FINAL REPORT
ON

HUMAN HEALTH
SCREENING LEVEL RISK ASSESSMENT
FOR MOUNT NANSEN MINE SITE

Prepared for:

Department of Indian Affairs
and Northern Development

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November 2003

Printed on Recycled Paper Containing Post-Consumer Fibre

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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 summarizes the screening level risk assessment for human health for existing conditions at the Mount Nansen Mine site. The human health risk assessment was undertaken for the purpose of determining whether there are contaminant levels present in the aquatic and soil environments 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, soil and sediment were used in the assessment.

An assessment of the potential implications to human health from exposure to contaminants was considered for an adult and child camper at the site for three months of the year and consuming drinking water, fish, berries and wild game. The camper was also assumed to be exposed through dermal and inhalation pathways. 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 conservative assumptions that lead to an overestimate of potential exposure. As noted above, the human receptor was assumed to obtain all food and water from the site while in the study area (three months per year) and to be exposed to maximum contaminant levels from each exposure pathway. 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 x 10^{-5} for risk level).

TABLE ES.1
CALCULATED HAZARD QUOTIENT VALUES

Contaminant	**Hazard Quotient**	
	Adult	**Child**
Aluminum	0.06	0.09
Antimony	**1.7**	**2.7**
Barium	0.07	0.10
Cobalt	0.05	0.07
Copper	**1.7**	**2.4**
Cyanide	**0.5**	**0.6**
Lead	0.4	**0.8**
Manganese	0.3	0.4
Molybdenum	**6.0**	**10**
Nickel	0.03	0.04
Selenium	0.02	0.02
Silver	0.04	0.05
Strontium	0.005	0.007
Thiocyanate	**9.2**	**11**
Uranium	**0.8**	**1.0**
Zinc	**0.9**	**1.4**
F1 Aliphatic	**1.4**	**2.8**
F1 Aromatic	**1.0**	**2.1**
F2 Aliphatic	**0.8**	**1.5**
F2 Aromatic	**2.1**	**4.1**
F3 Aliphatic	0.001	0.002
F3 Aromatic	0.3	**0.5**
TOTAL SITE	**27.4**	**41.2**

TABLE ES.2
CALCULATED RISKS OF CARCINOGENIC EFFECTS

Contaminant	**Risk Level**	
	Adult	**Composite**
Arsenic	**2.5 x 10^{-3}**	**6.4 x 10^{-3}**
Cobalt	2.3 x 10^{-8}	6.2 x 10^{-8}
Nickel	4.5 x 10^{-8}	1.2 x 10^{-7}
TOTAL SITE	**2.5 x 10^{-3}**	**6.4 x 10^{-3}**

The assessment of intake showed that the hazard quotient of antimony, copper, molybdenum, thiocyanate, uranium, zinc, and petroleum hydrocarbons (with the exception of F3 Aliphatic and Aromatic for the adult receptor and F3 Aliphatic for the child) exceeded the value of 0.5 selected for this site. The carcinogenic risk from arsenic exposure exceeded the risk level of 1 x 10^{-5} selected for this site. The ingestion pathway was the main source of these contaminants.

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 Mount Nansen site, the annual fatality rate was estimated to equal 2.9 x 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 Mount Nansen Mine 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 background 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 AND PHYSICAL HAZARDS

This section provides a brief description of the Mount Nansen Mine site and physical characteristics associated with the site.

2.1 SITE DESCRIPTION

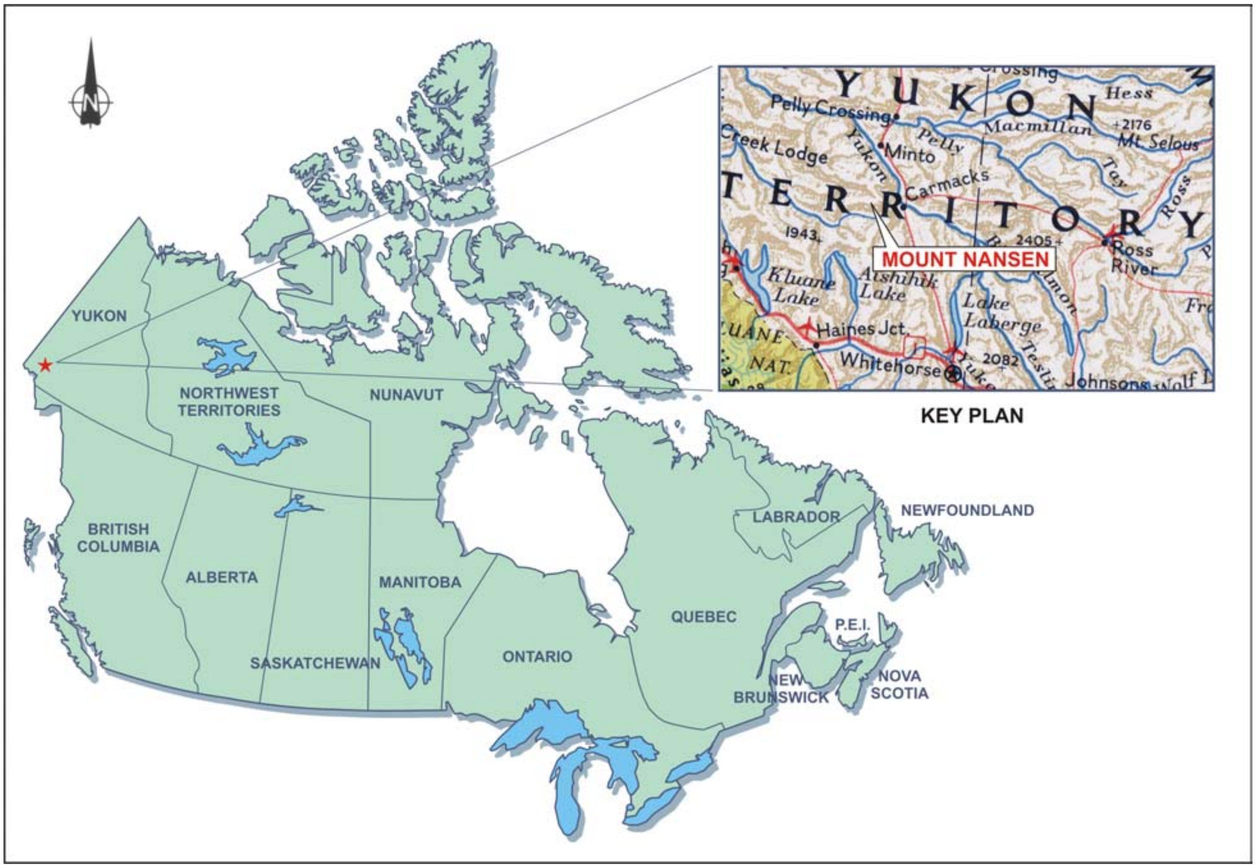
The Mount Nansen Mine is located in the remote Dawson Range in southeast Yukon, as shown in Figures 2.1 and 2.2. The Mount Nansen Area or Property refers to the 247 mineral claims and 30 mineral leases covering 5,300 ha within the Little Salmon/Carmacks First Nations traditional territory (Conor Pacific 2000). This area has been subjected to intermittent hard rock and extensive placer and trenching exploration since 1917. In the late 1960's, over 1 km of underground workings was developed in the area. The majority of activity in the area, however, occurred in the late 1990's at the Mount Nansen Mine site, which includes an open pit and mill, as shown in Figure 2.3. The open pit mine and mill were operated from 1997 to 1999, and produced approximately 258,000 m^3 of tailings and approximately 300,000 m^3 of waste rock. This area, the Mount Nansen Mine site proper, is the focus of the SLRA discussed in this report.

Carmacks, with a population of approximately 500, is the nearest community to the mine site, and is located approximately 60 km east (Wiatzka 2003). Whitehorse is located approximately 180 km south-southeast. Placer miners and recreation users frequent the site during the warmer summer months (Wiatzka 2003). The majority of users access the area by a road that runs adjacent to the open pit and near the mill site, as shown in Figure 2.4. An abandoned airfield may provide access to the site; however its current condition is unknown.

The main water bodies within the Mount Nansen Mine site include Pony and Dome Creeks. The Dome Creek watershed contains the Mount Nansen mill and tailings area (Figure 2.4). Pony Creek is influenced by seepage water from the Pony Creek Adit, which may be connected to the Brown-McDade Pit, as shown in Figure 2.4.

