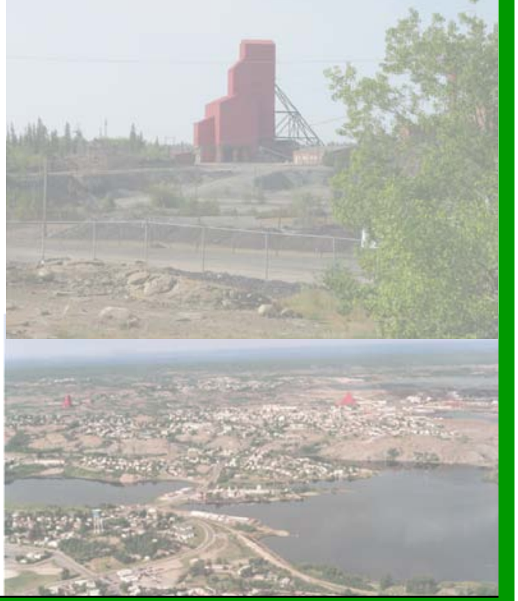
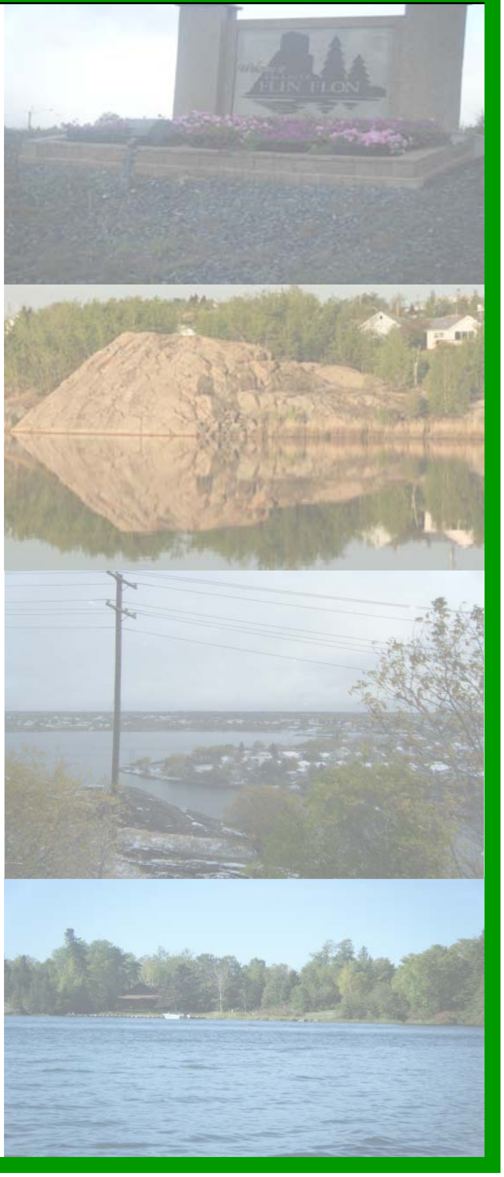


CHAPTER 3

PROBLEM FORMULATION



CHAPTER 3:

PROBLEM FORMULATION

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3.0 INTRODUCTION

Following the collection of necessary data, the next step in the Human Health Risk Assessment (HHRA) process is an information gathering and interpretation stage that plans and focuses the study on critical areas of concern for the area being evaluated. The Problem Formulation defines the nature and scope of the work to be conducted, permits practical boundaries to be placed on the overall scope of work, and ensures that the assessment is directed at the key areas and issues of concern. This step is critical to the success of the risk assessment as sound planning during the problem formulation step reduces the need for significant modifications once the risk assessment has begun. The data gathered and evaluated in this step provide information into the physical layout and characteristics of the study area, possible exposure pathways, potential human receptors, chemicals of concern (COC), and any other specific areas or issues of concern to be addressed.

The key tasks requiring evaluation within the problem formulation step include the following:

- *Site Characterization* – delineation of study area, and review of available site data to identify factors affecting the availability of contaminants to potential receptors, such as location and medium of contamination;

- *Identification of COC* - identification of the COC based on site environmental monitoring data;

- *Receptor Characterization* - identification of “receptors of concern”, which in this study include those persons with the greatest probability of exposure to chemicals from the site and those that have the greatest sensitivity to these chemicals; and,

- *Identification of Exposure Pathways and Scenarios* – consideration of various factors that influence the means by which receptors come into contact with COC in environmental media including: chemical-specific parameters, such as solubility and volatility; characteristics of the site, such as physical geography, geology, and hydrogeology; as well as the physiology and behaviour patterns of receptors.

