dangerous surface features. These features include open pits and/or vertical cliffs (highwalls) that are prone to collapse and unstable ground. When approached from the top, the vertical edge of a highwall may not be seen in time or may crumble, leading to a fatal fall.

Open pits can be partially filled with water, which in turn, can be highly acidic or laden with harmful chemicals. Drowning in open pits has been found to claim more lives than any of the other hazardous features of abandoned mine sites.

Waste Rock Piles

Waste rock piles are typically created at mine sites by dumping from haulage trucks or conveyor systems. These side slopes, which form at the natural angle of repose of the material, are generally unstable and thus, are subject to failure when disturbed. Hence, mine site visitors who may choose to climb these piles are at risk of serious injury.

Tailings Basins

Mining operations that featured ore processing on site usually have surface tailings impoundments. The impoundments generally are created by constructing one or more dams at low points and placement of the tailings behind the dams as a slurry. Hence, tailings impoundments characteristically contain a pond of water. Without ongoing care and maintenance, tailings dams deteriorate and are subject to failure and the subsequent release of tailings pond water and tailings solids. Because site visitors are naturally attracted to these impoundments, as they are usually easily accessible on foot or motorized vehicle, they are at risk of injury when crossing the dams or tailings surfaces.

Decayed Support Structures

Unstable equipment, scrap metal and lumber, and deteriorated buildings pose great danger to visitors of abandoned mine sites.

Underground Mines

Within a mine, the condition of structures and supports is harder to see. In many cases, shifting rock, caving walls, water and humidity cause wood to deteriorate much faster than wooden structures on the surface. With deterioration of support structures, the fractured roof or walls of a mine tunnel eventually collapse in response to vibrations and the force of gravity.

A few metres from the entrance, the mine becomes very dark. A person can easily become disoriented and lost. With a failed light source, the chances of getting out of an extensive mine, honeycombed with miles of workings, in absolute darkness, are remote.

Abandoned mines are also not ventilated. Gases such as methane, hydrogen sulfide and carbon dioxide (CO_2) occur naturally in some mines, particularly in coal mines. Pockets of carbon dioxide or other deadly gases displace oxygen with no visible sign. This is a deadly trap for the visitors of abandoned mine sites.

Explosives and Toxic Chemicals

Explosives and chemicals used in mining are often left behind when an operation is abandoned. Explosives such as dynamite and blasting caps become very unstable over time and can explode if disturbed. Storage containers, boxes, barrels and drums deteriorate, allowing toxic chemicals to leak or to combine into highly dangerous mixtures.

2.2.2 Physical Hazards at Clinton Creek Site

Table 2.1 summarizes some of the main physical features of the site.

TABLE 2.1
PHYSICAL FEATURES OF CLINTON CREEK MINE SITE

Physical Parameter	Key Features	Characteristics	Description
Tailings		General Information	Approx. 10 million tonnes of tailings deposited along dipslope below the mill, above Wolverine Creek.
		Dates of Tailings Deposition	1968 to 1978: deposited by stacker conveyor over the valley crest.
		Total Tailings Volume	Approx. 10 million tonnes (est. 26.5 million m^3).
		Tailings Surface Area	Not determined.
		Tailings Average Depth	Unknown, varies.
		Avg Depth to Water Table	Unknown, varies with location.
		Physical Stability	The South Lobe failure blocked Wolverine Creek in 1974. The North Lobe failure followed; the tailings continue to be unstable.
		Geochemical Characteristics, Acid Base Accounting (ABA)	No ABA data are available; however soil and water samples are consistently alkaline. Sulphides are not associated with the asbestos (serpentine) mine; ARD is not a concern. Although tailings are elevated in arsenic, chromium, mercury, nickel, and uranium, these contaminants were not detected in water samples.
		Groundwater Seepage Rate	Unknown.
		Surface Discharge Rate	Unknown.
		Cover Type	No cover.
		Vegetation	None.
		Erosion	Massive creep erosion, massive failures, tension cracks, etc.
		Accessibility	Accessible by foot (road washed out).
		Additional Information	Localized hot spots with elevated radiation levels in tailings (ambient air levels measured at site appear insignificant).
	Dams	General Information	None - although the slumped tailings have blocked Wolverine Creek.
		Dimensions	Not determined.
		Type of Construction	Slumped tailings.
		Discharge Structure	None, although surface water is flowing through and across the slumped tailings.
		Seepage	Not determined, although piping has been observed.
		Erosion	The North Lobe blockage is continually being eroded by Wolverine Creek.
		Stability	Tailings are continually eroding to Wolverine Creek. A reservoir has developed upstream of the tailings slump. The volume and stability of this reservoir is unknown.
		Additional Information	None at this time.

TABLE 2.1 (Cont'd)
PHYSICAL FEATURES OF CLINTON CREEK MINE SITE

Physical Parameter	Key Features	Characteristics	Description
Tailings	**Dykes**	General Information	None.
Pits		General Information	Three pits on site (Porcupine, Snowshoe, and Creek). Size of pits: Porcupine Pit >> Snowshoe >> Creek.
		Volume	Not determined.
		Depth	Porcupine Pit up to 200 m deep.
		Surface Area at grade level	Not determined.
		Contents of Pit	Porcupine Pit is flooded.
		Depth to Watertable	Water at elevation 385 m asl.
		Groundwater Seepage Rate	Not determined.
		Surface Discharge Rate	Not determined.
		Slopes	Porcupine Pit: 45 to 50 degree slopes.
		Stability	North and west sides unstable: ravelling, small wedge failures, scarp movements, tension cracks, and sloughing.
		Accessibility	Unknown.
		Underground Workings In Pit	None.
		Additional Information	None at this time.
Underground Workings		General Information	No underground mining was conducted at this site.
Waste Rock		General Information	Three waste rock dumps are on-site, Clinton Creek, Porcupine, and Snowshoe Waste Rock Dumps. Only the Clinton Creek Dump is described below. The Porcupine Dump is small (approx. 3 million tonnes), and geochemically stable. The Porcupine Dump is eroding into Porcupine Creek and has created a small blockage. No information is available on the Snowshoe Dump.
		Total Waste Rock Volume/Mass	Approximately 60 million tonnes.
	Clinton Creek Waste Rock Dump	General Information	The Clinton Creek Pile has blocked Clinton Creek, forming Hudgeon Lake (up to 27 m deep; 12 million m^3). The pile is composed of argillite waste rock and overburden sand, gravel, and cobbles.
		Location	N of Porcupine Pit, waste rock deposited on the south slope of Clinton Creek.
		Volume	Not determined.
		Surface Area	Not determined.
		Height/Depth	Not determined.
		Depth to Water Table	Not determined.

TABLE 2.1 (Cont'd)
PHYSICAL FEATURES OF CLINTON CREEK MINE SITE

Physical Parameter	Key Features	Characteristics	Description
Waste Rock	**Clinton Creek Waste Rock Dump**	Geochemical Characteristics, Acid Base Accounting (ABA)	No ABA data are available; however soil and water samples are consistently alkaline. Sulphides are not associated with the asbestos (serpentine) mine; ARD is not a concern. Although waste rock is elevated in arsenic, chromium, mercury, and nickel, these contaminants were not detected in water samples. Localized hot spots with elevated radiation levels in waste rock (ambient air levels measured at site appear insignificant).
		Groundwater Seepage Rate	Not determined.
		Surface Discharge Rate	Not determined.
		Cover (water, soil, sand, none, etc.)	None.
		Vegetation	None.
		Sloped/Graded Surfaces	No.
		Erosion	Massive slump erosion at a rate of approx. 30-50 cm/yr as well as massive failures, tension cracks, etc. toward Clinton Creek. Clinton Creek flooding wiped out erosion control works in 1997. Downcutting and incising of the waste rock by Clinton Creek continues.
		Physical Stability	Unstable. Active movement of the dump has continued since mine closure.
		Additional Information	Waste rock has slumped and blocked Clinton Creek, forming 27 m deep Hudgeon Lake. Danger of lake breaching waste rock dam, causing outburst flood. Currently a Gabion/rip-rap drop structure / spillway is being built to prevent waste rock dam from being breached (UMA 2003).
Infrastructure (Various)		General Information	Numerous buildings remain around the site, including: two conveyor shafts, two small structures, remnant aerial tram structures (towers and terminus), crusher building, 2 flooded conveyor tunnels, and abandoned equipment (excavator, drill rig, etc.)
		Date of Construction	Varies, presumably 1968 to 1978.
		Number of Buildings	3 or more.
		Type of Construction	Steel, wood, and concrete.
		Condition/Stability	Poor/Unstable/Flooded
		Accessibility	Accessible by foot as the road is washed out.
		Additional Information	Tramway and tanks are unstable and have insecure ladders and platforms

TABLE 2.1 (Cont'd)
PHYSICAL FEATURES OF CLINTON CREEK MINE SITE

Physical Parameter	Key Features	Characteristics	Description
Utilidor		General Information	A utilidor housing water and steam piping runs across the mill site (UMA 2003): Approx. 3 m below surface. Concrete, lined with boiler plate material. 6 openings to utilidor; 1.2 m to 2 m x up to 3 m deep. 5 openings within buildings or concrete foundations. 1 metal shaft, covered with insecure plywood.
		Date of Construction	Uncertain, presumably 1968 to 1978.
		Number of Buildings	1 Subsurface concrete structure.
		Type of Construction	Concrete, lined with boiler plate material.
		Condition/Stability	Stable.
		Accessibility	6 insecure openings.
		Additional Information	Shaft poses greatest physical hazard of openings.
Tank Farms		General Information	Two large above ground diesel storage tanks (ASTs) exist on site (approx. 4 m tall, 10 m wide).
		Type of Tanks and Number	2
		Contents and Volume	Unknown.
		Condition of Tanks	Rusting.
		Containment	No.
		Documented Spillage	No, however hydrocardon staining and odours were documented on site.
		Additional Information	Insecure ladders, insecure roof surfaces (popular with game hunters), and insecure hatch openings.
Fuels, Chemicals, PCBs		General Information	A detailed site inventory of chemicals and reagents has not been conducted or provided at this time as most studies have focused on the eminent hazards associated with mine waste instability.
Additional Physical Hazards		General Information	Slopes into flooded conveyor ramps may pose a hazard, especially in winter (UMA, 2003).

As seen in Table 2.1, the main areas of concern for the Clinton Creek Asbestos mine site are:

- unstable waste rock dumps and tailings piles that may lead to massive flooding;
- presence of asbestos on site; and
- failures and erosion of the tailings may transport eroded tailings downstream to the receiving creeks.

3.0 CHEMICAL HAZARD IDENTIFICATION

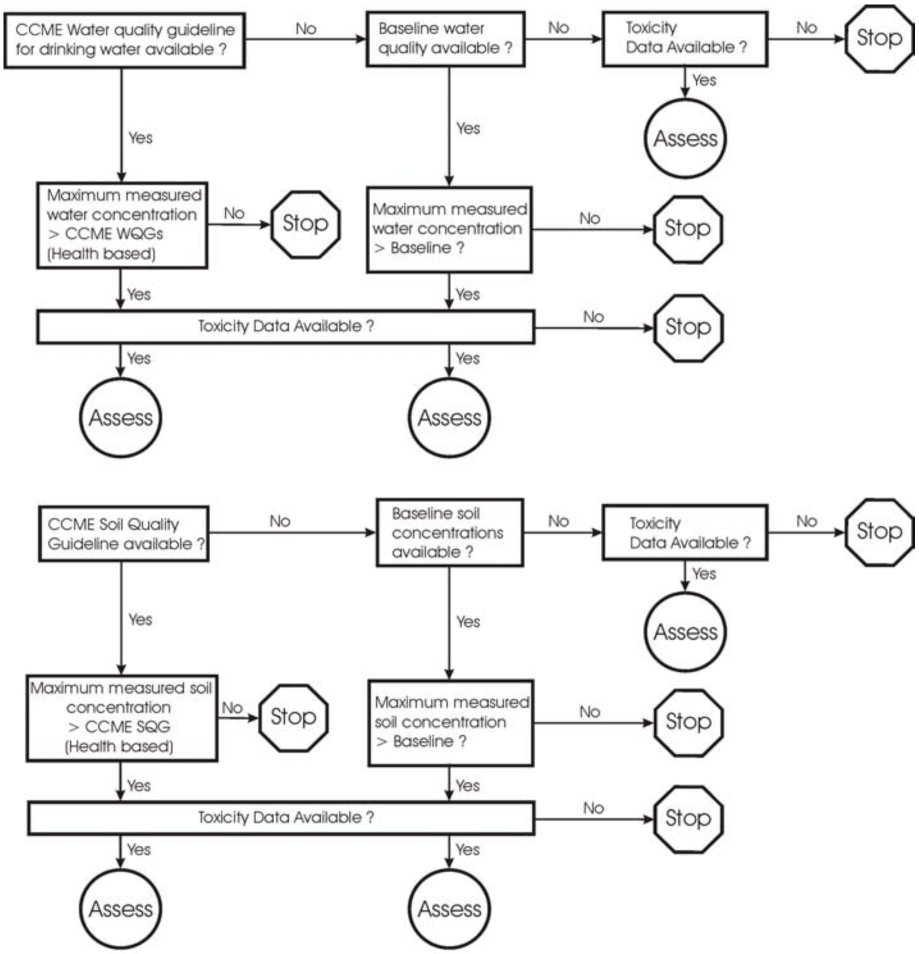
This section identifies the contaminants of concern that are selected for this assessment of potential human health effects from exposure to chemical contaminants.

3.1 SELECTION OF CONTAMINANTS OF POTENTIAL CONCERN

A selection process was performed to identify contaminants of potential concern (COPC) at the various sites based on human health considerations. The procedure followed for selection of COPC for human health is illustrated in Figure 3.1 and described below. COPC were selected by comparing measured concentrations in water and soil/tailings to the Canadian Council of Ministers of the Environment (CCME) guidelines. Drinking water guidelines developed by the Canadian Council of Ministers of the Environment (CCME), which are intended to protect human health and to provide water of a good aesthetic quality (CCME 2002), were used for surface water bodies. In addition, the human health component of CCME soil quality guidelines for residential/parkland use were applied to the soils or tailings data. It is recognized that comparing tailings to soil guidelines is not necessarily appropriate as the guidelines were not developed for application to this type of material; however, for the purpose of identifying COPC at a site (e.g. in wind blown dust and site drainage) it was felt to represent a reasonable approach.

All contaminants with concentrations below the respective guidelines were dropped from the assessment. Typically, if no guidelines were available, then the contaminants were compared to baseline concentrations. If measured concentrations were found to be below baseline concentrations then those contaminants were also dropped from further consideration. Only contaminants which exceeded guidelines or baseline levels (when no guidelines were available) were selected for further consideration. The final step in the selection of COPC involved determining whether toxicity benchmarks for human health were available for the contaminants selected for further assessment. Only contaminants for which toxicity benchmarks exist were retained on the COPC list.

FIGURE 3.1
SELECTION PROCEDURE FOR CONTAMINANTS OF POTENTIAL CONCERN



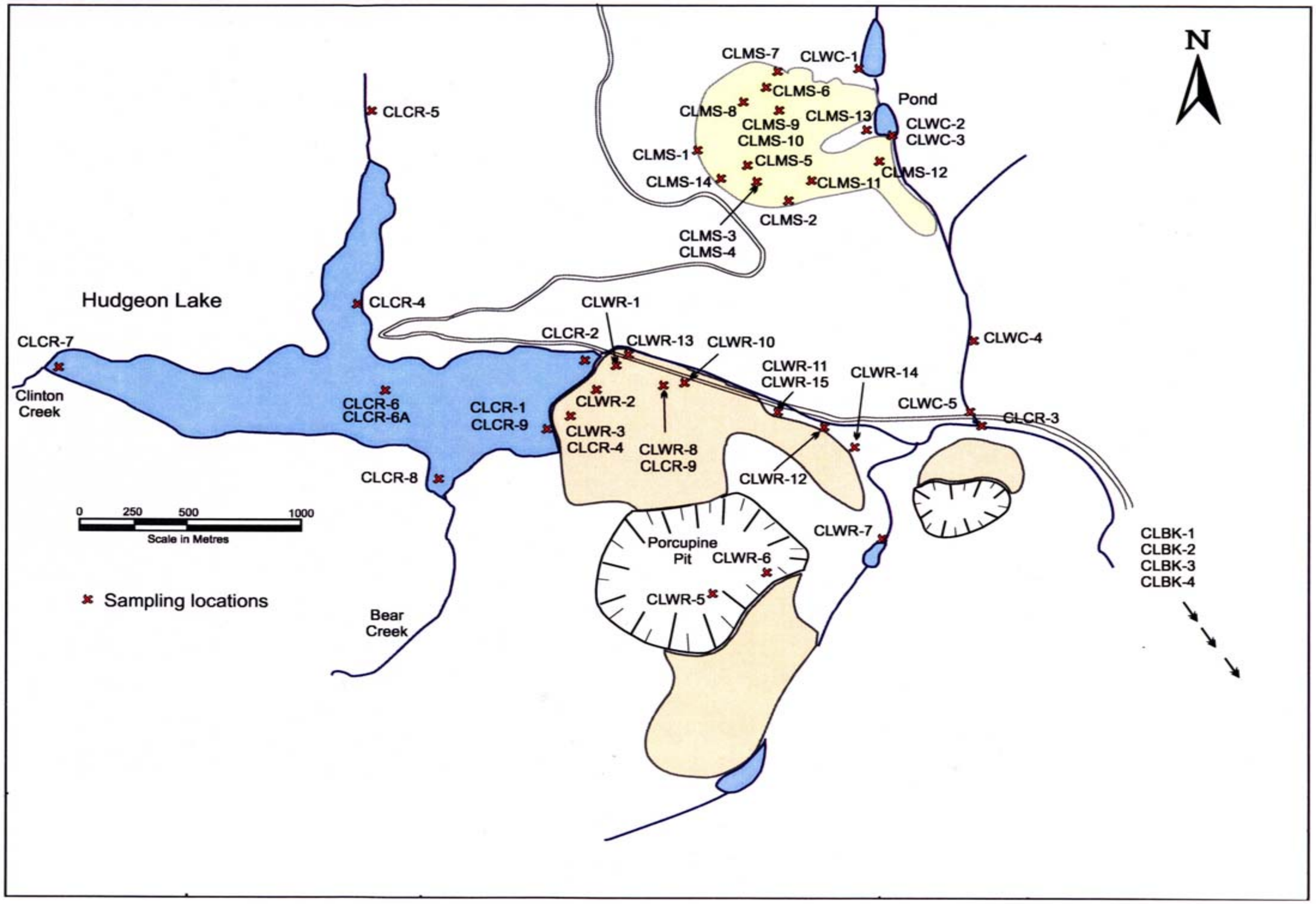
Note: Maximum is either the absolute maximum measured value, or the 95th percentile value where there were more than 10 samples.

