

**FINAL REPORT  
ON**

**HUMAN HEALTH  
SCREENING LEVEL RISK ASSESSMENT  
FOR THE UNITED KENO MINE SITE**

**Prepared for:**

**Department of Indian Affairs  
and Northern Development**

**Prepared by:**

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

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## **EXECUTIVE SUMMARY**

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

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

For the United Keno Mine site, measured concentrations of contaminants in water and tailings 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 resident of Keno City, consuming drinking water, fish and wild game from the study area. The resident was also assumed to be exposed through dermal pathways and inhalation. Exposure information, such as drinking water consumption, inhalation rates, and body weight, was obtained from data on the general Canadian population. Dietary characteristics, such as consumption of fish, animals and birds, were obtained from a food survey for indigenous populations in the Northwest Territories, in the absence of other data.

The human health risk assessment was conducted using assumptions that result in an overestimate of exposure. As noted above, the human receptor was assumed to obtain all food and water from the site for the entire year and to be exposed to maximum contaminant levels from each exposure pathway. The estimated exposures (or intakes) by the human receptors were compared to intake levels considered to be protective of human health (i.e. reference doses), calculating hazard quotients (HQ) for non-carcinogenic effects, and risk levels for carcinogenic effects. These values are shown in Tables ES-1 and ES-2. Values in **bold** are those exceeding the designated levels for this site (0.5 for HQ, and  $1 \times 10^{-5}$  for risk level).

The assessment of intake showed that the hazard quotients of antimony, barium, cadmium, copper, lead, manganese, selenium and zinc exceeded the value of 0.5 selected for this site. Arsenic exceeded the selected risk level of  $1 \times 10^{-5}$  selected for this site. The main source of these contaminants was consumption of fish.

**TABLE ES-1  
CALCULATED HAZARD QUOTIENT VALUES**

Contaminant	Hazard Quotient	
	Adult	Child
Antimony	7	10
Barium	0.5	0.8
Cadmium	2	3
Copper	3	4
Lead	1	2
Manganese	0.7	0.9
Nickel	0.2	0.3
Selenium	2	3
Silver	0.2	0.2
Strontium	0.01	0.01
Zinc	5	7
<b>TOTAL SITE</b>	<b>21.6</b>	<b>31.2</b>

**TABLE ES-2  
CALCULATED RISKS OF CARCINOGENIC EFFECTS**

Contaminant	Risk Level	
	Adult	Composite
Arsenic	$2.5 \times 10^{-3}$	$6.2 \times 10^{-3}$
Cadmium	$1.6 \times 10^{-6}$	$4.2 \times 10^{-6}$
Nickel	$9.0 \times 10^{-8}$	$2.4 \times 10^{-7}$
<b>TOTAL SITE</b>	<b><math>2.5 \times 10^{-3}</math></b>	<b><math>6.2 \times 10^{-3}</math></b>

Physical hazards at the United Keno site include numerous unsealed mine openings, waste rock piles, open pits and surface structures. For the physical hazards risk assessment, 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 United Keno site, the annual fatality rate was estimated to equal  $8.7 \times 10^{-6}$ .

## **1.0 INTRODUCTION**

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

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

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

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

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

Similarly, PCB contamination associated with paint and electrical equipment on-site are low in volatility, hence, exposure to PCBs from this material can only come from ingestion of this

material, a highly unlikely scenario. Therefore, exposure to PCB in these materials was not considered in the assessment.

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

1. First, the implications of discontinuing care and maintenance activities (e.g. stop treatment of mine water and/or tailings pond water, leave waste areas exposed to weathering conditions, etc.) were assessed to quantify the effects of the release of untreated waters and uncovered contaminated soils on human health;
2. Secondly, the hazards posed by on-site facilities (e.g. open pits, mine openings, waste rock piles, buildings, etc.) were assessed to quantify the potential risks of physical harm (fatality) to people accessing the sites; and
3. Thirdly, an inventory of chemical and fuel containers (e.g. barrels, tanks) and other equipment that pose potential hazards to people were compiled.

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

This report details the methodology and assumptions and presents the results of the SLRA for the United Keno Mine site.

## **1.1 SLRA APPROACH FOR CHEMICAL AND RADIOLOGICAL EXPOSURES**

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

Very few sites have measured concentrations of contaminants in air. In the absence of these concentrations, representative air concentrations from rural locations were used to calculate exposure from the air pathway. Professional experience suggests that the inhalation exposure pathway related to metals and less volatile organic contaminants such as polychlorinated aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) is insignificant in

comparison to the oral pathway. Therefore, the assumption of using representative rural concentrations is not unreasonable.

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

## **1.2 SLRA APPROACH FOR PHYSICAL HAZARDS**

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

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

## **1.3 REPORT STRUCTURE**

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

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

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

**Section 4 – Receptor Characterization:** Identifies the human receptors (i.e. adults) who may spend time in the study area based on the accessibility to the site and the proximity of nearby



communities. The pathways of exposure of human receptors and their respective dietary characteristics are described.

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

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

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

## 2.0 SITE CHARACTERIZATION AND PHYSICAL HAZARDS

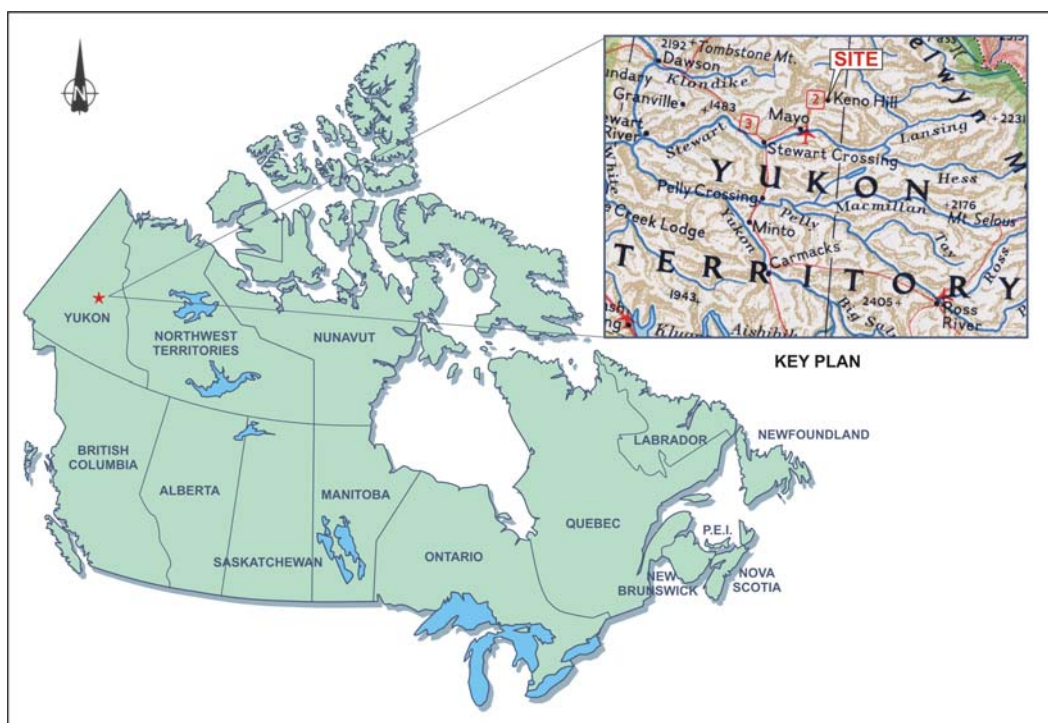
The Keno Hill site is located in the Yukon Territory and has been mined for lead, silver and zinc since the early 1900's. The last mining operations were completed in 1989 and following closure of the mine, the property was placed on care and maintenance. The Keno Hill mine is considered to be Canada's second largest producer of silver (Hatch 2003). From 1914 to 1989, about 6.8 million kg of silver was produced from 93 mine sites located around the property. The mining operations were spread over an area about 26 km by 6 km.

This section provides a brief description of the United Keno site and its physical characteristics.

### 2.1 SITE DESCRIPTION

The United Keno site is located in the central Yukon Territory, about 354 km north of Whitehorse (see Figure 2.1). Keno City and Elsa Village are in the vicinity of the site. Elsa Village is currently unoccupied following the shutdown of the Elsa Mine in 1989. At one time, 400 people lived in Elsa and there are many remaining buildings in various conditions. Keno City is currently occupied with 30 to 50 residents. It is a Yukon tourist destination on the Silver Trail, with several tourist attractions and accommodations. The area surrounding the Keno Hill site has been used for centuries by local First Nations for their traditional lifestyle.

**FIGURE 2.1  
LOCATION OF THE UNITED KENO SITE**

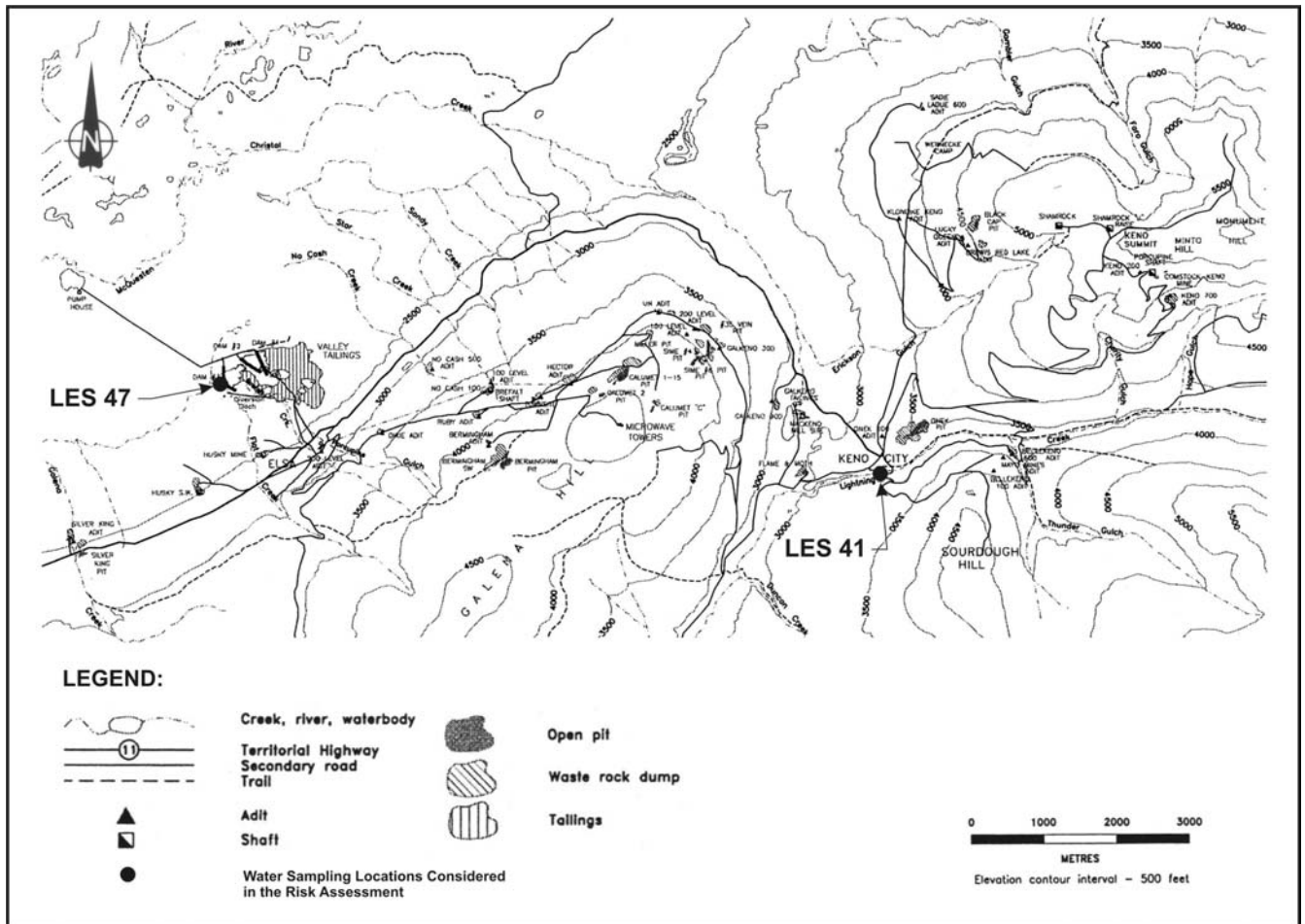


Source: National Geographic (1999).