The outcome of these tasks forms the exposure scenarios which are the basis of the approach taken in the risk assessment. This defines the scope of the HHRA and ensures concerns of all stakeholders are adequately addressed. Stakeholder consultation can be a critical component of the problem formulation step in ensuring that concerns of all stakeholders are identified from the outset.

3.1 Site Characterization

The city of Flin Flon (55^{o}N, 102^{o}W) is located in west-central Manitoba on the border with Saskatchewan. It has a population of approximately 6,000. The neighbouring town of Creighton, located just southwest of Flin Flon, in Saskatchewan, has a population of approximately 1,500. Both Flin Flon and Creighton were established in the 1930’s in response to demand for employment at the HBMS complex. The Flin Flon-Snow Lake greenstone belt in this area contains significant gold and base metal deposits, particularly rich in copper and zinc. Bedrock in this area is covered by discontinuous Quaternary and Holocene deposits, including till, glaciolacustrine sediments and peatlands (Henderson and McMartin, 1995). Forests are a mixed coniferous deciduous boreal community, which includes jack pine, black spruce, white spruce, balsam fir, trembling aspen, and balsam poplar (Hogan and Wotton, 1984). Wind direction is predominately towards the southeast and southwest but strong components also exist to the north-northwest and south (Environment Canada, 1990). As a result, atmospheric emissions from the HBMS complex are deposited within the Flin Flon and Creighton communities.

3.1.1 History of Soil Investigations

Details on historical soil sampling that has occurred in the Flin Flon area are provided in Chapter 2, Section 2.1.1.

To aid in the completion of the HHRA, HBMS contracted Jacques Whitford to complete an additional soil sampling program in fall of 2007. This program was focused on characterizing metal content in outdoor soil and indoor dust on residential properties. This program is described in Section 3.2.1.2.

3.1.2 Assessment of Individual Communities within the Study Area

The location of different communities within the Flin Flon-Creighton area relative to the HBMS complex may have a significant influence on the potential exposure of its residents. The proximity of the community to the smelter as well as the location relative to the predominant wind direction will determine the level of particulate in ambient air and the amount that is available for deposition. To address differences in exposures among residents of the Flin Flon-Creighton area, the HHRA will estimate exposure and risks to four separate communities of interest (COI) within the study area (refer to Figure 3-1):

- East Flin Flon (designated as the area bordered by highway 10 on the east and north, Ross Lake on the West, and the southern edge of residential streets to the south);
- West Flin Flon (designated as the area bordered by Ross Lake on the east, highway 10 on the west, the northern edge of residential streets to the north, and the Flin Flon City limits to the south);
- Channing; and,
- Creighton.

While exposure to COC in some media may be similar for residents of all COI, concentrations in other media, such as soil and air, may be very community-specific. The soil data collected within the Manitoba Conservation and Jacques Whitford studies includes a significant number of samples from each of these communities. This data was appropriately divided to allow for the derivation of exposure point concentrations (EPCs) for each COI. Other media that required the derivation of community-specific EPCs include indoor dust and drinking water.

In the assessment of exposure resulting from the inhalation of ambient air, data collected from one of three monitoring stations (*i.e.*, Ruth Betts, Creighton School, or the Provincial building) were selected for use depending on their proximity to the community and their location relative to the predominant wind direction. Based on these factors, air data collected from Ruth Betts was used to predict EPCs for East Flin Flon and Channing, air data collected from Creighton School was used for Creighton, and air data collected from the Provincial building was used for West Flin Flon (Figure 3-1).