Water Quality

A field investigation program was conducted in September 1998 by DIAND, Royal Roads University and Fisheries Resources. Grab surface water sample data were collected from Hudgeon Lake, Clinton Creek, Wolverine Creek, waste rock areas and background and they were analyzed for metals and inorganic non-metallic contaminants such as nitrate, nitrite, bromide, chloride, fluoride, sulphate and total alkalinity. Selected samples were also analyzed for asbestos (Royal Roads University 1999). Figure 3.2 shows the sampling locations. Another water sampling program was conducted by UMA Engineering Ltd. in September 2003. A total of 25 surface water samples were collected from Porcupine Creek, Hudgeon Lake, Wolverine Creek, Clinton Creek and Fortymile Creek. Two reference samples were also collected upstream of

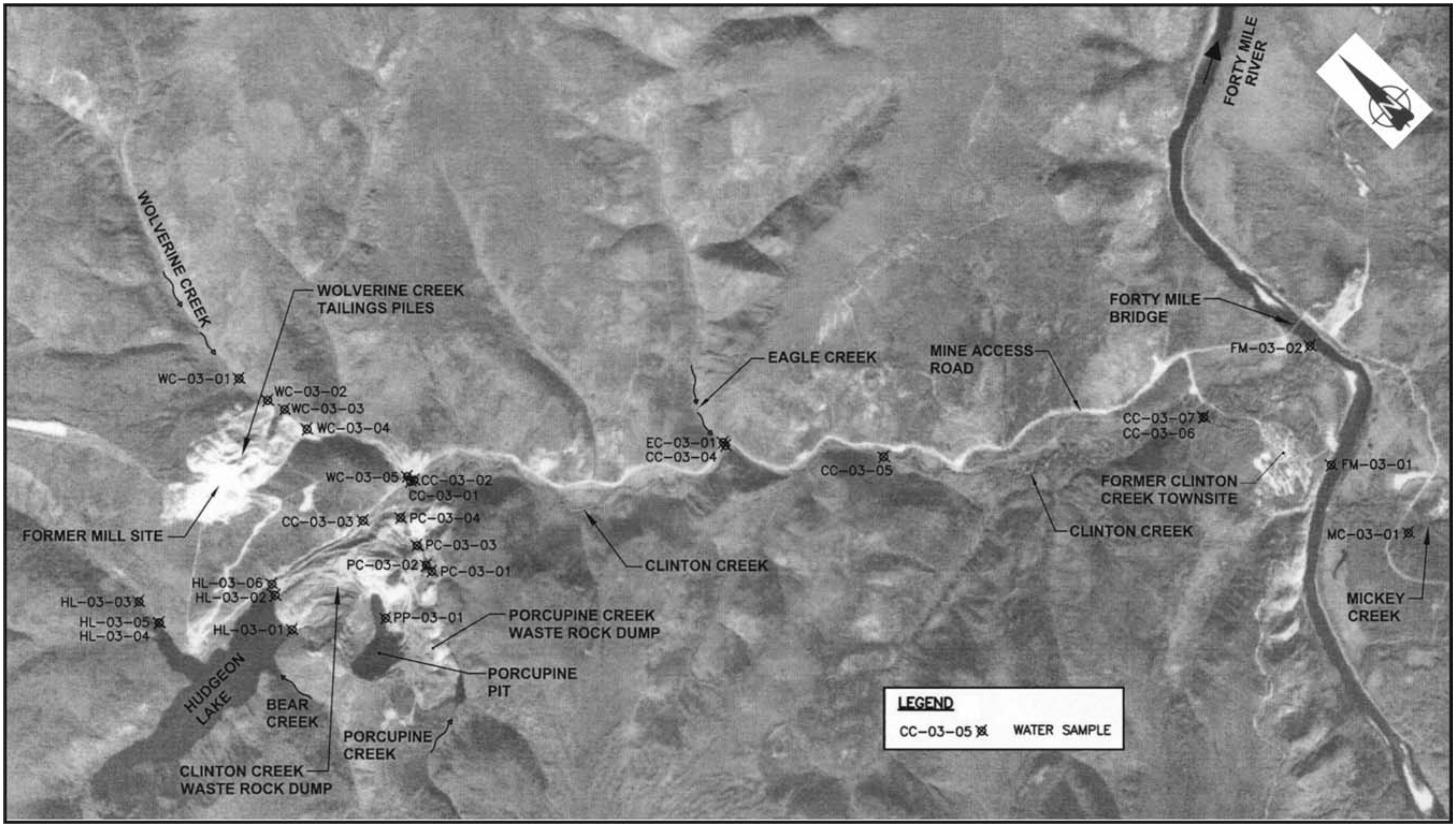
Wolverine Creek and Eagle Creek. Figure 3.3 shows the sampling locations of the 2003 water sampling program. In the 1998 sampling program, the method detection limits (MDLs) for antimony and arsenic were very high, with the MDL of arsenic being eight times the CCME guideline value and the MDL of antimony reported as thirty-three times the CCME guideline value. Therefore, the results from the latest sampling program by UMA (2003) were used in this assessment as the detection limits are lower. Appendix C presents the 2003 sampling results. The results are summarized in Table 3.1 together with the CCME Guidelines for Drinking Water Quality (CCME 2002). The measured concentrations reported in Table 3.1 are either calculated 95th percentile (≥ 10 samples) or maximum concentrations (< 10 samples).

FIGURE 3.2
CLINTON CREEK ASBESTOS MINE 1999 SAMPLING LOCATIONS



Source: Royal Roads University (1999).

FIGURE 3.3
2003 WATER SAMPLING LOCATIONS



Source: UMA (2003).

TABLE 3.1
SUMMARY OF SURFACE WATER QUALITY DATA

Contaminant	CCME Drinking Water Quality Guidelines [a] (mg/L)	Measured Water Quality [b] (mg/L)	Baseline Water Quality [c] (mg/L)
Total Metals			
Aluminum	0.2(0.1)[e]	**0.17**	0.03
Antimony	0.006	0.003	0.00025[f]
Arsenic	0.025	0.016	0.0004
Barium	1.0	0.05	0.05
Beryllium	-	0.0025[f]	0.0005[f]
Boron	5	0.1	0.05[f]
Cadmium	0.005	0.00015	0.00004
Chromium	0.05	0.0025	0.0005[f]
Cobalt	-	0.001	0.00015[f]
Copper	<1.0[d]	0.04	0.002
Iron	<0.3[d]	**0.59**	0.12
Lithium	-	0.036	0.0025[f]
Lead	0.01	0.0015	0.00025[f]
Magnesium	-	237	36.25
Manganese	<0.05[d]	**0.2**	0.024
Mercury	0.001	0.000025[f]	0.00003[f]
Molybdenum	-	0.025	0.0008
Nickel	-	0.04	0.0035
Selenium	0.01	**0.012**	0.0018
Silver	-	0.00005[f]	0.00001[f]
Thallium	-	0.0005[f]	0.0001[f]
Tin	-	0.0015[f]	0.00025[f]
Titanium	-	0.005[f]	0.005[f]
Uranium	0.02	0.006	0.003
Vanadium	-	0.015[f]	0.015[f]
Zinc	5.0[d]	0.015[f]	0.0025[f]
Asbestos (millions/L)			
Chrysotile (>10μm)	-	15.0	0.54[f]
Chrysotile (Total)	-	152.5	4.65

Notes:

Bold values indicate that measured water concentration is greater than the CCME guideline.

Dash (-) indicates that guideline is not available.

a - CCME Guidelines are for drinking water quality.

b - 95th percentile of measured water data summarized from UMA (2003) sampling program for total metals. Asbestos results are maximum concentrations from Appendix C-4, Royal Roads University (1999).

c - Average concentrations of the two reference samples from UMA (2003) sampling program for total metals. Asbestos results are average of three reference samples from Appendix C-4, Royal Roads University (1999.)

d - Guidelines for chloride, sulphate, copper, iron, manganese, sodium and zinc are aesthetic objectives.

e - Not a health based guideline, derived for operational guidance. The value in parenthesis is recommended for conventional treatment plants and 0.2 mg/L is recommended for other types of treatment plants.

f - all measured values were less than method detection limit (MDL), assumed to be ½ the MDL.

Contaminants with no CCME guideline as well as contaminants with sampled concentrations below the MDL are not considered further in the assessment. Beryllium, silver, thallium, tin, titanium and vanadium are therefore dropped from the assessment. As shown in Table 3.1, the measured concentrations of antimony, arsenic, barium, boron, cadmium, chromium, copper, lead, mercury, uranium and zinc are below CCME guidelines and are not assessed further. The measured concentrations of aluminum, iron, manganese and selenium exceed the CCME guideline. The iron concentrations exceed the CCME guideline, however, human toxicity data is not available for this contaminant and therefore, it cannot be assessed and is dropped from further assessment.

There is no CCME guideline for asbestos, cobalt, lithium, magnesium, molybdenum, nickel and asbestos. When compared to the baseline concentrations, all are higher than the corresponding baseline levels. However, human toxicity data is not available for lithium and magnesium and therefore, these contaminants cannot be assessed and are dropped from further assessment.

Therefore, the COPC identified from the water quality screening analysis are; aluminum, asbestos, cobalt, manganese, molybdenum, nickel and selenium.

Soil Quality

Surface tailings samples and waste rock samples were collected from several locations around the site as part of the field investigation program conducted in September 1998 (Royal Roads University 1999). Samples were also taken by SENES in September 2003 from the mill site, waste rock area at porcupine pit, tailings area, and crusher building. Only the samples collected from the tailings piles in 1998 were considered in this risk assessment. Eight of the nine tailings samples were analyzed for metals and five were analyzed for asbestos. Four baseline soil samples were also collected and all of them were analyzed for metals with two of them also analyzed for asbestos. One sample collected from the south side of concrete foundation on the southern edge of the Mill site near three standpipes was analyzed for PCBs as Aroclors. The sample was obtained from the base of the middle standpipe that contained an oily residue to ascertain if any PCB containing fluids had been spilled in the area. The concentration of PCBs in this sample was below the 0.5 mg/kg detection limit and are not considered further. Table 3.2 summarizes the concentrations of metals and asbestos in the tailings samples. Baseline soil concentrations from upstream of the site are also summarized in Table 3.2.

Since there are less than ten samples, the concentrations listed in Table 3.2 are maximum concentrations and are compared to CCME Guidelines for residential/parkland soil quality (CCME 2002).

TABLE 3.2
SUMMARY OF SOIL QUALITY DATA

Contaminant	CCME Soil Quality Guidelines [a] (Human Health) (mgkg)	Measured Maximum Tailings Concentration[b] (mg/kg)	Baseline Soil Concentration[c] (mg/kg)
Total Metals			
Antimony	20*	**50**[e]	42.5[e]
Arsenic	12	**321**	52.3
Barium	500*	**981**	1100
Beryllium	4*	1.5[e]	1.275
Cadmium	14	2	0.725
Chromium	220	**1650**	1149.5
Cobalt	50*	**111**	58.8
Copper	1100	30	27
Lead	140	**150**[e]	100[e]
Mercury	6.6	0.444	0.087
Molybdenum	10*	10[e]	8.25
Nickel	50*	**2300**	1139
Selenium	28	3.5	2.59
Silver	20*	5[e]	4.25[e]
Tin	50*	25[e]	17.5[e]
Vanadium	130*	34	36.75
Zinc	200*	133	69.5
Asbestos (%)			
Chrysotile[e]	-	40	2
Chrysotile[f]	-	60-80	2

Notes:

Bold values indicate that measured soil concentration is greater than the CCME guideline, or if there is no CCME guideline, measured soil concentration is greater than the baseline.

Dash (-) indicates that guideline is not available.

a - From CCME (2002) human health component for residential/parkland soil quality, except as noted (*) where the generic soil quality guideline is used in the absence of the human health component.

b - Measured soil data in tailings summarized from Table 4-6, Royal Roads University (1999): maximum concentrations reported (<10 samples).

c - Average concentrations of the four baseline samples obtained upstream from the site from Table 4-4, Royal Roads University (1999).

d - All measured values were less than method detection limit (MDL), assumed to be ½ the MDL.

e - Royal Roads University (1998).

f - SENES (2003).

From the table, it can be seen that antimony, arsenic, barium, chromium, cobalt, lead and nickel all exceed the CCME guidelines, and therefore are considered to be COPC. The average baseline concentrations of these identified COPC (except lead) also exceed the CCME guidelines, indicating elevated concentrations in the area that may not be related to the mine operation. There are no CCME guidelines for asbestos; since the asbestos concentrations exceed the baseline soil concentration, thus asbestos becomes a COPC.

The COPC determined for water and soil data assessments are then combined to form a list of designated COPC to use in the assessment. These are provided in Table 3.3.

TABLE 3.3
COPC SELECTED FOR THE ASSESSMENT

Aluminum
Antimony
Arsenic
Asbestos
Barium
Chromium
Cobalt
Lead
Manganese
Molybdenum
Nickel

Sediment Quality

Sediment samples were collected from shallow locations close to the shoreline of Hudgeon Lake (3 samples), Clinton Creek (6 samples), Wolverine Creek (3 samples) and baseline (3 samples). However, only the three samples collected from Wolverine Creek were analyzed for metals.

In the absence of sediment data from Hudgeon Lake and Clinton Creek, the Wolverine Creek sediment data were assumed to be representative of the site and are used in the SLRA. The measured antimony and lead concentrations in sediment are both below the MDL. Therefore, water-to-sediment distribution coefficients were used to estimate sediment concentrations for these two contaminants as described in Appendix A. Similarly, for aluminum and manganese, where no measurements were available, the sediment concentrations were estimated.

TABLE 3.4
MEASURED CONTAMINANT LEVELS OF SEDIMENT

COPC	Measured Sediment Concentration[a] (mg/kg)
Aluminum	-
Antimony	50[b]
Arsenic	11
Barium	223
Chromium	1670
Cobalt	89
Lead	150[b]
Manganese	-
Molybdenum	10
Nickel	1920

Notes: No sediment quality data are available for asbestos.
Bold values indicate values used in further assessment.
Dash (-) indicates no measurement.
a - Maximum sediment concentration from samples collected from Wolverine Creek, Table 4-15, Royal Roads University (1999).
b - All measured water concentrations were less than method detection limit (MDL), estimated using ½ the MDL.

Air Quality

Two sets of air quality data relating to asbestos fibre counts in air (area samples and personal air samples) were obtained from the Clinton Creek Mine. The first set of concentrations was obtained by UMA during September 2002 and August 2003, and the second set was obtained by SENES during September 2003. Table 3.5 shows the summary of asbestos counts in air samples for these two sampling events.

Phase Contrast Microscopy (PCM) has generally been the technique used in the calculation of exposure and risk estimates. Toxicity values relating asbestos exposure to risk have been fitted to data from epidemiological studies of occupational exposures and extrapolated to estimate risk at low levels. The data are often expressed in terms of concentration of fibres in air as measured by PCM. Transmission Electron Microscopy (TEM) can now detect smaller and thinner fibres than PCM, as well as TEM can also distinguish between asbestos and non-asbestos fibres. While TEM is the preferred method of measuring air concentrations, TEM measurements cannot be used directly in the equations related to risk exposure because the original risk data were generated from the older PCM methodology. Chesson *et.al*. (1990) have described a modeling approach for obtaining meaningful conversion factors that allows TEM measurements to be compared to PCM-based risk concentrations.

TABLE 3.5
SUMMARY OF RESULTS OF PCM AND TEM AIR SAMPLING

Date Of Sampling	Type Of Sample	Sample Description	Total Airborne Fibre Concentration (f/cc)[a]
September 2002	PCM[b]	Area sample collected in vicinity of creek channel repair work east of Hudgeon Lake	0.0075 0.0054 0.0113 0.0102 0.0109
12 August 2003	PCM	Area sample collected at bulldozer working at creek channel repair area, east of Hudgeon Lake	0.03
20 August 2003	PCM	Personal sample collected during reconnaissance of mill site	0.22 0.01
21 August 2003	PCM	Personal sample collected during survey of tailings pile	0.02
21 August 2003	PCM	Personal sample collected during reconnaissance of open pits	0.10
21 August 2003	PCM	Personal sample collected during reconnaissance of open pits	0.01
September 2003	TEM[c]	Area sample collected in tailings area	0.0088
September 2003	TEM	Personal Sample	0.043
September 2003	PCM	Personal Sample	0.019

Note:

a - f/cc – fibre counts per cubic cm.

b – Phase Contrast Microscopy (PCM).

c – Transmission Electron Microscopy (TEM).

Ground conditions were generally damp or snow covered across the site at the time the above samples were taken. Therefore, it is likely that when conditions are drier airborne asbestos fibre levels would be higher than those measured. In addition to the area samples, personal sample concentrations are also available.

The California Air Resource Board has developed a technique to estimate the airborne asbestos concentrations (TEM) based on the disturbance of the asbestos fibres on the surface (CARB 1992). Additionally, the Pennsylvania Department of Environmental Protection has also used a similar methodology to estimate a transfer factor from the surface to determine airborne asbestos concentrations for various scenarios (Pen. DEP 2000). Using this methodology, for moderate activity such as driving a car on-site and assuming a maximum surface concentration of 80%

asbestos, an airborne asbestos concentration of 0.25 f/cc (TEM) would be obtained for fibres longer than 5 micrometres at the vicinity of the activity.

Using the data presented on Table 3.5, the ratio of TEM to PCM measurements equals approximately 2. Using this conversion factor, a PCM concentration of 0.13 f/cc (0.25/2 f/cc) would be obtained for moderate activity, such as driving a car on-site based on a maximum surface concentration of 80% asbestos. This value is less than the maximum measured PCM concentration of 0.22 f/cc from the personal samplers. For area samples, the maximum PCM concentration is 0.01 f/cc, which may be considered to be representative of the asbestos concentration in air on undisturbed areas. Table 3.6 summarizes the airborne asbestos concentrations used in the assessment.

TABLE 3.6
SUMMARY OF AIRBORNE ASBESTOS CONCENTRATIONS

Condition On-Site	Asbestos Concentration f/cc
Disturbed	0.2
Undisturbed	0.01

Vegetation

Vegetation samples were collected as part of the 1998 field investigation program; however, they were archived for future contaminant analysis (Royal Roads University 1999). Therefore, contaminant concentrations in terrestrial vegetation were not available and soil-to-plant transfer factors were used to determine contaminant concentration in plants as described in Appendix A.

4.0 RECEPTOR CHARACTERIZATION

This section of the report discusses the characteristics of the receptor selected as well as the exposure pathways considered in this assessment of exposure to chemical hazards.

4.1 EXPOSURE SCENARIO AND RECEPTOR SELECTION

The scenario considered in this assessment involves exposure at the site in its current state since there is no active pumping of water at the site.

There are a few local residents around the Clinton Creek Mine site; a caretaker living at the junction of Fortymile River and Yukon River about 11 km from the site, a Placer miner living approximately 18 km west of the site, and a German tourist owning a property at Hudgeon Lake and planning to build a permanent home there. Occasional visitors and campers also visit the site and obtain fish, game and drinking water from the site.

