REPORT
ON

HUMAN HEALTH SCREENING LEVEL RISK ASSESSMENT FOR ROBERTS BAY SILVER MINE AND IDA BAY SILVER DEPOSIT

Prepared for:

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EXECUTIVE SUMMARY

This report summarizes the screening level risk assessment for human health for existing conditions at the Roberts Bay Silver Mine site and the Ida Bay Silver Deposit. 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 sites. The assessment included the following elements, which are proposed and readily accepted by regulatory agencies such as Environment Canada and the U.S. Environmental Protection Agency:

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

Measured concentrations of contaminants in water and soil were used in the assessment.

An assessment of the potential implications to human health from exposure to contaminants was considered for an adult and child camper at each site for three months of the year and consuming drinking water and wild game. The camper was also assumed to be exposed through dermal and inhalation pathways, where data was available. Exposure information, such as drinking water consumption, inhalation rates and body weight, was obtained from data on the general Canadian population. Dietary characteristics, were based on a food survey for indigenous populations in Inuit Communities, which provides data on consumption of traditional foods (animals and birds present in the north) as well as other foodstuffs.

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 to ES.4. Values in **bold** are those exceeding the designated levels for each site (0.5 for HQ at Roberts Bay and 0.2 for HQ at Ida Bay, and 1 in 100,000 (i.e. 1 x 10^{-5}) for risk level).

TABLE ES.1
CALCULATED HAZARD QUOTIENT VALUES FOR ROBERTS BAY

Contaminant	Hazard Quotient	
	Adult	Child
Aluminum	0.12	0.16
Barium	0.37	0.49
Cobalt	0.014	0.02
Copper	0.05	0.07
Lead	0.10	0.24
Manganese	0.04	0.05
Molybdenum	0.03	0.03
Nickel	0.10	0.13
Silver	0.19	0.25
Strontium	0.01	0.01
Vanadium	0.07	0.10
Zinc	0.005	0.01
Xylene	0.19	0.35
F1 Aliphatic	0.05	0.10
F1 Aromatic	0.04	0.07
F2 Aliphatic	0.34	0.47
F2 Aromatic	0.27	0.40
TOTAL SITE	**2.0**	**2.9**

TABLE ES.2
CALCULATED RISKS OF CARCINOGENIC EFFECTS AT ROBERTS BAY

Contaminant	Risk Level	
	Adult	Composite
Arsenic	**1.75×10^{-4}**	**4.26×10^{-4}**
TOTAL SITE	**1.75×10^{-4}**	**4.26×10^{-4}**

The assessment of intake showed that for Roberts Bay Silver Mine, none of the contaminants of potential concern has a HQ value greater than 0.5. The largest values are for barium, xylene and F2 petroleum hydrocarbons. The carcinogenic risk from arsenic exposure exceeded the risk level of 1×10^{-5} selected for this site. The ingestion pathway was the main source of arsenic, particularly the consumption of water.

TABLE ES.3
CALCULATED HAZARD QUOTIENT VALUES FOR IDA BAY

Contaminant	Hazard Quotient	
	Adult	Child
Cobalt	0.0001	0.0001
Strontium	0.0011	0.0012
TOTAL SITE	0.0011	0.0013

The assessment of intake showed that the hazard quotient level of 0.2 selected for the Ida Bay site was not exceeded by either contaminant.

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 Roberts Bay site, hazards include an adit, waste rock piles and mine equipment and facilities, based on these hazards the annual fatality rate was estimated to equal 1.5 x 10^{-8}. For the Ida Bay site, the hazards are an adit, exploration pits and a vent raise, based on these hazards, the annual fatality rate was estimated to equal 1.1 x 10^{-8}.

1.0 INTRODUCTION

In September 2004, SENES Consultants Limited was retained by Indian and Northern Affairs Canada (INAC) to undertake Screening Level Risk Assessment (SLRA) of the potential impacts on human health from exposure to hazards at Roberts Bay Silver Mine and Ida Bay Silver Deposit. The purpose of the SLRAs is to provide INAC 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 characterize the human health risks, the risk assessments were based on maximum likely exposures to chemical and physical hazards. It was assumed that people would be on the sites for some portion of the year, even though 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 conservative 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.

For these two sites, the assessments were carried out for a “do nothing” scenario, with no ongoing care or maintenance activities. A three-pronged approach was undertaken to assess the risks posed by the sites:

1. First, the implications of leaving the sites as they are (e.g. 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.

1.1 SLRA APPROACH FOR CHEMICAL EXPOSURES

The SLRA for exposure to chemical hazards undertaken in the assessment evaluated the probability of adverse health consequences to humans caused by the presence of chemical 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 measurement data, air concentrations were calculated for volatile organic compounds in the air mass immediately above contaminated areas using the maximum measured soil concentrations. The calculated contaminant levels were then used in the estimation of exposure via the air pathway to a person spending time on the contaminated area while on site. 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, exposure via the air pathway was not estimated for these contaminants.

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. 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 (e.g. 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 as an inventory of residual issues at 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, soil and water with guidelines and background concentrations.

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 Roberts Bay Silver Mine site, the Ida Bay Silver Deposit and physical characteristics associated with each site.

2.1 SITE DESCRIPTIONS

Roberts Bay Silver Mine is located approximately 125 kilometres southwest of Cambridge Bay in Nunavut, while Ida Bay Silver Deposit is 7 km north of Roberts Bay on the shore of Melville Sound. These sites are located within the ORO claim region. The location of these sites is shown on Figure 2.1.

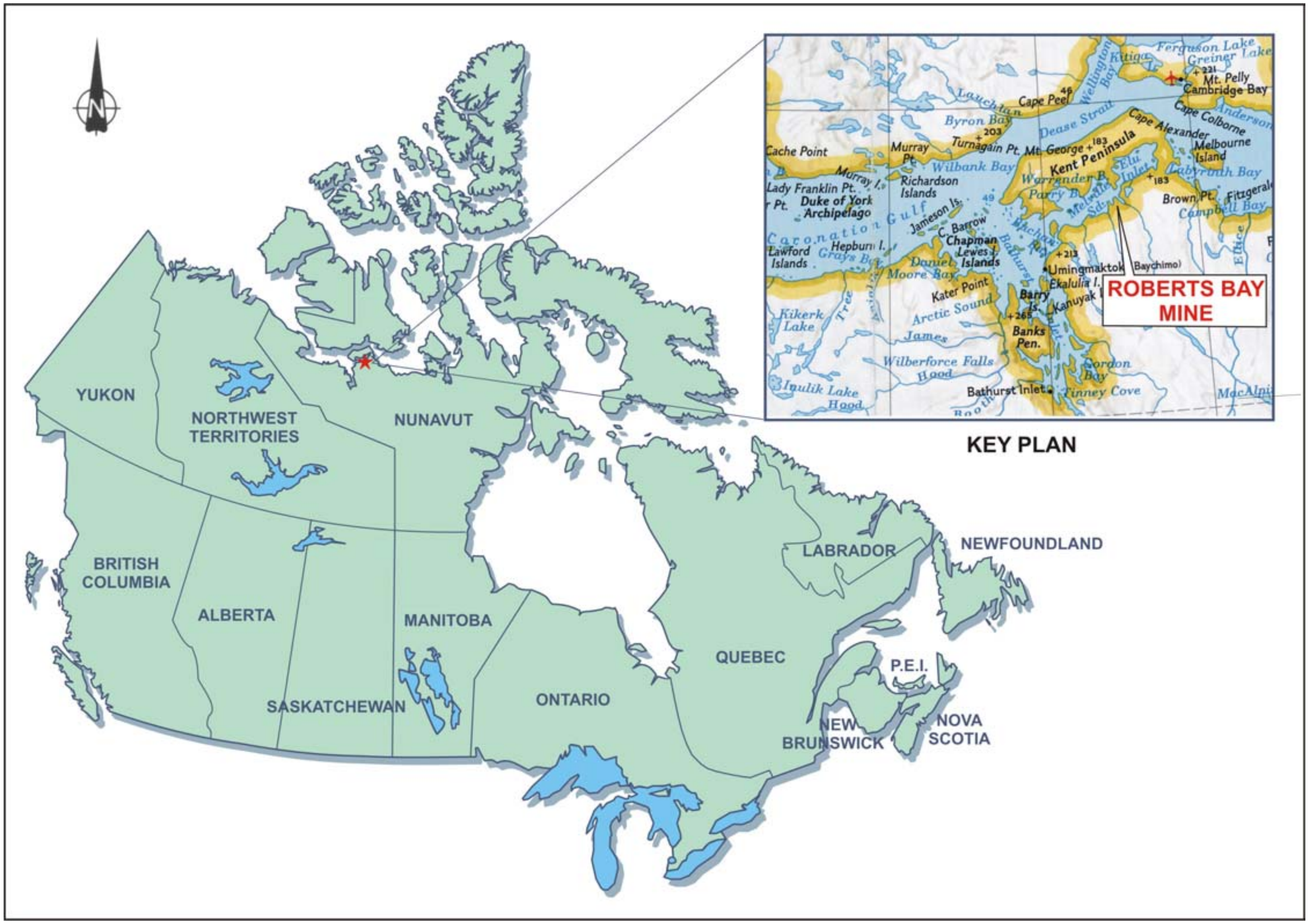
Silver deposits were discovered at Roberts Bay in 1965 and at Ida Bay in 1966. Exploration activities were conducted at both sites from 1967 to 1972. Mining activities occurred from 1973 to 1975 at both sites, while milling occurred only at the Roberts Bay site, which had a small milling operation. Further exploration was conducted in the 1980s and 1990s.