The site is accessible by a 407 km paved road from Whitehorse to Mayo and a 45 km all weather gravel road from Mayo to Keno City. Many of the mining sites around the Keno Hill area are visited by tourists. There are guiding-outfitting operations and two territorial campgrounds in the area. Trapping concessions are located within the Keno Valley area and trapping is an important way of life for many residents.

Mining occurred at 93 sites across three hills (Keno, Galena and Sourdough Hills). Lightning Creek drains to the south of the hills towards the Mayo River, which runs to the McQuesten River and on to the Stewart River. Flat Creek drains the south west side of Galena Hill, with headwaters including Porcupine Gulch, Brefalt Creek and Galena Creek. Flat Creek eventually joins the McQuesten River. Christal Creek drains the east side of Keno Hill and the north, east and west side of Galena Hill. The McQuesten River valley is to the north of the three hills. Figure 2.2 provides an overview of the site.

**FIGURE 2.2  
OVERVIEW OF THE UNITED KENO SITE**



Source: Hatch (2003).

## **2.2 PHYSICAL FEATURES**

### ***2.2.1 Physical Hazards at Mine Sites***

Typically, there are numerous potential 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 operation and to what degree closure and decommissioning measures have been implemented. The following paragraphs describe the most important hazardous features of abandoned mine sites.

#### ***Surface (Shaft) Openings***

Vertical mine openings associated with underground mines include shafts, ventilation raises and surface openings associated with mine workings. 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.

Ventilation raises are typically smaller than shafts and may be scattered at multiple locations. Surface openings may also include areas where underground working have intersected the surface or areas where the surface has collapsed into the underground mine.

#### ***Adits***

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

#### ***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<sub>2</sub>) occur naturally in some mines, particularly in coal mines. Pockets of carbon dioxide or other deadly gases displace oxygen with no visible sign. This is a deadly trap for the visitors of abandoned mine sites.

### ***Open Pits***

Not all mining is carried out 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 conditions. 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 (in southern mines associated with swimming) 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. The 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 saturated fines and a pond of water. Without ongoing care and maintenance, tailings dams deteriorate and are subject to failure resulting in 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 by 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.

### ***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 United Keno Site***

Table 2.1 summarizes the physical features and hazards present at the United Keno Mine site. These hazards present include:

- unsealed mine openings;
- steep loose rock piles;
- open pits; and
- unstable surface structures.

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

**TABLE 2.1  
PHYSICAL FEATURES OF THE UNITED KENO SITE**

Physical Parameter	Key Features	Characteristics	Description
<b>Tailings Impoundments</b>		General Information	6800 tonnes silver from >4.6 million tonnes of ore were produced from over 34 underground mine sites (425,600 tonnes of ore from one open pit).
		Total Tailings Volume	>4.6 million tonnes
		Dates of Tailings Deposition	Wernecke Mill (Keno Hill): 1924-1933; Elsa Mill (Galena Hill) 1935-1989.
	<b>Wernecke Mill Tailings</b>	General Information	The Wernecke Mill, 110 tpd mill at Keno Hill, was operated from 1924 to 1933 (relocated to Elsa in 1933). Tailings were assumed to be produced, but there is no mention of tailings deposition in this area.
		Additional Information	See Footnote 1
	<b>Christal Lake/Galkeno Tailings</b>	General Information	Mackeno Mill deposited Galkeno Tailings into Christal Creek, Christal Lake, and the eastern shore of Christal Lake.
		Tailings Volume	Approx. 40,000 tonnes
		Dates of Deposition	1952-1954
		Additional Information	See Footnote 1
	<b>Flat Creek/Elsa Tailings (Uncontained)</b>	General Information	Tailings were discharged from the mill and allowed to flow down Porcupine Gulch, along the adjacent hillside, and into the bog and headwaters of Flat Creek.
		Tailings Volume	See Footnote 1
		Dates of Deposition	1936-1961
		Tailings Surface Area	See Footnote 1
		Tailings Average Depth	See Footnote 1
		Avg Depth to Water Table	See Footnote 1
		Physical Stability	Unknown. Tailings remain unconfined on the hillside and in drainages.
		Geochemical Characteristics, Acid Base Accounting (ABA)	See Footnote 1
		Groundwater Seepage Rate	See Footnote 1
		Surface Discharge Rate	See Footnote 1
		Cover Type	None
Vegetation		See Footnote 1	
Erosion		Erosion is presumably ongoing as tailings remain unconfined.	

**TABLE 2.1 (Cont'd)**  
**PHYSICAL FEATURES OF THE UNITED KENO SITE**

Physical Parameter	Key Features	Characteristics	Description
<b>Tailings Impoundments</b>	<b>Flat Creek/Elsa Tailings (Uncontained)</b>	Accessibility	See Footnote 1
		Additional Information	Tailings released during two dam breach episodes in the 1960s and two dam failures since 1972 have transported additional tailings (volume not determined) downstream. Tailings are reportedly up to 20 km downstream in the South McQuestern River.
	<b>Elsa Tailings Contained Area</b>	General Information	A series of three dams were built in sequence on the western side of the bog at Flat Creek to contain tailings.
		Tailings Volume	4.6 million tonnes
		Dates of Deposition	1962-1979.
		Tailings Surface Area	Estimated 75 ha.
		Tailings Average Depth	See Footnote 1
		Avg Depth to Water Table	See Footnote 1
		Physical Stability	See Footnote 1
		Geochemical Characteristics, Acid Base Accounting (ABA)	See Footnote 1
		Groundwater Seepage Rate	See Footnote 1
		Surface Discharge Rate	See Footnote 1
		Cover Type	Most tailings are dry and uncovered. Some tailings are under water cover (volume unknown).
		Vegetation	Approx. 10% of tailings have naturally revegetated.
		Erosion	Drainage from Porcupine Gulch continues to erode tailings downstream into Flat Creek, especially in spring.
		Accessibility	Tailings are accessible.
	Additional Information	Tailings flowed down Porcupine Gulch to the containment area. Residual tailings remain in the gulch. In 1979, a diversion ditch was built to divert water around the tailings impoundment to prevent erosion. The ditch continues to erode tailings into Flat Creek.	
	<b>Dams</b>	General Information	Dam #1 built in 1962; Dam #2 built in 1972 and Dam #3 was built in 1979.
		Dimensions	See Footnote 1
		Type of Construction	Gravel and waste rock on top of frozen peat and silty till.
		Discharge Structure	No suitable spillways or discharge structures.
Seepage		Seepage, although not quantified, is significant.	
Erosion		See Footnote 1	



**TABLE 2.1 (Cont'd)**  
**PHYSICAL FEATURES OF THE UNITED KENO SITE**

Physical Parameter	Key Features	Characteristics	Description	
<b>Tailings Impoundments</b>	<b>Dams</b>	Stability	Dam #1 breached several times in the 1960s and has failed twice since 1972. Dams were considered marginally stable in 1996 (built on permafrost). A dam assessment has not been conducted.	
		Additional Information	In 1996 a toe berm was added to dam #1 and remedial lifts have been added to the subsiding dams up to 2001.	
	<b>Dykes</b>	General Information	No dykes were identified on the site.	
<b>Pits</b>		General Information	Beginning in 1977, several pits were excavated to develop 14 deposits. A total of approximately 425,600 tonnes of ore was produced from these pits.	
		Additional Information	See Footnote 1	
<b>Underground Workings</b>	<b>Surface Openings</b>	General Information	Numerous surface openings are associated with the 34 mine sites in the area. For specific information on all the openings, please see footnote 1.	
		General Information	Numerous surface openings provide access to the 34 underground mines in the area.	
		Volume	See Footnote 1	
		Depth	See Footnote 1	
		Contents of Workings	See Footnote 1	
		Depth to Watertable	See Footnote 1	
		Groundwater Seepage Rate	See Footnote 1	
		Surface Discharge Rate	Surface discharge is occurring from 5 adits (metal-enriched; mostly neutral pH): Galkeno 300 adit: 40-50 L/sec (123 ppm Zinc); No Cash 500; Galkeno 900; Silver King; and Bellekeno.	
		Stability	Ice plugs and ice plug failures are hazard (Onek adit near Keno City has had 3 documented ice plug failures).	
		Accessibility	See Footnote 1	
		Ventilation/Gases	See Footnote 1	
		Additional Information	The Hector-Calumet workings reportedly produced over half of the total ore from 1935-1972.	
		<b>Number and Type of Opening</b>	General Information	Onek Adit is within 100m of residents in Keno City and within 300 m of the community groundwater well supply.
			Volume	See Footnote 1
	Depth		See Footnote 1	
Contents of Workings	Flooded			
Depth to Watertable	Flooded (not determined)			

**TABLE 2.1 (Cont'd)**  
**PHYSICAL FEATURES OF THE UNITED KENO SITE**

Physical Parameter	Key Features	Characteristics	Description
<b>Underground Workings</b>	<b>Number and Type of Opening</b>	Groundwater Seepage Rate	See Footnote 1
		Surface Discharge Rate	Not determined. Surface water contained 0.998 ppm Cd and 24.2 ppm Zn in 1996. Water discharges from the adit and recharges into groundwater.
		Stability	Ice plugs and ice plug failures are hazard (Onek adit near Keno City has had 3 documented ice plug failures).
		Accessibility	See Footnote 1
		Ventilation/Gases	Flooded.
		Additional Information	See Footnote 1
<b>Waste Rock Piles</b>	<b>Husky Mine Waste Rock Pile</b>	General Information	There are numerous waste rock piles (>25) around the 34 mines at this site. These piles have not been described, neither by number, volume, or characteristics of material. Waste rock is currently assumed to not be acid generating (low pH seepage is uncommon); however its long-term stability is uncertain. The one ARD waste rock pile identified is from at Husky Mine.
		General Information	This is the only waste rock pile identified creating ARD.
	Location	Husky Mine, east of Silver King, downslope of Elsa.	
	Volume	See Footnote 1	
	Surface Area	See Footnote 1	
	Height/Depth	See Footnote 1	
	Depth to Water Table	See Footnote 1	
	Geochemical Characteristics, Acid Base Accounting (ABA)	Observations of iron and precipitate staining. Seepage had pH of 2.6 to 3.6 in 1999.	
	Groundwater Seepage Rate	See Footnote 1	
	Surface Discharge Rate	See Footnote 1	
	Cover (water, soil, sand, none, etc.)	See Footnote 1	
	Vegetation	See Footnote 1	
	Sloped/Graded Surfaces	See Footnote 1	
	Erosion	See Footnote 1	
	Physical Stability	See Footnote 1	
Additional Information	See Footnote 1		
<b>Other Waste Rock Piles</b>	General Information	Numerous small-scale waste rock piles exist adjacent to the workings of the underground mines in the area.	
	Additional Information	See Footnote 1	
<b>Infrastructure (Keno Hill)</b>		General Information	Documented evidence of spills around the fuel and oil tanks.
<b>Infrastructure (Mackeno Mill Site)</b>		General Information	No information on this mill site is available. Reportedly in operation from 1952-1954.