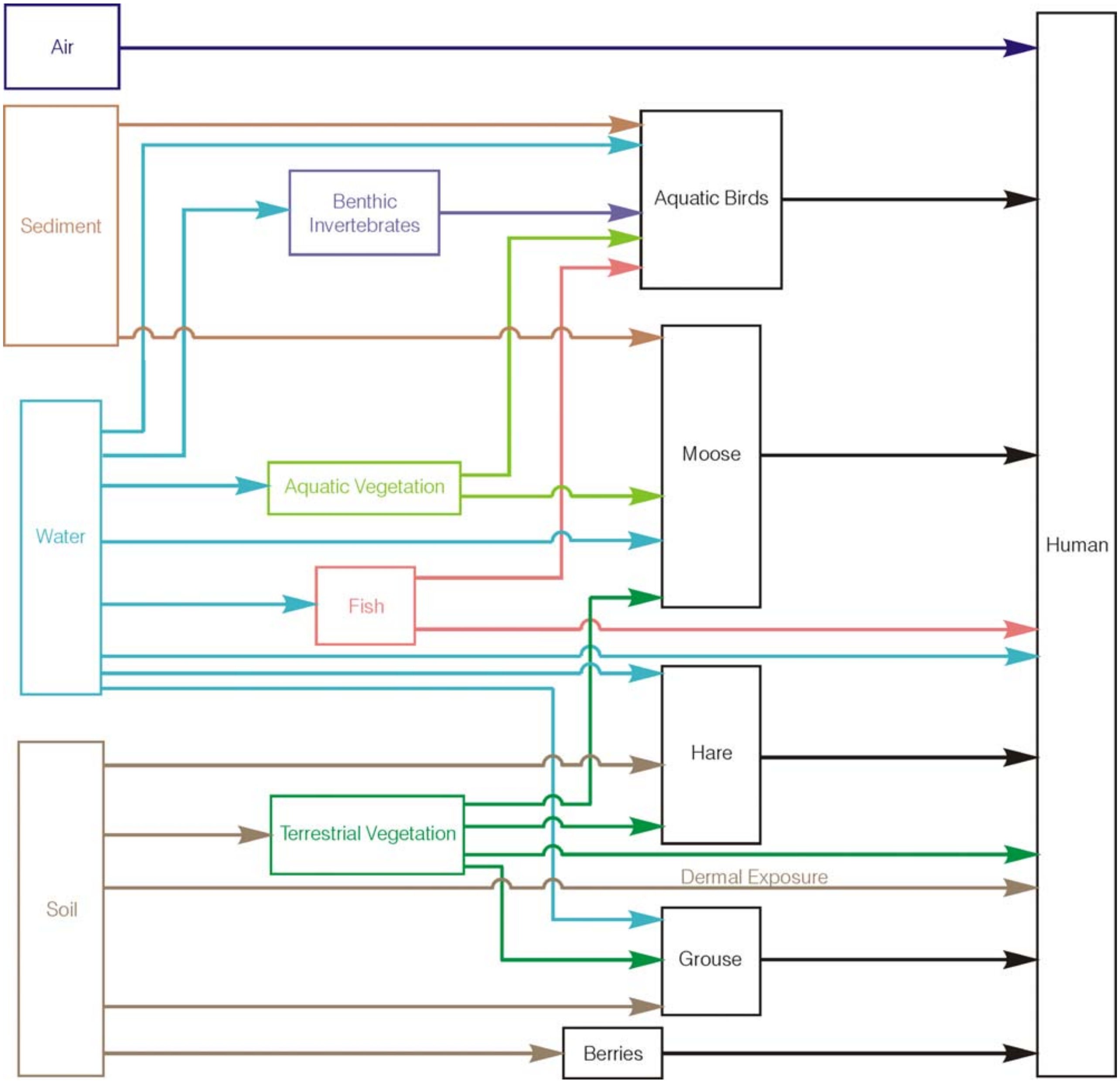
The human receptors considered in the assessment are defined as an adult and a child (age 5-11 years) who live in or near the Clinton Creek Mine site, and who are assumed to be exposed to contaminant intakes from drinking water and eating fish and wild game obtained from the area. Infants and toddlers are not considered because it is unlikely that a substantial part of their diet comprises of fish and wild game. Soil ingestion and dermal contact with exposed soil are only limited to the summer months, i.e. three months of the year.

4.2 EXPOSURE PATHWAYS

Figure 4.1 provides the conceptual model for the assessment. The pathways of exposure include:

- inhalation of air;
- consumption of berries, fish, moose, hare, aquatic and terrestrial birds;
- ingestion of water;
- inadvertent ingestion of soil; and
- dermal contact with soil.

FIGURE 4.1
EXPOSURE PATHWAYS FOR HUMAN RECEPTORS



4.3 RECEPTOR CHARACTERISTICS

Water intake, breathing rate, soil ingestion rate, body weight and other exposure properties for the human receptors were obtained from the *"Compendium of Canadian Human Exposure Factors for Risk Assessment"* (Richardson 1997) and are summarized in Table 4.1, along with other receptor characteristics used for the exposure calculations. Dietary data from a regional survey of First Nations people in the Northwest Territories were used to define the dietary characteristics for these individuals, as survey data for the Yukon were not available for this assessment. Data from two communities in the Northwest Territories (the Gwich'in and Sahtu communities) near the Yukon border were used for the dietary characteristics in the Clinton Creek area. The intakes of these two communities were averaged to determine the characteristics in Table 4.1. Using data from a Canada-wide survey carried out by Health Canada (Richardson 1997), a ratio of 74% was derived to account for the difference in the intakes between a child and adult. This ratio was applied to intakes from various dietary components, except berries.

TABLE 4.1
HUMAN RECEPTOR CHARACTERISTICS

Human Characteristics	Adult	Child	Reference
Fraction of year at site	1.0	1.0	Assumed 12 months/year
Fraction of year exposed to soil	0.25	0.25	Assumed 3 months/year
Breathing rate (m^3/d)	15.8	14.5	Richardson, 1997
Soil ingestion rate (g/d)	0.02	0.08[a]	Richardson, 1997
Water intake (L/d)	1.5	0.8	Richardson, 1997
Body weight (kg)	70.7	32.9	Richardson, 1997
Skin surface area (cm^2)	9110	5140	Health Canada, 1996
Exposed fraction of skin (-)	0.26	0.26	Assumed for short sleeves
Soil loading to exposed skin (g/cm^2) – hands - surfaces other than hands	$1x10^{-3}$ $1x10^{-4}$	$1x10^{-3}$ $1x10^{-4}$	Kissel *et al.*, 1996, 1998, for hands
Moose ingestion rate (g/d)	31	23	Receveur *et al,* 1996
Small mammal ingestion rate (g/d) (hare and grouse)	5	4	Receveur *et al,* 1996
Fish ingestion rate (g/d)	93	69	Receveur *et al*, 1996
Game bird ingestion rate (g/d)	2	1.5	Receveur *et al*, 1996
Berries ingestion rate (g/d)	1.8	8.5	CanNorth, 2000

Note:

[a] - It is assumed that a child (age 5-11 years) has the same ingestion rate as a toddler in order to overestimate exposure.

The soil loading values provided are for construction workers. The use of this number results in overestimate of exposure.

For the purpose of the assessment, it was assumed that while at the Clinton Creek Mine site, the human receptors would obtain all their drinking water, berries and wild game from local sources (i.e., relying on the site for their food and water).

4.4 EXPOSURE PATHWAYS – PHYSICAL HAZARDS

The Clinton Creek site is accessible by road. The physical hazard assessment is based on the fact that visitors to the area have unrestricted access to the site. The physical hazard assessment considers someone falling into the pit or falling off the waste rock areas or entering buildings on-site.

5.0 EXPOSURE ASSESSMENT

The exposure assessment phase of the SLRA entailed the quantification of exposure to potential chemical hazards for the selected receptors. Similarly, the likelihood of someone incurring physical harm was evaluated.

The pathways and assumptions applied in this assessment are described in this section. Appendix A documents the pathways calculations used in the assessment of contaminant intakes by the human receptors and the detailed results of the exposure assessment by pathway.

5.1 METAL BIOAVAILABILITY

Bioavailability of a chemical can be defined as the fraction of an administered dose that reaches the central (blood) compartment, whether through the gastrointestinal tract, skin or lungs (NEPI 2000). This type of bioavailability is known as “absolute bioavailability”.

In risk assessments, oral exposures are generally described in terms of an external dose or intake, as opposed to an absorbed dose or uptake. Intake occurs as an agent enters the body of a human or animal without passing an absorption barrier (e.g., through ingestion or inhalation), while uptake occurs as an agent passes across the absorption barrier (IPCS 2000). Not all materials (e.g., metals, nutrients) that enter the body as intake are absorbed into the body as uptake. Many are passed through the body and expelled without effect.

When calculating the intake via the oral route of exposure, it is customary to take into account the food, water and soil pathways. The default bioavailability value used in the screening level calculations is 100%.

5.2 CALCULATED INTAKES

The total intake of each contaminant by the human receptors were calculated using the equations provided in Appendix A. Measured data were used where possible. If no data were available for a given media (i.e. sediment or fish), generic distribution coefficients and transfer factors from the literature were used to calculate the concentrations in these media as outlined in Appendix A.

As shown in Table 3.6, two airborne asbestos concentrations were considered for this assessment. In the determination of asbestos exposure, it was assumed that the receptors would spend 1 hour a day on-site and would disturb the asbestos on the ground while travelling across the site. Thus, the exposure scenario considered for the on-site receptors was 23 hours a day of exposure to undisturbed concentrations and 1 hour a day of exposure to disturbed concentrations.

Tables 5.1 and 5.2 show the calculated intake from inhalation of air, ingestion of food, soil and water and dermal contact for the adult and child receptors respectively.

TABLE 5.1
CALCULATED TOTAL INTAKES BY PATHWAY - ADULT RECEPTOR

COPC	Ingestion Intake[a] (mg/(kg d))				Inhalation Intake[a] (mg/(kg d))	Dermal Exposure[a] (mg/(kg d))
	Water	Soil	Food	Total		
Aluminum	3.59×10^{-3}	4.76×10^{-6}	1.11×10^{-1}	1.15×10^{-1}	3.58×10^{-5}	5.63×10^{-5}
Antimony	6.36×10^{-5}	3.54×10^{-6}	5.05×10^{-4}	5.72×10^{-4}	-	4.19×10^{-5}
Arsenic	3.39×10^{-4}	2.27×10^{-5}	2.11×10^{-2}	2.15×10^{-2}	2.23×10^{-7}	8.60×10^{-5}
Barium	1.06×10^{-3}	6.94×10^{-5}	1.41×10^{-2}	1.52×10^{-2}	-	8.22×10^{-4}
Chromium	5.30×10^{-5}	1.17×10^{-4}	1.07×10^{-3}	1.24×10^{-3}	2.12×10^{-7}	1.24×10^{-3}
Cobalt	2.12×10^{-5}	7.85×10^{-6}	7.44×10^{-4}	7.74×10^{-4}	2.23×10^{-8}	9.30×10^{-5}
Lead	3.18×10^{-5}	1.06×10^{-5}	9.43×10^{-4}	9.85×10^{-4}	4.47×10^{-7}	7.54×10^{-6}
Manganese	4.18×10^{-3}	-	1.04×10^{-1}	1.08×10^{-1}	-	-
Molybdenum	5.30×10^{-4}	2.97×10^{-8}	3.58×10^{-4}	8.88×10^{-4}	2.23×10^{-7}	3.52×10^{-7}
Nickel	8.49×10^{-4}	1.63×10^{-4}	2.97×10^{-2}	3.07×10^{-2}	1.34×10^{-7}	6.74×10^{-3}
Asbestos[b]	-	-	-	-	4.40×10^{3}	-

Note: Dash (-) indicates no air/soil quality measurement.
a - Intake and exposures are reported as mg (COPC)/(kg (body weight) d).
b - Asbestos intake is reported in fibre/(kg (body weight d)).

As seen in Tables 5.1 and 5.2, the ingestion of wild game from the site represents the largest exposure pathway for the metals. For asbestos, the inhalation pathway is the only pathway considered.

TABLE 5.2
CALCULATED TOTAL INTAKES BY PATHWAY - CHILD RECEPTOR

COPC	Ingestion Intake[a] (mg/(kg d))				Inhalation Intake[a] (mg/(kg d))	Dermal Exposure[a] (mg/(kg d))
	Water	Soil	Food	Total		
Aluminum	4.11×10^{-3}	4.09×10^{-5}	1.77×10^{-1}	1.81×10^{-1}	7.05×10^{-5}	6.83×10^{-5}
Antimony	7.29×10^{-5}	3.04×10^{-5}	8.03×10^{-4}	9.06×10^{-4}	-	5.08×10^{-5}
Arsenic	2.89×10^{-4}	1.95×10^{-4}	3.36×10^{-2}	3.42×10^{-2}	4.41×10^{-7}	1.04×10^{-4}
Barium	1.22×10^{-3}	5.96×10^{-4}	2.24×10^{-2}	2.42×10^{-2}	-	9.96×10^{-4}
Chromium	6.08×10^{-5}	1.00×10^{-3}	1.70×10^{-3}	2.76×10^{-3}	4.19×10^{-7}	1.51×10^{-3}
Cobalt	2.43×10^{-5}	6.75×10^{-5}	1.18×10^{-3}	1.28×10^{-3}	4.41×10^{-8}	1.13×10^{-4}
Lead	3.65×10^{-5}	9.12×10^{-5}	1.50×10^{-3}	1.63×10^{-3}	8.81×10^{-7}	9.14×10^{-6}
Manganese	4.79×10^{-3}	-	1.65×10^{-1}	1.70×10^{-1}	-	-
Molybdenum	6.08×10^{-4}	2.56×10^{-7}	5.69×10^{-4}	1.18×10^{-3}	4.41×10^{-7}	4.27×10^{-7}
Nickel	9.73×10^{-4}	1.40×10^{-3}	4.72×10^{-2}	4.96×10^{-2}	2.64×10^{-7}	8.17×10^{-3}
Asbestos[b]	-	-	-	-	8.69×10^{3}	-

Notes: Dash (-) indicates no air/soil quality measurement.
a - Intake and exposures are reported as mg (COPC)/(kg (body weight) d).
b - Asbestos intake is in fibre/(kg (body weight d)).

5.3 PHYSICAL HAZARD EXPOSURE ASSESSMENT

The probability of accidents and loss of human life is normally estimated using existing statistical information for accidents involving injuries or fatalities. At present, such information is not available for abandoned mine sites in Canada. However, such information is available from the division of Abandoned Mine Lands (AML) and Mine Safety and Health Administration (MSHA), Bureau of Land Management (BLM), United States Department of the Interior.

Since 1999, more than 200 accidents resulting in fatality or injury have been reported at abandoned mine sites in the U.S. Approximately 50% of these accidents were fatal. The statistics reported by MSHA indicate that there are approximately 40 abandoned mine related accidents resulting in injuries or fatalities per year in the United States. The majority of the accidents were related to drowning in flooded open pits followed by falling into mine shafts and accidents associated with unstable rocks and structures. Table 5.3 summarizes the statistics for the fatal accidents at abandoned mine sites since 1999.

TABLE 5.3
MSHA STATISTICS OF THE FATAL ACCIDENTS AT ABANDONED MINE SITES

Hazard	**Number of Fatal Accidents**						**Percent of Total Fatalities**
	2003	**2002**	**2001**	**2000**	**1999**	**Average**	
Fall in open shaft	4	5	2	2	2	3	15
Death due to unstable rock and decayed support structures	1	2	2	3	1	1.8	9
Death due to toxic gases and lack of oxygen	1	2	0	0	1	0.8	4
Explosion and exposure to toxic chemicals	1	0	0	0	0	0.2	1
Death due to becoming lost and disoriented	1	0	0	0	0	0.2	1
Death due to fall from high walls	4	2	2	1	1	2	10
Drowning in flooded open pit*	14	17	11	7	8	11.4	59
TOTAL **(in the absence of drowning in flooded open pit)****	12	11	6	6	5	8**	41

Notes: * - deaths related to voluntary swimming in pits.
** - deaths due to drowning not included in average fatalities per year.

According to MSHA statistics, there are approximately 130,000 abandoned mine sites in the United States. Information on the number of people that visit mine sites each year and the frequency of such visits is not available. To estimate the probability of fatal accidents, it was assumed that one out of 100 Americans has access to mine sites. Based on a population of 280,000,000 this assumption implies that 2,800,000 people visit mine sites each year. Alternatively, the assumption can be interpreted to imply that there are 2,800,000 mine site visits each year with some individuals visiting mine sites regularly in pursuit of recreational activities. Given the latter context, the assumption is believed to be a reasonable approximation.

Considering the above information and assumptions, the rate of a fatal accident for the population that accesses the mine site can be calculated as follows:

$$\textit{Fatality Rate} = \frac{8}{280{,}000{,}000 \times \dfrac{1}{100}} = 2.9 \times 10^{-6} \qquad (5.1)$$

where:

$2.9\text{x}10^{-6}$ = average annual fatality rate
8 = average number of fatal accidents per year excluding drownings (see Table 5.3)
280,000,000 = total population in U.S.
1/100 = fraction of total population accessing mine sites

The above calculated number ($2.9\text{x}10^{-6}$) is an average estimate for an average member of the public for a typical mine site. In applying this number, site-specific information should be factored in to calculate a rate for a specific mine. The most important factors that need to be considered are the accessibility of the mine site to the public, proximity to population centers, and the features at the mine site that pose physical hazards to visitors.

Each mine site can be ranked for accessibility to the public based on proximity to population centers and the number of people living in those population centers. Assuming that there is a linear relationship between risk and accessibility, a ranking scheme such as the one presented in Table 5.4 can be established.

TABLE 5.4
PROPOSED ACCESSIBILITY FACTOR BASED ON THE ACCESSIBILITY AND PROXIMITY TO POPULATION CENTRES

Category	**Accessibility Factor**
Readily accessible to a large population base (> 10,000 people)	10
Readily accessible to a small population base	1
Limited access by a small population base within 100 km	0.1
Very remote to closest community (> 100 km)	0.01

Readily accessible sites are those that individuals can drive to and are within a reasonable travel distance from the population centre. Limited accessibility infers that a site is not accessible by road but may be accessed by plane, skidoo, boat or all terrain vehicle.

Similarly, each mine site can be ranked according to the features at the site that pose physical hazards to visitors. According to the available fatality statistics, the most important features that should be considered are:

- open mine shafts;
- steep rock faces with loose rock (e.g. waste rock piles and pit faces);
- high pit walls;
- unstable surface structures

Fatalities due to drowning have not been included in the analysis as it is very unlikely that people would swim in flooded pits in northern Canada as the water bodies are far too cold for this type of use.

Table 5.5 provides the proposed scheme for assessing hazards associated with each of the features described above. The scheme normalizes the hazard factor to between 0 and 1.

TABLE 5.5
PROPOSED HAZARD FACTOR BASED ON THE PRESENCE OF HAZARDOUS SITE FEATURES

Hazardous Features	Risk Factor
Unsealed mine openings	15/40
Steep loose rock piles	9/40
High pit walls	10/40
Unstable surface structures	6/40
Hazard Factor	sum

To account for differences in the scale of mining operations, a scaling factor is proposed to account for the expectation instinct that there must be greater risks associated with former large scale mining operations than with small scale mine sites. Table 5.6 summarizes the basis proposed to account for differences in the scale of mining operations.

TABLE 5.6
PROPOSED SCALING FACTOR BASED ON THE SIZE OF MINING OPERATIONS

Volume of Tailings and Waste Rock	Scaling Factor
> 10 million tonnes	3
1 to 10 million tonnes	2
< 1 million tonnes	1

Therefore, the general equation to estimate the site-specific fatality rate is:

$$Fatality\ Rate_{site} = Fatality\ Rate \times AF \times HF \times SF \tag{5.2}$$

where:

Fatality $\text{Rate}_{\text{site}}$ = site-specific fatality rate
Fatality Rate = calculated average annual fatality rate ($2.9\text{x}10^{-6}$)
AF = accessibility factor (Table 5.4)
HF = hazard factor (Table 5.5)
SF = scaling factor (Table 5.6)

For the Clinton Creek site, the following factors were identified:

- Accessibilty Factor = 1
- Hazard Factor = 25/40 (steeprock piles + high pit walls+ unstable surface structures)
- Scaling Factor = 3

Using these factors and an average annual fatality rate of $2.9 \text{ x } 10^{-6}$, the annual fatality rate was estimated to equal $5.4 \text{ x } 10^{-6}$.