Access to the site is limited. There are no roads or paved airstrips. The sites are accessible by boat, rotary wing aircraft or fixed wing aircraft with floats.

Vegetation and wildlife at the sites are typical of the arctic region.

Roberts Bay Silver mine is one kilometre north of Roberts Lake, which it drains into. Ida Bay Silver Deposit drains into Melville Sound.

FIGURE 2.1
ROBERTS BAY AREA LOCATION MAP



Source: Adapted from National Geographic Society (U.S.) Atlas of the World, Seventh Edition, 1999, Pg. 49

2.2 PHYSICAL FEATURES

2.2.1 Physical Hazards at Mine Sites

Typically, there are numerous physical hazards associated with abandoned mine sites. 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 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 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 Roberts Bay Silver Mine and Ida Bay Silver Deposit

Table 2.1 summarizes some of the main physical features of the Roberts Bay Silver Mine. The physical features at Ida Bay Silver Deposit are summarized in Table 2.2.

TABLE 2.1
PHYSICAL FEATURES OF ROBERTS BAY SILVER MINE SITE

Physical Parameter	Key Features	Characteristics	Description
Tailings Impoundment		General Information	There is one tailings pond and it located west of the mill building.
		Dates of Tailings Deposition	Likely 1973 to 1975
		Tailings Volume	Unknown
		Tailings Surface Area	30 m in diameter
		Tailings Average Depth	Unknown
		Avg Depth to Water Table	Approximately 60% of the tailings solids are submerged below the water line (at time of inspection).
		Physical Stability	Unknown
		Geochemical Characteristics, Acid Base Accounting (ABA)	No rusty oxidation staining noted on the tailings surface, but brittle while precipitate covers tailings (possibly gypsum). Three tailings samples were taken. The surface sample (Sample ID 1) had an NPR of 8.2. The Below Surface Sample (Sample ID 2) had an NPR of 42 and the Below Water Sample (Sample ID 3) had an NPR of 39. All of these indicate an extremely low potential to generate net acidity.
		Groundwater Seepage Rate	Unknown
		Surface Discharge Rate	Unknown
		Cover Type	Unknown
		Vegetation	Algae and grasses growing at northeast margin of the tailings
		Erosion	Exposed tailings are on a 2 to 5% slope, evenly distributed, no desiccation cracks or erosional features noted.
		Accessibility	Unknown
		Additional Information	Greenish grey in colour, comprised of silt and sand sized particles.
	Berm	General Information	There is an impoundment berm.
		Dimensions	Estimated to be 32.4 m^3
		Type of Construction	The berm is constructed of glacial till
		Discharge Structure	Unknown
		Seepage	Unknown
		Erosion	Berm not sufficiently armoured with crushed rock to limit long term erosion.
		Stability	No evidence of instability.
		Additional Information	Unknown

TABLE 2.1 (Cont'd)
PHYSICAL FEATURES OF ROBERTS BAY SILVER MINE SITE

Physical Parameter	Key Features	Characteristics	Description
Underground Workings		General Information	There is a main adit, a vertical shaft and a vent raise
		Volume	Not determined
		Depth	Not determined
		Contents of Workings	Not determined
		Depth to Water table	Not determined
		Groundwater Seepage Rate	Not determined
		Surface Discharge Rate	Not determined
		Accessibility/Stability	The adit has been covered with a wooden framework and plywood, with a layer of waste rock on top. The adit is surrounded by a chain-link fence, which is in good condition and prevents accidental access to the adit. The adit appears to be fully flooded. The vertical shaft is located on the side of a basaltic ridge and is accessible by climbing the ridge. The shaft is open and the walls look partially caved in. There is a fence surrounding 2/3 of the perimeter of the shaft, allowing access to the shaft opening. There are stability problems surrounding the collar. There is a vent raise that has been sealed with concrete.
		Ventilation/Gases	Not determined
		Additional Information	None at this time
Waste Rock		General Information	There are 7 waste rock piles, plus 4 berms and numerous rock pads constructed from waste rock.
		Location	The locations of the piles are: -Ore pad Berm NW of Mill -Berm around Fuel Bladder -Berm around camp landfill -Tailings Pond Berm -5 Waste Rock Piles South of Adit -Waste Rock Pile North of Adit -Waste Rock Pile North of Ore Pad
		Volume	The estimated volumes are: -Tailings Pond Berm (32.4m^3) -Ore pad Berm NW of Mill (20m^3) -Berm around Fuel Bladder (90m^3) -Berm around camp landfill (48m^3) -5 Waste Rock Piles South of Adit (65.5m^3) -Waste Rock Pile North of Adit (150 m^3) -Waste Rock Pile North of Ore Pad (75m^3) The total volume is 480.9 m^3

TABLE 2.1 (Cont'd)
PHYSICAL FEATURES OF ROBERTS BAY SILVER MINE SITE

<table>
<tr><th>Physical Parameter</th><th>Key Features</th><th>Characteristics</th><th>Description</th></tr>
<tr><td></td><td></td><td>Pile Dimensions</td><td>
<table>
<tr><th></th><th>Length</th><th>Width</th><th>Height</th></tr>
<tr><td>Tailings Pond Berm</td><td colspan="3">Section of 32 m diameter ring</td></tr>
<tr><td>Ore pad Berm NW of Mill</td><td>20 m</td><td>1 m</td><td>1 m</td></tr>
<tr><td>Berm around Fuel Bladder</td><td>30m x 20m sq</td><td>2.5 m</td><td>0.5</td></tr>
<tr><td>Berm around camp landfill</td><td>30 m</td><td>1 m</td><td>1 - 2 m (variable)</td></tr>
<tr><td>5 Waste Rock Piles South of Adit</td><td colspan="3">Cones with diameter of 5 m and height of 2 m</td></tr>
<tr><td>Waste Rock Pile North of Adit</td><td>20 m</td><td>5 m</td><td>3 m</td></tr>
<tr><td>Waste Rock Pile North of Ore Pad</td><td>15 m</td><td>4 m</td><td>2.5 m</td></tr>
</table>
</td></tr>
<tr><td></td><td></td><td>Depth to Water Table</td><td>Not determined</td></tr>
<tr><td></td><td></td><td>Geochemical Characteristics, Acid Base Accounting (ABA)</td><td>Comprised of black fine grained mafic volcanics with occasional quartz veinlettes and stringers.
1-2% visible sulphides concentrated on fracture surfaces and within quartz.
Trace amounts of oxidation staining concentrated around sulphides.
Of the 6 samples of waste rock taken at the Roberts Bay Silver Mine site, 4 had an NPR greater than 3, indicating low potential to generate net acidity. The sample collected from the berm around the fuel area had an NPR of 1.12, indicating uncertain potential to generate net acidity. The sample collected from the waste rock pile south of the garage had an NPR of 0.6, indicating a likely potential to generate acidity.</td></tr>
<tr><td></td><td></td><td>Groundwater Seepage Rate</td><td>Unknown</td></tr>
<tr><td></td><td></td><td>Surface Discharge Rate</td><td>Unknown</td></tr>
<tr><td></td><td></td><td>Cover (water, soil, sand, none, etc.)</td><td>Unknown</td></tr>
<tr><td></td><td></td><td>Vegetation</td><td>Unknown</td></tr>
<tr><td></td><td></td><td>Sloped/Graded Surfaces</td><td>Uniform side slopes, consolidated and stable.</td></tr>
<tr><td></td><td></td><td>Erosion</td><td></td></tr>
<tr><td></td><td></td><td>Physical Stability</td><td>Stable – Waste rock piles could be climbed without material being displaced (during site visit)
Berms are stable.</td></tr>
<tr><td></td><td></td><td>Additional Information</td><td>None at this time</td></tr>
</table>