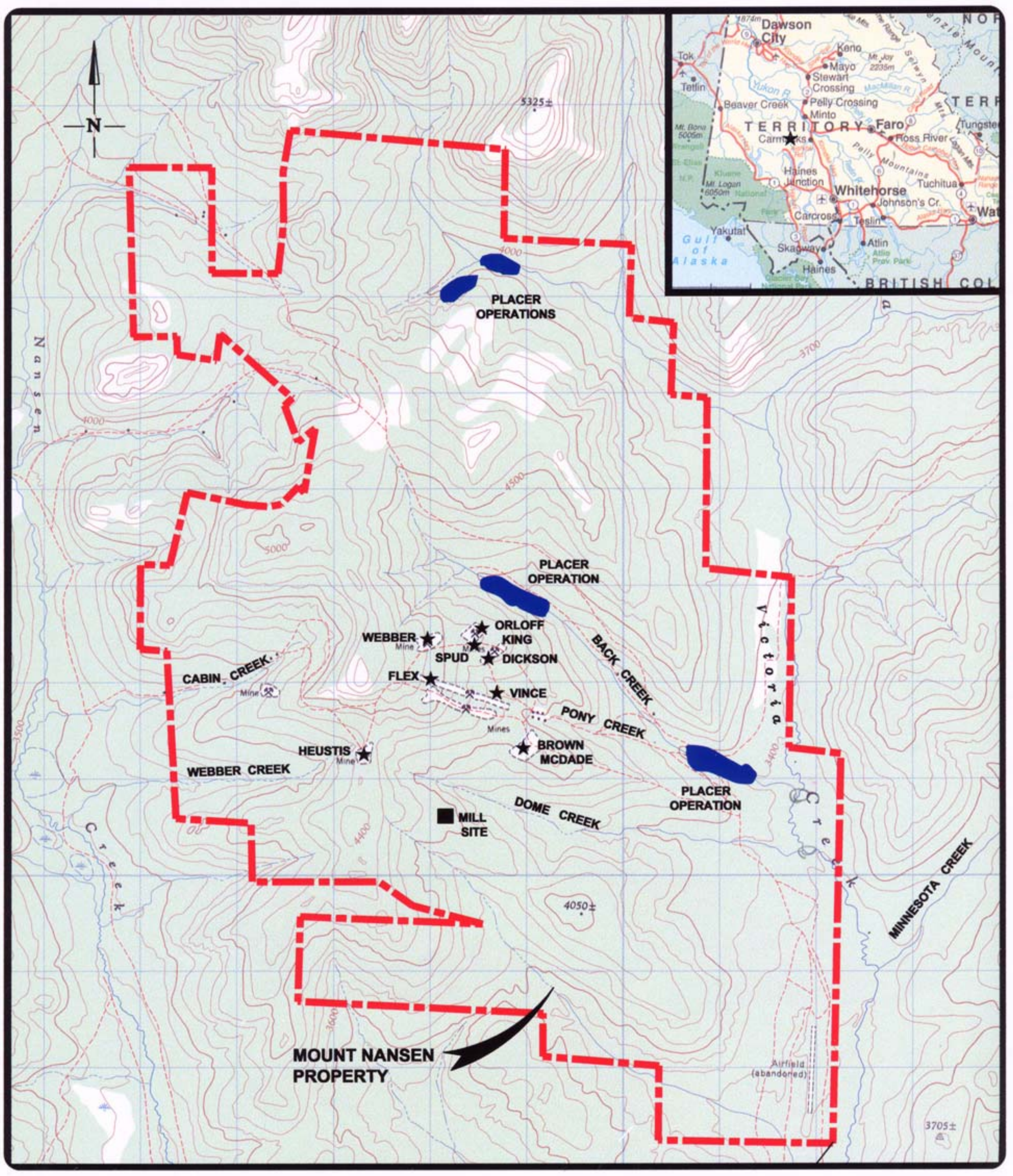
The area around the site which is sparsely vegetated provides habitat for moose, woodland caribou, and possibly mountain sheep.

FIGURE 2.1
MOUNT NANSEN AREA LOCATION MAP



Source: National Geographic (1999).

FIGURE 2.2
MOUNT NANSEN AREA SITE MAP



Source: Conor Pacific (2000).

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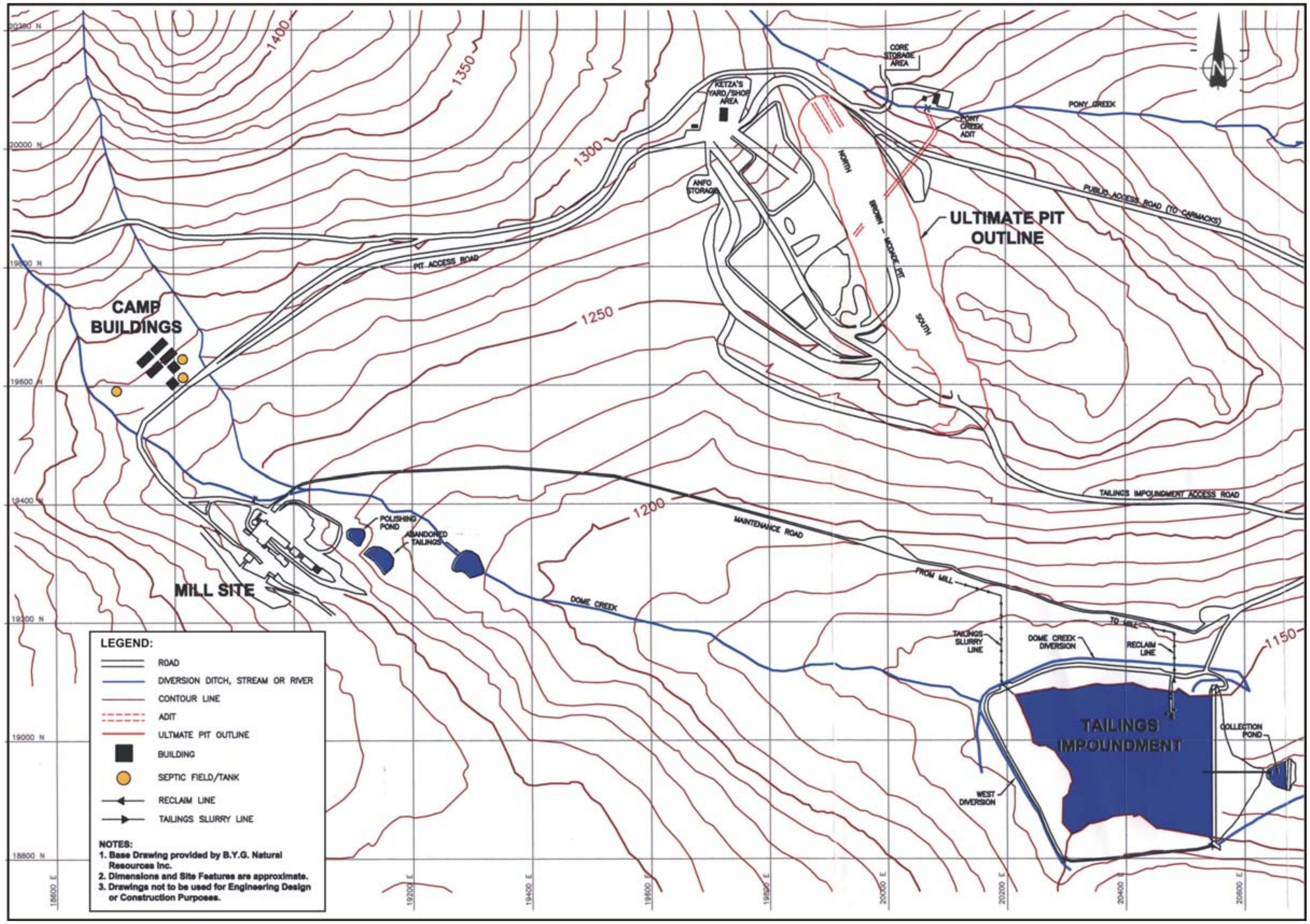
FIGURE 2.3
MOUNT NANSEN MINE PLAN



Source: Conor Pacific (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 methods. 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 sulphide 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 Mount Nansen

Table 2.1 summarizes some of the main physical features of the Mount Nansen Mine. It is noted that there were limited data available to characterize and quantify the remaining mine waste on the sites (tailings and waste rock). Tailings are mostly underwater and not acid producing; however, tailings may be a source of aluminum, ammonia, antimony, arsenic, copper, iron, lead, nickel, thiocyanate, and zinc to the receiving environment. Furthermore, waste rock material has not been thoroughly characterized and may be potentially acid and/or metal leach generating.

TABLE 2.1
PHYSICAL FEATURES OF THE MOUNT NANSEN MINE SITE

Physical Parameter	Key Features	Characteristics	Description
Tailings Impoundments		General Information	The main tailings impoundment is located in the Dome Creek drainage, downstream of the mill.
		Dates of Tailings Deposition	October 1996 to February 1999.
		Tailings Volume	250,000 tonnes (approx. 95,000 m^3)
		Tailings Surface Area	estimated 60,000 m^2
		Tailings Average Depth	estimated 1.5 meters (max depth approx. 10 m)
		Avg Depth to Water Table	mostly saturated (water cover)
		Physical Stability	Wet, saturated, unstable.
		Geochemical Characteristics, Acid Base Accounting (ABA)	Detailed assessment done by Kwong (2002); avg AP (sample #): 67 (8), 63 (10), 39 (3); avg NP (sample #): 24 (8), 24 (10), 16 (3); avg NNP (sample #): -43 (8), -39 (10), -23 (3). Tailings are reportedly moderately acid generating and are relatively chemically stable. Although thiocyanate and ammonia levels are of concern for the medium term, they are expected to improve with time *if the tailings remain under water cover*. If tailings dam were to fail, or water cover were removed, elevated levels of Ag, As, Cu, CN, Pb, Sb, and Zn along with increased acidity may be released to the environment.
		Groundwater Seepage Rate	Not determined
		Surface Discharge Rate	Not determined
		Cover Type	Not determined
		Vegetation	Not determined
		Erosion	Not determined
		Accessibility	Not determined
		Additional Information	Approx. 41,000 tonnes of tailings from previous mill operations are disposed of underwater in a small pond near the mill site. No additional information was provided.
	Dams	General Information	A single dam contains the tailings at Mt. Nansen
		Dimensions	Not determined
		Type of Construction	The dam is composed of 100,000 m^3 of silty, fine - medium grained sand, and was built on a foundation of frozen ice-rich, silty-sandy valley fill.
		Discharge Structure	Emergency spillway documented. Details unknown.
		Seepage	Modelling suggested less than 1 L/s; however observations demonstrate it is significantly higher. A seepage collection pond has since been built.