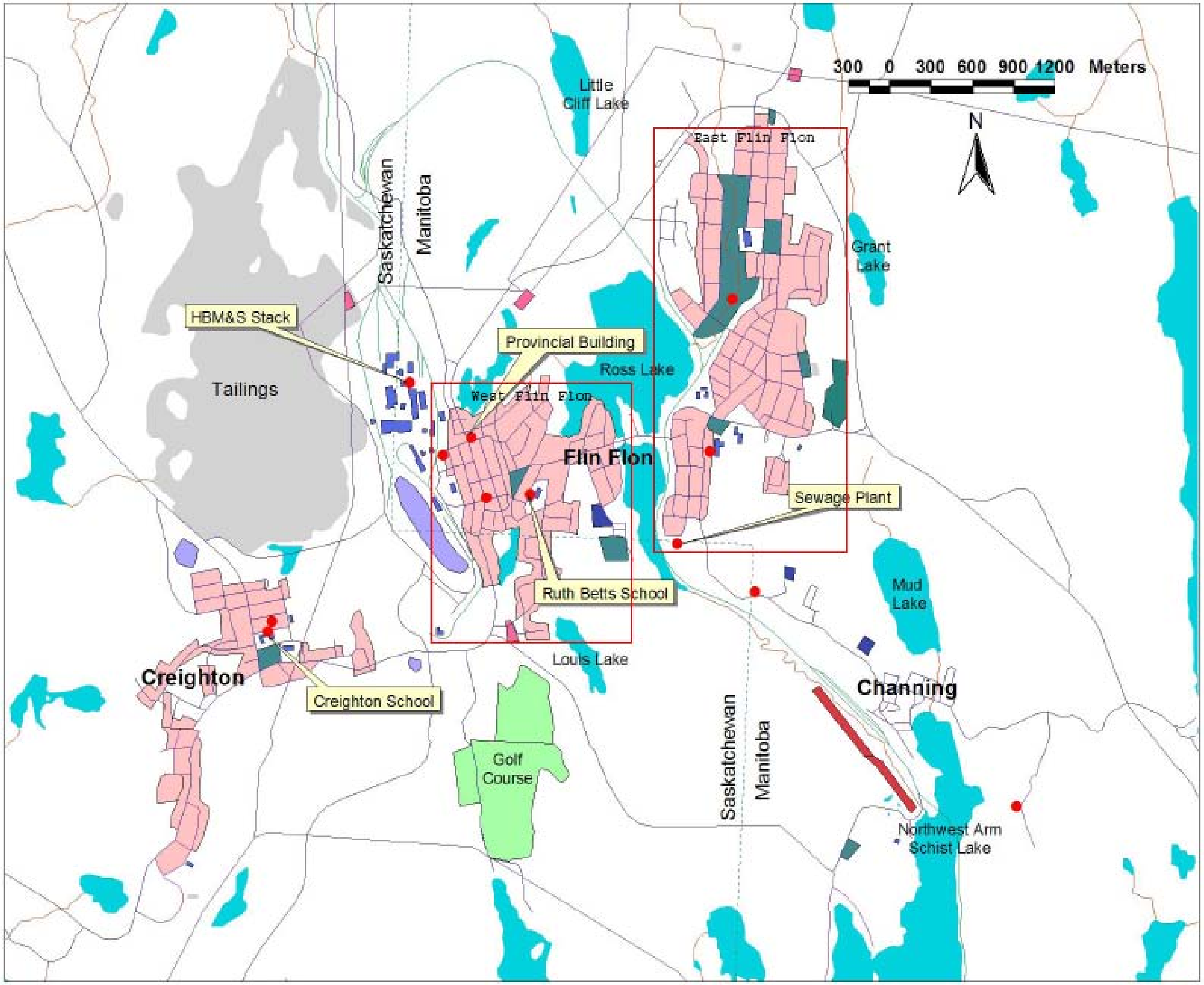

Figure 3-1 Locations of Air Quality Monitoring Stations in Flin Flon and Creighton

3.2 Identification of COC

It is common practice in HHRAs to limit the number of chemicals evaluated to those chemicals that, due to their environmental concentrations, distribution, or chemical and toxicological properties, have the greatest potential to contribute to health risks to individuals residing in the study area. However, it is important to note that the identification of an element as a COC does not automatically lead to the conclusion that the chemical is, in fact, a contributor to health risk. Rather, the appropriate conclusion is that those chemicals identified as COC should be the subject of further evaluation. This is done because it is impractical in terms of time and cost to conduct a risk assessment for every chemical that has been found to occur in a particular area. In addition, the concentrations of many chemicals associated with a particular area may be similar to chemical concentrations found naturally in the area, rather than as a result of current or former human activities. It is also preferable to comprehensively evaluate a smaller number of chemicals, which represent the greatest concern to people living in the area under consideration, than it is to conduct a less detailed risk assessment on a larger number of chemicals.

Since the focus of the HHRA was on soil-borne chemicals related to HBMS emissions, the COC selection process focused on soil data. As discussed in Chapter 2, a significant volume of data were collected related to chemical levels in environmental media (*i.e.*, air, drinking water, surface water, sediment, fish, dust, berries, home garden produce) in the Flin Flon area. Although not used in the selection of COC, all relevant environmental data were utilized in this HHRA, as discussed in Chapter 4.

3.2.1 Discussion of Data Used in the Selection of COC

The data used in the selection of the COC was taken from the Manitoba Conservation (2007) *Concentrations of Metals and Other Elements in Surface Soils of Flin Flon, Manitoba, and Creighton Saskatchewan*, and the residential soil-sampling program completed by Jacques Whitford in November, 2007 (Jacques Whitford, 2008). These studies are described in Sections 3.2.1.1 and 3.2.1.2, respectively.

3.2.1.1 Manitoba Conservation Surface Soil Sampling Program

Manitoba Conservation conducted a surface soil sampling program in August, 2006 which involved the collection of soil from 93 sites in Flin Flon and 13 sites in Creighton. The majority of these sites were within 3 km of the HBMS complex. Samples were collected from the top 2.5 cm of soil within publicly accessible lands such as boulevards, parks/playgrounds, schoolyards, vacant lots and undeveloped areas (Table 3-1). In addition, to characterize areas that are believed to be minimally impacted and non-impacted, samples were collected from Bakers Narrows Provincial Park (located 17.8 km southeast of the smelter) and Cranberry Portage (located 38.3 km southeast of the smelter), respectively.