6.0 DOSE RESPONSE ASSESSMENT

The dose response assessment phase of a human health risk assessment involves identification of contaminant concentrations or doses which have been shown to have adverse effects on the receptors of concern. The exposure concentrations or doses are generally determined from controlled laboratory tests or from epidemiology studies and are used to establish toxicity benchmarks which are protective of the receptors

6.1 TOXICITY TO HUMANS

The dose response assessment involves the identification of the potentially toxic effects of contaminants, and the determination of the appropriate toxicity benchmarks for the various contaminants. The toxicity benchmark is defined as the amount of contaminant exposure that can occur without any adverse health effects (for threshold or non-cancer causing contaminants), or that is associated with an acceptable level of risk (for non-threshold or cancer causing contaminants).

For this assessment, toxicity benchmarks were obtained from reputable regulatory agencies such as Health Canada and the U.S. EPA. Data were obtained on:

- Slope Factor (SF) - (for carcinogens) comprises a plausible upper bound estimate of the probability of a response per unit intake of a contaminant over a lifetime. It is used to evaluate the probability of a cancer developing due to a lifetime of exposure. For carcinogens, no threshold is assumed to exist (i.e., every dose presents some risk); or

- Tolerable Daily Intake (TDI) or Reference Dose (RfD) - (for non-carcinogens) comprises an estimate of the daily exposure level for a contaminant for the entire population, including sensitive people that is not anticipated to present an appreciable risk of an adverse effect.

Toxicity benchmarks from Health Canada were selected first; however, if more restrictive benchmarks were available from another regulatory agency such as the U.S. EPA, those values were selected instead of the Health Canada values to ensure that the risks calculated in the assessment were over-estimated. Additionally, if a contaminant had properties of both a carcinogen and a non-carcinogen by a specific pathway (i.e. oral exposure), then the carcinogenic effects were only assessed.

Table 6.1 provides a summary of the toxicity benchmarks for all the contaminants of concern for the northern sites. Contaminants that are shaded and bolded are the ones that pertain to this particular site.

TABLE 6.1
TOXICITY BENCHMARKS

Contaminant	Dermal	Oral Toxicity Benchmarks[b]				Inhalation Toxicity Benchmarks			
	RAF [a]	SFo		(TDI/RfDo)		SFi		RfDi	
	(-)	$(mg/(kg-d))^{-1}$		(mg/(kg-d))		$(mg/(kg-d))^{-1}$		(mg/(kg-d))	
Aluminum	**0.1**	**na**		**1**	**N**	**na**		**na**	
Antimony	**0.1**	**na**		**0.0004**	**I**	**na**		**na**	
Arsenic	**0.032**	**2.8**	**HC**	**na**		**28**	**HC**	**na**	
Asbestos	**na**	**na**	**na**	**na**		**$1.03x10^{-6}$**	**EPA**	**na**	
Barium	**0.1**	**na**		**0.016**	**HC**	**na**		**0.00014**	**H**
Benzene	0.08	0.31	HC	na		0.027	I		
Benzo(a)pyrene	0.2	7.3	I	na		0.22	HC	na	
Beryllium	0.03	na		0.002	I	8.4	H	na	
Boron	0.1	na		0.0175	HC	na		0.0057	H
Cadmium	0.14	na		0.0008	HC	42.9	HC	na	
Chromium	**0.09**	**na**		**0.001**	**HC**	**47.6**	**HC**	**na**	
Cobalt	**0.1**	**na**		**0.02**	**N**	**9.8**	**N**	**na**	
Copper	0.1	na		0.03	HC	na		na	
Cyanide	0.3	na		0.02	HC	na		0.0009	HC
Lead	**0.006**	**na**		**0.0019**	**I**	**na**		**na**	
Manganese	**0.1**	**na**		**0.14**	**I**	**na**		**na**	
Mercury	0.05	na		0.0003	H	na		na	
Molybdenum	**0.1**	**na**		**0.005**	**I**	**na**		**na**	
Nickel	**0.35**	**na**		**0.02**	**I**	**3.13**	**HC**	**na**	
Nitrate	0.1	na		1.6	I	na		na	
Polychlorinated biphenyls (PCBs)	0.1	2.0	I	0.001	HC	2.0	I	na	
Selenium	0.002	na		0.005	I	na		na	
Silver	0.25	na		0.005	I	na		na	
Strontium	0.1	na		0.6	I	na		na	
Thiocyanate	0.1	na		0.05	N	na		na	
Tin	0.1	na		0.6	H	na		na	
Uranium	0.1	na		0.0002	N	na		na	
Vanadium	0.1	na		0.007	H	na		na	
Xylene	0.12	na		0.2	I	na		0.03	I
Zinc	0.02	na		0.3	I	na		na	

TABLE 6.1 (Cont'd)
TOXICITY BENCHMARKS

Contaminant	**Dermal**	**Oral Toxicity Benchmarks**[b]				**Inhalation Toxicity Benchmarks**			
	RAF [a]	**SFo**		**(TDI/RfDo)**		**SFi**		**RfDi**	
	(-)	**$(mg/(kg\text{-}d))^{-1}$**		**(mg/(kg-d))**		**$(mg/(kg\text{-}d))^{-1}$**		**(mg/(kg-d))**	
TPH F1 –Aliphatic	0.1	na		3.10	TP	na		3.30	TP
TPH F1 – Aromatic	0.1	na		0.04	TP	na		0.057	TP
TPH F2 –Aliphatic	0.1	na		0.1	TP	na		0.290	TP
TPH F2 – Aromatic	0.1	na		0.04	TP	na		0.057	TP
TPH F3 –Aliphatic	0.1	na		32	TP	na		na	
TPH F3 – Aromatic	0.1	na		0.03	TP	na		na	

Notes: a - Dermal Relative Absorption Factors (RAF) from MOE (1996) unless noted otherwise. Dermal RAF set to default value of 0.1 (U.S. EPA 1992) where no data available.

b - In the absence of toxicity benchmarks for dermal exposure, the oral toxicity benchmarks are used

SF - Slope Factor for carcinogenic effects.

RfD - Reference Dose for threshold acting chemical (i.e., non-carcinogenic effects).

na	Not applicable
I	U.S. EPA IRIS (2002)
H	U.S. EPA HEAST (1997)
HC	Health Canada (2003) – See Appendix B
N	U.S. EPA NCEA (2002)
EPA	U.S. EPA (1986)
TP	CCME (2000)

7.0 RISK CHARACTERIZATION

Risk characterization involves the integration of the information from the exposure assessment and the toxicity assessment.

For carcinogenic contaminants, a risk is calculated by multiplying the estimated dose (in mg/(kg d)) by the appropriate slope factor (in per mg/(kg d)). This is shown in equation 7.1. The estimate corresponds to an incremental risk of an individual developing cancer over a lifetime as a result of exposure.

Risk is defined as follows:

$$Risk = \left(D_i \times SF_i\right) + \left(D_o \times SF_o\right) + \left(D_d \times SF_d\right) \tag{7.1}$$

Where:

D_i = Dose due to inhalation exposure (mg/(kg d))
D_o = Dose due to oral (ingestion) exposure (mg/(kg d))
D_d = Dose due to dermal exposure (mg/(kg d))
SF_i = Slope Factor for inhalation exposure $(mg/(kg\ d))^{-1}$
SF_o = Slope Factor for oral exposure $(mg/(kg\ d))^{-1}$
SF_d = Slope Factor for dermal exposure $(mg/(kg\ d))^{-1}$ (assumed equal to SF_o)

The doses for the different pathways of exposure are presented in Section 5 and the slope factors used in this assessment are presented in Section 6. The calculated risk is then compared to acceptable benchmarks. In this assessment, a risk level of 1×10^{-5} was used for the SLRA. Risk levels for child receptors are generally not calculated since the exposure of a child is not sufficient for carcinogenic effects to be observed. In this case a composite receptor is assessed. This composite receptor encompasses the exposure of a child to the site for 10 years and the exposure of this child as an adult for an additional 60 years. In simple terms, the SLRA considers that someone would visit the site throughout their lifetime from child to an adult.

For many non-carcinogenic effects, protective biological mechanisms must be overcome before an adverse effect is manifested from exposure to the contaminant. This is known as a "threshold" concept. A reference dose (RfD) is the value most often used in the evaluation of non-carcinogenic effects. Reference doses are discussed in Section 6.

For non-carcinogenic contaminants, the hazard quotient (HQ) is defined as follows:

$$HQ = \frac{D_i}{RfD_i} + \frac{D_o}{RfD_o} + \frac{D_d}{RfD_d} \tag{7.2}$$

Where:

D_i = Dose due to inhalation exposure (mg/(kg d))
D_o = Dose due to oral (ingestion) exposure (mg/(kg d))
D_d = Dose due to dermal exposure (mg/(kg d))
RfD_i = Reference Dose for inhalation exposure (mg/(kg d))
RfD_o = Reference Dose for oral exposure (mg/(kg d))
RfD_d = Reference Dose for dermal exposure (mg/(kg d)) (assumed equal to RfD_o)

In SLRAs, 20% of the dose or a hazard quotient of 0.2 is generally used to assess acceptable exposure from each individual pathway. In the SLRAs for mine and DEW Line sites, the following hazard quotient values are used:

- In applications where only a few pathways are considered in the assessment, a HQ value of 0.2 is used to identify acceptable exposure.
- Where multiple pathways are considered, such as inhalation, ingestion of water, soil and food from the site and dermal exposure, then a HQ value of 0.5 is used to assess acceptable exposures, given that the major dietary components are being included.

For the Clinton Creek site, a HQ value of 0.5 was used to assess acceptable exposures.

7.1 NON-CARCINOGENIC EFFECTS

Estimated exposures for the adult receptor were calculated using the human intakes presented in Section 5.2. These estimates were based on the 95th percentile of measured metal concentrations in water, and the maximum measured metal concentrations in soil. Estimated exposures were divided by the toxicity benchmarks (RfDs), presented in Section 6.1, to calculate the hazard quotients (HQ) shown in Table 7.1. HQ values in **bold** are those exceeding the value of 0.5 selected for this site.

Antimony, barium, chromium, lead, manganese, nickel and selenium all exceed the hazard quotient of 0.5. Consumption of fish is the dominant pathway of exposure. The sum of all HQs was determined to be 9.0 for adult receptor and 14.4 for child receptor.

TABLE 7.1
CALCULATED HAZARD QUOTIENT VALUES

Contaminant	**Hazard Quotient**	
	Adult	**Child**
Aluminum	0.1	0.2
Antimony	**1.5**	**2.4**
Barium	**1.0**	**1.6**
Chromium	**2.5**	**4.3**
Cobalt	0.04	0.07
Lead	**0.5**	**0.9**
Manganese	**0.8**	**1.2**
Molybdenum	0.2	0.2
Nickel	**1.9**	**2.9**
TOTAL SITE	**8.5**	**13.8**

7.2 CARCINOGENIC EFFECTS

Table 7.2 shows the risk levels calculated for the adult receptor for carcinogenic contaminants, namely asbestos, arsenic, chromium, cobalt and nickel. Risk levels higher than 1×10^{-5} are indicated in **bold.** There are no toxicity data to assess the potential risk from asbestos ingestion; however, based on the literature asbestos is only a concern form the inhalation pathway. Therefore, this pathway was evaluated.

TABLE 7.2
CALCULATED RISKS OF CARCINOGENIC EFFECTS

Contaminant	**Risk Level**	
	Adult	**Composite**
Arsenic	**2.6×10^{-2}**	**6.6×10^{-2}**
Asbestos	**4.5×10^{-3}**	**8.9×10^{-3}**
Chromium	4.3×10^{-6}	**1.2×10^{-5}**
Cobalt	9.4×10^{-8}	2.5×10^{-7}
Nickel	1.8×10^{-7}	4.8×10^{-7}
TOTAL SITE	**3.1×10^{-2}**	**7.5×10^{-2}**

As seen in Table 7.2, asbestos, arsenic (both adult and composite) and chromium (composite receptor only) risk levels are greater than 1×10^{-5}. Again, ingestion of fish is the dominant pathway for arsenic and inhalation is the major pathway for chromium. For arsenic exposure, the risk of incurring cancer is overstated as it was assumed in the SLRA that arsenic was present in a toxic form in all sources. In fact, a portion of the arsenic consumed will be in non-toxic forms, in particular the arsenic associated with fish. The total risk (sum of all risks) is 0.03 and 0.08 for adult and composite receptors respectively.

7.3 PHYSICAL RISKS

There are several features on the Clinton Creek Mine site that pose significant physical risks including steep waste rock dumps and tailings pile, high pit walls and unstable surface structures. These pose a risk to individuals who would go onto the site. The annual risk of fatality for the Clinton Creek site was evaluated in Section 5 to equal 5.4×10^{-6}.

The waste rock dumps and tailings pile are also prone to slumping. Failures in the past have resulted in blockage of natural water courses and the formation of pond/lakes behind the dams formed by the waste rock and tailings.

8.0 REFERENCES

California Air Resource Board (CARB) 1992. *Development of a Technique to Estimate Ambient Asbestos Downwind from Serpentine Covered Roadways. California Air Resource Board*, Research Division.

Canadian Council of Ministers of the Environment (CCME) 2002. *Canadian Environmental Quality Guidelines*.

Canadian Council of Ministers of the Environment (CCME) 2000. *Canada Wide Standards for Petroleum Hydrocarbons in Soil.*

Chesson, J., J.D. Rench, B.B. Schultz, and K.L. Milne. 1990. Interpretation of Airborne Asbestos Measurements. Risk Analysis, Volume 10, No. 3.

European Commission. 2002. Risk to Human Health from Chrysotile Asbestos and Organic Substitute. European Commission, Directorate General Health and Consumer Protection, Scientific Committee on Toxicity, Ecotoxicity, and the Environment, Brussels, Belgium.

Health Canada 2003. *Health Canada Toxicological Reference Values* (see Appendix B).

International Programme for Chemical Safety (IPCS) 2000. Short list definitions. Harmonization Project (Terminology). Exposure Assessment Planning Workgroup. (http://www.ipcsharmonize.org/).

Kissel J.C., J.H. Shirai, K.Y. Richter and R.A. Fenske 1998. *Investigation of Dermal Contact with Soil in Controlled Trails.* J. Soil Contam., 7(6) 737-752.

Kissel, J.C., K.Y. Richter and R.A. Fenske 1996. *Field Measurements of Dermal Soil Loading Attributable to Various Activities: Implications for Exposure Assessment.* Risk Anal., 16(1):115-125.

National Environmental Policy Institute (NEPI) 2000. *Assessing the Bioavailability of Metals in Soil for Use in Human Health Risk Assessments*. Bioavailability Policy Report Phase II: Metals Task Force Report. Summer 2000.

National Geographic Society 1999. *Altas of the World – 7th Edition*.

Ontario Ministry of the Environment (MOE). 1996. *Rationale for the Development and Application of Generic Soil, Groundwater and Sediment Criteria for Use at Contaminated Sites in Ontario*. May.

Pennsylvania Department of Environmental Protection 2000. *Report on Development of a media Specific Soil Standard for Asbestos*, Pen. DEP, Bureau of Land Recycling and Waste Management, Harrisburg, PA.

Receveur, O., M. Boulay, C. Mills, W. Carpenter and H.V. Kuhnlein 1996. *Variance in Food Use in Dene/Metis Communities.* Centre for Indigenous People's Nutrition and Environment.

Richardson, G.M. 1997. *Compendium of Canadian Human Exposure Factors for Risk Assessment.* O'Connor Associates Environmental Inc.

Roach, Patrick. 1998. *Abandoned Clinton Creek Asbestos Mine: A Water Contaminants Evaluation.* File No. 9590-2-6. Whitehorse, YT: Water Resources Division Northern Affairs Program. (As cited in Royal Roads University 1999.)

Royal Roads University – Applied Research Division (ARD) 1999. *An Environmental Review of the Clinton Creek Abandoned Asbestos Mine, Yukon, Canada*. Prepared for Indian and Northern Affairs Canada, Waste Management Program, Whitehorse, Yukon. March.

SENES Consultants Limited (SENES) 2003. *Air Sampling for Asbestos Fibres Clinton Creek Abandoned Mine*. Prepared for UMA Engineering Ltd. October

Stepanek, M. and H.F. McAlpine 1992. *Landslide Dams at Clinton Creek.* Proceedings of GeoHazards 1992. Vancouver, BC. (As cited in Royal Roads University 1999.)

UMA Engineering Ltd. 2003. Clinton Creek Mine Site Investigation.

UMA Engineering Ltd. 2000. *Abandoned Clinton Creek Asbestos Mine Condition Assessment Report*. Prepared for Indian and Northern Affairs Canada, April.

United States Environmental Protection Agency (U.S. EPA) IRIS. 2002 *Integrated Risk Information System – IRIS.* On-line database. http://www.epa.gov/iris.

United States Environmental Protection Agency (U.S. EPA) NCEA 2002. *National Center for Environmental Assessment – NCEA.*

United States Environmental Protection Agency (U.S. EPA) HEAST 1997. *Health Effects Assessment Summary Tables – HEAST.*

United States Environmental Protection Agency (U.S. EPA) 1992. *Dermal Exposure Assessment: Principles and Applications.* Interim Report. EPA/600/8-91/011B. January.

United States Environmental Protection Agency (U.S. EPA) 1986. *Airborne Asbestos Health Assessment Update*. U.S. Environmental Protection Agency. EPA 600/8-84-003F

FINAL

APPENDIX A

DETAILED EXPOSURE CALCULATIONS FOR THE HUMAN HEALTH RISK ASSESSMENT

LIST OF TABLES

APPENDIX A: DETAILED EXPOSURE CALCULATIONS FOR THE HUMAN HEALTH RISK ASSESSMENT

The exposure assessment for contaminants to humans considered the inhalation, dermal and ingestion pathways.

A.1 INHALATION PATHWAY

Inhalation intake by human receptors was calculated using the equation (A-1) for the air pathway:

$$I_{air} = \frac{C_{air} \times R_{air} \times F_{site}}{BW} \qquad \text{(A-1)}$$

where:

I_{air} = exposure to contaminant through the air pathway [mg/(kg d)]
C_{air} = air concentration [mg/m^3]
R_{air} = air inhalation rate [m^3/d]
F_{site} = fraction of time at site [-]
BW = body weight [kg]

Contaminant concentrations in air were used from measured data, if available. In the absence of measured air concentrations, typical air concentrations for rural areas (shown in Table A1.1) were used.