**TABLE 2.1 (Cont'd)**  
**PHYSICAL FEATURES OF THE UNITED KENO SITE**

Physical Parameter	Key Features	Characteristics	Description
<b>Infrastructure (Elsa)</b>		General Information	Town of Elsa inhabited by up to 400 people from 1929 to 1989.
		Date of Construction	1929-1980s
		Number of Buildings	Numerous (>57), including industrial buildings (poor condition), and school, recreation center, swimming pool building, bunkhouse, etc in relatively good/fair condition.
		Type of Construction	Varies, wood and steel.
		Condition/Stability	Varies from poor to good.
		Accessibility	Unknown
		Additional Information	21 buildings reportedly contain asbestos.
<b>Tank Farms</b>		General Information	Not determined, although numerous above and below ground fuel and oil storage tanks are reportedly on-site.
		Type of Tanks and Number	See Footnote 1
		Contents and Volume	See Footnote 1
		Condition of Tanks	See Footnote 1
		Containment	See Footnote 1
		Documented Spillage	See Footnote 1
		Additional Information	See Footnote 1
<b>Fuels, Chemicals, PCBs</b>	<b>PCB</b>	General Information	A comprehensive audit or inventory of hazardous waste has not been done for the Keno Mine Site.
		Contents and Volume	A PCB storage building in on-site, however contents of the shed and historical use of PCBs is unknown.
		Container Type and Number	See Footnote 1
		Condition of Containers	See Footnote 1
		Evidence of Leakage/Spillage	See Footnote 1
		Documented Incidents or Spills	See Footnote 1
		Additional Information	See Footnote 1
	<b>Contaminant Type</b>	Type of Contaminant	Numerous hazardous materials and containers exist on-site, including: above and below ground fuel and oil storage tanks, 8 solid waste dumps, flotation reagents, and other chemicals.
		Volume	See Footnote 1
		Condition of Container	See Footnote 1
		Evidence of Leakage/Spillage	Documented evidence of spills around the fuel and oil tanks.

**TABLE 2.1 (Cont'd)**  
**PHYSICAL FEATURES OF THE UNITED KENO SITE**

<b>Physical Parameter</b>	<b>Key Features</b>	<b>Characteristics</b>	<b>Description</b>
<b>Fuels, Chemicals, PCBs</b>	<b>Contaminant Type</b>	Documented Incidents or Spills	Not determined
		Additional Information	Reportedly no explosives or cyanide on-site.
<b>Additional Physical Hazards</b>		General Information	See Footnote 1

**Note:** 1. See individual site reports prepared by PWGSC (2000) for details.

### **3.0 CHEMICAL HAZARD IDENTIFICATION**

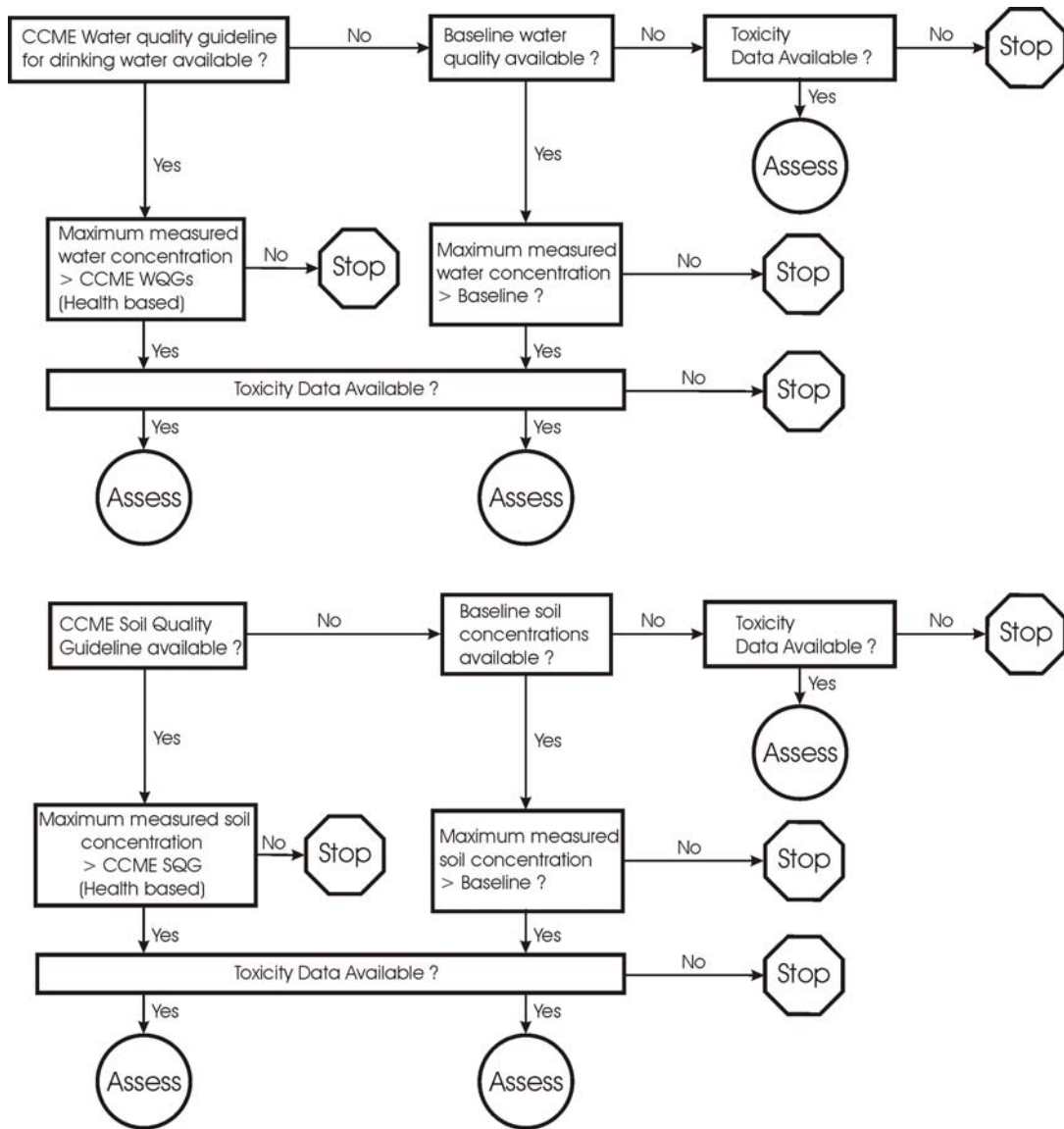
This section identifies the contaminants of concern that are selected for this assessment of potential human health effects from exposure to chemical contaminants. In addition, site features that pose risks of physical injury to site visitors are identified.

#### **3.1 SELECTION OF CONTAMINANTS OF POTENTIAL CONCERN**

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

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

**FIGURE 3.1**  
**SELECTION PROCEDURE FOR CONTAMINANTS OF POTENTIAL CONCERN**



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

**Water Quality**

Two locations in the United Keno Mine area were considered representative of potentially impacted water bodies from inputs of upstream mines. The first representative location was near Keno City, where Keno City Road crosses Lightning Creek (sampling point LES 41 (PWGSC 2000)). Lightning Creek drains the south side of Keno Hill, the north, east and west side of Bunker Hill, the south and west sides of Sourdough Hill and the south east side of Galena Hill.

Mine sites potentially impacting this location include: Flame and Moth, Onek, Bellekeno 100, Bellekeno 600, Mayo, Keno 200, Keno 700, Porcupine, Comstock 150 and Comstock 200.

The second representative location was in the Porcupine Diversion of Flat Creek, downstream of all inputs from mines in the local drainage area (sampling point LES 47, PWGSC (2000)). This location captures the contribution from the Elsa Tailings Impoundment, as well as Husky and Elsa mine sites.

The maximum measured contaminant concentrations from the combination of data from these two sampling locations are presented in Table 3.1 for a comparison with baseline information and CCME guidelines (2002). Baseline water quality in the area was characterized by measured data from Lightning Creek, upstream of Hope Gulch (sampling point LES 37, PWGSC (2000)). Concentrations that were measured below the method detection limit (MDL) were reported as ½ the detection limit.

As shown in Table 3.1, the measured concentrations of aluminum, barium, chromium, manganese, nitrate, nitrite and zinc were below the CCME guideline and were not assessed further. Beryllium, cobalt, molybdenum, silver, tin, titanium and vanadium concentrations were at baseline concentration levels and were also not considered further. Toxicity data were not available for ammonia, iron and magnesium and therefore, these contaminants cannot be assessed further for the human health risk assessment. The measured concentrations of antimony, arsenic, cadmium, copper, lead and selenium exceed the CCME guidelines and become COPC. Finally, nickel and strontium are also COPC, since the measured concentrations exceed baseline levels.

**TABLE 3.1  
SUMMARY OF WATER QUALITY DATA**

Contaminant	CCME Drinking Water Quality Guideline (mg/L)	Maximum Measured Water Concentration (mg/L) <sup>d</sup>	Lightning Creek Baseline Water Concentration (mg/L) <sup>e</sup>
<b>Metals</b>			
Aluminum	0.2 (0.1) <sup>a</sup>	0.08	0.03 <sup>c</sup>
Antimony	0.006	<b>0.03</b> <sup>c</sup>	0.03 <sup>c</sup>
Arsenic	0.025	<b>0.03</b> <sup>c</sup>	0.03 <sup>c</sup>
Barium	1.0	0.05	0.044
Beryllium	-	0.0005 <sup>c</sup>	0.0005 <sup>c</sup>
Cadmium	0.005	<b>0.044</b>	0.003 <sup>c</sup>
Chromium	0.05	0.018	0.009
Cobalt	-	0.003 <sup>c</sup>	0.003 <sup>c</sup>
Copper	1.0 <sup>b</sup>	<b>2.65</b>	0.003 <sup>c</sup>
Iron	0.3 <sup>b</sup>	<b>1.58</b>	0.096
Lead	0.010	<b>0.03</b> <sup>c</sup>	0.03 <sup>c</sup>
Magnesium	-	8.73	2.7
Manganese	0.05 <sup>b</sup>	0.015	0.015
Molybdenum	-	0.005 <sup>c</sup>	0.005 <sup>c</sup>
Nickel	-	0.19	0.01 <sup>c</sup>
Selenium	0.01	<b>0.09</b>	0.03 <sup>c</sup>
Silver	-	0.005 <sup>c</sup>	0.005 <sup>c</sup>
Strontium	-	0.057	0.048
Tin	-	0.03 <sup>c</sup>	0.03 <sup>c</sup>
Titanium	-	0.001 <sup>c</sup>	0.001 <sup>c</sup>
Vanadium	-	0.005 <sup>c</sup>	0.005 <sup>c</sup>
Zinc	5.0 <sup>b</sup>	3.85	0.004
<b>Other Contaminants</b>			
Ammonia	-	0.463	0.0025 <sup>c</sup>
Nitrate as N	10	0.276	0.03
Nitrite as N	3.2	0.0025 <sup>c</sup>	0.0025 <sup>c</sup>

Values in **bold** exceed the guideline.