TABLE 2.1 (Cont'd)
PHYSICAL FEATURES OF THE MOUNT NANSEN MINE SITE

Physical Parameter	Key Features	Characteristics	Description
Tailings Impoundments	**Dams**	Erosion	Not determined
		Stability	The impoundment dam has required repeated maintenance and repair. Cracking and differential thaw-settlement was mitigated in 1996 with a geosynthetic clay liner. Excessive seepage from the toe was remediated in 1997 with a toe berm to prevent piping. As of 1998, the dam foundation continued to show signs of thawing and seepage was at the upper limit of the design range.
		Additional Information	None identified at this time
	Dykes	General Information	None identified
Brown-McDade Pit		General Information	Pit walls are steep and unstable and the pit is flooding.
		Volume	Not determined
		Depth	Not determined
		Surface Area at grade level	Not determined
		Contents of Pit	Partially flooded
		Depth to Watertable	Not determined
		Groundwater Seepage Rate	Not determined
		Surface Discharge Rate	Not determined
		Slopes	Not determined
		Stability	Freeze-thaw action; rock fall; pit walls, overburden, and overlying waste rock are intensely fractured, weathered, and unstable; tension fractures exist along the upper edges of the pit.
		Accessibility (fenced?)	Unknown
		Underground Workings In Pit	4 adits within the pit, including the Pony Creek adit.
		Additional Information	None at this time
Pony Creek Underground Workings		General Information	Pony Creek underground workings are not well defined. These workings are presumably from early (pre-1940's) hard rock mining and later (post-1940's) exploration around the Brown-McDade vein. The locations of these workings is unknown, however they are assumed to be located in the Pony Creek drainage. These workings may have been removed upon excavation of the Brown-McDade Pit.

TABLE 2.1 (Cont'd)
PHYSICAL FEATURES OF THE MOUNT NANSEN MINE SITE

Physical Parameter	Key Features	Characteristics	Description
Pony Creek Underground Workings	**Number and Types of Openings**	General Information	The number and type of opening(s) is unknown, however four (4) adits are shown in figures of the Brown-McDade Pit.
		Volume	Unknown
		Depth	609 m of drifting and cross-cutting in 1947; 552 m of drilling and 216 m of underground development in 1964. 976 m drifting in 1968.
		Contents of Workings	Not determined
		Depth to Watertable	Not determined
		Groundwater Seepage Rate	Not determined
		Surface Discharge Rate	Not determined
		Stability	Not determined
		Accessibility	Not determined
		Ventilation/Gases	Not determined
		Additional Information	None at this time
Heustis Underground Workings		General Information	The Heustis underground workings are referred to by name, however the location, size, nature, and type of workings is unknown. The workings are apparently located in the Dome Creek Drainage.
		Volume	Unknown
		Depth	Unknown
		Contents of Workings	Unknown
		Depth to Watertable	Unknown
		Groundwater Seepage Rate	Unknown
		Surface Discharge Rate	Unknown
		Stability	Unknown
		Accessibility	Unknown
		Ventilation/Gases	Unknown
		Additional Information	None at this time
Waste Rock		General Information	Waste rock dumps are located in two main areas northeast and west of the pit on top of gentle sideslopes on the north side of Dome Creek valley.
		Location	Northeast and west of the pit.
		Volume	Originally planned for estimated 620,000 tonnes (actual mass on surface remains unknown)
		Surface Area	Not determined
		Height/Depth	Not determined
		Depth to Water Table	Not determined

TABLE 2.1 (Cont'd)
PHYSICAL FEATURES OF THE MOUNT NANSEN MINE SITE

Physical Parameter	Key Features	Characteristics	Description
Waste Rock		Geochemical Characteristics, Acid Base Accounting (ABA)	Unknown. Rock samples collected from pit walls (6) and from exploration samples (64) had an avg total sulphur of 0.6% and a range of NNP values between 100 and -400 with a mean value of 14.9. Previous studies suggest that ARD from waste rock was unlikely; however potential arsenic leaching was a concern.
		Groundwater Seepage Rate	Not determined
		Surface Discharge Rate	Not determined
		Cover (water, soil, sand, none, etc.)	Not determined
		Vegetation	Not determined
		Sloped/Graded Surfaces	Moderately steep to angle of repose.
		Erosion	Not determined
		Physical Stability	Appear to be unstable: tension fractures and drainage holes have been observed
		Additional Information	None at this time
Infrastructure		General Information	Buildings on site are in various states of condition. The mill and crusher have been damaged and many buildings are easily accessible. 2 floating barges in the tailings were in disrepair as of 2000.
		Date of Construction	Unknown, but majority is presumably post 1985.
		Number of Buildings	Numerous buildings. Exact number unknown.
		Type of Construction	Wood and steel.
		Condition/Stability	Varied
		Accessibility	Most buildings are insecure and open.
		Additional Information	The mill, loadout, crusher, and treatment buildings contain riggings, sumps, and misc. insecure hazards.
Tank Farms		General Information	None identified
Fuels, Chemicals, PCBs		General Information	Chemicals, reagents, and petroleum products have not been stored or disposed of safely at the site. Leaking containers, spilled powder, ripped bags, open barrels, and chemical spills have been documented. The various chemicals and estimated volumes are listed below. In addition, 275 empty barrels have been deposited throughout the site.
	Copper Sulphate	Contents and Volume	1000 kg
	Dense Soda Ash	Contents and Volume	324 bags (mass unknown)
	Hydrated Lime	Contents and Volume	18 bags (25 kg each)

TABLE 2.1 (Cont'd)
PHYSICAL FEATURES OF THE MOUNT NANSEN MINE SITE

Physical Parameter	Key Features	Characteristics	Description
Fuels, Chemicals, PCBs	**Hydrochloric Acid**	Contents and Volume	11 drums
	Hydrogen Peroxide	Contents and Volume	38 drums
	Sodium Metabisulphite	Contents and Volume	392 bags (22.67 kg each)
	Sodium Hydroxide	Contents and Volume	Not determined
	Sulphur Dioxide	Contents and Volume	Not determined
	Borax Dehydrate	Contents and Volume	100 bags (22.67 kg each)
	Lead Nitrate	Contents and Volume	12 cans (25 kg each)
	Manganese Dioxide	Contents and Volume	36 pails (25 L or 32.67 kg each)
	Sodium Nitrate	Contents and Volume	20 bags (22.67 kg each)
	Soidum Cyanide	Contents and Volume	Unknown
	Ammonium nitrate	Contents and Volume	2 pallets (2000 kg each)
	Sulphur Dioxide Tank	Contents and Volume	Tank reportedly empty by site personnel (unconfirmed)
		Container Type and Number	One 36 m^3 tank railcar
		Condition of Containers	Good condition (2000)
		Evidence of Leakage/Spillage	None identified
		Documented Incidents or Spills	None identified
		Additional Information	Tank was to be emptied and purged with dry air at closure.
	Petroleum Products	Type of Contaminant	Petroleum products and solvents, including grease, lubricant, antifreeze, heating oil, motor oil, transmission oil, antiscalant compounds and other reagents.
		Volume	Over 70 drums and various 25 L pails and buckets
		Condition of Container	Varied condition. Some lids loose or open.
		Evidence of Leakage/Spillage	Yes. Majority are stored outside and are exposed to the elements.
		Documented Incidents or Spills	Undetermined
		Additional Information	Stored in various areas around the mine site, both inside and outside.
	Gasoline and Diesel Tanks	Type of Contaminant	Gasoline and diesel fuel
		Volume	5 tanks totalling over 75,000 litres
		Condition of Container	Good condition (2000)

TABLE 2.1 (Cont'd)
PHYSICAL FEATURES OF THE MOUNT NANSEN MINE SITE

Physical Parameter	Key Features	Characteristics	Description
Fuels, Chemicals, PCBs	**Gasoline and Diesel Tanks**	Evidence of Leakage/Spillage	No, however slight hydrocarbon odour emanated from the soil of one tank at the Ketza yard.
		Documented Incidents or Spills	10,000 litres of diesel fuel spilled onto the ground from a broken fuel line in Sept 1996. Surface water and surface contamination was remediate, however no subsurface or groundwater remediation was conducted. Another diesel fuel spill occurred in May 1997; however details of the spill were not documented.
		Additional Information	None at this time
Additional Physical Hazards		General Information	Placer operations and extensive exploration trenching has caused enhanced erosion and gullying in places. These disturbances may be a hazard to unaware ATV and snowmobile users.
***Site data from Conor Pacific (2000) unless otherwise cited.**			

The main areas of concern for the Mount Nansen Mine site are:

- unstable open pit walls and surrounding waste rock and overburden;
- flooded open pit and workings;
- unstable tailings impoundment dam;
- unsealed mine entrances (including at least four adits);
- several ancillary and support buildings in advanced states of disrepair;
- numerous mine chemical and reagent supplies (PCBs, hydrocarbons, explosives, milling reagents, and assay chemicals);
- exposed tailings and tailings surface pond water;
- hydrocarbon impacted soils near the fuel tanks; and,
- an unknown quantity of submerged tailings.

Asbestos Containing Materials (ACM) in various forms exist at several of the sites assessed in this study. In most jurisdictions, ACM is defined as any material containing more than one percent (1%) asbestos. Based on this definition, most asbestos containing material found at the abandoned mine sites and former military sites (e.g. insulated piping, asbestos board) would be classified as ACM. Accidental or intentional disturbances of ACM can result in fibre release and consequently pose a health hazard to individuals handling the material. This particular health hazard has not been considered in these SLRAs.