TABLE A1.1
TYPICAL AIR CONCENTRATIONS IN RURAL AREAS

Contaminant	Value	Reference
Metals (mg/m^3)		
Aluminum	1.6×10^{-4}	Lee *et al.* 1994
Antimony		
Arsenic	1.0×10^{-6}	U.S. EPA 1996 – for rural areas
Barium		
Beryllium		
Boron		
Cadmium	7.6×10^{-7}	Lee *et al.* 1994
Chromium	9.5×10^{-7}	Lee *et al.* 1994
Cobalt	1.0×10^{-7}	U.S. EPA 1996 – for rural areas
Copper	3.0×10^{-6}	U.S. EPA 1996 – for rural areas
Lead	2.0×10^{-6}	U.S. EPA 1996 – for rural areas
Manganese		
Mercury	4.7×10^{-8}	Lee *et al.* 1994
Molybdenum	1.0×10^{-6}	U.S. EPA 1996 – for rural areas
Nickel	6.0×10^{-7}	U.S. EPA 1996 – for rural areas
Selenium	1.0×10^{-8}	U.S. EPA 1996 – for rural areas
Silver	7.0×10^{-8}	Lee *et al.* 1994
Strontium		
Tin		
Uranium		
Vanadium	4.5×10^{-6}	Lee *et al.* 1994
Zinc	1.1×10^{-5}	U.S. EPA 1996 – for rural areas
Organics and other contaminants (mg/m^3)		
Benzene	0.0	Assumed
Benzo(a)pyrene	0.0	Assumed
Cyanide	0.0	Assumed
Nitrate	0.0	Assumed
PCBs	0.0	Assumed
Thiocyanate	0.0	Assumed
Xylene	0.0	Assumed
Radionuclides (Bq/m^3)		
Thorium-230		
Lead-210		
Radium-226		
Polonium-210		

A.2 DERMAL PATHWAY

Dermal exposure for human receptors was calculated using equation (A-2) for the dermal pathway.

$$I_{dermal} = \frac{C_{soil} \times SA \times EA \times SL \times RAF \times EF \times F_{site}}{BW} \qquad \text{(A-2)}$$

where:

I_{dermal} = exposure to contaminant in soil through the dermal pathway [mg/(kg d)]
C_{soil} = soil concentration [mg/kg (dw)]
SA = skin surface area – total [cm^2]
EA = exposed fraction of skin [-]
SL = loading to exposed skin [kg (dw)/(cm^2 event)]
RAF = dermal absorption factor [-]
EF = exposure frequency [events/d]
F_{site} = fraction of time at site [-]
BW = body weight [kg]

Contaminant concentrations in soil were represented by measured data from the site, if available. In the absence of measured site data, soil concentrations were calculated using deposition from air, shown in equation (A-3). This incremental calculation neglects contaminant concentrations in soil from sources other than air (i.e., rock mineralization) and soil loss due to leaching, erosion and surface runoff.

$$C_{soil} = \frac{C_{air} \times V_{dep}}{d_s \times \rho} \times \left(\frac{3600 \times 24 \times 365 \times 1000}{100^3} \right) \times T \qquad \text{(A-3)}$$

where:

C_{soil} = soil concentration [mg/kg (dw)]
C_{air} = air concentration [mg/m^3]
V_{dep} = deposition velocity [cm/s] {assumed 2 cm/s, from SENES (1987)}
d_s = soil mixing depth [cm] {assumed 1 cm}
ρ = bulk soil density [g (dw)/cm^3] {assumed 1.5 g/cm^3, from Beak (1987)}
T = soil exposure duration [yr] {assumed 10 yr}
3600 = unit conversion factor [s/hr]
24 = unit conversion factor [hr/d]
365 = unit conversion factor [d/yr]
1000 = unit conversion factor [g/kg]
$1/100^3$ = unit conversion factor [m^3/cm^3]

A.3 INGESTION PATHWAY

Ingestion intake by human receptors was calculated using equation (A-4) for the water pathway, equation (A-5) for the soil pathway and equation (A-6) for the food pathway:

$$I_{water} = \frac{C_{water} \times R_{water} \times F_{site}}{BW} \qquad \text{(A-4)}$$

where:

I_{water} = exposure to contaminant through the water pathway [mg/(kg d)]
C_{water} = measured water concentration [mg/L]
R_{water} = water ingestion rate [L/d]
F_{site} = fraction of time at site [-]
BW = body weight [kg]

$$I_{soil} = \frac{C_{soil} \times R_{soil} \times F_{site}}{BW} \times \frac{1}{1000} \qquad \text{(A-5)}$$

where:

I_{soil} = exposure to contaminant through the soil pathway [mg/(kg d)]
C_{soil} = soil concentration [mg/kg (dw)]
R_{soil} = soil ingestion rate [g (dw)/d]
F_{site} = fraction of time at site [-]
BW = body weight [kg]
1/1000 = unit conversion factor [kg/g]

$$I_{food\ x} = \frac{C_x \times R_x \times F_{site}}{BW} \times \frac{1}{1000} \qquad \text{(A-6)}$$

where:

$I_{food\ x}$ = exposure to contaminant through the food pathway [mg/(kg d)], where x is berry, caribou, fish, grouse, hare, mallard, moose, muskrat and sheep, as applicable
C_x = concentration of contaminant [mg/kg (ww)] for each x, such that
C_{berry} –{calculated in equation (A-7)}
$C_{caribou}$ –{calculated in equation (A-8)}
C_{fish} –{calculated in equation (A-12)}
C_{grouse} –{calculated in equation (A-13)}
C_{hare} –{calculated in equation (A-14)}
$C_{mallard}$ –{calculated in equation (A-15)}
C_{moose} –{calculated in equation (A-19)}

$C_{muskrat}$ –{calculated in equation (A-20)}
C_{sheep} –{calculated in equation (A-21)}

R_x = food ingestion rate of x [g (ww)/d], where x is berry, caribou, fish, grouse, hare, mallard, moose, muskrat and sheep, as applicable
F_{site} = fraction of time at site [-]
BW = body weight [kg]
1/1000 = unit conversion factor [kg/g]

Contaminant concentrations in berry were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for berries, contaminant concentrations were calculated using equation (A-7):

$$C_{berry} = C_{soil} \times TF_{soil-to-berry} \qquad \text{(A-7)}$$

where:

C_{berry} = concentration of contaminant in berries [mg/kg (ww)]
C_{soil} = soil concentration [mg/kg (dw)]
$TF_{soil\text{-}to\text{-}berry}$ = soil-to-berry transfer factor [(mg/kg (ww))/(mg/kg (dw))] {Table A3.1}

The soil-to-berry transfer factors from literature used for this assessment are summarized in Table A3.1.

TABLE A3.1
SOIL-TO-BERRY TRANSFER FACTORS

Contaminant	Value	Reference
Metals ((mg/kg (ww))/(mg/kg (dw)))		
Aluminum	$2.6x10^{-3}$	NCRP 1996, Baes *et al*. 1984
Antimony	$8.0x\ 10^{-5}$	U.S. NRC 1992
Arsenic	$9.5x10^{-4}$	NCRP 1996, Baes *et al*. 1984, U.S. EPA 1998
Barium	$9.7x10^{-3}$	U.S. EPA 1998
Beryllium	$7.7x10^{-4}$	U.S. EPA 1998
Boron	0.03	NCRP 1996
Cadmium	$3.8x10^{-2}$	U.S. EPA 1998
Chromium	$1.5x10^{-3}$	U.S. EPA 1998
Cobalt	$7.0x10^{-3}$	U.S. NRC 1992
Copper	0.26	Baes *et al*. 1984
Lead	9.0×10^{-2}	U.S. NRC 1992
Manganese	0.05	U.S. NRC 1992
Mercury	$4.4x10^{-3}$	U.S. EPA 1998
Molybdenum	0.12	NCRP 1996, Baes *et al*. 1984
Nickel	$1.8x10^{-1}$	Baes *et al*. 1984
Selenium	2.9×10^{-3}	NCRP 1996, Baes *et al*. 1984, U.S.EPA 1998
Silver	$4.1x10^{-2}$	U.S. EPA 1998
Strontium	0.2	IAEA 1994
Tin	$6.0x10^{-3}$	Baes *et al*. 1984
Uranium	1.1×10^{-3}	Cassaday *et al.* 1985
Vanadium	$3.0x10^{-3}$	Baes *et al*. 1984
Zinc	0.99	NCRP 1996, IAEA 1994, Baes *et al*. 1984
Organics and other contaminants ((mg/kg (ww))/(mg/kg (dw)))		
Benzene	0.675	U.S. EPA 1998
Benzo(a)pyrene	0.003	U.S. EPA 1998
Cyanide	0.0	no transfer to vegetation
Nitrate	0.0	no transfer to vegetation
PCBs	$3.0x10^{-3}$	U.S. EPA 1998
Thiocyanate	3.5	McKone 1994
Xylene	$9.4x10^{-2}$	McKone 1994
Radionuclides ((Bq/kg (ww))/(Bq/kg (dw)))		
Thorium-230	8.5×10^{-5}	Baes *et al*. 1984
Lead-210	9.0×10^{-2}	U.S. NRC 1992
Radium-226	7.2×10^{-4}	Cassaday *et al.* 1985
Polonium-210	4.0×10^{-4}	Baes *et al*. 1984

Contaminant concentrations in woodland caribou were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for woodland caribou, contaminant concentrations were calculated using equation (A-8):

$$C_{caribou} = \left(Q_{water} \times C_{water} \times \frac{1}{1000} + \sum_i (Q_i \times C_i) \times \frac{1}{1000} + Q_{soil} \times C_{soil} \times \frac{1}{1000} \right) \times F_{site} \times TF_{feed-to-caribou} \quad \text{(A-8)}$$

where:

$C_{caribou}$ = concentration of contaminant in caribou flesh [mg/kg (ww)]

Q_{water} = water ingestion rate [g/d] {9,500 g/d, based on Kirk (1977) and Wales *et al.* (1975)}

C_{water} = measured water concentration [mg/L]

1/1000 = units conversion factor [L/g] or [kg/g]

Q_i = food ingestion rate [g/d] for each i, such that

Q_{forage} – 80 {calculated from U.S. EPA (1993) and based on Thomas and Barry (1991)}

Q_{browse} – 400 {calculated from U.S. EPA (1993) and based on Thomas and Barry (1991)}

Q_{lichen} – 7,520 {calculated from U.S. EPA (1993) and based on Thomas and Barry (1991)}

C_i = concentration of food [mg/kg (ww)] for each i, such that

C_{forage} – {calculated in equation (A-9)}

C_{browse} – {calculated in equation (A-10)}

C_{lichen} – {calculated in equation (A-11)}

Q_{soil} = soil ingestion rate [g/d] {104 g/d, calculated from Beyer *et al.* (1994)}

C_{soil} = soil concentration [mg/kg (dw)]

F_{site} = fraction of time caribou at site [-] {assumed to be 0.10}

$TF_{feed-to-caribou}$ = feed-to-caribou transfer factor [d/kg (ww)] {Table A3.4}

Measured contaminant concentrations in forage were used from the site, when available. In the absence of measured data, contaminant concentrations in forage were estimated following equation (A-9):

$$C_{forage} = C_{soil} \times TF_{soil-to-forage} \quad \text{(A-9)}$$

where:

C_{forage} = concentration of contaminant in forage [mg/kg (ww)]

C_{soil} = soil concentration [mg/kg (dw)]

$TF_{soil-to-forage}$ = soil-to-forage transfer factor [(mg/kg (ww))/(mg/kg (dw))] {Table A3.2}

The soil-to-forage transfer factors from literature used for this assessment are summarized in Table A3.2.

TABLE A3.2
SOIL-TO-FORAGE TRANSFER FACTORS

Contaminant	**Value**	**Reference**
Metals ((mg/kg (ww))/(mg/kg (dw)))		
Aluminum	0.03	NCRP 1996
Antimony	0.20	Baes et al. 1984
Arsenic	0.1	NCRP 1996, U.S. EPA 1998
Barium	0.029	NCRP 1996, U.S. EPA 1998, CSA 1987
Beryllium	0.017	NCRP 1996, U.S. EPA 1998
Boron	0.03	NCRP 1996
Cadmium	0.2	NCRP 1996, U.S. EPA 1998
Chromium	0.013	NCRP 1996, U.S. EPA 1998, CSA 1987
Cobalt	0.045	NCRP 1996, IAEA 1994, CSA 1987
Copper	0.8	NCRP 1996
Lead	0.03	Létourneau 1987, NCRP 1996, U.S. EPA 1998
Manganese	0.29	U.S. NRC 1992
Mercury	0.3	NCRP 1996
Molybdenum	0.4	NCRP 1996
Nickel	0.07	NCRP 1996, IAEA 1994, U.S. EPA 1998
Selenium	0.25	NCRP 1996, U.S. EPA 1998
Silver	0.35	NCRP 1996, U.S. EPA 1998, CSA 1987
Strontium	0.13	U.S. NRC 1992
Tin	0.03	Baes et al. 1984
Uranium	1.8×10^{-2}	Létourneau 1987, NCRP 1996, IAEA 1994
Vanadium	0.1	NCRP 1996
Zinc	0.24	NCRP 1996, IAEA 1994, U.S. EPA 1998
Organics and other contaminants ((mg/kg (ww))/(mg/kg (dw)))		
Benzene	0.675	U.S. EPA 1998
Benzo(a)pyrene	0.003	U.S. EPA 1998
Cyanide	0.0	no transfer to vegetation
Nitrate	0.0	no transfer to vegetation
PCBs	$3.0\text{x}10^{-3}$	U.S. EPA 1998
Thiocyanate	3.5	McKone 1994
Xylene	$9.4\text{x}10^{-2}$	McKone 1994
Radionuclides ((Bq/kg (ww))/(Bq/kg (dw)))		
Thorium-230	9.2×10^{-3}	Létourneau 1987, NCRP 1996, IAEA 1994
Lead-210	0.03	Létourneau 1987, NCRP 1996, U.S. EPA 1998
Radium-226	0.093	Létourneau 1987, NCRP 1996, IAEA 1994
Polonium-210	0.021	Létourneau 1987, NCRP 1996, IAEA 1994

Measured contaminant concentrations in browse were used from the site, when available. In the absence of measured data, contaminant concentrations in browse were estimated following equation (A-10):

$$C_{browse} = C_{soil} \times TF_{soil-to-browse} \qquad \text{(A-10)}$$

where:

C_{browse} = concentration of contaminant in browse [mg/kg (ww)]
C_{soil} = soil concentration [mg/kg (dw)]
$TF_{soil\text{-}to\text{-}browse}$ = soil-to-browse transfer factor [(mg/kg (ww))/(mg/kg (dw))] {Table A3.3}

The soil-to-browse transfer factors from literature used for this assessment are summarized in Table A3.3.

TABLE A3.3
SOIL-TO-BROWSE TRANSFER FACTORS

Contaminant	**Value**	**Reference**
Metals ((mg/kg (ww))/(mg/kg (dw)))		
Aluminum	2.6×10^{-3}	NCRP 1996, Baes et al. 1984
Antimony	0.20	Baes et al. 1984
Arsenic	7.7×10^{-3}	NCRP 1996, Baes et al. 1984, U.S. EPA 1998
Barium	4.5×10^{-3}	U.S. EPA 1998
Beryllium	4.5×10^{-4}	U.S. EPA 1998
Boron	0.03	NCRP 1996
Cadmium	1.9×10^{-2}	U.S. EPA 1998
Chromium	1.4×10^{-3}	U.S. EPA 1998
Cobalt	0.045	NCRP 1996, IAEA 1994, CSA 1987
Copper	0.055	NCRP 1996, Baes et al. 1984
Lead	5.0×10^{-3}	Baes et al. 1984, IAEA 1994, NCRP 1996, U.S. EPA 1998
Manganese	0.29	U.S. NRC 1992
Mercury	0.3	NCRP 1996
Molybdenum	0.07	NCRP 1996, Baes et al. 1984
Nickel	8.6×10^{-3}	NCRP 1996, Baes et al. 1984, U.S.EPA 1998
Selenium	0.01	NCRP 1996, Baes et al. 1984, U.S.EPA 1998
Silver	3.0×10^{-2}	U.S. EPA 1998
Strontium	0.13	U.S. NRC 1992
Tin	0.03	Baes et al. 1984
Uranium	1.2×10^{-3}	Baes et al. 1984, IAEA 1994, NCRP 1996
Vanadium	5.5×10^{-3}	Baes et al. 1984
Zinc	0.27	NCRP 1996, IAEA 1994, Baes et al. 1984
Organics and other contaminants ((mg/kg (ww))/(mg/kg (dw)))		
Benzene	0.47	McKone 1994
Benzo(a)pyrene	0.022	McKone 1994
Cyanide	0.0	no transfer to vegetation
Nitrate	0.0	no transfer to vegetation
PCBs	3.0×10^{-3}	U.S. EPA 1998
Thiocyanate	3.5	McKone 1994
Xylene	9.4×10^{-2}	McKone 1994
Radionuclides ((Bq/kg (ww))/(Bq/kg (dw)))		
Thorium-230	1.4×10^{-4}	Baes et al. 1984, IAEA 1994, NCRP 1996
Lead-210	5.0×10^{-3}	Baes et al. 1984, IAEA 1994, NCRP 1996, U.S. EPA 1998
Radium-226	3.7×10^{-3}	Baes et al. 1984, IAEA 1994, NCRP 1996
Polonium-210	6.9×10^{-4}	Baes et al. 1984, NCRP 1996

Measured contaminant concentrations in lichen were used from the site, when available. In the absence of measured data, contaminant concentrations in lichen were estimated following equation (A-11). It is assumed that contaminant transfer to lichen occurs entirely through the air pathway and therefore, there is no contaminant transfer to lichen through the soil pathway.

$$C_{lichen} = \frac{C_{air} \times V_{dep} \times F_{in} \times F_{rv} \times E_v}{Y_v \times \lambda_w} \times \frac{1000}{100} \qquad \text{(A-11)}$$

where:

C_{lichen} = concentration of contaminant in lichen [mg/kg (ww)]
C_{air} = air concentration [mg/m^3]
V_{dep} = deposition velocity [cm/s] {assumed 2 cm/s, from SENES (1987)}
F_{in} = fraction of deposition intercepted by lichen [-] {assumed to be 1}
F_{rv} = fraction of deposition retained on lichen [-] {0.95, from SENES (1987)}
E_v = fraction of deposition on edible portion of lichen [-] {1, from SENES (1987)}
Y_v = yield density [g (ww)/m^2] {500 g/m^2, from SENES (1987)}
λ_w = weathering loss decay constant [1/s] {2.2×10^{-9}, from SENES (1987)}
1000 = units conversion factor [g/kg]
1/100 = units conversion factor [m/cm]

Feed-to-caribou transfer factors were obtained from literature sources, as summarized in Table A3.4.

TABLE A3.4
FEED-TO-CARIBOU[a] TRANSFER FACTORS

Contaminant	**Value**	**Reference**
Metals (d/kg (ww))		
Aluminum	1.0 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Antimony	1.0 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Arsenic	2.0 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Barium	1.6 x 10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Beryllium	2.3 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Boron	6.7 x 10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Cadmium	5.2 x 10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Chromium	5.5 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Cobalt	1.0 x 10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Copper	1.0 x 10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Lead	1.0 x 10^{-3}	Thomas *et al.* 1994[b]
Manganese	5.0 x 10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Mercury	8.8 x 10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Molybdenum	1.0 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Nickel	6.0 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Selenium	1.5 x 10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Silver	3.0 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Strontium	5.0 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Tin	4.0 x 10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Uranium	3.0 x 10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Vanadium	2.5 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Zinc	1.0 x 10^{-1}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Organics and other contaminants (d/kg (ww))		
Benzene	3.4 x 10^{-6}	U.S. EPA 1998
Benzo(a)pyrene	3.4 x 10^{-2}	U.S. EPA 1998
Cyanide	1.6 x 10^{-2}	McKone 1994
Nitrate	0.0	no food chain transfer
PCBs	4.0 x 10^{-2}	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	9.5 x 10^{-8}	McKone 1994
Xylene	4.0 x 10^{-5}	U.S. EPA 1998, based on m-xylene
Radionuclides (d/kg (ww))		
Thorium-230	2.0 x 10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Lead-210	1.0 x 10^{-3}	Thomas *et al.* 1994[b]
Radium-226	1.0 x 10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Polonium-210	8.5 x 10^{-3}	Thomas *et al.* 1994[b]

Note : a – Based mainly on feed-to-beef transfer factors.

b – Calculated from lichen to caribou data for Pb-210 and Po-210 in Thomas *et al.* 1994.

c – Based on feed-to-beef transfer factor information available in IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987.