Note:

a – 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.

b – Guideline is based on aesthetic concerns.

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

d – The maximum of the measured concentrations from one sample at Lightning Creek at Keno City Road Crossing (LES 41) and three samples at Porcupine Diversion (Flat Creek) downstream of all inputs (LES 47), from PWGSC (2000), Volume 1, Appendix A.

e – From one sample collected at Lightning Creek upstream of Hope Gulch (LES 37), from PWGSC (2000), Volume 1, Appendix A.



**Soil Quality**

The next step in the selection process involved a comparison of the maximum contaminant levels measured in soil to available CCME soil quality guidelines (SQG), as shown in Table 3.2. This process identified additional COPC. Soil quality for the United Keno Mine area were not available for the current assessment. Tailings contaminant levels in the United Keno Mine area were characterized by measured levels in tailings at the Elsa Tailings Impoundment. The maximum measured concentrations are presented in Table 3.2.

Concentrations that were measured below the method detection limit (MDL) were reported as ½ the detection limit. Maximum measured concentrations of beryllium, chromium, cobalt, copper, mercury, molybdenum, nickel, selenium, tin and vanadium were below the CCME SQG for human health and therefore, these contaminants were dropped from further assessment. Similarly, aluminum, iron, strontium, titanium and uranium were below baseline levels in typical soils and these contaminants were dropped from further assessment. Toxicity data were not available for bismuth and therefore this contaminant was not selected.

Maximum measured concentrations of antimony, arsenic, barium, cadmium, lead, silver and zinc at the United Keno site exceed the CCME SQG for human health and therefore these contaminants were selected for the assessment. The maximum measured concentration of manganese exceeded baseline soil concentrations, so this contaminant was also included in the assessment.

**TABLE 3.2  
SUMMARY OF TAILINGS/SOIL QUALITY DATA**

Contaminant	CCME Soil Quality Guideline (Human Health) (mg/kg) <sup>a</sup>	Maximum Measured Tailings Concentration (mg/kg) <sup>b</sup>	Typical Soil Concentration (mg/kg) <sup>c</sup>
<b>Metals</b>			
Aluminum	-	27,800	155,000
Antimony	20 *	<b>230</b>	5.3
Arsenic	12	<b>1,800</b>	20.5
Barium	500 *	<b>606</b>	1800
Beryllium	4 *	0.6	20.1
Bismuth	-	2.5 <sup>d</sup>	n/a
Cadmium	14	<b>174</b>	3.5
Chromium	220	35.1	1,503
Cobalt	50 *	9.5	20.5
Copper	1,100	149	51
Iron	-	130,000	278,000
Lead	140	<b>8,100</b>	101

**TABLE 3.2 (Cont'd)  
SUMMARY OF TAILINGS SOIL QUALITY DATA**

Manganese	-	50,100	2,050
Mercury	6.6	1	0.05
Molybdenum	10 *	4	2.6
Nickel	50 *	23.5	503
Selenium	1 *	1 <sup>d</sup>	1.05
Silver	20 *	<b>149</b>	2.6
Strontium	-	51	525
Tin	50 *	6	101
Titanium	-	802	5,500
Uranium	-	2.5 <sup>d</sup>	5.0
Vanadium	130 *	63	260
Zinc	200 *	<b>9,960</b>	155

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

- a – From CCME (2002), human health component of the soil quality guideline for residential/parkland, except as noted (\*) where the soil quality guideline is used in the absence of a human health component.
- b – Maximum concentrations of the five tailings samples reported in PWGSC (2000), Volume 5, Site 79, Table 2.
- c – Typical concentrations in native soil for various locations, from Dragun (1998).
- d – Measured value was less than method detection limit (MDL), thus was set to half MDL

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

**TABLE 3.3  
COPC SELECTED FOR THE ASSESSMENT**

Antimony
Arsenic
Barium
Cadmium
Copper
Lead
Manganese
Nickel
Selenium
Silver
Strontium
Zinc

### 3.2 SUMMARY OF OTHER CHEMICAL DATA FOR SLRA

The screening level risk assessment for the United Keno Mine site used available measured data where possible. There were measured fish data available, in addition to the measured water and tailings data presented in the previous section.

#### ***Fish Data***

White Mountain Environmental Consulting completed a fish habitat and fish tissue analysis for the United Keno Hill Mine area, *Fish and Fish Habitat Assessment Conducted near Elsa, Yukon for United Keno Hill Mines August 1994 – September 1995* (White Mountain Environmental Consulting 1995). Data on fish muscle analyzed from Christal Creek were used for the current assessment. Maximum measured concentrations of the 6 reported samples are shown in Table 3.4 for COPC.

**TABLE 3.4  
MEASURED FISH CONCENTRATIONS**

<b>Contaminant</b>	<b>Maximum Measured Concentration in Fish Muscle (mg/kg (ww))<sup>a</sup></b>
Antimony	-
Arsenic	1 <sup>b</sup>
Barium	-
Cadmium	0.20
Copper	1.8
Lead	2.0
Manganese	-
Nickel	2.4
Selenium	-
Silver	-
Strontium	-
Zinc	231

Note:

a – Maximum measured concentrations in fish muscle were calculated from Christal Creek samples CDS 1 to 5 presented in Table 9 of White Mountain Environmental Consulting (1995). Units were assumed to be in mg/kg (ww).

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

-- Not reported.

## **4.0 RECEPTOR CHARACTERIZATION**

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

### **4.1 EXPOSURE SCENARIO AND RECEPTOR SELECTION**

The scenario examined in this assessment involved the abandonment of the site in its existing condition. Given the proximity of the site to the Keno City community, it is not unreasonable to consider that residents of that community would visit the site frequently. There are several trapping concessions within the property, a campground near Lightning Creek in Keno City and lots of local rivers, streams and lakes for boating and fishing. Therefore, an adult and child (5 to 11 years) residents were assumed to obtain fish, wild game and drinking water from the site for six months of the year. While other visitors (e.g., inspectors and tourists) may visit the site, the resident receptor represents the most exposed individuals.

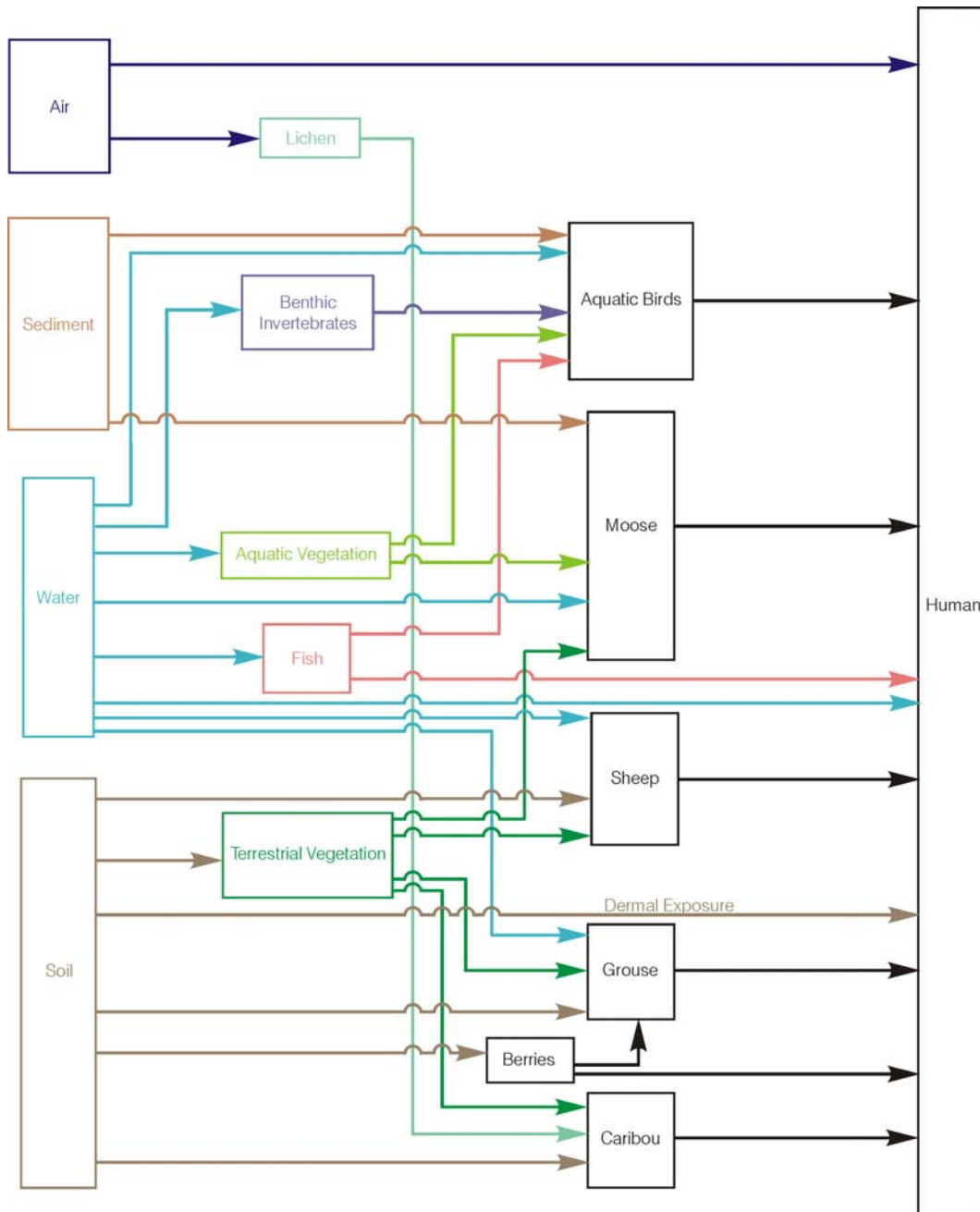
### **4.2 EXPOSURE PATHWAYS CONSIDERED**

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

- a) Inhalation of dust;
- b) Ingestion of tailings;
- c) Ingestion of food – food includes fish, moose, sheep, caribou, aquatic and terrestrial birds;
- d) Ingestion of berries;
- e) Ingestion of water; and
- f) Dermal contact with exposed tailings.