3.0 CHEMICAL HAZARD IDENTIFICATION

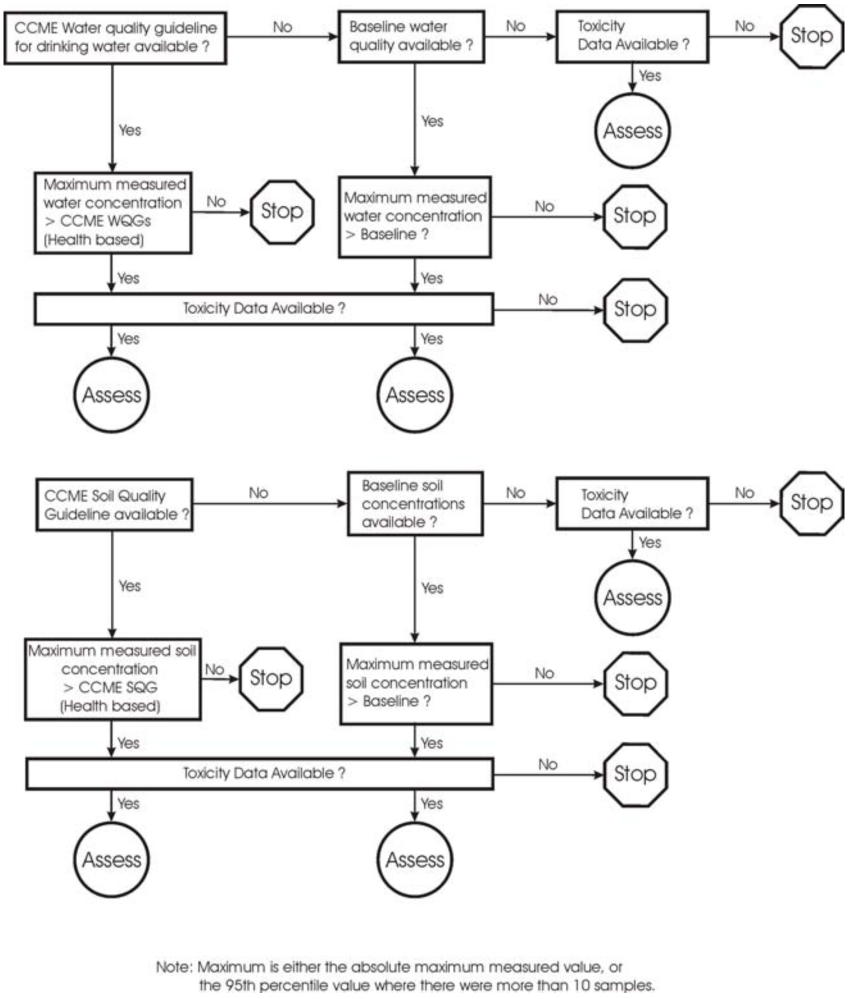
This section identifies the contaminants of concern that are selected for this assessment of potential human health effects from exposure to chemical contaminants.

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.

Environmental data (water, soil, and sediment data) was taken from Conor Pacific (2000); *Mount Nansen Minesite Historical Review, Site Assessment, and Field Sampling Program.* The data used from this report was acquired from a field sampling program conducted in September and October of 1999.

Water Quality

Water quality was measured at several locations within the Dome Creek, Pony Creek, and Victoria Creek drainages surrounding the Mount Nansen Mine site (Figure 2.2). The Dome Creek watershed is the most impacted from mining at Mount Nansen, as it contains the mill site and tailings facility. Currently, the tailings facility is being maintained and water from the tailings pond is treated before discharge into Dome Creek (Conor Pacific 2000). Water quality from sampling locations in Dome Creek presumably reflects the effects of treatment.

The objective of this SLRA was to assess a scenario in which maintenance or treatment of mine facilities has ceased. Due to the lack of data, and lack of information to make predictions on water quality within Dome Creek for post-mill operation and post-water treatment, it was decided to use water quality from a tailings seepage sampling location, labelled D3 to represent the scenario. This sample location has been assumed to represent seepage emanating directly from the tailings facility with minimal effects of natural attenuation or dilution and is therefore assumed to be a conservative estimate of long-term contamination in Dome Creek. Table 3.1 shows these concentrations. Concentrations that were measured below the method detection limit (MDL) were reported as ½ the detection limit, as indicated on the table.

As shown in Table 3.1, the measured concentrations of barium, cadmium, chromium, lead, mercury, nitrate, nitrite and zinc were below CCME guidelines and were not assessed further. The measured concentrations of aluminum, antimony, arsenic, copper, manganese, nickel, selenium, uranium and cyanide exceed CCME guidelines and are considered contaminants of potential concern (COPC). Beryllium, molybdenum, tin, and vanadium do not have CCME guidelines; however the concentrations were at baseline levels and were not considered further. Toxicity data are not available for ammonia, iron, lithium, magnesium, and titanium and therefore, these contaminants were dropped from further assessment. Finally, cobalt, silver, strontium, and thiocyanate were also identified as COPC since the measured concentrations exceed baseline levels at the site and toxicity data are available for these species.

TABLE 3.1
SUMMARY OF WATER QUALITY DATA

Contaminant	CCME Drinking Water Guideline (mg/L)	Measured Seepage Water Quality at Mount Nansen[a] (mg/L)	Baseline Water Concentration[b] (mg/L)
Metals			
Aluminum	0.2 (0.1)[c]	**2.45**	0.068
Antimony	0.006	**0.01**[e]	0.1[e]
Arsenic	0.025	**0.18**	0.1[e]
Barium	1.0	0.103	0.05
Beryllium	-	0.0001[e]	0.0001[e]
Cadmium	0.005	0.0015	0.00025[e]
Chromium	0.05	0.004	0.0005[e]
Cobalt	-	0.1	0.0005[e]
Copper	< 1.0[d]	**4.82**	0.0088

TABLE 3.1 (Cont'd)
SUMMARY OF WATER QUALITY DATA

Contaminant	CCME Drinking Water Guideline (mg/L)	Measured Seepage Water Quality at Mount Nansen[a] (mg/L)	Baseline Water Concentration[b] (mg/L)
Iron	< 0.3[d]	**11.3**	0.18
Lead	0.010	0.0025[e]	0.0025[e]
Lithium	-	0.004	0.0025
Magnesium	-	32	9.5
Manganese	< 0.05[d]	**7.99**	0.067
Mercury	0.001	0.0001	0.00005[e]
Molybdenum	-	0.0025[e]	0.0025[e]
Nickel	-	0.059	0.001[e]
Selenium	0.01	**0.01[e]**	0.015
Silver	-	0.022	0.0005[e]
Strontium	-	0.433	0.191
Tin	-	0.0025[e]	0.0025[c]
Titanium	-	0.142	0.0014
Uranium	0.02	**0.03[e]**	0.038
Vanadium	-	0.001[e]	0.001[c]
Zinc	5.0[d]	0.088	0.029
Organic Contaminants			
Ammonia – N	-	11.8	0.025
Cyanide	0.2[f]	**2[f]**	0.002
Nitrate – N	10	2.35	0.115
Nitrite – N	3.2	0.05	0.0015
Thiocyanates	-	86.4	0.61

Notes: Values in **bold** exceed the guideline.

- indicates that a CCME guideline for drinking water is not available.

a - From sampling location D3 (tailings impoundment seepage into Dome Creek) Appendix F, Conor Pacific (2000).

b - Average water quality of samples from four "upstream" sample locations within the Nisling River, Victoria Creek, and Dome Creek (NS1, V1, V3, and D1). Appendix F, Conor Pacific (2000).

c - 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.

d - Guideline is based on aesthetic concerns.

e - Measured value was less than method detection limit (MDL), thus was set to half MDL.

f - Estimated total cyanide concentrations from Figure 5, Kwong (2002).

Soil Quality

The next step in the screening selection process involved a comparison of the maximum contaminant levels measured in soil to available CCME soil quality guidelines (CCME 2002), as shown in Table 3.2. Soil sampling of five locations on the Mount Nansen Mine site was completed in 2000. These sampling locations focused on suspected contaminated areas or spill areas (Conor Pacific 2000). Maximum measured concentrations of metals and suspected contaminants in soil from these five locations across the mine site are presented in Table 3.2. Total petroleum hydrocarbons (TPH) were measured and the following fractions were reported:

- VPH – Volatile Petroleum Hydrocarbons (C6-C10 Purgeable), which does not include BTEX compounds; and
- EPH – Extractable Petroleum Hydrocarbons (C10-C19 and C19-C32).

The CCME released (May 2000) a standard for Petroleum Hydrocarbons in soil, which is used in this assessment. In assessing TPH, the CCME recommends that the fractions be broken down into:

Fraction 1, represented as F1	nC6 to nC10
Fraction 2, represented as F2	>nC10 to nC16
Fraction 3, represented as F3	>nC16 to nC34
Fraction 4, represented as F4	nC35+

For purposes of this assessment, it was assumed that the purgeable fraction (VPH) is directly equivalent to F1. The total extractable petroleum hydrocarbons EPH, as reported above, are represented by C10 to C32. This range encompasses both the F2 and F3 fractions. In this assessment, the F2 fraction was used to represent the entire concentration of EPH (i.e. F2+F3). This is a conservative approach since the F3 fraction is less volatile and soluble than the F2 fraction.

Maximum measured concentrations of beryllium, cadmium, chromium, cobalt, copper, nickel, selenium, silver, tin, vanadium, benzene, toluene, ethylbenzene, and xylenes were below the CCME guidelines for human health and therefore, these contaminants were dropped from further assessment. Similarly, aluminum, iron, manganese, strontium, titanium, and uranium were below typical levels in soil and were dropped from further assessment

Maximum measured concentrations of antimony, arsenic, barium, lead, molybdenum, zinc, and total petroleum hydrocarbons (F1, F2, and F3) exceed the CCME guidelines for human health and therefore these contaminants are considered COPC.

TABLE 3.2
SUMMARY OF SOIL QUALITY DATA

Contaminant	CCME Soil Quality Guideline (Human Health)[a] (mg/kg)	Maximum Measured Soil Concentration[b] (mg/kg)	Typical Soil Concentration[c] (mg/kg)
Metals			
Aluminum	-	40,800	155,000
Antimony	20 *	**310**	5.3
Arsenic	12	**1,240**	20.5
Barium	500 *	**530**	1800
Beryllium	4 *	0.7	20.1
Bismuth	-	10	n/a
Cadmium	14	8.5	3.5
Chromium	220	72.9	1,503
Cobalt	50 *	12.9	20.5
Copper	1,100	255	51
Iron	-	92,000	278,000
Lead	140	**760**	101
Manganese	-	1,850	2,050
Molybdenum	10 *	**13,700**	2.6
Nickel	50 *	49.2	503
Selenium	28	1[d]	28
Silver	20 *	11.9	2.6
Strontium	-	130	525
Tin	50	2	101
Titanium	-	1330	5,500
Uranium	-	2.5[d]	5.0
Vanadium	130 *	79	260
Zinc	200 *	**1790**	155
Organic Contaminants			
Benzene	0.5*	0.17	-
Toluene	0.8	0.01	-
Ethylbenzene	1.2*	0.01	-
Xylenes	5	0.42	-
Total Petroleum Hydrocarbons (C6-C10) – Fraction 1	50[e] 1,500[f]	**61**	-
TPH (C10-19) – Fraction 2	240[e] 8,000[f]	**54,100**	-
TPH (C19-32) – Fraction 3	18,000[f]	**50,700**	-

Notes: Values in **bold** exceed the guideline. **-** Denotes that data is not available.