Contaminant concentrations in fish were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for fish, contaminant concentrations were calculated using equation (A-12):

$$C_{fish} = C_{water} \times TF_{water-to-fish} \qquad \text{(A-12)}$$

where:

C_{fish} = concentration of contaminant in fish [mg/kg (ww)]
C_{water} = water concentration [mg/L]
$TF_{water\text{-}to\text{-}fish}$ = water-to-fish transfer factor [(mg/kg (ww))/(mg/L)] {Table A3.5}

The water-to-fish transfer factors from literature used for this assessment are summarized in Table A3.5.

Cyanide water-to-fish transfer factors were not considered since there are no reports of cyanide biomagnification or cycling in living organisms since it is rapidly detoxified (Eisler 1991). In addition, fish retrieved from cyanide-poisoned environments can be consumed by humans because muscle cyanide residues are generally considered as low (Eisler 1991).

TABLE A3.5
WATER-TO-FISH TRANSFER FACTORS

Contaminant	Value	Reference
Metals ((mg/kg (ww))/(mg/L))		
Aluminum	500	NCRP 1996
Antimony	100	IAEA 1994
Arsenic	1000	CSA 1987
Barium	210	IAEA 1994, NCRP 1996, CSA 1987, U.S. EPA 1998
Beryllium	100	IAEA 1994, NCRP 1996
Boron	5.0	NCRP 1996
Cadmium	200	NCRP 1996
Chromium	200	IAEA 1994, NCRP 1996, CSA 1987
Cobalt	300	IAEA 1994, NCRP 1996
Copper	200	IAEA 1994, NCRP 1996
Lead	300	IAEA 1994, NCRP 1996
Manganese	400	IAEA 1994
Mercury	4000	IAEA 1994, NCRP 1996, CSA 1987
Molybdenum	10	IAEA 1994
Nickel	310	U.S. EPA 1998
Selenium	130	U.S. EPA 1998, ATSDR 1997
Silver	10	NCRP 1996, CSA 1987
Strontium	60	IAEA 1994
Tin	3000	IAEA 1994
Uranium	20	CSA 1987
Vanadium	200	IAEA 1994, NCRP 1996
Zinc	1000	IAEA 1994
Organics and other contaminants ((mg/kg (ww))/(mg/L))		
Benzene	25	U.S. EPA 1998
Benzo(a)pyrene	9950	U.S. EPA 1998, BAF
Nitrate	0.0	no food chain transfer
PCBs	6.6×10^5	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	0.0	no food chain transfer
Xylene	160	U.S. EPA 1998, m-xylene
Radionuclides ((Bq/kg (ww))/(Bq/L))		
Thorium-230	100	IAEA 1994, NCRP 1996
Lead-210	300	IAEA 1994, NCRP 1996
Radium-226	50	IAEA 1994, NCRP 1996
Polonium-210	50	IAEA 1994

Contaminant concentrations in grouse were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for grouse, contaminant concentrations were calculated using equation (A-13):

$$C_{grouse} = \left(Q_{water} \times C_{water} \times \frac{1}{1000} + \sum_i \left(Q_i \times C_i \right) \times \frac{1}{1000} + Q_{soil} \times C_{soil} \times \frac{1}{1000} \right) \times F_{site} \times TF_{feed-to-grouse} \quad \text{(A-13)}$$

where:

C_{grouse} = concentration of contaminant in grouse flesh [mg/kg (ww)]
Q_{water} = water ingestion rate [g/d] {51 g/d, calculated from U.S. EPA (1993)}
C_{water} = measured water concentration [mg/L]
1/1000 = units conversion factor [L/g] or [kg/g]
Q_i = food ingestion rate [g/d] for each i, such that
Q_{browse} – 97 {U.S. EPA (1993)}
Q_{berry} – 12 {U.S. EPA (1993)}
C_i = concentration of food [mg/kg (ww)] for each i, such that
C_{browse} – {calculated in equation (A-10)}
C_{berry} – {calculated in equation (A-7)}
Q_{soil} = soil ingestion rate [g/d] {1.02 g/d, calculated from Beyer *et al.* (1994)}
C_{soil} = soil concentration [mg/kg (dw)]
F_{site} = fraction of time grouse at site [-] {assumed to be 1.0}
$TF_{feed-to-grouse}$ = feed-to-grouse transfer factor [d/kg (ww)] {Table A3.6}

Feed-to-grouse transfer factors were obtained from literature sources, as summarized in Table A3.6.

TABLE A3.6
FEED-TO-GROUSE[a] TRANSFER FACTORS

Contaminant	**Value**	**Reference**
Metals (d/kg (ww))		
Aluminum	0.5	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Antimony	0.5	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Arsenic	1.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Barium	0.08	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Beryllium	1.15	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Boron	0.34	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Cadmium	0.8	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Chromium	6.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Cobalt	2.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Copper	0.5	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Lead	0.2	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Manganese	0.05	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Mercury	0.027	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Molybdenum	1.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Nickel	3.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Selenium	9.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Silver	2.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Strontium	0.06	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Tin	20	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Uranium	1.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Vanadium	1.3	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Zinc	7.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Organics and other contaminants (d/kg (ww))		
Benzene	2.7×10^{-6}	U.S. EPA 1998
Benzo(a)pyrene	0.027	U.S. EPA 1998
Cyanide	8.0	McKone 1994
Nitrate	0.0	no food chain transfer
PCBs	0.032	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	4.8×10^{-5}	McKone 1994
Xylene	0.032	U.S. EPA 1998, based on m-xylene
Radionuclides (d/kg (ww))		
Thorium-230	0.10	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Lead-210	0.20	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Radium-226	0.30	Clulow *et al.* 1992[c]
Polonium-210	2.5	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]

Note : a – Based on information for poultry.

b – Based on feed-to-poultry information available in IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987. When transfer factors were not available for poultry (As, Pb, Ni, V, Po, Th) the beef transfer factors was multiplied by a factor of 500 derived from the geometric mean of the ratio between the transfer factors for beef:chicken for Cd, Cu, Mo, Se, Zn, U, Ra.

c – Default value for radium based on grouse from Clulow *et al.* 1992. Based on a concentration ratio (CR) of 0.075fw and a feed ingestion rate of 224 g/d.

Contaminant concentrations in hare were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for hare, contaminant concentrations were calculated using equation (A-14):

$$C_{hare} = \left(Q_{water} \times C_{water} \times \frac{1}{1000} + \sum_{i} (Q_i \times C_i) \times \frac{1}{1000} + Q_{soil} \times C_{soil} \times \frac{1}{1000} \right) \times F_{site} \times TF_{feed-to-hare} \quad \text{(A-14)}$$

where:

C_{hare} = concentration of contaminant in hare flesh [mg/kg (ww)]
Q_{water} = water ingestion rate [g/d] {140 g/d, calculated from U.S. EPA (1993)}
C_{water} = measured water concentration [mg/L]
1/1000 = units conversion factor [L/g] or [kg/g]
Q_i = food ingestion rate [g/d] for each i, such that
  Q_{forage} – 120 {Pease *et al.* (1979), U.S. EPA (1993)}
  Q_{browse} – 180 {Pease *et al.* (1979), U.S. EPA (1993)}
C_i = concentration of food [mg/kg (ww)] for each i, such that
  C_{forage} – {calculated in equation (A-9)}
  C_{browse} – {calculated in equation (A-10)}
Q_{soil} = soil ingestion rate [g/d] {7.0 g/d, calculated from Beyer *et al.* (1994)}
C_{soil} = soil concentration [mg/kg (dw)]
F_{site} = fraction of time hare at site [-] {assumed to be 1.0}
$TF_{feed-to-hare}$ = feed-to-hare transfer factor [d/kg (ww)] {Table A3.7}

Feed-to-hare transfer factors were obtained from literature sources, as summarized in Table A3.7.

TABLE A3.7
FEED-TO-HARE[a] TRANSFER FACTORS

Contaminant	Value	Reference
Metals (d/kg (ww))		
Aluminum	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Antimony	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Arsenic	2.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Barium	1.6×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Beryllium	2.3×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Boron	6.7×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Cadmium	5.2×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Chromium	5.5×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Cobalt	1.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Copper	1.0×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Lead	1.4×10^{-1}	Thomas 1997[b]
Manganese	5.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Mercury	8.8×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Molybdenum	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Nickel	6.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Selenium	1.5×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Silver	3.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Strontium	5.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Tin	4.0×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Uranium	3.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Vanadium	2.5×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Zinc	1.0×10^{-1}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Organics and other contaminants (d/kg (ww))		
Benzene	3.4×10^{-6}	U.S. EPA 1998
Benzo(a)pyrene	3.4×10^{-2}	U.S. EPA 1998
Cyanide	1.6×10^{-2}	McKone 1994
Nitrate	0.0	no food chain transfer
PCBs	4.0×10^{-2}	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	9.5×10^{-8}	McKone 1994
Xylene	4.0×10^{-5}	U.S. EPA 1998, based on m-xylene
Radionuclides (d/kg (ww))		
Thorium-230	2.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Lead-210	1.4×10^{-1}	Thomas 1997[b]
Radium-226	2.5	Thomas 1997[b]
Polonium-210	4.3×10^{-1}	Thomas 1997[b]

Note : a – Based in part on feed-to-beef transfer factors.

b – Based on food chain concentration ratios for vegetation and voles in Thomas 1997.

c – Based on feed-to-beef transfer factor information available in IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987.

Contaminant concentrations in mallard were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for mallard, contaminant concentrations were calculated using equation (A-15):

$$C_{mallard} = \left(Q_{water} \times C_{water} \times \frac{1}{1000} + \sum_i \left(Q_i \times C_i \right) \times \frac{1}{1000} + Q_{sed} \times C_{sed} \times \frac{1}{1000} \right) \times F_{site} \times TF_{feed-to-mallard} \quad \text{(A-15)}$$

where:

$C_{mallard}$ = concentration of contaminant in mallard flesh [mg/kg (ww)]
Q_{water} = water ingestion rate [g/d] {64 g/d, U.S. EPA (1993)}
C_{water} = measured water concentration [mg/L]
1/1000 = units conversion factor [L/g] or [kg/g]
Q_i = food ingestion rate [g/d] for each i, such that
  $Q_{aquatic\ vegetation}$ – 47 {U.S. EPA (1993)}
  $Q_{benthic\ invertebrates}$ – 142 {U.S. EPA (1993)}
C_i = concentration of food [mg/kg (ww)] for each i, such that
  $C_{aquatic\ vegetation}$ – {calculated in equation (A-16)}
  $C_{benthic\ invertebrate}$ – {calculated in equation (A-17)}
Q_{sed} = sediment ingestion rate [g/d] {1.89 g/d, calculated from Beyer *et al.* (1994)}
C_{sed} = sediment concentration [mg/kg (dw)] {calculated in equation (A-18)}
F_{site} = fraction of time mallard at site [-] {assumed to be 0.50}
$TF_{feed-to-mallard}$ = feed-to-mallard transfer factor [d/kg (ww)] {Table A3.11}

Contaminant concentrations in aquatic vegetation were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for aquatic vegetation, contaminant concentrations were calculated using equation (A-16):

$$C_{aqveg} = C_{water} \times TF_{water-to-aqveg} \quad \text{(A-16)}$$

where:

C_{aqveg} = concentration of contaminant in aquatic vegetation [mg/kg (ww)]
C_{water} = water concentration [mg/L]
$TF_{water-to-aqveg}$ = water-to-aquatic vegetation transfer factor [(mg/kg (ww))/(mg/L)] {Table A3.8}

The water-to-aquatic vegetation transfer factors from literature used for this assessment are summarized in Table A3.8.

TABLE A3.8
WATER-TO-AQUATIC VEGETATION TRANSFER FACTORS

Contaminant	**Value**	**Reference**
Metals ((mg/kg (ww))/(mg/L))		
Aluminum	0.0	not available
Antimony	1500	NRCC 1983
Arsenic	200	NTIS 1988, CSA 1987
Barium	500	NRCC 1983
Beryllium	38	Santschi and Honeyman 1989
Boron	0.0	not available
Cadmium	1900	Bird and Schwartz 1996
Chromium	0.12	Bird and Schwartz 1996
Cobalt	1200	Bird and Schwartz 1996
Copper	1000	ORNL 1976
Lead	320	Santschi and Honeyman 1989, ORNL 1976
Manganese	170	Bird and Schwartz 1996
Mercury	530	Bird and Schwartz 1996
Molybdenum	1000	ORNL 1976, NTIS 1989
Nickel	50	ORNL 1976
Selenium	63	Santschi and Honeyman 1989
Silver	200	NRCC 1983
Strontium	260	Bird and Schwartz 1996
Tin	100	NRCC 1983
Uranium	200	Santschi and Honeyman 1989, ORNL 1976, Bird and Schwartz 1996, Létourneau 1987
Vanadium	2000	U.S. NRC 1977
Zinc	550	NTIS 1988, CSA 1987
Organics and other contaminants ((mg/kg (ww))/(mg/L))		
Benzene	15	Freitag et al. 1984
Benzo(a)pyrene	3100	Freitag et al. 1985
Cyanide	0.0	not available
Nitrate	0.0	not available
PCBs	0.0	not available
Thiocyanate	0.0	not available
Xylene	0.0	not available
Radionuclides ((Bq/kg (ww))/(Bq/L))		
Thorium-230	2600	Santschi and Honeyman 1989, ORNL 1976, Bird and Schwartz 1996, Létourneau 1987
Lead-210	320	Santschi and Honeyman 1989, ORNL 1976
Radium-226	970	Santschi and Honeyman 1989, ORNL 1976, Bird and Schwartz 1996, Létourneau 1987
Polonium-210	1800	Santschi and Honeyman 1989, ORNL 1976

Contaminant concentrations in benthic invertebrates were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for benthic invertebrates, contaminant concentrations were calculated using equation (A-17):

$$C_{benthos} = C_{water} \times TF_{water-to-benthos} \qquad \text{(A-17)}$$

where:

$C_{benthos}$ = concentration of contaminant in benthic invertebrates [mg/kg (ww)]
C_{water} = water concentration [mg/L]
$TF_{water\text{-}to\text{-}benthos}$ = water-to-benthic invertebrate transfer factor [(mg/kg (ww))/(mg/L)] {Table A3.9}

The water-to-benthic invertebrate transfer factors from literature used for this assessment are summarized in Table A3.9.

TABLE A3.9
WATER-TO-BENTHIC INVERTEBRATE TRANSFER FACTORS

Contaminant	**Value**	**Reference**
Metals ((mg/kg (ww))/(mg/L))		
Aluminum	0.0	not available
Antimony	10	NRCC 1983
Arsenic	1700	U.S. EPA 1979
Barium	200	NRCC 1983
Beryllium	0.0	not available
Boron	0.0	not available
Cadmium	4000	U.S. EPA 1979
Chromium	20	NRCC 1983
Cobalt	1000	assumed from copper, nickel and selenium
Copper	1000	U.S. EPA 1979
Lead	100	U.S. EPA 1979
Manganese	7.5×10^{-2}	Bird and Schwartz 1996
Mercury	530	Bird and Schwartz 1996
Molybdenum	4000	U.S. EPA 1979, NTIS 1989
Nickel	100	U.S. EPA 1979
Selenium	680	NTIS 1985 and measured data from Northern Ontario, Elliot Lake
Silver	770	NRCC 1983
Strontium	450	Bird and Schwartz 1996
Tin	1000	NRCC 1983
Uranium	100	U.S. EPA 1979
Vanadium	100	NRCC 1983, assumed same as niobium
Zinc	40000	U.S. EPA 1979
Organics and other contaminants ((mg/kg (ww))/(mg/L))		
Benzene	0.0	not available
Benzo(a)pyrene	0.0	not available
Cyanide	0.0	not available
Nitrate	0.0	not available
PCBs	0.0	not available
Thiocyanate	0.0	not available
Xylene	0.0	not available
Radionuclides ((Bq/kg (ww))/(Bq/L))		
Thorium-230	500	U.S. EPA 1979, Létourneau 1987
Lead-210	100	U.S. EPA 1979
Radium-226	250	U.S. EPA 1979
Polonium-210	20000	U.S. EPA 1979

Contaminant concentrations in sediment were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for sediment, contaminant concentrations were calculated using equation (A-18):

$$C_{sed} = C_{water} \times K_d \tag{A-18}$$

where:

C_{sed} = concentration of contaminant in sediment [mg/kg (dw)]
C_{water} = water concentration [mg/L]
K_d = water-to-sediment distribution coefficient [(mg/kg (dw))/(mg/L)] {Table A3.10}

The water-to-sediment distribution coefficients from literature used for this assessment are summarized in Table A3.10.

TABLE A3.10
WATER-TO-SEDIMENT DISTRIBUTION COEFFICIENTS

Contaminant	**Value**	**Reference**
Metals ((mg/kg (dw))/(mg/L))		
Aluminum	1500	Baes et al. 1998
Antimony	45	U.S. EPA 1998
Arsenic	31	U.S. EPA 1998
Barium	60	Bechtel Jacobs 1998
Beryllium	790	U.S. EPA 1998
Boron	3.0	Baes et al. 1998
Cadmium	4300	U.S. EPA 1998
Chromium	30	Bechtel Jacobs 1998
Cobalt	5000	IAEA 1994, Bechtel Jacobs 1998
Copper	10000	U.S. EPA 1998
Lead	900	U.S. EPA 1998
Manganese	1000	IAEA 1994
Mercury	1000	U.S. EPA 1998
Molybdenum	900	Sheppard and Thibault 1990, for clay soil with a factor of 10
Nickel	1900	U.S. EPA 1998
Selenium	2.2	U.S. EPA 1998
Silver	1100	U.S. EPA 1998
Strontium	1000	IAEA 1994
Tin	13000	U.S. NRC 1992
Uranium	50	IAEA 1994, Bechtel Jacobs 1998
Vanadium	50	U.S. EPA 1998
Zinc	500	IAEA 1994, Bechtel Jacobs 1998
Organics and other contaminants ((mg/kg (dw))/(mg/L))		
Benzene	4.7	U.S. EPA 1998
Benzo(a)pyrene	730	U.S. EPA 1998
Cyanide	0.0	not available
Nitrate	0.0	not available
PCBs	3930	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	0.0	not available
Xylene	23	U.S. EPA 1998, for p-xylene
Radionuclides ((Bq/kg (dw))/(Bq/L))		
Thorium-230	10000	IAEA 1994, Bechtel Jacobs 1998
Lead-210	900	U.S. EPA 1998
Radium-226	500	IAEA 1994, Bechtel Jacobs 1998
Polonium-210	150	Bechtel Jacobs 1998

Feed-to-mallard transfer factors were obtained from literature sources, as summarized in Table A3.11.