Because the current assessment used measured tailings concentrations at the United Keno Mine site, it is assumed that all wildlife that consumes soil and terrestrial vegetation (e.g., moose, sheep, caribou and terrestrial birds) and the human receptors are only present at the tailings area 10% of their time while in the study area.

**FIGURE 4.1  
EXPOSURE PATHWAYS FOR HUMAN RECEPTORS**



### 4.3 RECEPTOR CHARACTERISTICS

The human receptor characteristics for the Keno City resident used for the assessment are shown in Table 4.1. In the absence of specific data for the community, intake values were obtained from a food survey from the Sahtu community, NWT (Receveur *et al.* 1996).

**TABLE 4.1**  
**HUMAN RECEPTOR CHARACTERISTICS SELECTED FOR ASSESSMENT**

	Adult	Child (5 to 11 years)
Fraction of year at site (-) <sup>a,b</sup>	0.5	0.5
Fraction of traditional food from local sources while at the site (-) <sup>b</sup>	1.0	1.0
Fraction of water from local sources while at the site (-) <sup>b</sup>	1.0	1.0
Fraction of time at site at the tailings area (-) <sup>b</sup>	0.1	0.1
Body weight (kg) <sup>c</sup>	70.7	32.9
Soil ingestion rate (g/d) <sup>c, f</sup>	0.02	0.08
Food ingestion rate – meat sources (g/d) <sup>d</sup>	456	337
Grouse ingestion rate (g/d) <sup>d</sup>	2.3	1.7
Aquatic bird ingestion rate (g/d) <sup>d</sup>	1.3	0.96
Moose ingestion rate (g/d) <sup>d</sup>	58	42.9
Sheep ingestion rate (g/d) <sup>d</sup>	58	42.9
Caribou ingestion rate (g/d) <sup>d</sup>	243	180
Fish ingestion rate (g/d) <sup>d</sup>	93.5	69
Water ingestion rate (L/d) <sup>c</sup>	1.5	0.8
Berry ingestion rate (g/d) <sup>d, g</sup>	0	0
Breathing rate (m <sup>3</sup> /d) <sup>c</sup>	15.8	14.5
Skin surface area - total (m <sup>2</sup> ) <sup>c</sup>	0.911	0.514
Exposed fraction of skin <sup>b</sup>	0.26	0.26
Soil loading to exposed skin (g/cm <sup>2</sup> ) <sup>c</sup>	hands	1 x 10 <sup>-3</sup>
	surfaces other than hands	1 x 10 <sup>-4</sup>

Note:

a – Keno City resident was assessed.

b – assumed.

f – assumed that a child 5 to 11 years old has the same soil ingestion rate as a toddler in order to overestimate exposure.

g – it was assumed that berries do not grow on the tailings area.

c – from Richardson (1997).

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

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

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

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

#### **4.4 EXPOSURE PATHWAYS – PHYSICAL HAZARDS**

The United Keno site is accessible by an all-weather road. The physical hazard assessment is based on the fact that visitors to the area have unrestricted access to the site. There are considerable physical hazards at the Keno Hill site. The physical hazard assessment considers someone falling into easily accessible open shafts and adits, falling from waste rock piles or into open pits. In addition, there are a number of collapsing buildings on the site that someone may enter to explore.

## **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 United Keno site. Table 5.2 shows the total intakes for ingestion, inhalation and dermal exposure for the adult receptor. Tables 5.3 and 5.4 summarize the results for the child human receptor.



**TABLE 5.1**  
**CALCULATED INGESTION INTAKES BY PATHWAY –**  
**ADULT RECEPTOR**

Contaminant	Intake through Ingestion Pathways (mg/(kg d))							
	Water	Fish	Moose	Caribou	Sheep	Grouse	Mallard	Soil
Antimony	3.18x10 <sup>-4</sup>	1.98x10 <sup>-3</sup>	8.20x10 <sup>-5</sup>	8.40x10 <sup>-7</sup>	2.91x10 <sup>-6</sup>	3.85x10 <sup>-6</sup>	4.99x10 <sup>-6</sup>	3.25x10 <sup>-6</sup>
Arsenic	3.18x10 <sup>-4</sup>	6.61x10 <sup>-4</sup>	3.58x10 <sup>-5</sup>	1.17x10 <sup>-5</sup>	2.41x10 <sup>-5</sup>	5.24x10 <sup>-6</sup>	3.41x10 <sup>-5</sup>	2.55x10 <sup>-5</sup>
Barium	4.99x10 <sup>-4</sup>	6.53x10 <sup>-3</sup>	4.05x10 <sup>-6</sup>	1.92x10 <sup>-7</sup>	2.46x10 <sup>-7</sup>	1.28x10 <sup>-7</sup>	8.95x10 <sup>-7</sup>	8.57x10 <sup>-6</sup>
Cadmium	4.67x10 <sup>-4</sup>	1.32x10 <sup>-4</sup>	4.19x10 <sup>-4</sup>	1.12x10 <sup>-6</sup>	1.15x10 <sup>-6</sup>	7.85x10 <sup>-7</sup>	2.37x10 <sup>-4</sup>	2.46x10 <sup>-6</sup>
Copper	2.81x10 <sup>-2</sup>	1.19x10 <sup>-3</sup>	4.54x10 <sup>-2</sup>	4.81x10 <sup>-5</sup>	8.83x10 <sup>-5</sup>	2.26x10 <sup>-6</sup>	1.26x10 <sup>-3</sup>	2.11x10 <sup>-6</sup>
Lead	3.18x10 <sup>-4</sup>	1.32x10 <sup>-3</sup>	1.84x10 <sup>-5</sup>	1.96x10 <sup>-5</sup>	8.30x10 <sup>-6</sup>	6.90x10 <sup>-6</sup>	8.51x10 <sup>-7</sup>	1.15x10 <sup>-4</sup>
Manganese	1.59x10 <sup>-4</sup>	3.97x10 <sup>-3</sup>	6.17x10 <sup>-3</sup>	1.05x10 <sup>-4</sup>	4.49x10 <sup>-4</sup>	1.22x10 <sup>-4</sup>	3.45x10 <sup>-8</sup>	7.09x10 <sup>-4</sup>
Nickel	2.02x10 <sup>-3</sup>	1.59x10 <sup>-3</sup>	2.33x10 <sup>-4</sup>	1.02x10 <sup>-5</sup>	1.22x10 <sup>-6</sup>	9.40x10 <sup>-7</sup>	5.24x10 <sup>-5</sup>	3.32x10 <sup>-7</sup>
Selenium	9.55x10 <sup>-4</sup>	7.74x10 <sup>-3</sup>	9.83x10 <sup>-5</sup>	2.24x10 <sup>-6</sup>	8.56x10 <sup>-7</sup>	7.02x10 <sup>-7</sup>	3.65x10 <sup>-4</sup>	1.41x10 <sup>-8</sup>
Silver	5.30x10 <sup>-5</sup>	3.31x10 <sup>-5</sup>	1.57x10 <sup>-5</sup>	1.60x10 <sup>-6</sup>	9.61x10 <sup>-6</sup>	2.16x10 <sup>-6</sup>	5.48x10 <sup>-6</sup>	2.11x10 <sup>-6</sup>
Strontium	6.05x10 <sup>-4</sup>	2.26x10 <sup>-3</sup>	1.23x10 <sup>-4</sup>	1.19x10 <sup>-6</sup>	2.29x10 <sup>-6</sup>	8.32x10 <sup>-8</sup>	1.21x10 <sup>-6</sup>	7.21x10 <sup>-7</sup>
Zinc	4.08x10 <sup>-2</sup>	1.53x10 <sup>-1</sup>	4.48x10 <sup>-1</sup>	7.04x10 <sup>-3</sup>	1.51x10 <sup>-2</sup>	4.50x10 <sup>-3</sup>	6.96x10 <sup>-1</sup>	1.41x10 <sup>-4</sup>

**TABLE 5.2**  
**CALCULATED TOTAL INTAKES BY PATHWAY –**  
**ADULT RECEPTOR**

Contaminant	Ingestion Pathway (mg/(kg d))	Inhalation Pathway (mg/(kg d))	Dermal Pathway (mg/(kg d))	Total All Pathways (mg/(kg d))
Antimony	2.40x10 <sup>-3</sup>	-	3.85x10 <sup>-4</sup>	2.79x10 <sup>-3</sup>
Arsenic	1.12x10 <sup>-3</sup>	1.12x10 <sup>-7</sup>	9.65x10 <sup>-4</sup>	2.08x10 <sup>-3</sup>
Barium	7.04x10 <sup>-3</sup>	-	1.02x10 <sup>-3</sup>	8.05x10 <sup>-3</sup>
Cadmium	1.26x10 <sup>-3</sup>	8.49x10 <sup>-8</sup>	4.08x10 <sup>-4</sup>	1.67x10 <sup>-3</sup>
Copper	7.61x10 <sup>-2</sup>	-	2.50x10 <sup>-4</sup>	7.64x10 <sup>-2</sup>
Lead	1.81x10 <sup>-3</sup>	2.23x10 <sup>-7</sup>	8.14x10 <sup>-4</sup>	2.62x10 <sup>-3</sup>
Manganese	1.17x10 <sup>-2</sup>	-	8.39x10 <sup>-2</sup>	9.56x10 <sup>-2</sup>
Nickel	3.90x10 <sup>-3</sup>	6.70x10 <sup>-8</sup>	1.38x10 <sup>-4</sup>	4.04x10 <sup>-3</sup>
Selenium	9.16x10 <sup>-3</sup>	-	3.35x10 <sup>-8</sup>	9.16x10 <sup>-3</sup>
Silver	1.23x10 <sup>-4</sup>	7.82x10 <sup>-9</sup>	6.24x10 <sup>-4</sup>	7.47x10 <sup>-4</sup>
Strontium	2.99x10 <sup>-3</sup>	-	8.54x10 <sup>-5</sup>	3.08x10 <sup>-3</sup>
Zinc	1.36	1.23x10 <sup>-6</sup>	3.34x10 <sup>-3</sup>	1.37