TABLE 2.1 (Cont'd)
PHYSICAL FEATURES OF ROBERTS BAY SILVER MINE SITE

Physical Parameter	Key Features	Characteristics	Description
Infrastructure		General Information	There are numerous building in four main areas. 1 – Exploration Camp • 7 tent-cabin frame an outhouse and shed 2 – Mine Camp Area • no remaining structures 3 – Mill Area • metal frames of mill and assay lab • mill equipment and generators within building frames 4 – Adit/Garage Area • metal frame of garage and mine entrance
		Date of Construction	Unknown, presumably from 1967 to 1975
		Number of Buildings	See above
		Type of Construction	Wood and metal.
		Condition/Stability	Unknown
		Accessibility	Most buildings are open. There is a fence around the mine entrance.
		Additional Information	None identified

Physical Parameter	Key Features	**Location**	**Description**	**Volume**
Non – Hazardous Waste Material		Exploration Camp		
			66 empty drums	7 m^3
			wood debris (cabins)	20 m^3
			metal debris	1 m^3
			overturned core and core racks	4 m^3
		Mine Camp		
			20 empty barrels	2 m^3
			wood debris	25 m^3
			metal debris	15 m^3
			burlap sacks	4 m^3
			overturned core and core racks	6 m^3
		Mill Area		
			26 empty drums	3 m^3
			wood debris	20 m^3
			metal debris	80 m^3
			burlap sacks	2 m^3
		Adit / Garage Area		
			60 empty barrels	6 m^3
			wood debris	43 m^3
			metal debris	58 m^3
			10 tires	2.5 m^3
			cables and rubber hoses	4.0 m^3
			cement mix	1 m^3
			shredded canvas and tarps	1.5 m^3
		Volume of Non-hazardous Waste at Roberts Bay		305 m^3

TABLE 2.1 (Cont'd)
PHYSICAL FEATURES OF ROBERTS BAY SILVER MINE SITE

Physical Parameter	Key Features	Characteristics	Description
Hazardous Waste Material		Exploration Camp	
			15 drums of gasoline, Jet B, motor oil
			4 empty propane cylinders
		East of exploration camp adjacent to float plane docking area	110 empty drums, one full drum of AvGas
		Mine Camp	
			2 lead acid batteries
		Mill Area	
			9 drums with unknown content
			1 drum of lead acid batteries
			2- 20L drums with unknown content
			3 – 8L pails with unknown contents
		Adit / Garage Area	
			1- 20L pail waste oil
			1-8L pail waste grease
			1 compressed gas cylinder
			1 oil filled transformer (suspect PCB)
			6 drums with unknown contents
			3 compressed gas cylinders
Additional Physical Hazards		General Information	Non-hazardous debris including scrap metal, wooden debris and old mining and milling equipment was identified throughout the site and is a physical hazard.
***Site data from PWGSC and Rescan (2004)**			

The main areas of concern for the Roberts Bay Silver Mine site are:

- Potential of two waste rock piles to generate net acidity;
- Storage of petroleum hydrocarbons in drums and pails;
- Presence of hazardous materials including lead acid batteries, unknown chemicals and possibly PCBs;
- Vent shaft accessible and unstable; and
- A substantial amount of non-hazardous waste littered on site, posing a physical hazard.

TABLE 2.2
PHYSICAL FEATURES OF IDA BAY SILVER DEPOSIT SITE

Physical Parameter	Key Features	Characteristics	Description
Underground Workings		General Information	There is one adit, a 180m decline, 3 waste rock piles, a covered vent raise and three exploration drenches. • The adit is 15 m from the ocean shoreline and is fully flooded. There is no physical barrier to the adit entrance, nor any warning signs posted. Timber supports of uncertain condition are in place. • A boarded vent raise is located south of the adit. The raise is covered by plywood and filled with water. The plywood is in poor condition. There are no physical barriers preventing access to the vent raise. • There are three exploration trenches that are 1.2 m wide, 2 m long and 1.2 m deep. They are filled with water and are not identified with any warning signs.
		Volume	Not determined
		Depth	Not determined
		Contents of Workings	Not determined
		Depth to Watertable	Not determined
		Groundwater Seepage Rate	Not determined
		Surface Discharge Rate	Not determined
		Accessibility/Stability	Not determined
		Ventilation/Gases	Not determined
		Additional Information	None at this time
Waste Rock		General Information	There are 3 waste rock piles.
		Location	The piles are all close to the adit.
		Pile Dimensions	Pile North of Adit: L=20 m W=10m H=1 m, Vol=200m^3 Conical Pile west of adit: diameter 20 , H= 2.5 m, Vol = 260m^3 Elongated pile west of adit: L=53 m, Width=9-16 m, H = 0.5-1.5m, Vol = 600 m^3 Total estimated volume = 1060 m^3
		Depth to Water Table	Not determined
		Geochemical Characteristics, Acid Base Accounting (ABA)	Composed of black fine grain basalt with approximately 1% pyrite coating on fracture surfaces, no visible oxidation staining. One sample was taken and had an NPR of 1.12, indicating uncertain acid generating potential.
		Groundwater Seepage Rate	Unknown
		Surface Discharge Rate	Unknown
		Cover (water, soil, sand, none, etc.)	Unknown
		Vegetation	Unknown
		Sloped/Graded Surfaces	Stable slopes
		Erosion	Unknown
		Physical Stability	Stable slopes
		Additional Information	None at this time

TABLE 2.1 (Cont'd)
PHYSICAL FEATURES OF IDA BAY SILVER DEPOSIT SITE

Physical Parameter	Key Features	Characteristics	Description	
Infrastructure		General Information	No trace of previous camp	
Non – Hazardous Waste Material		**Location**	**Description**	**Volume**
		Ida Bay Site	3 empty barrels	0.3 m^3
			wood debris	5 m^3
			metal debris	2 m^3
			overturned core and core racks	1 m^3
Hazardous Material		General Description	None identified	
Additional Physical Hazards		General Information	None identified	

***Site data from PWGSC and Rescan (2004)**

The main areas of concern for the Ida Bay Silver Deposit site are:

- One waste rock sample indicated that there is uncertain potential to generate net acidity;
- The adit has not been closed off and timbers bracing the adit opening are old;
- The vent raise is covered by plywood that is in poor condition;
- Three exploration pits are unmarked and filled with water; and
- A small amount of non-hazardous waste littered on site, posing a physical hazard.

3.0 CHEMICAL HAZARD IDENTIFICATION

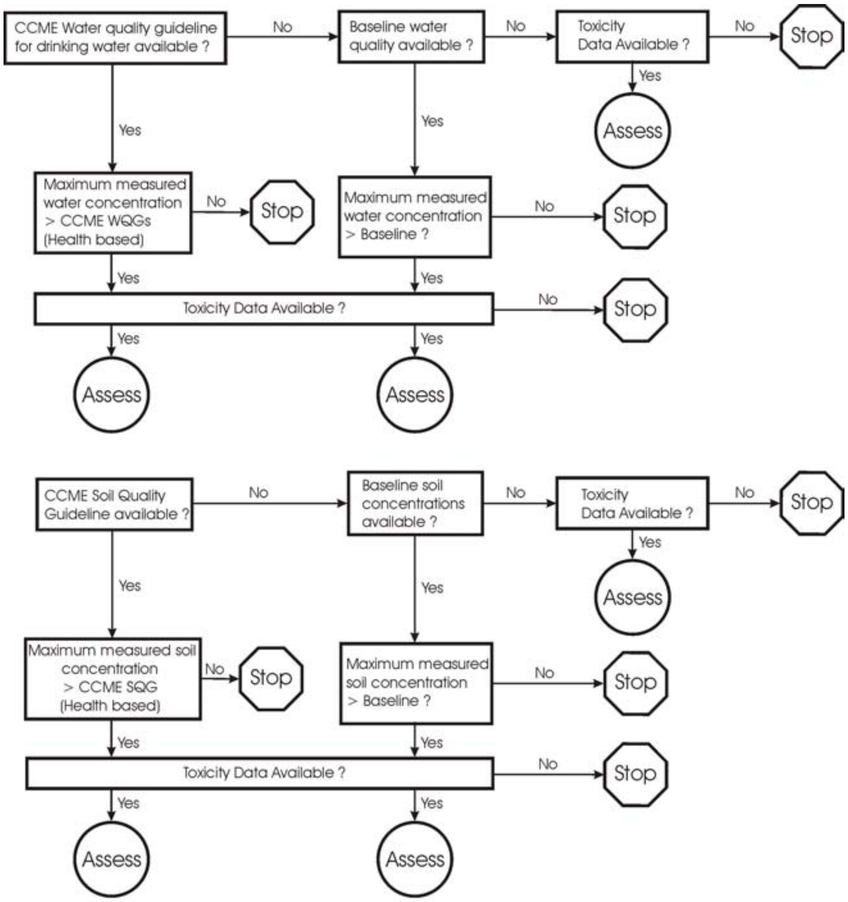
This section identifies the contaminants of concern that are selected for this assessment of potential human health effects from exposure to chemical contaminants.