TABLE A3.11
FEED-TO-MALLARD[a] TRANSFER FACTORS

Contaminant	**Value**	**Reference**
Metals (d/kg (ww))		
Aluminum	0.5	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Antimony	0.5	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Arsenic	1.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Barium	0.08	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Beryllium	1.15	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Boron	0.34	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Cadmium	0.8	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Chromium	6.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Cobalt	2.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Copper	0.5	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Lead	0.2	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Manganese	0.05	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Mercury	0.027	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Molybdenum	1.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Nickel	3.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Selenium	9.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Silver	2.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Strontium	0.06	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Tin	20	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Uranium	1.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Vanadium	1.3	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Zinc	7.0	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Organics and other contaminants (d/kg (ww))		
Benzene	2.7×10^{-6}	U.S. EPA 1998
Benzo(a)pyrene	0.027	U.S. EPA 1998
Cyanide	8.0	McKone 1994
Nitrate	0.0	no food chain transfer
PCBs	0.032	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	4.8×10^{-5}	McKone 1994
Xylene	0.032	U.S. EPA 1998, based on m-xylene
Radionuclides (d/kg (ww))		
Thorium-230	0.10	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Lead-210	0.20	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Radium-226	0.30	Clulow *et al.* 1992[c]
Polonium-210	2.5	IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]

Note : a – Based on information for poultry.

b – Based on feed-to-poultry information available in IAEA 1994, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987. When transfer factors were not available for poultry (As, Pb, Ni, V, Po, Th) the beef transfer factors was multiplied by a factor of 500 derived from the geometric mean of the ratio between the transfer factors for beef:chicken for Cd, Cu, Mo, Se, Zn, U, Ra.

c – Default value for radium based on grouse from Clulow *et al.* 1992. Based on a concentration ratio (CR) of 0.075fw and a feed ingestion rate of 224 g/d.

Contaminant concentrations in moose were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for moose, contaminant concentrations were calculated using equation (A-19):

$$C_{moose} = \left(Q_{water} \times C_{water} \times \frac{1}{1000} + \sum_{i} \left(Q_i \times C_i \right) \times \frac{1}{1000} + Q_{sed} \times C_{sed} \times \frac{1}{1000} \right) \times F_{site} \times TF_{feed-to-moose} \tag{A-19}$$

where:

C_{moose} = concentration of contaminant in moose flesh [mg/kg (ww)]
Q_{water} = water ingestion rate [g/d] {32,000 g/d, calculated from U.S. EPA (1993)}
C_{water} = measured water concentration [mg/L]
1/1000 = units conversion factor [L/g] or [kg/g]
Q_i = food ingestion rate [g/d] for each i, such that
    Q_{aqveg} – 2,300 {Canadian Wildlife Service (1997), Belovsky *et al.* (1973)}
    Q_{browse} – 20,700 {Canadian Wildlife Service (1997), Belovsky *et al.* (1973)}
C_i = concentration of food [mg/kg (ww)] for each i, such that
    C_{browse} – {calculated in equation (A-10)}
    C_{aqveg} – {calculated in equation (A-16)}
Q_{sed} = sediment ingestion rate [g/d] {184 g/d, calculated from Beyer *et al.* (1994)}
C_{sed} = sediment concentration [mg/kg (dw)] {calculated in equation (A-18)}
F_{site} = fraction of time moose at site [-] {assumed to be 1.0}
$TF_{feed-to-moose}$ = feed-to-moose transfer factor [d/kg (ww)] {Table A3.12}

Feed-to-moose transfer factors were obtained from literature sources, as summarized in Table A3.12.

TABLE A3.12
FEED-TO-MOOSE[a] TRANSFER FACTORS

Contaminant	**Value**	**Reference**
Metals (d/kg (ww))		
Aluminum	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Antimony	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Arsenic	2.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Barium	1.6×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Beryllium	2.3×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Boron	6.7×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Cadmium	5.2×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Chromium	5.5×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Cobalt	1.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Copper	1.0×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Lead	4.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Manganese	5.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Mercury	8.8×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Molybdenum	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Nickel	6.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Selenium	1.5×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Silver	3.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Strontium	5.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Tin	4.0×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Uranium	3.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Vanadium	2.5×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Zinc	1.0×10^{-1}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Organics and other contaminants (d/kg (ww))		
Benzene	3.4×10^{-6}	U.S. EPA 1998
Benzo(a)pyrene	3.4×10^{-2}	U.S. EPA 1998
Cyanide	1.6×10^{-2}	McKone 1994
Nitrate	0.0	no food chain transfer
PCBs	4.0×10^{-2}	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	9.5×10^{-8}	McKone 1994
Xylene	4.0×10^{-5}	U.S. EPA 1998, based on m-xylene
Radionuclides (d/kg (ww))		
Thorium-230	2.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Lead-210	4.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Radium-226	1.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Polonium-210	5.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]

Note : a – Based on feed-to-beef transfer factors.

b – Based on feed-to-beef transfer factor information available in IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987.

Contaminant concentrations in muskrat were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for muskrat, contaminant concentrations were calculated using equation (A-20):

$$C_{muskrat} = \left(Q_{water} \times C_{water} \times \frac{1}{1000} + \sum_i \left(Q_i \times C_i \right) \times \frac{1}{1000} + Q_{sed} \times C_{sed} \times \frac{1}{1000} \right) \times F_{site} \times TF_{feed-to-muskrat} \quad \text{(A-20)}$$

where:

$C_{muskrat}$ = concentration of contaminant in muskrat flesh [mg/kg (ww)]
Q_{water} = water ingestion rate [g/d] {120 g/d, calculated from U.S. EPA (1993)}
C_{water} = measured water concentration [mg/L]
1/1000 = units conversion factor [L/g] or [kg/g]
Q_i = food ingestion rate [g/d] for each i, such that
Q_{aqveg} – 356 {U.S. EPA (1993)}
C_i = concentration of food [mg/kg (ww)] for each i, such that
C_{aqveg} – {calculated in equation (A-16)}
Q_{sed} = sediment ingestion rate [g/d] {4.0 g/d, calculated from Beyer *et al.* (1994)}
C_{sed} = sediment concentration [mg/kg (dw)] {calculated in equation (A-18)}
F_{site} = fraction of time muskrat at site [-] {assumed to be 1.0}
$TF_{feed-to-muskrat}$ = feed-to-muskrat transfer factor [d/kg (ww)] {Table A3.13}

Feed-to-muskrat transfer factors were obtained from literature sources, as summarized in Table A3.13.

TABLE A3.13
FEED-TO-MUSKRAT[a] TRANSFER FACTORS

Contaminant	Value	Reference
Metals (d/kg (ww))		
Aluminum	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Antimony	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Arsenic	2.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Barium	1.6×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Beryllium	2.3×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Boron	6.7×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Cadmium	5.2×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Chromium	5.5×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Cobalt	1.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Copper	1.0×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Lead	1.4×10^{-1}	Thomas 1997[b]
Manganese	5.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Mercury	8.8×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Molybdenum	1.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Nickel	6.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Selenium	1.5×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Silver	3.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Strontium	5.0×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Tin	4.0×10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Uranium	3.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Vanadium	2.5×10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Zinc	1.0×10^{-1}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Organics and other contaminants (d/kg (ww))		
Benzene	3.4×10^{-6}	U.S. EPA 1998
Benzo(a)pyrene	3.4×10^{-2}	U.S. EPA 1998
Cyanide	1.6×10^{-2}	McKone 1994
Nitrate	0.0	no food chain transfer
PCBs	4.0×10^{-2}	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	9.5×10^{-8}	McKone 1994
Xylene	4.0×10^{-5}	U.S. EPA 1998, based on m-xylene
Radionuclides (d/kg (ww))		
Thorium-230	2.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Lead-210	1.4×10^{-1}	Thomas 1997[b]
Radium-226	2.5	Thomas 1997[b]
Polonium-210	4.3×10^{-1}	Thomas 1997[b]

Note : a – Based in part on feed-to-beef transfer factors.

b – Based on food chain concentration ratios for vegetation and voles in Thomas 1997.

c – Based on feed-to-beef transfer factor information available in IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987.

Contaminant concentrations in sheep were assumed to equal measured concentrations from the site, when available. In the absence of measured site data for sheep, contaminant concentrations were calculated using equation (A-21):

$$C_{sheep} = \left(Q_{water} \times C_{water} \times \frac{1}{1000} + \sum_i \left(Q_i \times C_i \right) \times \frac{1}{1000} + Q_{soil} \times C_{soil} \times \frac{1}{1000} \right) \times F_{site} \times TF_{feed-to-sheep} \quad \text{(A-21)}$$

where:

C_{sheep} = concentration of contaminant in sheep flesh [mg/kg (ww)]
Q_{water} = water ingestion rate [g/d] {4,500 g/d, calculated from U.S. EPA (1993)}
C_{water} = measured water concentration [mg/L]
1/1000 = units conversion factor [L/g] or [kg/g]
Q_i = food ingestion rate [g/d] for each i, such that Q_{forage} – 5,760 {U.S. EPA (1993)}
C_i = concentration of food [mg/kg (ww)] for each i, such that C_{forage} – {calculated in equation (A-9)}
Q_{soil} = soil ingestion rate [g/d] {76.9 g/d, calculated from Beyer *et al.* (1994)}
C_{soil} = soil concentration [mg/kg (dw)]
F_{site} = fraction of time sheep at site [-] {assumed to be 0.25}
$TF_{feed-to-sheep}$ = feed-to-sheep transfer factor [d/kg (ww)] {Table A3.14}

Feed-to-sheep transfer factors were obtained from literature sources, as summarized in Table A3.14.

TABLE A3.14
FEED-TO-SHEEP[a] TRANSFER FACTORS

Contaminant	Value	Reference
Metals (d/kg (ww))		
Aluminum	1.0 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Antimony	1.0 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Arsenic	2.0 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Barium	1.6 x 10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Beryllium	2.3 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Boron	6.7 x 10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Cadmium	5.2 x 10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Chromium	5.5 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Cobalt	1.0 x 10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Copper	1.0 x 10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Lead	4.0 x 10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Manganese	5.0 x 10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Mercury	8.8 x 10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Molybdenum	1.0 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Nickel	6.0 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Selenium	1.5 x 10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Silver	3.0 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Strontium	5.0 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Tin	4.0 x 10^{-2}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Uranium	3.0 x 10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Vanadium	2.5 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Zinc	1.0 x 10^{-1}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Organics and other contaminants (d/kg (ww))		
Benzene	3.4 x 10^{-6}	U.S. EPA 1998
Benzo(a)pyrene	3.4 x 10^{-2}	U.S. EPA 1998
Cyanide	1.6 x 10^{-2}	McKone 1994
Nitrate	0.0	no food chain transfer
PCBs	4.0 x 10^{-2}	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	9.5 x 10^{-8}	McKone 1994
Xylene	4.0 x 10^{-5}	U.S. EPA 1998, based on m-xylene
Radionuclides (d/kg (ww))		
Thorium-230	2.0 x 10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Lead-210	4.0 x 10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Radium-226	1.0 x 10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]
Polonium-210	5.0 x 10^{-3}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[b]

Note : a – Based on feed-to-beef transfer factors.

b – Based on feed-to-beef transfer factor information available in IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987.

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR) 1997. *Toxicological Profile for Selenium.* December.

Baes, C.F., R.D. Sharp, A.L. Sjoreen, and R.W. Shar 1984. *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides Through Agriculture*. ORNL-5786.

Beak Consultants Limited (Beak) 1987. *Application of the National Uranium Tailings Program Probabilistic System Model (UTAP) to the Rabbit Lake Uranium Tailings Site.* Research report prepared for the National Uranium Tailings Program, CANMET, EMR, Ottawa.

Bechtel Jacobs. 1998. *Radiological Benchmarks for Screening Contaminants of Potential Concern for Effects on Aquatic Biota at ORNL*. BJC/OR-80.

Belovsky, G.E., P.A. Jordan, and D.B. Botkin. 1973. *Summer Browsing by Moose in Relation to Preference, and Animal Density: A New Quantitative Approach*. Proceedings of the 9th North American Moose Conference and Workshop, Quebec, City, March.

Beyer, W. N., E. Connor, and S. Gerould. 1994. *Survey of Soil Ingestion by Wildlife*. Journal of Wildlife Management 58:375-382.

Bird, G.A. and W. Schwartz. 1996. *Nuclide Concentration Factors for Freshwater Biota*. AECL. Technical Record TR-703.

Canadian Standards Association (CSA). 1987. *Guidelines for Calculating Derived Release Rate Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities*. CAN ICSA-N288.1-M87.

Canadian Wildlife Service (CWS). 1997. *Hinterland Who's Who: Moose On-Line Report*. Environment Canada. http://www.cws-scf.ec.gc.ca/. Accessed on June 10, 2003.

Cassaday, V.J., B.E. Halbert and D. Stone. 1985. *The Data Base Available to Develop Distributions for Use in Modelling the Transfer of Airborne Radioactivity to Terrestrial Vegetation. Presented in a Report Entitled – Probabilistic Model Development for the Assessment of the Long-Term Effects of Uranium Mill Tailings in Canada*: Phase II, Vol. 2. Prepared by SENES Consultants Limited for the National Uranium Tailings Program, Canada Centre for Mineral and Water Technology, Energy, Mines and Resources Canada, Ottawa, Ontario.

Clulow, F.V., T.P. Lim, N.K. Davé and R. Avadhanula. 1992. *Radium-226 Levels and Concentration Ratios Between Water, Vegetation, and Tissues of Ruffed Grouse (Bonasa umbellus) from a Watershed with Uranium Tailings Near Elliot Lake, Canada.* Environmental Pollution Vol. 77:39-50. September.

Eisler, R. 1991. *Cyanide Hazards to Fish, Wildlife, and Invertebrates: a Synoptic Review. Contaminant Hazard Reviews Report 23.* U.S. Department of the Interior Fish and Wildlife Service. December.

Freitag, D. 1984. *Environmental hazard profile-test results as related structures and translation into the environment.* In: QSAR in Environmental Toxicology. Kaiser, K.L.E., Editor, D. Reidel Publishing Company, Dordrect, Netherlands.

Freitag, D., L. Ballhorn, H. Geyer, F. Korte. 1985. *Environmental hazard profile of organic chemicals. An experimental method for the assessment of the behaviour of chemicals in the ecosphere by simple laboratory tests with c-14 labelled chemicals.* Chemosphere 14, 1589-616.

International Atomic Energy Agency (IAEA). 1994. *Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments.* International Atomic Energy Agency, Vienna.

Kirk, R.W. (ed.) 1977. *Current Veterinary Therapy.* W.B. Saunders Co., Toronto, pp 1418.

Lee, D.S., J.A. Garland, A.A. Fox 1994. *Atmospheric Concentrations of Trace Elements in Urban Areas of the United Kingdom.* Atmos. Environ.28(16): 2691-2713.

Létourneau, C. 1987. *Transfer of Radionuclides of the Uranium and Thorium Decay Chains in Aquatic and Terrestrial Environments.* Prepared for Atomic Energy Control Board. April.

McKone, T. E. 1994. *Uncertainty and variability in human exposures to soil contaminants through home-grown food: a Monte Carlo assessment.* Risk Anal. 14(4):449-463.

National Research Council of Canada (NRCC). 1983. *Radioactivity in the Canadian Aquatic Environment.* 19250.

Oak Ridge National Laboratory (ORNL). 1976. *A Methodology for Calculating Radiation Doses from Radioactivity Released to the Environment.* Environmental Sciences Division Publication No. 660, March.

Pease, J.L., R.H. Vowles and L.B. Keith. 1979. *Interaction of Snowshoe Hares and Woody Vegetation*. J. Wildl. Manage. 43: 43-60.

Santschi, P.H. and B.D. Honeyman. 1989. *Radionuclides in Aquatic Environments Radiation*. Physics and Chemistry. Volume 34, No. 2.

SENES Consultants Limited (SENES) 1987. *Uranium Tailings Assessment Program (UTAP.3): Component Model Documentation.* Prepared for National Uranium Tailings Program, CANMET, EMR under Contract No. 23317-6-1728/01-SQ.

Sheppard, M.I. and D.H. Thibault 1990. *Default soil solid/liquid partition coefficients, K_Ds, for four major soil types: a compendium*. Health Physics, Vol. 59, No. 4, pp. 471-482.

Thomas, D.C. and S.J. Barry. 1991. *Microhistological Analyses of Caribou Diet: Fecal Versus Rumen Samples and Other Variables*. Pages 516-529 in Proc. Fourth North Amer. Caribou Workshop. C.E. Buttler and S.P. Mahoney (eds). Newf.-Lab. Wildl. Div., St. John's, Newfoundland.

Thomas, P.A. 1997. *The Ecological Distribution and Bioavailability of Uranium-Series Radionuclides in Terrestrial Food Chains: Key Lake Uranium Operations, Northern Saskatchewan*. Prepared for Environment Canada – Environmental Protection – Prairie and Northern Region, December.

Thomas, P.A., J.W. Sheard and S. Swanson 1994. *Transfer of Po-210 and Pb-210 Through the Lichen-Caribou-Wolf Food Chain of Northern Canada*. Health Physics, Vol. 66, No. 6, June, pp. 666-677.

United States Department of Commerce (U.S. DOC) National Technical Information Service (NTIS). 1985. *Selenium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*. Ronald Eisler, U.S. Fish & Wildlife Service. October.

United States Department of Commerce (U.S. DOC) National Technical Information Service (NTIS) 1988. *Arsenic Hazards to Fish, Wildlife, and Invertebrates: a synoptic review.* Ronald Eisler, U.S. Fish & Wildlife Service. January.

United States Department of Commerce (U.S. DOC) National Technical Information Service (NTIS) 1989. *Molybdenum Hazards to Fish, Wildlife, and Invertebrates: a synoptic review*. U.S. Patuxent Wildlife Research Center, Laurel, M.D. August.

United States Environmental Protection Agency (U.S. EPA). 1979. *Water-Related Environmental Fate of 129 Priority Pollutants, Volume 1*. EPA-4401 4-79-029a. Office of Water Planning and Standards, Washington, D.C.

United States Environmental Protection Agency (U.S. EPA). 1993. *Wildlife Exposure Factors Handbook*. EPA/600/R-93/187).

United States Environmental Protection Agency (U.S. EPA) 1996. *Particulate Matter: Air Quality Criteria.* EPA/600/AP-95/001. Research Triangle Park, NC: Environmental Protection Agency.

United States Environmental Protection Agency (U.S. EPA). 1998. *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities*. Peer Review Draft. EPA 530-D-98-001.

United States National Council on Radiation Protection and Measurements (NCRP). 1996. *Screening Models for Release of Radionuclides to Atmosphere, Surface Water and Ground*. NCRP Report No. 123.

United States National Research Council (U.S. NRC) 1977. *Drinking Water and Health. Volume 1*. Washington, D.C. National Research Council, National Academy Press.

United States Nuclear Regulatory Commission (U.S. NRC) 1992. *Residual Radioactive Contamination from Decommissioning: Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent*. NUREG/CR-5512.

Wales, R.A., L.P. Milligan and E.H. McEwan. 1975. *Urea Recycling in Caribou, Cattle and Sheep*. In First Int. Reindeer and Caribou Sympo. J.R. Luick, P.C. Lent, D.R. Klein and R.G. White (eds), Univ. Alaska, Fairbanks, pp. 297-307.