**TABLE 5.3**  
**CALCULATED INGESTION INTAKES BY PATHWAY –**  
**CHILD RECEPTOR**

Contaminant	Intake through Ingestion Pathways (mg/(kg d))							
	Water	Fish	Moose	Caribou	Sheep	Grouse	Mallard	Soil
Antimony	3.65x10 <sup>-4</sup>	3.15x10 <sup>-3</sup>	1.30x10 <sup>-4</sup>	1.33x10 <sup>-6</sup>	4.63x10 <sup>-6</sup>	6.12x10 <sup>-6</sup>	7.94x10 <sup>-6</sup>	2.80x10 <sup>-5</sup>
Arsenic	3.65x10 <sup>-4</sup>	1.05x10 <sup>-3</sup>	5.69x10 <sup>-5</sup>	1.86x10 <sup>-5</sup>	3.84x10 <sup>-5</sup>	8.34x10 <sup>-6</sup>	5.42x10 <sup>-5</sup>	2.19x10 <sup>-4</sup>
Barium	5.71x10 <sup>-4</sup>	1.04x10 <sup>-2</sup>	6.44x10 <sup>-6</sup>	3.06x10 <sup>-7</sup>	3.91x10 <sup>-7</sup>	2.03x10 <sup>-7</sup>	1.42x10 <sup>-6</sup>	7.37x10 <sup>-5</sup>
Cadmium	5.35x10 <sup>-4</sup>	2.10x10 <sup>-4</sup>	6.67x10 <sup>-4</sup>	1.78x10 <sup>-6</sup>	1.83x10 <sup>-6</sup>	1.25x10 <sup>-6</sup>	3.77x10 <sup>-4</sup>	2.12x10 <sup>-5</sup>
Copper	3.22x10 <sup>-2</sup>	1.89x10 <sup>-3</sup>	7.22x10 <sup>-2</sup>	7.65x10 <sup>-5</sup>	1.33x10 <sup>-4</sup>	3.59x10 <sup>-6</sup>	2.00x10 <sup>-3</sup>	1.81x10 <sup>-5</sup>
Lead	3.65x10 <sup>-4</sup>	2.10x10 <sup>-3</sup>	2.92x10 <sup>-5</sup>	3.12x10 <sup>-5</sup>	1.32x10 <sup>-5</sup>	1.10x10 <sup>-5</sup>	1.35x10 <sup>-6</sup>	9.85x10 <sup>-4</sup>
Manganese	1.82x10 <sup>-4</sup>	6.31x10 <sup>-3</sup>	9.81x10 <sup>-3</sup>	1.67x10 <sup>-4</sup>	7.14x10 <sup>-4</sup>	1.94x10 <sup>-4</sup>	5.48x10 <sup>-8</sup>	6.09x10 <sup>-3</sup>
Nickel	2.31x10 <sup>-3</sup>	2.52x10 <sup>-3</sup>	3.71x10 <sup>-4</sup>	1.62x10 <sup>-5</sup>	1.94x10 <sup>-6</sup>	1.50x10 <sup>-6</sup>	8.33x10 <sup>-5</sup>	2.86x10 <sup>-6</sup>
Selenium	1.09x10 <sup>-3</sup>	1.23x10 <sup>-2</sup>	1.56x10 <sup>-4</sup>	3.56x10 <sup>-6</sup>	1.36x10 <sup>-6</sup>	1.12x10 <sup>-6</sup>	5.81x10 <sup>-4</sup>	1.22x10 <sup>-7</sup>
Silver	6.08x10 <sup>-5</sup>	5.26x10 <sup>-5</sup>	2.49x10 <sup>-5</sup>	2.54x10 <sup>-6</sup>	1.53x10 <sup>-5</sup>	3.44x10 <sup>-6</sup>	8.72x10 <sup>-6</sup>	1.81x10 <sup>-5</sup>
Strontium	6.93x10 <sup>-4</sup>	3.60x10 <sup>-3</sup>	1.96x10 <sup>-4</sup>	1.90x10 <sup>-6</sup>	3.64x10 <sup>-6</sup>	1.32x10 <sup>-7</sup>	1.93x10 <sup>-6</sup>	6.20x10 <sup>-6</sup>
Zinc	4.68x10 <sup>-2</sup>	2.43x10 <sup>-1</sup>	7.12x10 <sup>-1</sup>	1.12x10 <sup>-2</sup>	2.40x10 <sup>-2</sup>	7.16x10 <sup>-3</sup>	1.11	1.21x10 <sup>-3</sup>

**TABLE 5.4**  
**CALCULATED TOTAL INTAKES BY PATHWAY –**  
**CHILD RECEPTOR**

Contaminant	Ingestion Pathway (mg/(kg d))	Inhalation Pathway (mg/(kg d))	Dermal Pathway (mg/(kg d))	Total All Pathways (mg/(kg d))
Antimony	3.70x10 <sup>-3</sup>	-	4.67x10 <sup>-4</sup>	4.16x10 <sup>-3</sup>
Arsenic	1.81x10 <sup>-3</sup>	2.20x10 <sup>-7</sup>	1.17x10 <sup>-3</sup>	2.98x10 <sup>-3</sup>
Barium	1.10x10 <sup>-2</sup>	-	1.23x10 <sup>-3</sup>	1.23x10 <sup>-2</sup>
Cadmium	1.82x10 <sup>-3</sup>	1.67x10 <sup>-7</sup>	4.95x10 <sup>-4</sup>	2.31x10 <sup>-3</sup>
Copper	1.09x10 <sup>-1</sup>	-	3.03x10 <sup>-4</sup>	1.09x10 <sup>-1</sup>
Lead	3.54x10 <sup>-3</sup>	4.41x10 <sup>-7</sup>	9.87x10 <sup>-4</sup>	4.53x10 <sup>-3</sup>
Manganese	2.35x10 <sup>-2</sup>	-	1.02x10 <sup>-1</sup>	1.25x10 <sup>-1</sup>
Nickel	5.31x10 <sup>-3</sup>	1.32x10 <sup>-7</sup>	1.67x10 <sup>-4</sup>	5.48x10 <sup>-3</sup>
Selenium	1.41x10 <sup>-2</sup>	-	4.06x10 <sup>-8</sup>	1.41x10 <sup>-2</sup>
Silver	1.86x10 <sup>-4</sup>	1.54x10 <sup>-8</sup>	7.57x10 <sup>-4</sup>	9.43x10 <sup>-4</sup>
Strontium	4.50x10 <sup>-3</sup>	-	1.04x10 <sup>-4</sup>	4.60x10 <sup>-3</sup>
Zinc	2.5	2.42x10 <sup>-6</sup>	4.05x10 <sup>-3</sup>	2.16

### 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 United States. 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 (i.e. 2,800,000 person-day visits per 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:

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

where:

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

Each mine site can be ranked for accessibility to the public based on proximity to population centers and the number of people living in those population centers. Assuming that there is a linear relationship between risk and accessibility, a ranking scheme such as the one presented in Table 5.6 can be established.

**TABLE 5.6  
PROPOSED ACCESSIBILITY FACTOR BASED ON THE ACCESSIBILITY AND  
PROXIMITY TO POPULATION CENTRES**

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

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

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

- open mine shafts;

- steep rock faces with loose rock (e.g. waste rock piles and pit faces); and
- high pit walls.

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
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:

$$Fatality\ Rate_{site} = Fatality\ Rate \times AF \times HF \times SF \quad (5.2)$$

where:

- Fatality Rate<sub>site</sub> = site-specific fatality rate
- Fatality Rate = calculated average annual fatality rate (2.6 x 10<sup>-6</sup>)
- AF = accessibility factor (Table 5.6)
- HF = hazard factor (Table 5.7)
- SF = scaling factor (Table 5.8)

For the United Keno site, the following factors were identified:

- Accessibility Factor = 1
- Hazard Factor = 40/40 (unsealed mine openings, steep loose rock piles, high pit walls, surface structures)
- Scaling Factor = 3

Using these factors and an average annual fatality rate of  $2.9 \times 10^{-6}$ , the annual fatality rate was estimated to equal  $8.7 \times 10^{-6}$ .

## 6.0 DOSE RESPONSE ASSESSMENT

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

### 6.1 TOXICITY TO HUMANS

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

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

- Slope Factor (SF) - (for carcinogens) comprises a plausible upper bound estimate of the probability of a response per unit intake of a contaminant over a lifetime. It is used to evaluate the probability of a cancer developing due to a lifetime of exposure. For carcinogens, no threshold is assumed to exist (i.e., every dose presents some risk); or
- Tolerable Daily Intake (TDI) or Reference Dose (RfD) - (for non-carcinogens) comprises an estimate of the daily exposure level for a contaminant for the entire population, including sensitive people that is not anticipated to present an appreciable risk of an adverse effect.

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

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

**TABLE 6.1  
TOXICITY BENCHMARKS**

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



**TABLE 6.1 (Cont'd)**  
**TOXICITY BENCHMARKS**

Contaminant	Dermal	Oral Toxicity Benchmarks <sup>b</sup>				Inhalation Toxicity Benchmarks			
	RAF <sup>a</sup>	SF <sub>o</sub>		(TDI/RfDo)		SF <sub>i</sub>		RfD <sub>i</sub>	
	(-)	(mg/(kg-d)) <sup>-1</sup>		(mg/(kg-d))		(mg/(kg-d)) <sup>-1</sup>		(mg/(kg-d))	
TPH F1 –Aliphatic	0.1	na		3.10	TP	na		3.30	TP
TPH F1 – Aromatic	0.1	na		0.04	TP	na		0.057	TP
TPH F2 –Aliphatic	0.1	na		0.1	TP	na		0.290	TP
TPH F2 – Aromatic	0.1	na		0.04	TP	na		0.057	TP
TPH F3 –Aliphatic	0.1	na		32	TP	na		na	
TPH F3 – Aromatic	0.1	na		0.03	TP	na		na	

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

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

SF Slope Factor for carcinogenic effects.

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

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

## 7.0 RISK CHARACTERIZATION

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

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

Risk is defined as follows:

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

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))<sup>-1</sup>
- $SF_o$  = Slope Factor for oral exposure (mg/(kg d))<sup>-1</sup>
- $SF_d$  = Slope Factor for dermal exposure (mg/(kg d))<sup>-1</sup> (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  $1 \times 10^{-5}$  was used for the SLRA. Risk levels for child receptors are generally not calculated since the exposure of a child is not sufficient for carcinogenic effects to be observed. In this case a composite receptor is assessed. This composite receptor encompasses the exposure of a child to the site for 10 years and the exposure of this child as an adult for another 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:

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

Where:

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

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

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

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

## 7.1 NON-CARCINOGENIC EFFECTS

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

**TABLE 7.1**  
**HAZARD QUOTIENTS CALCULATED FOR ADULT AND CHILD**  
**AT UNITED KENO SITE**

Contaminant	Hazard Quotient	
	Adult	Child
Antimony	7	10
Barium	0.5	0.8
Cadmium	2	3
Copper	3	4
Lead	1	2
Manganese	0.7	0.9
Nickel	0.2	0.3
Selenium	2	3
Silver	0.2	0.2
Strontium	0.01	0.01
Zinc	5	7
<b>TOTAL SITE</b>	<b>21.6</b>	<b>31.2</b>

From Table 7.1, it can be seen that the hazard quotients calculated for nickel, silver and strontium are below the critical value of 0.5. The hazard quotient values calculated for antimony, barium, cadmium, copper, lead, manganese, selenium and zinc for the adult and child at the United Keno Mine site exceed the critical value of 0.5. The sum of all HQs was determined to be 21.6 for the adult and 31.2 for the child.

## 7.2 CARCINOGENIC EFFECTS

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

**TABLE 7.2**  
**RISK LEVELS CALCULATED FOR ADULT AND COMPOSITE RECEPTOR**  
**AT THE UNITED KENO SITE**

Contaminant	Risk Level	
	Adult	Composite
Arsenic	$2.5 \times 10^{-3}$	$6.2 \times 10^{-3}$
Cadmium	$1.6 \times 10^{-6}$	$4.2 \times 10^{-6}$
Nickel	$9.0 \times 10^{-8}$	$2.4 \times 10^{-7}$
<b>TOTAL SITE</b>	<b><math>2.5 \times 10^{-3}</math></b>	<b><math>6.2 \times 10^{-3}</math></b>

The estimated risk levels for cadmium and nickel are below the accepted risk level of  $1 \times 10^{-5}$ . The risk level for arsenic exceeds the accepted risk level. Arsenic exposure to receptors at the United Keno Mine site is dominated by the ingestion pathway, and in particular, the ingestion of fish and soil. Dermal exposure is also a significant pathway. It should be noted that 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. In fact, a portion of the arsenic consumed will be in non-toxic forms, in particular the arsenic associated with fish. The total risk level was determined to be  $2.5 \times 10^{-3}$  for the adult and  $6.2 \times 10^{-3}$  for the composite receptor.