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

b - Maximum concentrations of the five soil samples from Mount Nansen Mine Site (SAG-GS1; Mill-GS2; Polish Pond-GS3; Ketza-GS4; and Ketza-GS5) reported in Appendix F, Conor Pacific (2000).

c - Typical concentrations in native soil for various locations, from Dragun (1998).

d - Measured value was less than method detection limit (MDL), thus was set to half MDL.

e - Canada-Wide Standard for Petroleum Hydrocarbons in Soil – Vapour Inhalation (Indoor, slab-on-grade) from CCME 2000 residential land use.

f - Canada-Wide Standard for Petroleum Hydrocarbons in Soil – Soil Ingestion from CCME 2000 residential land use.

In order to assess the different fractions of TPH, the CCME breaks down the fractions into an aromatic and aliphatic portion and recommend an aliphatic:aromatic ratio of 80:20. This ratio is applied in this assessment.

The COPC determined for the water and soil data assessments are combined to form a list of designated COPC for use in the assessment. The complete list of COPC considered in the assessment is shown in Table 3.3.

TABLE 3.3
COPC SELECTED FOR THE ASSESSMENT

Aluminum
Antimony
Arsenic
Barium
Cobalt
Copper
Cyanide
Lead
Manganese
Molybdenum
Nickel
Selenium
Silver
Strontium
Thiocyanate
Uranium
Zinc
F1-TPH (C6-C10)
F2-TPH (C10-C16)
F3-TPH (C16-C34)

3.2 SUMMARY OF OTHER CHEMICAL DATA FOR SLRA

The screening level risk assessment for the Mount Nansen Mine used available measured data where possible. In addition to measured water and soil data, measured data for sediment were available.

Sediment Concentrations

Measured sediment concentrations were available from nine sampling locations within Dome Creek, Pony Creek, and Victoria Creek (Figure 1-2). The maximum measured concentration of COPC listed in Table 3.3 from these nine sediments is shown in Table 3.4.

TABLE 3.4
MEASURED CONTAMINANT LEVELS IN SEDIMENT

Contaminant	**Measured Sediment Concentration (mg/kg)** [a]
Metals	
Aluminum	57,900
Antimony	310
Arsenic	4480
Barium	669
Cobalt	21.7
Copper	1150
Cyanide	-
Lead	4090
Manganese	6210
Molybdenum	5
Nickel	20.3
Selenium	1[b]
Silver	98.9
Strontium	93
Thiocyanate	-
Uranium	2.5[a]
Zinc	2070
Petroleum Hydrocarbons	-

Notes:

a – Maximum measured concentration of nine sediment sample locations from Mount Nansen Mine. Data from Conor Pacific (2000) Appendix F, samples V1, V4, V5, P1, P2, D1, D2, D3, and V6.

b – Measured value was less than method detection limit (MDL), thus was set to half MDL.

\- No data available.

4.0 RECEPTOR CHARACTERIZATION

This section of the report discusses the characteristics of the receptors selected as well as the exposure pathways considered in the assessment of exposure to chemical hazards. Exposure pathways for assessment of the risks of physical harm are also identified.

4.1 EXPOSURE SCENARIO AND RECEPTOR SELECTION

The scenario examined in this assessment involved the abandonment of the site in its existing condition. Given the proximity of the site to currently active placer mining operations (Wiatzka 2003), it is not unreasonable to consider that individuals would visit the site to camp. The mine site is within Little Salmon/Carmacks First Nations traditional territory, and is within the migratory route of woodland caribou and mountain sheep (Conor Pacific 2000).

An adult and child (5 to 11 years) were assumed to camp adjacent to Dome Creek, downstream of the tailings facility where the access road crosses Dome Creek (Figure 2.2). These individuals were assumed to spend three months of the year on the site and obtain wild game, berries, and drinking water from the mine site area. While other visitors (e.g., inspectors) may visit the site, the camper receptor represents the most exposed individuals.

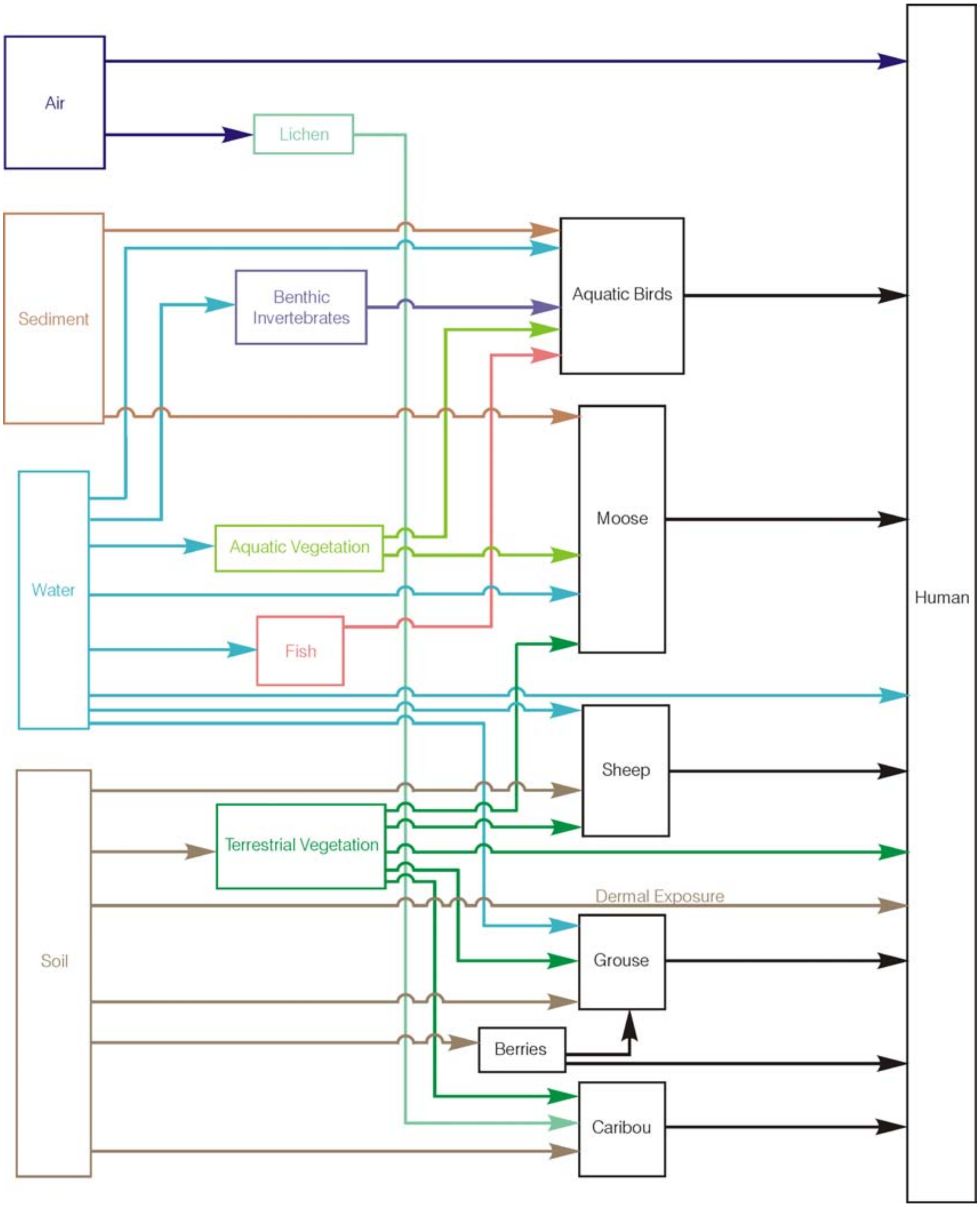
Fish have not been included as intake to the human receptor for two reasons. (1) Dome Creek and Pony Creek, which run through the mine site, were considered to be too small to have significant fisheries habitat according to Conor Pacific (2000); and (2) there is no data for representative water quality downstream of the mine site for post-water treatment conditions. Furthermore, the closest confluence, Victoria Creek, is several kilometres downstream and was classified as a Type IV stream under the authority of the Yukon Placer Authorization of the federal *Fisheries Act* (Conor Pacific, 2000). Type IV streams either have no fish at all, fish of no significant commercial or cultural value, or fish that are widespread enough that the streams do not contribute to biodiversity.

4.2 EXPOSURE PATHWAYS CONSIDERED – CHEMICAL HAZARDS

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

- inhalation of air;
- consumption of berries, moose, woodland caribou, sheep, 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. In lieu of diet and intake estimates for communities in the region, a diet was derived from the Sahtu community in the NWT (Receveur *et al.* 1996). The Sahtu community was assumed to be similar and therefore representative of a native diet for the Mount Nansen area. These intake estimates were adjusted for the game known to inhabit the Mount Nansen Mine site, namely woodland caribou and sheep. It was assumed that the human receptors ate moose, woodland caribou, sheep, grouse, mallard and berries. The uptake rates of game, water, soil, air, and other exposures for adult and child receptors are listed below in Table 4.1.