FINAL

APPENDIX B

HEALTH CANADA
TOXICOLOGICAL REFERENCE VALUES

Prepared by:
Dr. Mark Richardson

APPENDIX B: HEALTH CANADA TOXICOLOGICAL REFERENCE VALUES

Name	Non-Carcinogenic Toxicological Reference Values		Carcinogenic Toxicological Reference Values			
	HC TDI [a] mg/kg-d	HC TDC mg/m3	Oral slope factor from TD$_{05}$ [b] (mg/kg-d)$^{-1}$	Inhalation slope factor from TC$_{05}$ [b,c] (mg/kg-d)$^{-1}$	Inhalation unit risk from TC$_{05}$ [b] (mg/m^3)$^{-1}$	Oral slope factor from DWQG [a] (mg/kg-d)$^{-1}$
Aldicarb	0.001					
Aldrin + dieldrin	0.0001					
Aniline	0.007 [b]					
Arsenic			2.8	2.80E+01	6.40E+00	1.7 [g]
atrazine + metabolites	0.0005					
azinphos-methyl	0.0025					
barium	0.016					
Bendiocarb	0.004					
Benzene				1.46E-02	3.30E-03	3.10E-01
Benzo(a)pyrene				1.37E-01	3.10E-02	2.30
Benzo(b)fluoranthene				8.20E-03	1.90E-03	
Benzo(j)fluoranthene				6.80E-03	1.60E-03	
Benzo(k)fluoranthene				5.50E-03	1.30E-03	
Bis(2-ehtyl-hexyl) phthalate	0.044 [b]					
Bis(Chloro-methyl) ether				4.13E+01	9.43E+00	
Boron	0.0175					
Bromoxynil	0.0005					
Cadmium	0.0008			4.29E+01	9.80E+00	
Carbaryl	0.01					
Carbofuran	0.01					
Carbon tetrachloride						4.90E-02
Chloramine, mono	0.048					
Chlorobenzene	0.43 [b]	0.01 [b]				
Chlorpyrifos	0.01					
Chromium, hexavalent	0.001			3.31E+02	7.58E+01	
Chromium, total	0.001			4.76E+01	1.09E+01	
Copper	0.03 [d]					
Cyanazine	0.0013					
Cyanide, free	0.02 [d]					
DDT	0.01 [e]					
Diazinon	0.002					
Dibutyl phthalate	0.063 [b]					
Dicamba	0.0125					
Dichlorobenzene, 1,2-	0.43 [b]					
Dichlorobenzene, 1,4-	0.11 [b]	0.095 [b]				
Dichlorobenzidine, 3,3'-			6.76E-02			

	Non-Carcinogenic Toxicological Reference Values		Carcinogenic Toxicological Reference Values			
Name	**HC TDI [a] mg/kg-d**	**HC TDC mg/m3**	**Oral slope factor from TD_{05} [b] $(mg/kg\text{-}d)^{-1}$**	**Inhalation slope factor from TC_{05} [b,c] $(mg/kg\text{-}d)^{-1}$**	**Inhalation unit risk from TC_{05} [b] $(mg/m^3)^{-1}$**	**Oral slope factor from DWQG [a] $(mg/kg\text{-}d)^{-1}$**
Dichloroethane, 1,2-			8.06E-03			7.50E-02 [h]
Dichloroethylene, 1,1	0.003					
Dichloromethane	0.05 [b]			9.90E-05	2.30E-05	7.90E-05
2,4-D	0.01					
Dichorophenol, 2,4-	0.1					
Diclofop-methyl	0.001					
Dimethoate	0.002					
Dinoseb	0.001					
Diquat	0.008					
Diuron	0.0156					
Fluoride, inorganic	0.122					
Glyphosate	0.03					
Hexachlorobenzene	0.0005 [b]		8.33E-01			
Indeno(1,2,3-cd)pyrene				1.62E-02	3.70E-03	
Lead	0.0035					
Malathion	0.02					
Mercury, inorganic (ionic)	0.0003 [d]					
Methoxychlor	0.1					
Methyl methacrylate	0.01 [b]	0.037 [b]				
Metolachlor	0.005					
Metribuzin	0.0083					
Monochlorobenzene	0.0089					
Nickel chloride	0.0013 [b]					
Nickel oxide		0.00002 [b]				
Nickel subsulphide		0.000018 [b]				
Nickel sulfate	0.05 [b]	0.0000035 [b]				
Nickel, metallic		0.000018 [b]				
Nickel, oxidic				5.47E+00	1.25E+00	
Nickel, soluble				3.13E+00	7.14E-01	
Nickel, sulphidic						
Nitrilotriacetic acid (NTA)	0.01					
Paraquat (as dichloride)	0.001					
Parathion	0.005					
Pentachlorobenzene	0.001 [b]					
Pentachlorophenol	0.006					
Phenol	0.06 [d]					
Phorate	0.0002					
Picloram	0.02					
PCBs	0.001					
PCDD/PCDF	1.00E-08 [b]					

Name	Non-Carcinogenic Toxicological Reference Values		Carcinogenic Toxicological Reference Values			
	HC TDI [a] mg/kg-d	HC TDC mg/m3	Oral slope factor from TD_{05} [b] $(mg/kg\text{-}d)^{-1}$	Inhalation slope factor from TC_{05} [b,c] $(mg/kg\text{-}d)^{-1}$	Inhalation unit risk from TC_{05} [b] $(mg/m^3)^{-1}$	Oral slope factor from DWQG [a] $(mg/kg\text{-}d)^{-1}$
PCDD/PCDF	2.3E-09 [g]					
Simazine	0.0013					
Styrene	0.12 [b]	0.092 [b]				
Terbufos	0.00005					
Tetrachlorobenzene, 1,2,3,4-	0.0034 [b]					
Tetrachlorobenzene, 1,2,3,5-	0.00041 [b]					
Tetrachlorobenzene, 1,2,4,5-	0.00021 [b]					
Tetrachloroethylene	0.014 [b]	0.36 [b]				
Tetrachlorophenol, 2,3,4,6-	0.01					
Toluene	0.22 [b]	3.8 [b]				
Trichlorobenzene, 1,2,3-	0.0015 [b]					
Trichlorobenzene, 1,2,4-	0.0016 [b]	0.007 [b]				
Trichlorobenzene, 1,2,5-	0.0015 [b]	0.0036 [b]				
Trichloroethylene			2.50E-04	2.70E-03	6.10E-04	
Trichlorophenol,2,4,6-						2.00E-02
Trifluralin	0.0048					
Uranium (non-radiological)	0.0006 [d]					
Vinyl chloride						2.60E-01
Xylene, mixed isomers	1.5 [b]	0.18 [b]				

Notes:

a – from Canadian Guidelines for Drinking Water Quality, Supporting Documentation, unless otherwise indicated.

b – from HC, 1996

c – inhalation slope factor derived assuming 24 hour adult inhalation rate of 16 m^3/24 hours (Allan and Richardson, 1998; Richardson, 1997) and an adult body weight of 70.7 kg (Richardson, 1997)

d – from CCME Soil Quality Guidelines and supporting documentation on health-based guidelines prepared by Health Canada

e – WHO/FAO Joint Meeting on Pesticide Residues (the Food Directorate, Health Canada, generally endorses and applies the TDIs for pesticide residues derived by the JMPR)

f – Grant, D.L. 1983 (this TDI is still applied by Health Canada for the assessment of PCB exposure from foods and other sources)

g – Officially, the Health Canada TDI for PCDD/PCDF is 10 pg/kg-d; however the WHO/FAO Joint Expert Committee on Food Additives and Contaminants recently proposed a revised TDI of 2 pg/kg-d. The Food Directorate, Health Canada, generally endorses and applies the TDIs for food contaminants derived by the JECFA and it is anticipated that this revised TDI will be implemented. Therefore, it is recommended that SLRAs for PCDD/PCDF in Canada employ this more conservative TDI.

h – although the TRV from the Canadian Drinking Water Quality Guidelines Supporting Documentation is presented, it is recommended that the comparable TRV from the more recent assessment (HC, 1996) be employed for risk characterization.

FINAL

APPENDIX C

2003 WATER QUALITY DATA FROM UMA

Project	6029-00500 Water Analysis
Report to	UMA Engineering Ltd.
ALS File No.	T4585
Date Received	9/29/2003
Date:	10/14/2003

RESULTS OF ANALYSIS

Sample ID	**Water Quality Guideline**	**Source**	PC-03-01	PC-03-02	PC-03-03	PC-03-04	PP-03-01	HL-03-01	HL-03-02	HL-03-03	HL-03-04	HL-03-05	HL-03-06	WC-03-01	WC-03-02	WC-03-03	WC-03-04	WC-03-05	CC-03-01	CC-03-02	CC-03-03	CC-03-04	CC-03-05	CC-03-06	CC-03-07	EC-03-01	FM-03-01	FM-03-02	MC-03-01
Date Sampled	**(freshwater aquatic life)**		9/23/2003	9/23/2003	9/23/2003	9/23/2003	9/23/2003	9/23/2003	9/23/2003	9/23/2003	9/23/2003	9/23/2003	9/23/2003	9/24/2003	9/24/2003	9/24/2003	9/24/2003	9/24/2003	9/24/2003	9/24/2003	9/24/2003	9/24/2003	9/24/2003	9/24/2003	9/24/2003	9/24/2003	9/24/2003	9/24/2003	9/24/2003
Time Sampled			15:45	15:55	16:25	16:45	17:10	17:50	18:05	18:45	19:00	19:05	19:35	11:45	12:00	12:10	12:30	12:45	12:50	12:55	14:30	14:50	15:10	15:20	15:25	14:45	15:45	16:10	16:20
ALS Sample ID			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Nature			Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
Physical Tests			Porcupine Cr.	Porcupine Cr.	Porcupine Cr.	Porcupine Cr.	Porcupine Pit	Hudgeon L.	Hudgeon L.	Hudgeon L. Creek inflow to N.	Hudgeon L.	Hudgeon L.	Hudgeon L.	Wolverine Cr. Upstream ref.	Wolverine Cr.	Wolverine Cr. Between lobes	Wolverine Cr.	Wolverine Cr.	Clinton Creek	Clinton Creek	Clinton Creek	Clinton Creek	Clinton Creek	Clinton Creek	Clinton Creek	Eagle Cr.	Fortymile Cr.	Fortymile Cr.	Fortymile Cr.
Hardness CaCO3			1440	1410	1250	1630	2630	209	206	322	220	212	214	362	364	346	342	364	300	305	254	282	405	419	425	257	113	299	131
Dissolved Anions																													
Bromide Br			<0.05	<0.05	<0.05	<0.05	0.14	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chloride Cl	150	B.C. Approved Water Qualit	0.8	0.8	0.7	3.7	40	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.8	0.8	1.1	<0.5	0.6	<0.5	0.8	1.4	1.6	1.6	<0.5	1.1	1.4	<0.5
Fluoride F	0.3	B.C. Approved Water Qualit	0.3	0.29	0.28	0.17	0.07	0.11	0.1	0.19	0.1	0.1	0.1	0.15	0.15	0.12	0.12	0.14	0.11	0.12	0.11	0.12	0.13	0.13	0.12	0.13	0.11	0.12	0.08
Sulphate SO4	100	B.C. Approved Water Qualit	1090	1070	966	1200	2290	111	112	144	112	110	112	235	221	206	208	202	164	169	133	161	237	242	242	115	43	150	45
Nutrients																													
Ammonia Nitrogen N	1.98	B.C. Approved Water Qualit	<0.005	<0.005	0.011	<0.005	<0.005	0.017	0.016	<0.005	0.017	0.016	0.014	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate Nitrogen N	40	B.C. Approved Water Qualit	0.313	0.319	0.35	0.379	0.499	0.161	0.162	0.048	0.16	0.164	0.161	0.079	0.066	0.11	0.122	0.098	0.154	0.14	0.159	0.158	0.129	0.122	0.126	0.178	0.136	0.123	0.32
Nitrite Nitrogen N	0.02	B.C. Approved Water Qualit	<0.001	<0.001	0.001	0.002	0.023	0.002	0.002	<0.001	0.002	0.002	0.002	0.001	0.001	0.008	0.012	0.005	0.002	0.002	0.002	0.002	0.002	0.002	0.002	<0.001	0.001	0.001	<0.001
Total Metals																													
Aluminum T-Al	0.005-0.1	CCME	<0.03	<0.03	<0.03	<0.03	<0.05	0.174	0.188	0.014	0.123	0.132	0.148	0.046	0.026	0.026	0.025	0.031	0.081	0.06	0.111	0.048	0.04	0.07	0.03	0.023	0.039	0.035	0.011
Antimony T-Sb			0.003	<0.003	0.003	<0.003	**0.023**	<0.0005	<0.0005	0.0006	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0009	0.0009	0.0014	<0.0005	0.0006	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.0005	<0.0005
Arsenic T-As	0.005	CCME	0.017	0.016	0.016	0.003	<0.005	0.0009	0.0009	0.0007	0.0007	0.0007	0.0007	<0.0005	0.0005	0.0008	0.0008	0.0018	0.001	0.0011	0.0007	0.0007	<0.001	<0.001	<0.001	0.0006	<0.0005	0.0005	<0.0005
Barium T-Ba			0.02	<0.02	0.02	0.03	<0.02	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.04	0.04	0.05	0.05	0.05	0.05	0.06	0.04	0.04	0.04	0.06	0.04	0.05	0.05
Beryllium T-Be			<0.005	<0.005	<0.005	<0.005	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.002	<0.002	<0.002	<0.001	<0.001	<0.001	<0.001
Boron T-B	1.2	B.C. Approved Water Qualit	<0.1	<0.1	<0.1	0.1	5.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium T-Cd	0.000017	CCME	<0.0003	<0.0003	<0.0003	<0.0003	<0.0005	0.00007	0.00009	<0.00005	0.00007	0.00006	0.00006	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.00006	0.00005	0.00006	0.00007	<0.0001	<0.0001	<0.0001	0.00005	<0.00005	<0.00005	<0.00005
Calcium T-Ca			316	310	278	231	139	43.9	43.2	60.5	46.8	44.9	45.3	67.4	67.7	56.7	55.8	54.6	59.1	56.5	52.7	59.4	69.8	72.5	74.1	60.4	29	56.3	35
Chromium T-Cr	0.0089	CCME (Cr(III))	<0.005	<0.005	<0.005	<0.005	<0.01	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.002	<0.002	<0.002	<0.001	<0.001	<0.001	<0.001
Cobalt T-Co			<0.002	<0.002	<0.002	<0.002	<0.003	0.0007	0.0008	<0.0003	0.0005	0.0004	0.0005	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	0.0005	0.0005	0.0004	<0.0003	0.0007	0.0007	0.0007	<0.0003	<0.0003	<0.0003	<0.0003
Copper T-Cu	0.002-0.004	CCME	<0.005	<0.005	<0.005	<0.005	<0.01	0.004	0.004	0.001	0.004	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.002	0.002	0.003	0.002	0.002	0.003	0.002
Iron T-Fe	0.3	CCME	<0.03	<0.03	<0.03	<0.03	0.04	0.63	0.67	0.17	0.40	0.36	0.41	0.19	0.20	0.17	0.17	0.09	0.31	0.28	0.35	0.17	0.33	0.33	0.34	0.05	0.09	0.14	<0.03
Lead T-Pb	0.001-0.007	CCME	<0.003	<0.003	<0.003	<0.003	<0.005	<0.0005	0.0006	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.0005	<0.0005
Lithium T-Li			<0.03	<0.03	<0.03	0.04	0.16	<0.005	<0.005	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.008	0.005	0.006	0.005	<0.005	0.01	0.02	0.02	<0.005	<0.005	0.012	<0.005
Magnesium T-Mg			158	154	135	257	554	24.1	23.8	41.4	25.2	24.3	24.5	46.9	47.4	49.5	49.2	55.2	37.1	39.8	29.6	32.4	55.9	57.7	58.4	25.8	9.7	38.6	10.7
Manganese T-Mn	1.9	B.C. Approved Water Qualit	<0.002	<0.002	<0.002	<0.002	0.021	0.164	0.161	0.0786	0.172	0.162	0.161	0.0413	0.0651	0.0467	0.0435	0.0336	0.113	0.0951	0.0973	0.0519	0.179	0.201	0.203	0.006	0.0112	0.0685	0.0029
Mercury T-Hg	0.0001	CCME	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Molybdenum T-Mo	0.073	CCME	<0.005	<0.005	<0.005	<0.005	0.010	0.001	0.001	<0.001	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001	0.001	0.001	<0.002	<0.002	<0.002	0.001	<0.001	0.001	<0.001
Nickel T-Ni	0.025-0.150	CCME	0.022	0.022	0.022	0.092	0.05	0.008	0.005	0.002	0.005	0.005	0.005	0.003	0.003	0.005	0.006	0.014	0.01	0.011	0.006	0.008	0.019	0.02	0.02	0.004	0.002	0.009	0.001
Potassium T-K			<2	<2	<2	<2	5	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Selenium T-Se	0.001	CCME	0.011	0.012	0.016	<0.005	<0.01	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001	0.002	<0.002	<0.002	<0.002	0.003	<0.001	<0.001	<0.001
Silver T-Ag	0.0001	CCME	<0.0001	<0.0001	<0.0001	<0.0001	<0.0002	<0.00006	<0.00003	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00004	<0.00002	<0.00002	<0.00002	<0.00002	<0.00004	<0.00004	<0.00004	<0.00002	<0.00002	<0.00002	<0.00002
Sodium T-Na			3	3	3	11	40	2	2	3	2	2	2	3	4	3	3	4	3	3	2	4	5	5	5	3	5	5	<2
Thallium T-Tl			<0.001	<0.001	<0.001	<0.001	<0.002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0004	<0.0004	<0.0004	<0.0002	<0.0002	<0.0002	<0.0002
Tin T-Sn			<0.003	<0.003	<0.003	<0.003	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.0005	<0.0005
Titanium T-Ti			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium T-U			0.006	0.006	0.005	0.006	0.01	0.0018	0.0019	0.0049	0.0019	0.0018	0.0018	0.0044	0.004	0.0029	0.0028	0.0021	0.002	0.0021	0.0023	0.0021	0.0023	0.0024	0.0024	0.0019	0.0012	0.0019	0.0013
Vanadium T-V			<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Zinc T-Zn	0.03	CCME	<0.03	<0.03	<0.03	<0.03	<0.05	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.01	<0.005	<0.005	<0.005	<0.005

NOTES: Results are expressed as milligrams per litre except where noted.

1) Wolverine Creek - no downstream trends past tailings: Upstream ref = downstream lev < = Less than the detection limit indicated.

2) Procupine Creek - elevated in arsenic. No other samples exceed As WQG. PC also elevated in selenium and sulphate. Attributed to geological source materials in watershed, possibly augmented by mine disturbance.

3) Porcupine Pit - Only exceedance of Aquatic Life WQG is boron.

4) Hudgeon L. - elevated iron and cadmium due to anoxic bottom conditions. Note lack of Fe and Cd elevation in creek to N.

5) Note elevated cadmium in upper reaches of Clinton Creek, downstream from the Hudgeon L. outflow. Note also elevated iron.

6) Influence of Hudgeon Lake on Clinton Creek is spatially limited to upstream from Fortymile Creek. No evidence of impacted water quality in Fortymile Cr.