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 in the 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 comparable to or 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 and soil data) was taken from PWGSC and Rescan (2004); *Phase I/II Environmental Site Assessment Roberts Bay Silver Mine and Ida Bay Silver Deposit Nunavut.* The data used from this report were acquired from a field sampling program conducted in August of 2003.

Water Quality-Roberts Bay

Water quality was measured at several locations within the Roberts Bay site including the tailings pond and locations where there were pools of standing water. A background sample was also taken as part of the study, although some of the background sample concentrations exceed the CCME drinking water guidelines.

The objective of this SLRA was to assess a scenario where the site is left in its current state, with no further decommissioning of the site. Because of the limited amount of sampling data, the maximum water quality values from the five non-background samples taken at Roberts Bay were used to represent the scenario. 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 arsenic, barium, boron, cadmium, chromium, copper, zinc and cyanide were below CCME drinking water guidelines and were not assessed further. The measured concentrations of aluminum, lead and manganese exceed CCME drinking water guidelines and are considered contaminants of potential concern (COPC). The CCME has not proposed drinking water guidelines for beryllium, silver, thallium, PCBs and TPH; however the measured concentrations were equal to or below baseline levels and were not considered further. Toxicity data are not available for iron or titanium and therefore, these contaminants were dropped from further assessment. Finally, cobalt, molybdenum, nickel, strontium, and vanadium were also identified as COPC since the measured concentrations exceed baseline levels at the site and toxicity data are available for these species.

Note that although concentrations of benzene, toluene, ethylbenzene and xylene all exceed the CCME drinking water guidelines, they were all measured below the method detection limit and were therefore dropped from further assessment.

Water Quality-Ida Bay

One water quality sample was taken at the Ida Bay site, from the adit. This data was used to evaluate the COPC at this location and the same background data was used for both Ida Bay and Roberts Bay. The data are presented in Table 3.1. Following the selection procedure outlined above and the same rationale used for the Roberts Bay data, cobalt and strontium were assessed as COPC. The measured values of both of these contaminants were above their respective background concentrations.

TABLE 3.1
SUMMARY OF WATER QUALITY DATA

Contaminant	**CCME Drinking Water Guideline (mg/L)**	**Maximum Measured Water Quality at Roberts Bay[a] (mg/L)**	**Maximum Measured Water Quality at Ida Bay[a] (mg/L)**	**Baseline Water Concentration[b] (mg/L)**
Metals				
Aluminum	0.2 (0.1)[c]	**0.37**	0.12	0.11
Arsenic	0.025	0.02	0.0005[e]	0.0005[e]
Barium	1.0	0.16	0.02	0.005[e]
Beryllium	-	0.0005[e]	0.0005[e]	0.0005[e]
Boron	5	0.5	0.025[e]	0.025[e]
Cadmium	0.005	0.001	0.0003	0.0008
Chromium	0.05	0.007	0.003	0.003
Cobalt	-	**0.0007**	**0.0002**	0.0001[e]
Copper	< 1.0[d]	0.012	0.008	0.002
Iron	< 0.3[d]	2.38	0.1	0.08
Lead	0.010	**0.013**	0.002	0.0005[e]
Manganese	< 0.05[d]	**0.172**	0.028	0.029
Molybdenum	-	**0.019**	0.0025[e]	0.0025[e]
Nickel	-	**0.006**	0.0025[e]	0.0025[e]
Silver	-	0.0002	0.0001	0.0002
Strontium	-	**0.64**	**0.123**	0.051
Thallium		0.0005[e]	0.0005[e]	0.0005[e]
Titanium	-	0.02	0.005[e]	0.005[e]
Vanadium	-	**0.003**	0.0005[e]	0.0005[e]
Zinc	5.0[d]	0.036	0.0025[e]	0.0025[e]
Organic Contaminants				
PCBs	-	0.05[e]	0.05[e]	0.05[e]
Cyanide	0.2	0.011	0.013	0.013
Benzene	0.005	0.025[e]	0.025[e]	0.025[e]
Toluene	0.024[d]	0.025[e]	0.025[e]	0.025[e]
Ethylbenzene	0.0024[d]	0.025[e]	0.025[e]	0.025[e]
Xylene	0.3[d]	0.75[e]	0.75[e]	0.75[e]
TPH	-	0.1[e]	0.1[e]	0.1[e]

Notes: Values in **bold** are COPC.

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

a - Roberts Bay: Maximum from samples RBSM-1, RBSM-2, RBSM-3, RBSM-Gar-w-1, and RBSM-Val-1
Ida Bay: Sample IDA-1
Source: PWGSC and Rescan (2004).

b - Sample RBSM-4, PWGSC and Rescan Environmental Services (2004).

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.

Soil Quality – Roberts Bay

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 samples for Roberts Bay were collected in the fuel area as well as localized stained areas within the garage and mill. Three tailings sample were collected and considered in the assessment. The maximum measured concentrations of metals and suspected contaminants in soil or tailings from these locations are presented in Table 3.2. In the case of petroleum hydrocarbons, a significant number of soil samples were collected (n=18 to 20). Because of the larger data set for these contaminants, the measured data presented are calculated 95th percentile concentrations. For all other contaminants, the absolute maximum concentrations are presented, which is consistent with the methodology used by SENES in previous assessments when fewer than ten samples were available.

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+

Total petroleum hydrocarbons (TPH) were measured in this assessment as outlined above and BTEX concentrations were also evaluated.

Maximum measured concentrations of beryllium, cadmium, chromium, copper, thallium, cyanide, PCBs, benzene, toluene, ethylbenzene and TPH (F3) were below the CCME guidelines for human health and therefore, these contaminants were dropped from further assessment. Similarly, aluminum, iron, manganese, strontium and titanium were below typical levels in soil and were dropped from further assessment. Toxicity data do not exist for Fraction 4 of TPH since this fraction is not very toxic, and this contaminant was not considered further.

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

Note that the soil value carried forward in the assessment is the greater of the maximum measured soil or the maximum tailings sample, except in the case of arsenic and thallium. The tailings measurements for these two contaminants were below the detection limit. However, the method detection limit used in the soil sampling was considerably lower, and therefore more accurate. As such, the soil values were used in the assessment for these two contaminants.

Soil Quality – Ida Bay

No soil samples were taken at the Ida Bay site.

TABLE 3.2
SUMMARY OF SOIL QUALITY DATA

Contaminant	CCME Soil Quality Guideline (Human Health)[a] (mg/kg)	Maximum Measured Tailings Concentration[b] (mg/kg)	Maximum Measured Soil Concentration[c] (mg/kg)	Typical Soil Concentration[d] (mg/kg)
Metals				
Aluminum	-	35,300	25,300	155,000
Arsenic	12	**50**[e]	**35.6**	20.5
Barium	500 *	**1530**	455	1800
Beryllium	4 *	0.25[e]	0.5[e]	20.1
Cadmium	14	1[e]	6.9	3.5
Chromium	220	118	166	1,503
Cobalt	50 *	24	**81**	20.5
Copper	1,100	86	426	51
Iron	-	44,300	97,700	278,000
Lead	140	**304**	**420**	101
Manganese	-	1110	1220	2,050
Molybdenum	10 *	2[e]	**11**	2.6
Nickel	50 *	**172**	**105**	503
Silver	20 *	10	**117**	2.6
Strontium	-	102	52	525
Thallium	1	25[e,h]	0.5[e]	
Titanium	-	1750	1750	5,500
Vanadium	130 *	**152**	**152**	260
Zinc	200 *	**282**	**329**	155
Organic Contaminants				
Cyanide	1.3	-	0.05[e]	-
PCBs	0.9	-	0.05[e]	-
Benzene	0.5*	-	0.05[e]	-
Toluene	0.8	-	0.1[e]	-
Ethylbenzene	1.2*	-	0.4	-
Xylene	5	**-**	**16.9**	-
TPH (C5-C10) – Fraction 1	50[f] 1,500[g]	**-**	**63**	-