### 7.3 PHYSICAL RISKS

Surface openings and deteriorating buildings pose the most significant risk of physical harm to people who may visit the site. In addition, there are numerous open pits and waste rock piles. The annual risk of fatality for the United Keno site was evaluated in Section 5 to equal  $8.7 \times 10^{-6}$ .

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**FINAL**

**APPENDIX A**

**DETAILED EXPOSURE CALCULATIONS FOR  
THE HUMAN HEALTH RISK ASSESSMENT**



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

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

### A.1 INHALATION PATHWAY

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

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

where:

$I_{air}$	=	exposure to contaminant through the air pathway [mg/(kg d)]
$C_{air}$	=	air concentration [ $\text{mg}/\text{m}^3$ ]
$R_{air}$	=	air inhalation rate [ $\text{m}^3/\text{d}$ ]
$F_{site}$	=	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
<b>Metals (mg/m<sup>3</sup>)</b>		
Aluminum	1.6 x 10 <sup>-4</sup>	Lee <i>et al.</i> 1994
Antimony		
Arsenic	1.0 x 10 <sup>-6</sup>	U.S. EPA 1996 – for rural areas
Barium		
Beryllium		
Boron		
Cadmium	7.6 x 10 <sup>-7</sup>	Lee <i>et al.</i> 1994
Chromium	9.5 x 10 <sup>-7</sup>	Lee <i>et al.</i> 1994
Cobalt	1.0 x 10 <sup>-7</sup>	U.S. EPA 1996 – for rural areas
Copper	3.0 x 10 <sup>-6</sup>	U.S. EPA 1996 – for rural areas
Lead	2.0 x 10 <sup>-6</sup>	U.S. EPA 1996 – for rural areas
Manganese		
Mercury	4.7 x 10 <sup>-8</sup>	Lee <i>et al.</i> 1994
Molybdenum	1.0 x 10 <sup>-6</sup>	U.S. EPA 1996 – for rural areas
Nickel	6.0 x 10 <sup>-7</sup>	U.S. EPA 1996 – for rural areas
Selenium	1.0 x 10 <sup>-8</sup>	U.S. EPA 1996 – for rural areas
Silver	7.0 x 10 <sup>-8</sup>	Lee <i>et al.</i> 1994
Strontium		
Tin		
Uranium		
Vanadium	4.5 x 10 <sup>-6</sup>	Lee <i>et al.</i> 1994
Zinc	1.1 x 10 <sup>-5</sup>	U.S. EPA 1996 – for rural areas
<b>Organics and other contaminants (mg/m<sup>3</sup>)</b>		
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
<b>Radionuclides (Bq/m<sup>3</sup>)</b>		
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.

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

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 <sup>2</sup> ]
EA	=	exposed fraction of skin [-]
SL	=	loading to exposed skin [kg (dw)/(cm <sup>2</sup> 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.

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

where:

$C_{soil}$	=	soil concentration [mg/kg (dw)]
$C_{air}$	=	air concentration [mg/m <sup>3</sup> ]
$V_{dep}$	=	deposition velocity [cm/s] {assumed 2 cm/s, from SENES (1987)}
$d_s$	=	soil mixing depth [cm] {assumed 1 cm}
$\rho$	=	bulk soil density [g (dw)/cm <sup>3</sup> ] {assumed 1.5 g/cm <sup>3</sup> , 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 <sup>3</sup>	=	unit conversion factor [m <sup>3</sup> /cm <sup>3</sup> ]

### 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:

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

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]

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

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]

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

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)}

	$C_{\text{muskrat}}$	– {calculated in equation (A-20)}
	$C_{\text{sheep}}$	– {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
$F_{\text{site}}$	=	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):

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

where:

$C_{\text{berry}}$	=	concentration of contaminant in berries [mg/kg (ww)]
$C_{\text{soil}}$	=	soil concentration [mg/kg (dw)]
$TF_{\text{soil-to-berry}}$	=	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
<b>Metals ((mg/kg (ww))/(mg/kg (dw)))</b>		
Aluminum	$2.6 \times 10^{-3}$	NCRP 1996, Baes <i>et al.</i> 1984
Antimony	$8.0 \times 10^{-5}$	U.S. NRC 1992
Arsenic	$9.5 \times 10^{-4}$	NCRP 1996, Baes <i>et al.</i> 1984, U.S. EPA 1998
Barium	$9.7 \times 10^{-3}$	U.S. EPA 1998
Beryllium	$7.7 \times 10^{-4}$	U.S. EPA 1998
Boron	0.03	NCRP 1996
Cadmium	$3.8 \times 10^{-2}$	U.S. EPA 1998
Chromium	$1.5 \times 10^{-3}$	U.S. EPA 1998
Cobalt	$7.0 \times 10^{-3}$	U.S. NRC 1992
Copper	0.26	Baes <i>et al.</i> 1984
Lead	$9.0 \times 10^{-2}$	U.S. NRC 1992
Manganese	0.05	U.S. NRC 1992
Mercury	$4.4 \times 10^{-3}$	U.S. EPA 1998
Molybdenum	0.12	NCRP 1996, Baes <i>et al.</i> 1984
Nickel	$1.8 \times 10^{-1}$	Baes <i>et al.</i> 1984
Selenium	$2.9 \times 10^{-3}$	NCRP 1996, Baes <i>et al.</i> 1984, U.S. EPA 1998
Silver	$4.1 \times 10^{-2}$	U.S. EPA 1998
Strontium	0.2	IAEA 1994
Tin	$6.0 \times 10^{-3}$	Baes <i>et al.</i> 1984
Uranium	$1.1 \times 10^{-3}$	Cassaday <i>et al.</i> 1985
Vanadium	$3.0 \times 10^{-3}$	Baes <i>et al.</i> 1984
Zinc	0.99	NCRP 1996, IAEA 1994, Baes <i>et al.</i> 1984
<b>Organics and other contaminants ((mg/kg (ww))/(mg/kg (dw)))</b>		
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	$3.0 \times 10^{-3}$	U.S. EPA 1998
Thiocyanate	3.5	McKone 1994
Xylene	$9.4 \times 10^{-2}$	McKone 1994
<b>Radionuclides ((Bq/kg (ww))/(Bq/kg (dw)))</b>		
Thorium-230	$8.5 \times 10^{-5}$	Baes <i>et al.</i> 1984
Lead-210	$9.0 \times 10^{-2}$	U.S. NRC 1992
Radium-226	$7.2 \times 10^{-4}$	Cassaday <i>et al.</i> 1985
Polonium-210	$4.0 \times 10^{-4}$	Baes <i>et al.</i> 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):

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

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):

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

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
<b>Metals ((mg/kg (ww))/(mg/kg (dw)))</b>		
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	$1.8 \times 10^{-2}$	Létourneau 1987, NCRP 1996, IAEA 1994
Vanadium	0.1	NCRP 1996
Zinc	0.24	NCRP 1996, IAEA 1994, U.S. EPA 1998
<b>Organics and other contaminants ((mg/kg (ww))/(mg/kg (dw)))</b>		
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	$3.0 \times 10^{-3}$	U.S. EPA 1998
Thiocyanate	3.5	McKone 1994
Xylene	$9.4 \times 10^{-2}$	McKone 1994
<b>Radionuclides ((Bq/kg (ww))/(Bq/kg (dw)))</b>		
Thorium-230	$9.2 \times 10^{-3}$	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):

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

where:

- $C_{browse}$  = concentration of contaminant in browse [mg/kg (ww)]
- $C_{soil}$  = soil concentration [mg/kg (dw)]
- $TF_{soil-to-browse}$  = 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
<b>Metals ((mg/kg (ww))/(mg/kg (dw)))</b>		
Aluminum	$2.6 \times 10^{-3}$	NCRP 1996, Baes et al. 1984
Antimony	0.20	Baes et al. 1984
Arsenic	$7.7 \times 10^{-3}$	NCRP 1996, Baes et al. 1984, U.S. EPA 1998
Barium	$4.5 \times 10^{-3}$	U.S. EPA 1998
Beryllium	$4.5 \times 10^{-4}$	U.S. EPA 1998
Boron	0.03	NCRP 1996
Cadmium	$1.9 \times 10^{-2}$	U.S. EPA 1998
Chromium	$1.4 \times 10^{-3}$	U.S. EPA 1998
Cobalt	0.045	NCRP 1996, IAEA 1994, CSA 1987
Copper	0.055	NCRP 1996, Baes et al. 1984
Lead	$5.0 \times 10^{-3}$	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	$8.6 \times 10^{-3}$	NCRP 1996, Baes et al. 1984, U.S. EPA 1998
Selenium	0.01	NCRP 1996, Baes et al. 1984, U.S. EPA 1998
Silver	$3.0 \times 10^{-2}$	U.S. EPA 1998
Strontium	0.13	U.S. NRC 1992
Tin	0.03	Baes et al. 1984
Uranium	$1.2 \times 10^{-3}$	Baes et al. 1984, IAEA 1994, NCRP 1996
Vanadium	$5.5 \times 10^{-3}$	Baes et al. 1984
Zinc	0.27	NCRP 1996, IAEA 1994, Baes et al. 1984
<b>Organics and other contaminants ((mg/kg (ww))/(mg/kg (dw)))</b>		
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	$3.0 \times 10^{-3}$	U.S. EPA 1998
Thiocyanate	3.5	McKone 1994
Xylene	$9.4 \times 10^{-2}$	McKone 1994
<b>Radionuclides ((Bq/kg (ww))/(Bq/kg (dw)))</b>		
Thorium-230	$1.4 \times 10^{-4}$	Baes et al. 1984, IAEA 1994, NCRP 1996
Lead-210	$5.0 \times 10^{-3}$	Baes et al. 1984, IAEA 1994, NCRP 1996, U.S. EPA 1998
Radium-226	$3.7 \times 10^{-3}$	Baes et al. 1984, IAEA 1994, NCRP 1996
Polonium-210	$6.9 \times 10^{-4}$	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.