TABLE 4.1
HUMAN RECEPTOR CHARACTERISTICS

	Adult	**Child (5 to 11 years)**
Fraction of year at site (-) [a,b]	0.25	0.25
Fraction of traditional food from local sources while at site the site (-) [b]	1.0	1.0
Fraction of water from site (-) [b]	1.0	1.0
Body weight (kg) [c]	70.7	32.9
Soil ingestion rate (g/d)[c, f]	0.02	0.08
Food ingestion rate – meat sources (g/d) [d]	456	337
Grouse ingestion rate (g/d) [d]	2.3	1.7
Aquatic bird ingestion rate (g/d) [d]	1.3	0.96
Moose ingestion rate (g/d) [d]	58	42.9
Sheep ingestion rate (g/d) [d]	58	42.9
Caribou ingestion rate (g/d) [d]	243	180
Water ingestion rate (L/d)[c]	1.5	0.8
Berry ingestion rate (g/d) [d]	0	0
Breathing rate (m^3/d)[c]	15.8	14.5
Skin surface area - total (m^2) [c]	0.911	0.514
Exposed fraction of skin [b]	0.26	0.26
Soil loading to exposed skin (g/cm^2) [e]		
hands	1×10^{-3}	1×10^{-3}
surfaces other than hands	1×10^{-4}	1×10^{-4}

Notes:

a – equal to three months of the year.

b – assumed.

c – from Richardson (1997).

d – based on Receveur *et al.* (1996).

e – from Kissel *et al.* (1996, 1998).

f – assumed that a child 5 to 11 years old has the same soil 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.

Using data from a Canada-wide survey carried out by Health Canada (Richardson 1997), a ratio of 74% was derived for the intake of a child compared to an adult. This ratio was applied to intakes of the various dietary components.

For the calculations, drinking water, and food components were linked to the measured concentrations from the sample locations around the Mount Nansen Mine Site, as described in Chapter 3.

4.4 EXPOSURE PATHWAYS – PHYSICAL HAZARDS

The Mount Nansen Mine site is accessible by car (summer), skidoo (winter) and presumably by plane (condition of the runway is unknown). 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 flooded open pit, entering one of four known adits to explore the mine, or entering a deteriorated building.

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 receptor 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 receptor was calculated using the equations provided in Appendix A.

Table 5.1 summarizes the calculated ingestion intakes of COPC by pathway for the selected adult human receptors at the Mount Nansen site. Table 5.2 shows the total intakes for ingestion, inhalation and dermal exposure for the adult receptor. Tables 5.3 and 5.4 summarize the results for the child human receptor.

TABLE 5.1
CALCULATED INGESTION INTAKES BY PATHWAY – ADULT RECEPTOR

Contaminant	Intake through Ingestion Pathways (mg/(kg d))								
	Water	**Moose**	**Caribou**	**Sheep**	**Grouse**	**Mallard**	**Berries**	**Soil**	**Air**
Aluminum	$1.30\text{x}10^{-2}$	$2.65\text{x}10^{-3}$	$2.16\text{x}10^{-3}$	$1.93\text{x}10^{-4}$	$2.17\text{x}10^{-4}$	$1.26\text{x}10^{-4}$	$6.75\text{x}10^{-4}$	$2.89\text{x}10^{-3}$	$8.94\text{x}10^{-6}$
Antimony	$5.30\text{x}10^{-5}$	$2.82\text{x}10^{-4}$	$5.34\text{x}10^{-6}$	$1.95\text{x}10^{-5}$	$2.59\text{x}10^{-5}$	$1.50\text{x}10^{-6}$	$1.58\text{x}10^{-7}$	$2.19\text{x}10^{-5}$	-
Arsenic	$9.55\text{x}10^{-4}$	$4.56\text{x}10^{-4}$	$4.71\text{x}10^{-5}$	$8.31\text{x}10^{-5}$	$1.80\text{x}10^{-5}$	$1.22\text{x}10^{-4}$	$7.50\text{x}10^{-6}$	$8.77\text{x}10^{-5}$	$5.59\text{x}10^{-8}$
Barium	$5.46\text{x}10^{-4}$	$9.65\text{x}10^{-6}$	$8.01\text{x}10^{-7}$	$1.06\text{x}10^{-6}$	$5.48\text{x}10^{-7}$	$1.21\text{x}10^{-6}$	$3.27\text{x}10^{-5}$	$3.75\text{x}10^{-5}$	-
Cobalt	$5.30\text{x}10^{-4}$	$3.33\text{x}10^{-4}$	$7.35\text{x}10^{-6}$	$1.35\text{x}10^{-6}$	$1.24\text{x}10^{-6}$	$9.06\text{x}10^{-5}$	$5.75\text{x}10^{-7}$	$9.12\text{x}10^{-7}$	$5.59\text{x}10^{-9}$
Copper	$2.56\text{x}10^{-2}$	$2.41\text{x}10^{-2}$	$4.16\text{x}10^{-4}$	$6.24\text{x}10^{-4}$	$1.09\text{x}10^{-5}$	$1.04\text{x}10^{-3}$	$4.22\text{x}10^{-4}$	$1.80\text{x}10^{-5}$	$1.68\text{x}10^{-7}$
Cyanide	$1.06\text{x}10^{-2}$	$2.10\text{x}10^{-4}$	$2.61\text{x}10^{-5}$	$7.38\text{x}10^{-6}$	$6.64\text{x}10^{-6}$	$2.35\text{x}10^{-6}$	-	-	-
Lead	$1.33\text{x}10^{-5}$	$6.83\text{x}10^{-5}$	$2.94\text{x}10^{-5}$	$3.89\text{x}10^{-6}$	$3.23\text{x}10^{-6}$	$3.59\text{x}10^{-6}$	$4.35\text{x}10^{-4}$	$5.37\text{x}10^{-5}$	$1.12\text{x}10^{-7}$
Manganese	$4.24\text{x}10^{-2}$	$1.60\text{x}10^{-3}$	$2.26\text{x}10^{-5}$	$8.38\text{x}10^{-5}$	$2.27\text{x}10^{-5}$	$8.79\text{x}10^{-6}$	$5.89\text{x}10^{-4}$	$1.31\text{x}10^{-4}$	-
Molybdenum	$1.33\text{x}10^{-5}$	$4.07\text{x}10^{-3}$	$2.04\text{x}10^{-4}$	$1.67\text{x}10^{-3}$	$1.04\text{x}10^{-3}$	$3.51\text{x}10^{-6}$	$1.05\text{x}10^{-2}$	$9.69\text{x}10^{-4}$	$5.59\text{x}10^{-8}$
Nickel	$3.13\text{x}10^{-4}$	$2.60\text{x}10^{-5}$	$4.33\text{x}10^{-5}$	$7.35\text{x}10^{-6}$	$4.97\text{x}10^{-6}$	$6.94\text{x}10^{-6}$	$5.64\text{x}10^{-5}$	$3.48\text{x}10^{-6}$	$3.35\text{x}10^{-8}$
Selenium	$5.30\text{x}10^{-5}$	$6.64\text{x}10^{-6}$	$1.96\text{x}10^{-6}$	$1.20\text{x}10^{-6}$	$1.86\text{x}10^{-7}$	$2.03\text{x}10^{-5}$	$1.85\text{x}10^{-8}$	$7.07\text{x}10^{-8}$	$5.59\text{x}10^{-10}$
Silver	$1.17\text{x}10^{-4}$	$2.24\text{x}10^{-5}$	$2.84\text{x}10^{-6}$	$3.85\text{x}10^{-6}$	$8.79\text{x}10^{-7}$	$1.27\text{x}10^{-5}$	$3.11\text{x}10^{-6}$	$8.42\text{x}10^{-7}$	$3.91\text{x}10^{-9}$
Strontium	$2.30\text{x}10^{-3}$	$6.56\text{x}10^{-4}$	$1.11\text{x}10^{-5}$	$2.80\text{x}10^{-5}$	$1.04\text{x}10^{-6}$	$4.52\text{x}10^{-6}$	$1.65\text{x}10^{-4}$	$9.19\text{x}10^{-6}$	-
Thiocyanate	$4.58\text{x}10^{-1}$	$5.39\text{x}10^{-8}$	$6.70\text{x}10^{-9}$	$1.89\text{x}10^{-9}$	$1.70\text{x}10^{-9}$	$6.04\text{x}10^{-10}$	-	-	-
Uranium	$1.59\text{x}10^{-4}$	$9.40\text{x}10^{-7}$	$1.41\text{x}10^{-8}$	$6.18\text{x}10^{-7}$	$3.58\text{x}10^{-8}$	$1.63\text{x}10^{-6}$	$1.75\text{x}10^{-8}$	$1.77\text{x}10^{-7}$	-
Zinc	$4.67\text{x}10^{-4}$	$2.15\text{x}10^{-1}$	$1.58\text{x}10^{-2}$	$1.34\text{x}10^{-2}$	$4.03\text{x}10^{-3}$	$8.02\text{x}10^{-3}$	$1.13\text{x}10^{-2}$	$1.27\text{x}10^{-4}$	$6.15\text{x}10^{-7}$
F1 Aliphatic	-	-	-	-	-	-	-	$3.45\text{x}10^{-6}$	4.75
F1 Aromatic	-	-	-	-	-	-	-	$8.63\text{x}10^{-7}$	$5.96\text{x}10^{-2}$
F2 Aliphatic	-	-	-	-	-	-	-	$3.06\text{x}10^{-3}$	$1.17\text{x}10^{-1}$
F2 Aromatic	-	-	-	-	-	-	-	$7.65\text{x}10^{-4}$	$1.05\text{x}10^{-1}$
F3 Aliphatic	-	-	-	-	-	-	-	$2.87\text{x}10^{-3}$	$1.12\text{x}10^{-4}$
F3 Aromatic	-	-	-	-	-	-	-	$7.17\text{x}10^{-4}$	$1.96\text{x}10^{-9}$