Contaminant	CCME Soil Quality Guideline (Human Health)[a] (mg/kg)	Maximum Measured Tailings Concentration[b] (mg/kg)	Maximum Measured Soil Concentration[c] (mg/kg)	Typical Soil Concentration[d] (mg/kg)
TPH (C10-16) – Fraction 2	240[f] 8,000[g]	-	**12,350**	-
TPH (C16-C34) – Fraction 3	18,000[g]	-	5975	-
TPH (C34-C50) – Fraction 4	-	-	1349	

Notes: Values in **bold** are COPC.
- 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 three tailings samples, from PWGSC and Rescan (2004)
c - Maximum concentrations of soil samples, from PWGSC and Rescan (2004). Absolute maximum used for all conctaminants, except hydrocarbons, for which the 95th percentile was used.
d - Typical concentrations in native soil for various locations, from Dragun (1998).
e - Measured value was less than method detection limit (MDL), thus was set to half MDL.
f - Canada-Wide Standard for Petroleum Hydrocarbons in Soil – Vapour Inhalation (Indoor, slab-on-grade) from CCME 2000 residential land use.
g - Canada-Wide Standard for Petroleum Hydrocarbons in Soil – Soil Ingestion from CCME 2000 residential land use.
h - The tailings thallium value is below the MDL, and the soil MDL is more accurate, hence thallium was not considered a COPC.

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 for Roberts Bay Silver Mine is shown in Table 3.3. The list of COPC considered for Ida Bay is shown in Table 3.4.

TABLE 3.3
COPC SELECTED FOR THE ROBERTS BAY ASSESSMENT

Aluminum
Arsenic
Barium
Cobalt
Copper
Lead
Manganese
Molybdenum
Nickel
Silver
Strontium
Titanium
Zinc
F1-TPH (C6-C10)
F2-TPH (C10-C16)

TABLE 3.4
COPC SELECTED FOR THE IDA BAY ASSESSMENT

Cobalt
Strontium

3.2 SUMMARY OF OTHER CHEMICAL DATA FOR SLRA

Waste rock samples were taken at the Roberts Bay and Ida Bay sites in the PWGSC and Rescan study. Acid-base accounting (ABA) testing indicated that the majority of samples had a low acid generating potential. At the Roberts Bay site, four of six samples indicated low potential of generating net acidity, one indicated an uncertain potential to generate acidity and one indicate a likely potential to generate acidity. The sample taken at the Ida Bay site indicated an uncertain potential to generate net acidity.

Six waste rock grab samples from Roberts Bay and one sample from Ida Bay were tested for water leachable metals and total metals (PWGSC and Rescan 2004). The maximum values from each site are presented in Table 3.5.

TABLE 3.5
SUMMARY OF WASTE ROCK QUALITY DATA

Contaminant	**Maximum Measured Waste Rock Analysis Extractable Metals mg/L**		**Maximum Measured Waste Rock Analysis Total Metals mg/kg**	
	Roberts Bay site[a]	Ida Bay site[b]	Roberts Bay site[a]	Ida Bay site[b]
Aluminum	0.761	0.51	26500	18300
Arsenic	0.0932	0.0072	10[c]	10[c]
Barium	0.38	0.01	501	50[c]
Beryllium	0.0025[c]	0.0025[c]	0.25[c]	0.25[c]
Cadmium	0.000025[c]	0.000025[c]	1[c]	1[c]
Chromium	0.005[c]	0.005[c]	61	7
Cobalt	0.005[c]	0.005[c]	45	21
Copper	0.0042	0.0012	1790	64
Iron	0.015[c]	0.04	54700	46900
Lead	0.0004	0.0006	269	263
Manganese	0.011	0.0025[c]	2320	541
Molybdenum	0.04	0.015[c]	6	2[c]
Nickel	0.0009	0.00025[c]	229	10
Silver	0.0008	0.00005[c]	924	3
Strontium	0.173	0.016	924	6.3
Thallium	0.00005[c]	0.00005[c]	25[c]	25[c]
Titanium	0.005[c]	0.005[c]	1350	854
Vanadium	0.015[c]	0.015[c]	103	109
Zinc	0.01[c]	0.01[c]	139	1050

a - Maximum concentrations of six waste rock samples from Roberts Bay (Samples 4,5,6,7,9 and 10), from PWGSC and Rescan (2004)

b - Maximum concentration from Sample 8 from Ida Bay, from PWGSC and Rescan (2004)

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

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. The Roberts Bay Silver Mine is approximately 125 southwest of the Hamlet of Cambridge Bay. Ida Bay Silver Deposit is located 7 km north of Roberts Bay. Access to the site is limited as there no access roads or airstrips. The sites are only accessible by rotary wing aircraft, fixed wing aircrafts with floats or by boat.

Two hypothetical human receptors (Inuit) were considered for the assessment of potential exposures from the sites. One adult and one child (5 to 11 years) were assumed to visit the site annually and to camp on the site for a maximum of 3 months of the year. While on-site, the receptors were assumed to inadvertently come in contact with and ingest contaminated soil. It was assumed that receptors obtain hare and ptarmigan and drinking water from the site area. While other people (e.g., inspectors) may visit the site, the camper receptors represent the most exposed individuals.

Hare and ptarmigan were selected for inclusion as food sources in the human health risk assessment as they have small home ranges and are may be exposed to contaminants on site. Larger animals, such as caribou, fox, moose, muskox and wolverine, that inhabit the region are not expected to be on the site for a significant time and therefore they would not accumulate contaminants from the site. Vegetation found at the site includes lichens, moss, sedge tussocks, least willow, blueberries and northern Labrador tea.

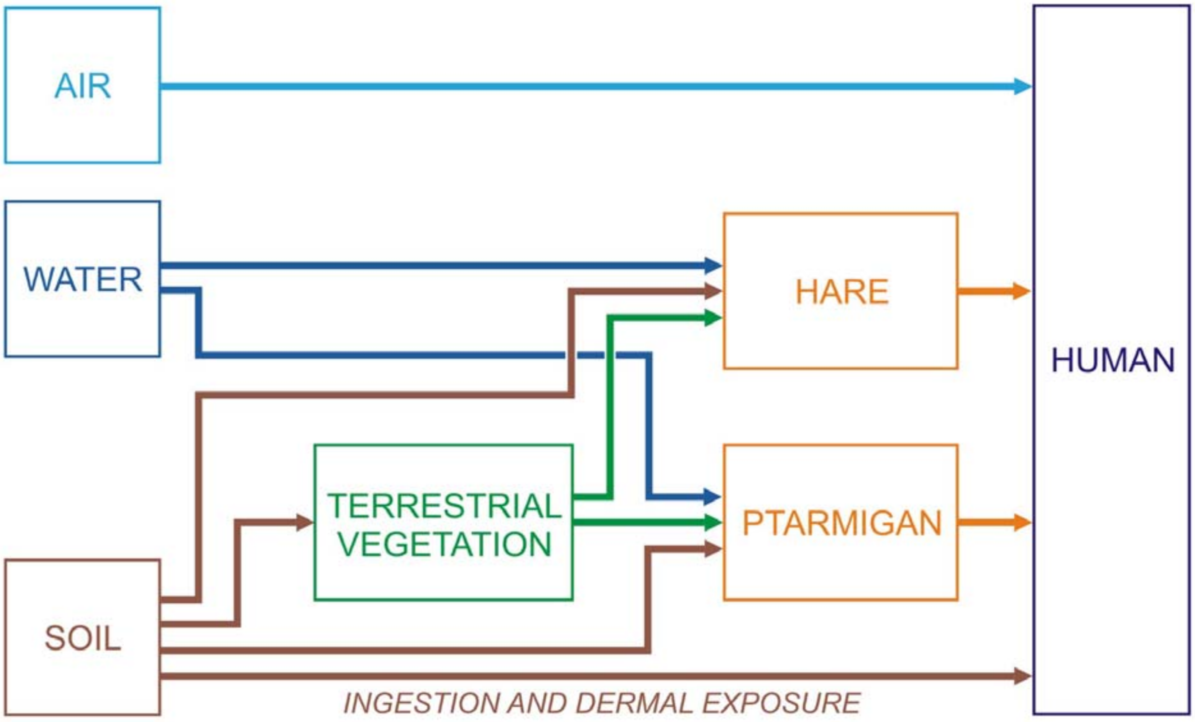
4.2 EXPOSURE PATHWAYS CONSIDERED – CHEMICAL HAZARDS

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

- inhalation of air;
- consumption of hare and grouse;
- ingestion of water;
- inadvertent ingestion of soil; and
- dermal contact with soil.