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

where:

$C_{lichen}$	=	concentration of contaminant in lichen [mg/kg (ww)]
$C_{air}$	=	air concentration [mg/m <sup>3</sup> ]
$V_{dep}$	=	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 <sup>2</sup> ] {500 g/m <sup>2</sup> , from SENES (1987)}
$\lambda_w$	=	weathering loss decay constant [1/s] {2.2x10 <sup>-9</sup> , 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<sup>a</sup> TRANSFER FACTORS**

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

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):

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

where:

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

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

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

**TABLE A3.5**  
**WATER-TO-FISH TRANSFER FACTORS**

Contaminant	Value	Reference
<b>Metals ((mg/kg (ww))/(mg/L))</b>		
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
<b>Organics and other contaminants ((mg/kg (ww))/(mg/L))</b>		
Benzene	25	U.S. EPA 1998
Benzo(a)pyrene	9950	U.S. EPA 1998, BAF
Nitrate	0.0	no food chain transfer
PCBs	$6.6 \times 10^5$	U.S. EPA 1998, based on aroclor 1254
Thiocyanate	0.0	no food chain transfer
Xylene	160	U.S. EPA 1998, m-xylene
<b>Radionuclides ((Bq/kg (ww))/(Bq/L))</b>		
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):

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

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 <i>et al.</i> (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<sup>a</sup> TRANSFER FACTORS**

Contaminant	Value	Reference
<b>Metals (d/kg (ww))</b>		
Aluminum	0.5	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Antimony	0.5	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Arsenic	1.0	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Barium	0.08	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Beryllium	1.15	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Boron	0.34	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Cadmium	0.8	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Chromium	6.0	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Cobalt	2.0	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Copper	0.5	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Lead	0.2	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Manganese	0.05	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Mercury	0.027	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Molybdenum	1.0	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Nickel	3.0	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Selenium	9.0	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Silver	2.0	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Strontium	0.06	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Tin	20	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Uranium	1.0	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Vanadium	1.3	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Zinc	7.0	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
<b>Organics and other contaminants (d/kg (ww))</b>		
Benzene	2.7 x 10 <sup>-6</sup>	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 x 10 <sup>-5</sup>	McKone 1994
Xylene	0.032	U.S. EPA 1998, based on m-xylene
<b>Radionuclides (d/kg (ww))</b>		
Thorium-230	0.10	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Lead-210	0.20	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Radium-226	0.30	Clulow <i>et al.</i> 1992 <sup>c</sup>
Polonium-210	2.5	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>

Note : a – Based on information for poultry.

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

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

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

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

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 <i>et al.</i> (1979), U.S. EPA (1993)} $Q_{browse} - 180$ {Pease <i>et al.</i> (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 <i>et al.</i> (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<sup>a</sup> TRANSFER FACTORS**

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

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):

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

where:

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

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

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

where:

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

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

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

<b>Contaminant</b>	<b>Value</b>	<b>Reference</b>
<b><i>Metals ((mg/kg (ww))/(mg/L))</i></b>		
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
<b><i>Organics and other contaminants ((mg/kg (ww))/(mg/L))</i></b>		
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
<b><i>Radionuclides ((Bq/kg (ww))/(Bq/L))</i></b>		
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):

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

where:

- $C_{benthos}$  = concentration of contaminant in benthic invertebrates [mg/kg (ww)]
- $C_{water}$  = water concentration [mg/L]
- $TF_{water-to-benthos}$  = 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**

<b>Contaminant</b>	<b>Value</b>	<b>Reference</b>
<b><i>Metals ((mg/kg (ww))/(mg/L))</i></b>		
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	$7.5 \times 10^{-2}$	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
<b><i>Organics and other contaminants ((mg/kg (ww))/(mg/L))</i></b>		
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
<b><i>Radionuclides ((Bq/kg (ww))/(Bq/L))</i></b>		
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):

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

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**

<b>Contaminant</b>	<b>Value</b>	<b>Reference</b>
<b><i>Metals ((mg/kg (dw))/(mg/L))</i></b>		
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
<b><i>Organics and other contaminants ((mg/kg (dw))/(mg/L))</i></b>		
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
<b><i>Radionuclides ((Bq/kg (dw))/(Bq/L))</i></b>		
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<sup>a</sup> TRANSFER FACTORS**

Contaminant	Value	Reference
<b>Metals (d/kg (ww))</b>		
Aluminum	0.5	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Antimony	0.5	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Arsenic	1.0	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Barium	0.08	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Beryllium	1.15	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Boron	0.34	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Cadmium	0.8	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Chromium	6.0	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Cobalt	2.0	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Copper	0.5	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Lead	0.2	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Manganese	0.05	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Mercury	0.027	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Molybdenum	1.0	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Nickel	3.0	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Selenium	9.0	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Silver	2.0	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Strontium	0.06	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Tin	20	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Uranium	1.0	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Vanadium	1.3	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Zinc	7.0	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
<b>Organics and other contaminants (d/kg (ww))</b>		
Benzene	2.7 x 10 <sup>-6</sup>	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 x 10 <sup>-5</sup>	McKone 1994
Xylene	0.032	U.S. EPA 1998, based on m-xylene
<b>Radionuclides (d/kg (ww))</b>		
Thorium-230	0.10	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Lead-210	0.20	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>
Radium-226	0.30	Clulow <i>et al.</i> 1992 <sup>c</sup>
Polonium-210	2.5	IAEA 1994, Baes <i>et al.</i> 1984, U.S. EPA 1998, CSA 1987 <sup>b</sup>

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):

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

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 <i>et al.</i> (1973)} $Q_{browse} - 20,700$ {Canadian Wildlife Service (1997), Belovsky <i>et al.</i> (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 <i>et al.</i> (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<sup>a</sup> TRANSFER FACTORS**

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

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):

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

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<sup>a</sup> TRANSFER FACTORS**

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

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):

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

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<sup>a</sup> TRANSFER FACTORS**

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

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

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



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**FINAL**

**APPENDIX B**

**HEALTH CANADA  
TOXICOLOGICAL REFERENCE VALUES**

**Prepared by:  
Dr. Mark Richardson**

**APPENDIX B: HEALTH CANADA  
TOXICOLOGICAL REFERENCE VALUES**

Name	Non-Carcinogenic Toxicological Reference Values		Carcinogenic Toxicological Reference Values			
	HC TDI <sup>a</sup>	HC TDC	Oral slope factor from TD <sub>05</sub> <sup>b</sup>	Inhalation slope factor from TC <sub>05</sub> <sup>b,c</sup>	Inhalation unit risk from TC <sub>05</sub> <sup>b</sup>	Oral slope factor from DWQG <sup>a</sup>
	mg/kg-d	mg/m3	(mg/kg-d) <sup>-1</sup>	(mg/kg-d) <sup>-1</sup>	(mg/m <sup>3</sup> ) <sup>-1</sup>	(mg/kg-d) <sup>-1</sup>
Aldicarb	0.001					
Aldrin + dieldrin	0.0001					
Aniline	0.007 <sup>b</sup>					
Arsenic			2.8	2.80E+01	6.40E+00	1.7 <sup>g</sup>
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-ethyl-hexyl) phthalate	0.044 <sup>b</sup>					
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 <sup>b</sup>	0.01 <sup>b</sup>				
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 <sup>d</sup>					
Cyanazine	0.0013					
Cyanide, free	0.02 <sup>d</sup>					
DDT	0.01 <sup>e</sup>					
Diazinon	0.002					
Dibutyl phthalate	0.063 <sup>b</sup>					
Dicamba	0.0125					
Dichlorobenzene, 1,2-	0.43 <sup>b</sup>					
Dichlorobenzene, 1,4-	0.11 <sup>b</sup>	0.095 <sup>b</sup>				
Dichlorobenzidine, 3,3'-			6.76E-02			

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Name	Non-Carcinogenic Toxicological Reference Values		Carcinogenic Toxicological Reference Values			
	HC TDI <sup>a</sup>	HC TDC	Oral slope factor from TD <sub>05</sub> <sup>b</sup>	Inhalation slope factor from TC <sub>05</sub> <sup>b,c</sup>	Inhalation unit risk from TC <sub>05</sub> <sup>b</sup>	Oral slope factor from DWQG <sup>a</sup>
	mg/kg-d	mg/m <sup>3</sup>	(mg/kg-d) <sup>-1</sup>	(mg/kg-d) <sup>-1</sup>	(mg/m <sup>3</sup> ) <sup>-1</sup>	(mg/kg-d) <sup>-1</sup>
Dichloroethane, 1,2-			8.06E-03			7.50E-02 <sup>h</sup>
Dichloroethylene, 1,1	0.003					
Dichloromethane	0.05 <sup>b</sup>			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 <sup>b</sup>		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 <sup>d</sup>					
Methoxychlor	0.1					
Methyl methacrylate	0.01 <sup>b</sup>	0.037 <sup>b</sup>				
Metolachlor	0.005					
Metribuzin	0.0083					
Monochlorobenzene	0.0089					
Nickel chloride	0.0013 <sup>b</sup>					
Nickel oxide		0.00002 <sup>b</sup>				
Nickel subsulphide		0.000018 <sup>b</sup>				
Nickel sulfate	0.05 <sup>b</sup>	0.0000035 <sup>b</sup>				
Nickel, metallic		0.000018 <sup>b</sup>				
Nickel, oxidic				5.47E+00	1.25E+00	
Nickel, soluble				3.13E+00	7.14E-01	
Nickel, sulphidic						
Nitritotriacetic acid (NTA)	0.01					
Paraquat (as dichloride)	0.001					
Parathion	0.005					
Pentachlorobenzene	0.001 <sup>b</sup>					
Pentachlorophenol	0.006					
Phenol	0.06 <sup>d</sup>					
Phorate	0.0002					
Picloram	0.02					
PCBs	0.001					
PCDD/PCDF	1.00E-08 <sup>b</sup>					

*Screening Level Human Health Risk Assessment – Appendix B*

Name	Non-Carcinogenic Toxicological Reference Values		Carcinogenic Toxicological Reference Values			
	HC TDI <sup>a</sup>	HC TDC	Oral slope factor from TD <sub>05</sub> <sup>b</sup>	Inhalation slope factor from TC <sub>05</sub> <sup>b,c</sup>	Inhalation unit risk from TC <sub>05</sub> <sup>b</sup>	Oral slope factor from DWQG <sup>a</sup>
	mg/kg-d	mg/m <sup>3</sup>	(mg/kg-d) <sup>-1</sup>	(mg/kg-d) <sup>-1</sup>	(mg/m <sup>3</sup> ) <sup>-1</sup>	(mg/kg-d) <sup>-1</sup>
PCDD/PCDF	2.3E-09 <sup>g</sup>					
Simazine	0.0013					
Styrene	0.12 <sup>b</sup>	0.092 <sup>b</sup>				
Terbufos	0.00005					
Tetrachlorobenzene, 1,2,3,4-	0.0034 <sup>b</sup>					
Tetrachlorobenzene, 1,2,3,5-	0.00041 <sup>b</sup>					
Tetrachlorobenzene, 1,2,4,5-	0.00021 <sup>b</sup>					
Tetrachloroethylene	0.014 <sup>b</sup>	0.36 <sup>b</sup>				
Tetrachlorophenol, 2,3,4,6-	0.01					
Toluene	0.22 <sup>b</sup>	3.8 <sup>b</sup>				
Trichlorobenzene, 1,2,3-	0.0015 <sup>b</sup>					
Trichlorobenzene, 1,2,4-	0.0016 <sup>b</sup>	0.007 <sup>b</sup>				
Trichlorobenzene, 1,2,5-	0.0015 <sup>b</sup>	0.0036 <sup>b</sup>				
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 <sup>d</sup>					
Vinyl chloride						2.60E-01
Xylene, mixed isomers	1.5 <sup>b</sup>	0.18 <sup>b</sup>				

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<sup>3</sup>/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.