TABLE 5.2
CALCULATED TOTAL INTAKES BY PATHWAY – ADULT RECEPTOR

Contaminant	Inhalation	Ingestion	Dermal	Total
	Pathway (mg/kg d)	Pathway (mg/kg d)	Pathway (mg/kg d)	Pathway (mg/kg d)
Aluminum	8.94x10^{-6}	2.19x10^{-2}	3.42x10^{-2}	5.61x10^{-2}
Antimony	-	4.09x10^{-4}	2.60x10^{-4}	6.69x10^{-4}
Arsenic	5.59x10^{-8}	1.78x10^{-3}	3.32x10^{-4}	2.11x10^{-3}
Barium	-	6.30x10^{-4}	4.44x10^{-4}	1.07x10^{-3}
Cobalt	5.59x10^{-9}	9.65x10^{-4}	1.08x10^{-5}	9.76x10^{-4}
Copper	1.68x10^{-7}	5.22x10^{-2}	2.14x10^{-4}	5.24x10^{-2}
Cyanide				
Cyanide	-	1.09x10^{-2}	-	1.09x10^{-2}
Lead	1.12x10^{-7}	6.11x10^{-4}	3.82x10^{-5}	6.49x10^{-4}
Manganese	-	4.48x10^{-2}	1.55x10^{-3}	4.64x10^{-2}
Molybdenum	5.59x10^{-8}	1.84x10^{-2}	1.15x10^{-2}	2.99x10^{-2}
Nickel	3.35x10^{-8}	4.61x10^{-4}	1.44x10^{-4}	6.06x10^{-4}
Selenium	5.59x10^{-10}	8.35x10^{-5}	1.68x10^{-8}	8.35x10^{-5}
Silver	3.91x10^{-9}	1.63x10^{-4}	2.49x10^{-5}	1.88x10^{-4}
Strontium	-	3.17x10^{-3}	1.09x10^{-4}	3.28x10^{-3}
Thiocyanate	-	4.58x10^{-1}	-	4.58x10^{-1}
Uranium	-	1.63x10^{-4}	2.09x10^{-6}	1.65x10^{-4}
Zinc	6.15x10^{-7}	2.68x10^{-1}	3.00x10^{-4}	2.69x10^{-1}
F1 Aliphatic	4.75	3.45x10^{-6}	4.09x10^{-5}	4.75
F1 Aromatic	5.96x10^{-2}	8.63x10^{-7}	1.02x10^{-5}	5.96x10^{-2}
F2 Aliphatic	1.17x10^{-1}	3.06x10^{-3}	3.62x10^{-2}	1.56x10^{-1}
F2 Aromatic	1.05x10^{-1}	7.65x10^{-4}	9.06x10^{-3}	1.15x10^{-1}
F3 Aliphatic	1.12x10^{-4}	2.87x10^{-3}	3.40x10^{-2}	3.70x10^{-2}
F3 Aromatic	1.96x10^{-9}	7.17x10^{-4}	8.49x10^{-3}	9.21x10^{-3}

TABLE 5.3
CALCULATED INGESTION INTAKES BY PATHWAY – CHILD RECEPTOR

Contaminant	Intake through Ingestion Pathways (mg/(kg d))								
	Water	**Moose**	**Caribou**	**Sheep**	**Grouse**	**Mallard**	**Berries**	**Soil**	**Air**
Aluminum	1.49x10^{-2}	4.22x10^{-3}	3.43x10^{-3}	3.07x10^{-4}	3.45x10^{-4}	2.00x10^{-4}	1.07x10^{-3}	2.48x10^{-2}	1.76x10^{-5}
Antimony	6.08x10^{-5}	4.49x10^{-4}	8.48x10^{-6}	3.11x10^{-5}	4.11x10^{-5}	2.39x10^{-6}	2.51x10^{-7}	1.88x10^{-4}	-
Arsenic	1.09x10^{-3}	7.24x10^{-4}	7.50x10^{-5}	1.32x10^{-4}	2.87x10^{-5}	1.94x10^{-4}	1.19x10^{-5}	7.54x10^{-4}	1.10x10^{-7}
Barium	6.26x10^{-4}	1.54x10^{-5}	1.27x10^{-6}	1.69x10^{-6}	8.71x10^{-7}	1.93x10^{-6}	5.20x10^{-5}	3.22x10^{-4}	-
Cobalt	6.08x10^{-4}	5.30x10^{-4}	1.17x10^{-5}	2.15x10^{-6}	1.96x10^{-6}	1.44x10^{-4}	9.14x10^{-7}	7.84x10^{-6}	1.10x10^{-8}
Copper	2.93x10^{-2}	3.83x10^{-2}	6.61x10^{-4}	9.92x10^{-4}	1.74x10^{-5}	1.65x10^{-3}	6.71x10^{-4}	1.55x10^{-4}	3.31x10^{-7}
Cyanide	1.22x10^{-2}	3.34x10^{-4}	4.15x10^{-5}	1.17x10^{-5}	1.06x10^{-5}	3.74x10^{-6}	-	-	-
Lead	1.52x10^{-5}	1.09x10^{-4}	4.68x10^{-5}	6.19x10^{-6}	5.14x10^{-6}	5.70x10^{-6}	6.92x10^{-4}	4.62x10^{-4}	2.20x10^{-7}
Manganese	4.86x10^{-2}	2.55x10^{-3}	3.59x10^{-5}	1.33x10^{-4}	3.60x10^{-5}	1.40x10^{-5}	9.36x10^{-4}	1.12x10^{-3}	-
Molybdenum	1.52x10^{-5}	6.48x10^{-3}	3.25x10^{-4}	2.66x10^{-3}	1.65x10^{-3}	5.58x10^{-6}	1.66x10^{-2}	8.33x10^{-3}	1.10x10^{-7}
Nickel	3.59x10^{-4}	4.14x10^{-5}	6.89x10^{-5}	1.17x10^{-5}	7.90x10^{-6}	1.10x10^{-5}	8.96x10^{-5}	2.99x10^{-5}	6.61x10^{-8}
Selenium	6.08x10^{-5}	1.06x10^{-5}	3.12x10^{-6}	1.91x10^{-6}	2.96x10^{-7}	3.23x10^{-5}	2.94x10^{-8}	6.08x10^{-7}	1.10x10^{-9}
Silver	1.34x10^{-4}	3.56x10^{-5}	4.52x10^{-6}	6.12x10^{-6}	1.40x10^{-6}	2.02x10^{-5}	4.94x10^{-6}	7.23x10^{-6}	7.71x10^{-9}
Strontium	2.63x10^{-3}	1.04x10^{-3}	1.76x10^{-5}	4.46x10^{-5}	1.65x10^{-6}	7.19x10^{-6}	2.63x10^{-4}	7.90x10^{-5}	-
Thiocyanate	5.25x10^{-1}	8.57x10^{-8}	1.07x10^{-8}	3.01x10^{-9}	2.71x10^{-9}	9.60x10^{-10}	-	-	-
Uranium	1.82x10^{-4}	1.50x10^{-6}	2.24x10^{-8}	9.83x10^{-7}	5.70x10^{-8}	2.59x10^{-6}	2.78x10^{-8}	1.52x10^{-6}	-
Zinc	5.35x10^{-4}	3.42x10^{-1}	2.52x10^{-2}	2.13x10^{-2}	6.41x10^{-3}	1.28x10^{-2}	1.79x10^{-2}	1.09x10^{-3}	1.21x10^{-6}
F1 Aliphatic	-	-	-	-	-	-	-	2.97x10^{-5}	9.37
F1 Aromatic	-	-	-	-	-	-	-	7.42x10^{-6}	1.17x10^{-1}
F2 Aliphatic	-	-	-	-	-	-	-	2.63x10^{-2}	2.30x10^{-1}
F2 Aromatic	-	-	-	-	-	-	-	6.58x10^{-3}	2.07x10^{-1}
F3 Aliphatic	-	-	-	-	-	-	-	2.47x10^{-2}	2.20x10^{-4}
F3 Aromatic	-	-	-	-	-	-	-	6.16x10^{-3}	3.86x10^{-9}

TABLE 5.4
CALCULATED TOTAL INTAKES BY PATHWAY – CHILD RECEPTOR

Contaminant	Inhalation Pathway (mg/kg d)	Ingestion Pathway (mg/kg d)	Dermal Pathway (mg/kg d)	Total Pathway (mg/kg d)
Aluminum	1.76x10^{-5}	4.93x10^{-2}	4.14x10^{-2}	9.07x10^{-2}
Antimony	-	7.81x10^{-4}	3.15x10^{-4}	1.10x10^{-3}
Arsenic	1.10x10^{-7}	3.01x10^{-3}	4.03x10^{-4}	3.42x10^{-3}
Barium	-	1.02x10^{-3}	5.38x10^{-4}	1.56x10^{-3}
Cobalt	1.10x10^{-8}	1.31x10^{-3}	1.31x10^{-5}	1.32x10^{-3}
Copper	3.31x10^{-7}	7.17x10^{-2}	2.59x10^{-4}	7.20x10^{-2}
Cyanide				
Cyanide	-	1.26x10^{-2}	-	1.26x10^{-2}
Lead	2.20x10^{-7}	1.34x10^{-3}	4.63x10^{-5}	1.39x10^{-3}
Manganese	-	5.34x10^{-2}	1.88x10^{-3}	5.53x10^{-2}
Molybdenum	1.10x10^{-7}	3.61x10^{-2}	1.39x10^{-2}	5.00x10^{-2}
Nickel	6.61x10^{-8}	6.19x10^{-4}	1.75x10^{-4}	7.94x10^{-4}
Selenium	1.10x10^{-9}	1.10x10^{-4}	2.03x10^{-8}	1.10x10^{-4}
Silver	7.71x10^{-9}	2.14x10^{-4}	3.02x10^{-5}	2.44x10^{-4}
Strontium	-	4.09x10^{-3}	1.32x10^{-4}	4.22x10^{-3}
Thiocyanate	-	5.25x10^{-1}	-	5.25x10^{-1}
Uranium	-	1.89x10^{-4}	2.54x10^{-6}	1.92x10^{-4}
Zinc	1.21x10^{-6}	4.28x10^{-1}	3.64x10^{-4}	4.28x10^{-1}
F1 Aliphatic	9.37	2.97x10^{-5}	4.96x10^{-5}	9.37
F1 Aromatic	1.17x10^{-1}	7.42x10^{-6}	1.24x10^{-5}	1.18x10^{-1}
F2 Aliphatic	2.30x10^{-1}	2.63x10^{-2}	4.40x10^{-2}	3.00x10^{-1}
F2 Aromatic	2.07x10^{-1}	6.58x10^{-3}	1.10x10^{-2}	2.25x10^{-1}
F3 Aliphatic	2.20x10^{-4}	2.47x10^{-2}	4.12x10^{-2}	6.61x10^{-2}
F3 Aromatic	3.86x10^{-9}	6.16x10^{-3}	1.03x10^{-2}	1.65x10^{-2}

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 5.5 summarizes the statistics for the fatal accidents at abandoned mine sites since 1999.