Note that because there is no soil data for the Ida Bay site, no soil pathways were considered for the receptors at this location.

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. Diet and intake estimates for communities near the Roberts Bay site were derived from Kitikmeot communities near or on the Coronation Gulf in Nunavit (Kuhnlein *et al.* 2000). The diet of the Kitikmeot communities was assumed to be representative of a native diet for the Roberts Bay and Ida Bay areas. The uptake rates of game, water, soil, air, and other exposures for adult and child receptors are listed below in Table 4.1.

While reported typical vegetation of the region included blueberries (PWGSC and Rescan 2004), the diet report did not indicate any berry consumption for the 20 to 60+ years age group, although there was data for 15-20 year old females. Of the 3 communities comprising the Kitikmeot, most had a very low intake of berries except for moderate intake of blueberries and crowberries in the summer (2-4 times a month) by residents of Kugluktuk. Therefore, this is not likely a significant source of exposure and was not included in the assessment.

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]	344	255
Ptarmigan ingestion rate (g/d) [d]	3.6	2.7
Hare ingestion rate (g/d) [d]	0.8	0.6
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
Exposed skin surface area - total (m^2) [c]	0.911	0.514
Soil loading to exposed skin (g/cm^2) [e, g]		
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 Kuhnlein et al. (2000).
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 to overestimate exposure.
g - soil loading values are for construction workers. The use of these 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 Roberts Bay Mine Site and Ida Bay Silver Deposit, as described in Chapter 3.

4.4 EXPOSURE PATHWAYS – PHYSICAL HAZARDS

The Roberts Bay and Ida Bay sites are accessible only by float plane, rotary winged aircraft or boat. 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 vertical shaft at the Roberts Bay site, or into the flooded adit or vent raise at the Ida Bay site.

5.0 EXPOSURE ASSESSMENT

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

The pathways and assumptions applied in this assessment are described in this section. Appendix A documents the pathways calculations used in the assessment of contaminant intakes by the human 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 Roberts Bay and Ida Bay sites. 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	**Hare**	**Ptarmigan**	**Soil**	**Air**
Roberts Bay Silver Mine					
Aluminum	1.96×10^{-3}	7.81×10^{-7}	2.93×10^{-4}	2.50×10^{-3}	-
Arsenic	1.06×10^{-4}	4.13×10^{-9}	8.21×10^{-7}	2.52×10^{-6}	-
Barium	8.49×10^{-4}	7.86×10^{-9}	2.47×10^{-6}	1.08×10^{-4}	-
Cobalt	3.71×10^{-6}	4.71×10^{-10}	1.13×10^{-5}	5.73×10^{-6}	-
Copper	6.36×10^{-5}	1.36×10^{-6}	2.60×10^{-5}	3.01×10^{-5}	-
Lead	6.90×10^{-5}	1.92×10^{-6}	2.80×10^{-6}	2.97×10^{-5}	-
Manganese	9.12×10^{-4}	1.62×10^{-7}	2.32×10^{-5}	8.63×10^{-5}	-
Molybdenum	1.01×10^{-4}	2.11×10^{-9}	1.32×10^{-6}	7.78×10^{-7}	-
Nickel	3.18×10^{-5}	4.96×10^{-8}	2.68×10^{-5}	1.22×10^{-5}	-
Silver	1.06×10^{-6}	5.41×10^{-8}	1.33×10^{-5}	8.27×10^{-6}	-
Strontium	3.39×10^{-3}	6.77×10^{-8}	1.28×10^{-6}	7.21×10^{-6}	-
Vanadium	1.59×10^{-5}	2.15×10^{-8}	4.01×10^{-6}	1.07×10^{-5}	-
Zinc	1.91×10^{-4}	7.86×10^{-6}	1.16×10^{-3}	2.33×10^{-5}	-
Xylene	3.98×10^{-3}	3.68×10^{-11}	4.38×10^{-11}	4.43×10^{-7}	4.99×10^{-3}
F1 Aliphatic	-	-	-	3.56×10^{-6}	1.65×10^{-1}
F1 Aromatic	-	-	-	8.91×10^{-7}	2.07×10^{-3}
F2 Aliphatic	-	-	-	6.99×10^{-4}	3.92×10^{-3}
F2 Aromatic	-	-	-	1.75×10^{-4}	3.53×10^{-3}
Ida Bay Silver Deposit					
Cobalt	1.06×10^{-6}	7.92×10^{-15}	2.60×10^{-10}	-	-
Strontium	6.52×10^{-4}	2.44×10^{-10}	4.79×10^{-9}	-	-

TABLE 5.2
CALCULATED TOTAL INTAKES BY PATHWAY – ADULT RECEPTOR

Contaminant	Inhalation Pathway (mg/kg d)	Ingestion Pathway (mg/kg d)	Dermal Pathway (mg/kg d)	Total Pathway (mg/kg d)
Roberts Bay Silver Mine				
Aluminum	-	4.75x10^{-3}	1.14x10^{-1}	1.18x10^{-1}
Arsenic	-	1.09x10^{-4}	3.67x10^{-5}	1.46x10^{-4}
Barium	-	9.59x10^{-4}	4.93x10^{-3}	5.89x10^{-3}
Cobalt	-	2.08x10^{-5}	2.61x10^{-4}	2.82x10^{-4}
Copper	-	1.21x10^{-4}	1.37x10^{-3}	1.49x10^{-3}
Lead	-	1.03x10^{-4}	8.12x10^{-5}	1.85x10^{-4}
Manganese	-	1.02x10^{-3}	3.93x10^{-3}	4.95x10^{-3}
Molybdenum	-	1.03x10^{-4}	3.54x10^{-5}	1.38x10^{-4}
Nickel	-	7.08x10^{-5}	1.94x10^{-3}	2.01x10^{-3}
Silver	-	2.26x10^{-5}	9.42x10^{-4}	9.65x10^{-4}
Strontium	-	3.40x10^{-3}	3.29x10^{-4}	3.73x10^{-3}
Vanadium	-	3.07x10^{-5}	4.90x10^{-4}	5.20x10^{-4}
Zinc	-	1.38x10^{-3}	2.12x10^{-4}	1.59x10^{-3}
Xylene	4.99x10^{-3}	3.98x10^{-3}	2.42x10^{-5}	8.99x10^{-3}
F1 Aliphatic	1.65x10^{-1}	3.56x10^{-6}	1.62x10^{-4}	1.65x10^{-1}
F1 Aromatic	2.07x10^{-3}	8.91x10^{-7}	4.06x10^{-5}	2.11x10^{-3}
F2 Aliphatic	3.92x10^{-3}	6.99x10^{-4}	3.18x10^{-2}	3.64x10^{-2}
F2 Aromatic	3.53x10^{-3}	1.75x10^{-4}	7.96x10^{-3}	1.17x10^{-2}
Ida Bay Silver Deposit				
Cobalt	-	1.06x10^{-6}	-	1.06x10^{-6}
Strontium	-	6.52x10^{-4}	-	6.52x10^{-4}