TABLE 5.5
MSHA STATISTICS OF THE FATAL ACCIDENTS AT ABANDONED MINE SITES

Hazard	**Number of Fatal Accidents**						**Percent**
	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 collapse of 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:
* - Voluntary swimming in pit, therefore not considered in the assessment.
** - 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:

$$\textit{Fatality Rate} = \frac{8.0}{280{,}000{,}000 \times \frac{1}{100}} = 2.9 \times 10^{-6} \qquad (5.1)$$

where:

$2.9\text{x}10^{-6}$ = average annual fatality rate
8 = average number of fatal accidents per year excluding drownings (see Table 5.5)
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, any site-specific information should be factored in for the calculation of 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 5.6 can be established.

TABLE 5.6
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

While unstable surface structures are not specifically mentioned in the fatality statistics, they are an obvious site feature that poses a serious risk to visitors to mine sites. This feature was accordingly included in the assessment.

Table 5.7 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 5.7
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 that there must be greater risks associated with former large scale mining operations than with small scale mine sites. Table 5.8 summarizes the basis proposed to account for differences in the scale of mining operations.

TABLE 5.8
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 Rate$_{site}$ = site-specific fatality rate
Fatality Rate = calculated average annual fatality rate (2.6×10^{-6})
AF = accessibility factor (Table 5.6)

HF = hazard factor (Table 5.7)
SF = scaling factor (Table 5.8)

For the Mount Nansen site, the following factors were identified:

- Accessibility Factor = 1
- Hazard Factor = 40/40 (unsealed mine openings + high pit walls + steep loose rock piles unstable surface structures)
- Scaling Factor = 1

Using these factors and an average annual fatality rate of 2.9 x 10^{-6}, the annual fatality rate from the Mount Nansen Mine site was estimated to equal 2.9 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 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 COPC 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	
	(-)	$(mg/(kg\text{-}d))^{-1}$		(mg/(kg-d))		$(mg/(kg\text{-}d))^{-1}$		(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**	
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)
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:

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

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 year. 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 former military 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 Mount Nansen site, a HQ value of 0.5 was used to assess acceptable exposures.

7.1 NON-CARCINOGENIC EFFECTS

Estimated exposures for the human receptor were calculated using the intakes presented in Section 5.2. These estimates were based on the measured concentrations in water, soil and sediment. 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.

TABLE 7.1
HAZARD QUOTIENTS CALCULATED FOR ADULT AND CHILD AT MOUNT NANSEN SITE

Contaminant	**Hazard Quotient**	
	Adult	**Child**
Aluminum	0.06	0.09
Antimony	**1.7**	**2.7**
Barium	0.07	0.10
Cobalt	0.05	0.07
Copper	**1.7**	**2.4**
Cyanide	**0.5**	**0.6**
Lead	0.4	**0.8**
Manganese	0.3	0.4
Molybdenum	**6.0**	**10**
Nickel	0.03	0.04
Selenium	0.02	0.02
Silver	0.04	0.05
Strontium	0.005	0.007
Thiocyanate	**9.2**	**11**
Uranium	**0.8**	**1.0**
Zinc	**0.9**	**1.4**
F1 Aliphatic	**1.4**	**2.8**
F1 Aromatic	**1.0**	**2.1**
F2 Aliphatic	**0.8**	**1.5**
F2 Aromatic	**2.1**	**4.1**
F3 Aliphatic	0.001	0.002
F3 Aromatic	0.3	**0.5**
TOTAL SITE	**27.4**	**41.2**

From Table 7.1, it can be seen that the hazard quotients calculated for antimony (ingestion and dermal pathways), copper, cyanide, molybdenum, thiocyanate (ingestion pathways), uranium (ingestion and dermal pathways), zinc, petroleum hydrocarbons F1 and F2 (Aliphatic and Aromatic), and F3 Aromatic (child only) exceed the critical value of 0.5. The sum of all HQs was determined to be 27.4 for the adult and 41.2 for the child.

7.2 CARCINOGENIC EFFECTS

Risk levels for exposure to arsenic, cobalt and nickel (via ingestion, dermal and inhalation pathways) are presented in Table 7.2.

TABLE 7.2
RISK LEVELS CALCULATED FOR ADULT AND COMPOSITE RECEPTOR AT THE MOUNT NANSEN SITE

Contaminant	**Risk Level**	
	Adult	**Composite**
Arsenic	**2.5×10^{-3}**	**6.4×10^{-3}**
Cobalt	2.3×10^{-8}	6.2×10^{-8}
Nickel	4.5×10^{-8}	1.2×10^{-7}
TOTAL SITE	**2.5×10^{-3}**	**6.4×10^{-3}**

The estimated risk levels for cobalt and nickel are well below the accepted risk level of 1 x 10^{-5}; however, the risk level for arsenic exceeds the accepted risk level. Arsenic exposure to receptors at the Mount Nansen site is dominated by the ingestion pathway, and in particular, the ingestion of fish. It should be noted that the risk of incurring cancer from arsenic exposure is overstated as it was assumed in the SLRA that arsenic was present in a toxic form in all sources. Typically a portion of arsenic consumed will be in non-toxic forms, in particular the arsenic associated with fish. The total risk level was determined to be 2.5 x 10^{-3} for the adult and 6.4 x 10^{-3} for the composite receptor.

7.3 PHYSICAL RISKS

Currently, physical risks at the site are relatively minor. The flooded pit, unstable pit surfaces and walls, steep waste rock piles, surface openings, and deteriorating buildings pose the most significant risk of physical harm to people who may visit the site. The annual risk of fatality for the Mount Nansen site was evaluated in Section 5 to equal 2.9 x 10^{-6}.

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FINAL DRAFT

APPENDIX A

DETAILED EXPOSURE CALCULATIONS FOR THE HUMAN HEALTH RISK ASSESSMENT

LIST OF TABLES

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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.

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

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.

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

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:

$$I_{water} = \frac{C_{water} \times R_{water} \times F_{site}}{BW} \tag{A-4}$$

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]

$$I_{soil} = \frac{C_{soil} \times R_{soil} \times F_{site}}{BW} \times \frac{1}{1000} \tag{A-5}$$

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]

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

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):

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

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):

$$C_{browse} = C_{soil} \times TF_{soil-to-browse} \tag{A-10}$$

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	$2.6x10^{-3}$	NCRP 1996, Baes et al. 1984
Antimony	0.20	Baes et al. 1984
Arsenic	$7.7x10^{-3}$	NCRP 1996, Baes et al. 1984, U.S. EPA 1998
Barium	$4.5x10^{-3}$	U.S. EPA 1998
Beryllium	$4.5x10^{-4}$	U.S. EPA 1998
Boron	0.03	NCRP 1996
Cadmium	$1.9x10^{-2}$	U.S. EPA 1998
Chromium	$1.4x10^{-3}$	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	$8.6x10^{-3}$	NCRP 1996, Baes et al. 1984, U.S.EPA 1998
Selenium	0.01	NCRP 1996, Baes et al. 1984, U.S.EPA 1998
Silver	$3.0x10^{-2}$	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	$5.5x10^{-3}$	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	$3.0x10^{-3}$	U.S. EPA 1998
Thiocyanate	3.5	McKone 1994
Xylene	$9.4x10^{-2}$	McKone 1994
Radionuclides ((Bq/kg (ww))/(Bq/kg (dw)))		
Thorium-230	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	$3.7x10^{-3}$	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] {2.2x10^{-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	1.0×10^{-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	1.0×10^{-3}	Thomas *et al.* 1994[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	1.0×10^{-3}	Thomas *et al.* 1994[b]
Radium-226	1.0×10^{-4}	IAEA 1994, NCRP 1996, Baes *et al.* 1984, U.S. EPA 1998, CSA 1987[c]
Polonium-210	8.5×10^{-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]
$TF_{\text{water-to-fish}}$ = 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):

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

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
$Q_{\text{aquatic vegetation}}$ – 47 {U.S. EPA (1993)}
$Q_{\text{benthic invertebrates}}$ – 142 {U.S. EPA (1993)}
C_i = concentration of food [mg/kg (ww)] for each i, such that
$C_{\text{aquatic vegetation}}$ – {calculated in equation (A-16)}
$C_{\text{benthic invertebrate}}$ – {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}
$TF_{\text{feed-to-mallard}}$ = 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]
$TF_{\text{water-to-aqveg}}$ = 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):

$$C_{sed} = C_{water} \times K_d \qquad \text{(A-18)}$$

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):

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

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	1.0×10^{-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.

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FINAL DRAFT

APPENDIX B

HEALTH CANADA
TOXICOLOGICAL REFERENCE VALUES

Prepared by:
Dr. Mark Richardson

APPENDIX B: HEALTH CANADA TOXICOLOGICAL REFERENCE VALUES

	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-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			

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)$^{-1}$
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-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)$^{-1}$
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.