TABLE 5.3
CALCULATED INGESTION INTAKES BY PATHWAY – CHILD RECEPTOR

Contaminant	**Intake through Ingestion Pathways (mg/(kg d))**				
	Water	**Hare**	**Ptarmigan**	**Soil**	**Air**
Roberts Bay Silver Mine					
Aluminum	2.25x10^{-3}	1.24x10^{-6}	4.67x10^{-4}	2.15x10^{-2}	-
Arsenic	1.22x10^{-4}	6.57x10^{-9}	1.30x10^{-6}	2.16x10^{-5}	-
Barium	9.73x10^{-4}	1.25x10^{-8}	3.92x10^{-6}	9.30x10^{-4}	-
Cobalt	4.26x10^{-6}	7.48x10^{-10}	1.80x10^{-5}	4.92x10^{-5}	-
Copper	7.29x10^{-5}	2.16x10^{-6}	4.13x10^{-5}	2.59x10^{-4}	-
Lead	7.90x10^{-5}	3.05x10^{-6}	4.45x10^{-6}	2.55x10^{-4}	-
Manganese	1.05x10^{-3}	2.58x10^{-7}	3.69x10^{-5}	7.42x10^{-4}	-
Molybdenum	1.16x10^{-4}	3.36x10^{-9}	2.09x10^{-6}	6.69x10^{-6}	-
Nickel	3.65x10^{-5}	7.89x10^{-8}	4.26x10^{-5}	1.05x10^{-4}	-
Silver	1.22x10^{-6}	8.60x10^{-8}	2.11x10^{-5}	7.11x10^{-5}	-
Strontium	3.89x10^{-3}	1.08x10^{-7}	2.04x10^{-6}	6.20x10^{-5}	-
Vanadium	1.82x10^{-5}	3.42x10^{-8}	6.38x10^{-6}	9.24x10^{-5}	-
Zinc	2.19x10^{-4}	1.25x10^{-5}	1.84x10^{-3}	2.00x10^{-4}	-
Xylene	4.56x10^{-3}	5.84x10^{-11}	6.96x10^{-11}	3.81x10^{-6}	9.83x10^{-3}
F1 Aliphatic	-	-	-	3.06x10^{-5}	3.25x10^{-1}
F1 Aromatic	-	-	-	7.66x10^{-6}	4.08x10^{-3}
F2 Aliphatic	-	-	-	6.01x10^{-3}	7.74x10^{-3}
F2 Aromatic	-	-	-	1.50x10^{-3}	6.97x10^{-3}
Ida Bay Silver Deposit					
Cobalt	1.22x10^{-6}	1.26x10^{-14}	4.13x10^{-10}	-	-
Strontium	7.48x10^{-4}	3.87x10^{-10}	7.62x10^{-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)
Roberts Bay Silver Mine				
Aluminum	-	$2.42x10^{-2}$	$1.38x10^{-1}$	$1.62x10^{-1}$
Arsenic	-	$1.45x10^{-4}$	$4.45x10^{-5}$	$1.89x10^{-4}$
Barium	-	$1.91x10^{-3}$	$5.98x10^{-3}$	$7.88x10^{-3}$
Cobalt	-	$7.15x10^{-5}$	$3.16x10^{-4}$	$3.88x10^{-4}$
Copper	-	$3.75x10^{-4}$	$1.66x10^{-3}$	$2.04x10^{-3}$
Lead	-	$3.42x10^{-4}$	$9.84x10^{-5}$	$4.40x10^{-4}$
Manganese	-	$1.82x10^{-3}$	$4.77x10^{-3}$	$6.59x10^{-3}$
Molybdenum	-	$1.24x10^{-4}$	$4.30x10^{-5}$	$1.67x10^{-4}$
Nickel	-	$1.84x10^{-4}$	$2.35x10^{-3}$	$2.53x10^{-3}$
Silver	-	$9.35x10^{-5}$	$1.14x10^{-3}$	$1.24x10^{-3}$
Strontium	-	$3.95x10^{-3}$	$3.98x10^{-4}$	$4.35x10^{-3}$
Vanadium	-	$1.17x10^{-4}$	$5.94x10^{-4}$	$7.11x10^{-4}$
Zinc	-	$2.27x10^{-3}$	$2.57x10^{-4}$	$2.53x10^{-3}$
Xylene	$9.83x10^{-3}$	$4.56x10^{-3}$	$2.93x10^{-5}$	$1.44x10^{-2}$
F1 Aliphatic	$3.25x10^{-1}$	$3.06x10^{-5}$	$1.97x10^{-4}$	$3.26x10^{-1}$
F1 Aromatic	$4.08x10^{-3}$	$7.66x10^{-6}$	$4.92x10^{-5}$	$4.14x10^{-3}$
F2 Aliphatic	$7.74x10^{-3}$	$6.01x10^{-3}$	$3.86x10^{-2}$	$5.23x10^{-2}$
F2 Aromatic	$6.97x10^{-3}$	$1.50x10^{-3}$	$9.65x10^{-3}$	$1.81x10^{-2}$
Ida Bay Silver Deposit				
Cobalt	-	$1.22x10^{-6}$	-	$1.22x10^{-6}$
Strontium	-	$7.48x10^{-4}$	-	$7.48x10^{-4}$

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:

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

where:

2.9×10^{-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 (2.9×10^{-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 vehicles.

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 Roberts Bay Silver Mine site, the following factors were identified:

- Accessibility Factor = 0.01
- Hazard Factor = 21/40 (access to vertical shaft + stability problems with collar surrounding the shaft)
- Scaling Factor = 1

Using these factors and an average annual fatality rate of 2.9 x 10^{-6}, the annual fatality rate from the Roberts Bay Silver Mine site was estimated to equal 1.5 x 10^{-8}.

For the Ida Bay Silver Deposit site, the following factors were identified:

- Accessibility Factor = 0.01
- Hazard Factor = 15/40 (access to adit, vent raise)
- Scaling Factor = 1 (note that the scale of the operation was quite small and a smaller scaling factor could be justified)

Using these factors and an average annual fatality rate of 2.9 x 10^{-6}, the annual fatality rate from the Ida Bay Silver Deposit site was estimated to equal 1.1 x 10^{-8}.

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 only the carcinogenic effects were assessed.

Table 6.1 provides a summary of the toxicity benchmarks for all the COPC for Roberts Bay and Ida Bay.

TABLE 6.1
TOXICITY BENCHMARKS

Contaminant	Dermal	Oral Toxicity Benchmarks[b]				Inhalation Toxicity Benchmarks			
	RAF [a]	Sf_o		(TDI/RfD_o)		SF_i		RfD_i	
	(-)	(mg/(kg d))$^{-1}$		(mg/(kg d))		(mg/(kg d))$^{-1}$		(mg/(kg d))	
Aluminum	0.1	na		1	N	na		na	
Arsenic	0.032	2.8	HC	na		28	HC	na	
Barium	0.1	na		0.016	HC	na		0.00014	H
Cobalt	0.1	na		0.02	N	9.8	N	na	
Copper	0.1	na		0.03	HC	na		na	
Lead	0.006	na		0.0019	I	na		na	
Manganese	0.1	na		0.14	I	na		na	
Molybdenum	0.1	na		0.005	I	na		na	
Nickel	0.35	na		0.02	I	3.13	HC	na	
Silver	0.25	na		0.005	I	na		na	
Strontium	0.1	na		0.6	I	na		na	
Vanadium	0.1	na		0.007	H	na		na	
Zinc	0.02	na		0.3	I	na		na	
Xylene	0.12	na		0.2	I	na		0.03	I
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

<u>Notes:</u> 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:

$$Risk = (D_i \times SF_i) + (D_o \times SF_o) + (D_d \times SF_d) \qquad (7.1)$$

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 x 10^{-5} (i.e. 1 in 100,000) was used for the SLRA. Risk levels for child receptors are generally not calculated since the exposure of a child is not sufficient for carcinogenic effects to be observed. In this case a composite receptor is assessed. This composite receptor encompasses the exposure of a child to the site for 10 years and the exposure of this child as an adult for an additional 60 years. In simple terms, the SLRA considers that someone would visit the site throughout their lifetime from child to an adult.

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

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

$$HQ = \frac{D_i}{RfD_i} + \frac{D_o}{RfD_o} + \frac{D_d}{RfD_d} \qquad (7.2)$$

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 this SLRA, the following hazard quotient values are used:

- In applications where only one pathway (e.g. the inhalation pathway) is 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 Roberts Bay site, a HQ value of 0.5 was used to assess acceptable exposures. For the Ida Bay site, a HQ value of 0.2 was used to assess acceptable exposures, as fewer pathways were considered in this assessment.

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 and soil. Estimated exposures were divided by the toxicity benchmarks (RfDs), presented in Section 6.1, to calculate the hazard quotients (HQ). The HQ values for Roberts Bay are shown in Table 7.1. HQ values in **bold** are those exceeding the value of 0.5 selected for this site. The HQ values for Ida Bay are shown in Table 7.2.

TABLE 7.1
HAZARD QUOTIENTS CALCULATED FOR ADULT AND CHILD AT ROBERTS BAY SITE

Contaminant	**Hazard Quotient**	
	Adult	**Child**
Aluminum	0.12	0.16
Barium	0.37	0.49
Cobalt	0.014	0.02
Copper	0.05	0.07
Lead	0.10	0.24
Manganese	0.04	0.05
Molybdenum	0.03	0.03
Nickel	0.10	0.13
Silver	0.19	0.25
Strontium	0.01	0.01
Vanadium	0.07	0.10
Zinc	0.005	0.01
Xylene	0.19	0.35
F1 Aliphatic	0.05	0.10
F1 Aromatic	0.04	0.07
F2 Aliphatic	0.34	0.47
F2 Aromatic	0.27	0.40
TOTAL SITE	**2.0**	**2.9**

From Table 7.1, it can be seen that none of the hazard quotients calculated for the COPC exceed the critical value of 0.5. However, the total site hazard quotient for both the adult and the child exceed the critical value. The sum of all HQs was determined to be 2.0 for the adult and 2.9 for the child. The greatest contributors to the total site HQ are barium, xylene and petroleum hydrocarbon (F2).

TABLE 7.2
HAZARD QUOTIENTS CALCULATED FOR ADULT AND CHILD AT IDA BAY SITE

Contaminant	**Hazard Quotient**	
	Adult	**Child**
Cobalt	0.0001	0.0001
Strontium	0.0011	0.001
TOTAL SITE	0.0011	0.0013

From Table 7.2, it can be seen that the hazard quotients calculated for cobalt and strontium are well below the critical value of 0.2. The total site HQ was determined to be 0.0011 for the adult and 0.0013 for the child.

7.2 CARCINOGENIC EFFECTS

For Roberts Bay, risk levels for exposure to arsenic (via ingestion, dermal and inhalation pathways) are presented in Table 7.3.

TABLE 7.3
RISK LEVELS CALCULATED FOR ADULT AND COMPOSITE RECEPTOR AT THE ROBERTS BAY SITE

Contaminant	Risk Level	
	Adult	Composite
Arsenic	1.75×10^{-4}	4.26×10^{-4}
TOTAL SITE	1.75×10^{-4}	4.26×10^{-4}

The risk level for arsenic exceeds the accepted risk level. Arsenic exposure to receptors at the Roberts Bay site is dominated by the ingestion pathway, and in particular, the consumption of water. 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. The total risk level was determined to be 1.75×10^{-4} for the adult and 4.26×10^{-4} for the composite receptor.

For Ida Bay, arsenic is not a COPC and thus no risk levels were calculated.

7.3 PHYSICAL RISKS

At Roberts Bay, the main adit is covered over with a wooden framework and is surrounded by a chain-link fence. The adit appears fully flooded (PWGSC and Rescan Environmental 2004). There is a vertical shaft that is accessible as it has a fence that only surrounds 2/3 of the perimeter of the shaft. There are stability problems with the collar surrounding the shaft. There is also a vent raise that is sealed with concrete, waste rock piles and berms that appear to be stable. There is general debris that could pose a physical hazard.

At the Ida Bay Site, there is a flooded adit with timber supports. The adit is not fenced or demarked. There is a vent raise covered with plywood, of which the condition is poor. There are three waste rock piles with stable slopes and three exploration trenches that are 1.2 metres deep and full of water.

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APPENDIX A

DETAILED EXPOSURE CALCULATIONS FOR THE HUMAN HEALTH RISK ASSESSMENT

LIST OF TABLES

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

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

A.1 INHALATION PATHWAY

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

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

where:

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

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

TABLE A1.1
TYPICAL AIR CONCENTRATIONS IN RURAL AREAS

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

A.2 DERMAL PATHWAY

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

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

where:

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

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

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

where:

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

A.3 INGESTION PATHWAY

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

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

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	$2.6 \mathrm{x} 10^{-3}$	NCRP 1996, Baes *et al*. 1984
Antimony	$8.0 \mathrm{x}\ 10^{-5}$	U.S. NRC 1992
Arsenic	$9.5 \mathrm{x} 10^{-4}$	NCRP 1996, Baes *et al*. 1984, U.S. EPA 1998
Barium	$9.7 \mathrm{x} 10^{-3}$	U.S. EPA 1998
Beryllium	$7.7 \mathrm{x} 10^{-4}$	U.S. EPA 1998
Boron	0.03	NCRP 1996
Cadmium	$3.8 \mathrm{x} 10^{-2}$	U.S. EPA 1998
Chromium	$1.5 \mathrm{x} 10^{-3}$	U.S. EPA 1998
Cobalt	$7.0 \mathrm{x} 10^{-3}$	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	$4.4 \mathrm{x} 10^{-3}$	U.S. EPA 1998
Molybdenum	0.12	NCRP 1996, Baes *et al*. 1984
Nickel	$1.8 \mathrm{x} 10^{-1}$	Baes *et al*. 1984
Selenium	2.9×10^{-3}	NCRP 1996, Baes *et al*. 1984, U.S.EPA 1998
Silver	$4.1 \mathrm{x} 10^{-2}$	U.S. EPA 1998
Strontium	0.2	IAEA 1994
Tin	$6.0 \mathrm{x} 10^{-3}$	Baes *et al*. 1984
Uranium	1.1×10^{-3}	Cassaday *et al.* 1985
Vanadium	$3.0 \mathrm{x} 10^{-3}$	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	$3.0 \mathrm{x} 10^{-3}$	U.S. EPA 1998
Thiocyanate	3.5	McKone 1994
Xylene	$9.4 \mathrm{x} 10^{-2}$	McKone 1994
Radionuclides ((Bq/kg (ww))/(Bq/kg (dw)))		
Thorium-230	8.5×10^{-5}	Baes *et al*. 1984
Lead-210	9.0×10^{-2}	U.S. NRC 1992
Radium-226	7.2×10^{-4}	Cassaday *et al.* 1985
Polonium-210	4.0×10^{-4}	Baes *et al*. 1984

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

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

where:

$C_{caribou}$ = concentration of contaminant in caribou flesh [mg/kg (ww)]
Q_{water} = water ingestion rate [g/d] {9,500 g/d, based on Kirk (1977) and Wales *et al.* (1975)}
C_{water} = measured water concentration [mg/L]
1/1000 = units conversion factor [L/g] or [kg/g]
Q_i = food ingestion rate [g/d] for each i, such that
Q_{forage} – 80 {calculated from U.S. EPA (1993) and based on Thomas and Barry (1991)}
Q_{browse} – 400 {calculated from U.S. EPA (1993) and based on Thomas and Barry (1991)}
Q_{lichen} – 7,520 {calculated from U.S. EPA (1993) and based on Thomas and Barry (1991)}
C_i = concentration of food [mg/kg (ww)] for each i, such that
C_{forage} – {calculated in equation (A-9)}
C_{browse} – {calculated in equation (A-10)}
C_{lichen} – {calculated in equation (A-11)}
Q_{soil} = soil ingestion rate [g/d] {104 g/d, calculated from Beyer *et al.* (1994)}
C_{soil} = soil concentration [mg/kg (dw)]
F_{site} = fraction of time caribou at site [-] {assumed to be 0.10}
$TF_{feed-to-caribou}$ = feed-to-caribou transfer factor [d/kg (ww)] {Table A3.4}

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

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

where:

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

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

TABLE A3.2
SOIL-TO-FORAGE TRANSFER FACTORS

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

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

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

where:

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

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

TABLE A3.3
SOIL-TO-BROWSE TRANSFER FACTORS

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

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

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

where:

C_{lichen} = concentration of contaminant in lichen [mg/kg (ww)]
C_{air} = air concentration [mg/m^3]
V_{dep} = deposition velocity [cm/s] {assumed 2 cm/s, from SENES (1987)}
F_{in} = fraction of deposition intercepted by lichen [-] {assumed to be 1}
F_{rv} = fraction of deposition retained on lichen [-] {0.95, from SENES (1987)}
E_v = fraction of deposition on edible portion of lichen [-] {1, from SENES (1987)}
Y_v = yield density [g (ww)/m^2] {500 g/m^2, from SENES (1987)}
λ_w = weathering loss decay constant [1/s] {2.2x10^{-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):

$$C_{fish} = C_{water} \times TF_{water-to-fish} \tag{A-12}$$

where:

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

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

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

TABLE A3.5
WATER-TO-FISH TRANSFER FACTORS

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

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

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

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):

$$C_{benthos} = C_{water} \times TF_{water-to-benthos} \tag{A-17}$$

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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APPENDIX B

HEALTH CANADA TOXICOLOGICAL REFERENCE VALUES

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

Name	Non-Carcinogenic Toxicological Reference Values		Carcinogenic Toxicological Reference Values			
	HC TDI [a]	HC TDC	Oral slope factor from TD_{05} [b]	Inhalation slope factor from TC_{05} [b,c]	Inhalation unit risk from TC_{05} [b]	Oral slope factor from DWQG [a]
	mg/kg-d	mg/m3	(mg/kg-d)$^{-1}$	(mg/kg-d)$^{-1}$	(mg/m^3)$^{-1}$	(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.