Table 3-1 Locations Sampled as Part of the Manitoba Conservation (2007) Soils Study

Site Type	***Number of Sites Sampled***		
	Flin Flon	***Creighton***	***Total***
Park/playground	31	5	36[a]
Boulevard	31	3	34
Undeveloped vacant land	12	1	13
Vacant land	9	1	10
School-yard	5	1	6
Golf course	3	0	3
Cemetery	2	0	2
Residence	0	2	2

[a] Does not include the Bakers Narrows Provincial Park site and the Cranberry Portage site (Manitoba Conservation, 2007).

Manitoba Conservation selected sites that were located away from potential sources of contamination such as roads, parking lots, fences, play structures, and buildings. A small diameter (1.5 cm) coring tool was used to extract soil from the top 2.5 cm. Each sample was a composite of 20 cores collected at intervals of approximately 5 cm along a randomly placed metre stick to ensure that there was sufficient soil for analysis. This was repeated three times at each site to provide three replicate samples per site. The mean concentrations for each site were calculated from the three replicate samples (Manitoba Conservation, 2007).

The results of this study indicated that concentrations of the following twelve chemicals were found to be elevated relative to concentrations measured in the Cranberry Portage reference area:

- Antimony;
- Arsenic;
- Cadmium;
- Copper;
- Lead;
- Mercury;
- Molybdenum;
- Selenium;
- Silver;
- Sulphur;
- Thallium; and,
- Zinc.

In addition to the finding that concentrations of these compounds were elevated across much of the study area, they were also strongly inter-correlated and are known to be past or present constituents of the HBMS smelter emissions. When compared to the CCME soil quality guidelines and interim remediation criteria for soils under a residential or parkland scenario, concentrations of arsenic, cadmium, copper, lead, mercury, selenium, and thallium all exceeded their guidelines. Although concentrations of zinc exceeded the CCME guideline, this guideline is protective of environmental health and does not contain a human health component. Concentrations of antimony, molybdenum, silver, and sulphur did not exceed their corresponding interim remediation criterion.

Overall, Manitoba Conservation concluded that the results of the soil-sampling program suggest that arsenic, cadmium, copper, lead, mercury, and selenium are present in surface soils of

Flin Flon and Creighton at concentrations that may create risks to human health, however, preliminary review suggests that the risk to human health is most likely low (Manitoba Conservation, 2007).

For the purpose of selecting the COC, each of the three replicate samples collected from sites in Flin Flon and Creighton were considered on an individual basis rather than selecting the average of the replicates. This was done as a conservative measure to ensure that all elevated measurements were considered in the COC screening process and were not under-represented due to averaging with lower replicates.

3.2.1.2 Jacques Whitford Residential Soil Sampling Program

Although the Manitoba Conservation soils study effectively characterized concentrations of metals in the soils of public areas, an HHRA will commonly assume that chronic exposure events, for children in particular, will occur at the home. Exposure to metals in soil *via* incidental ingestion and dermal contact, as well as inhalation of re-suspended dusts, is most accurately characterized using values measured from children’s play areas on residential properties.

To address uncertainties associated with characterizing concentrations of metals in soil on residential properties, HBMS contracted Jacques Whitford to complete a soil-sampling program focused on residential properties (Jacques Whitford, 2008). In October, 2007, Jacques Whitford collected 369 soil samples (107 in West Flin Flon, 141 in East Flin Flon, 68 in Creighton, 18 in Channing, and 35 at undisturbed locations at varying distances from Flin Flon). A minimum of 10 soil cores were collected in an “X” pattern at each sample location and were combined to produce a composite sample (Jacques Whitford, 2008). In addition, 12 duplicate samples were also collected for QA/QC purposes. Homes were primarily selected on a volunteer basis.

3.2.2 Summary of the Maximum Measured Concentrations of Elements in Soil

Based on the results of the Manitoba Conservation and Jacques Whitford soil studies, the maximum concentration of each element measured in soil was identified for use in the initial stage of the COC screening process (Table 3-2). While factors such as the number of samples exceeding the criteria, concentrations relative to regional background levels, and past and present association with smelter emissions, will be considered in subsequent stages, the initial stage in the selection of the COC involves a comparison of the maximum concentration of each element to the screening criteria selected in Section 3.2.3.

Several major elements that were measured as part of one or both of these studies were excluded from the COC screening process on the basis that they all have a high natural abundance in soils unaffected by point source emissions and are essential nutrients or minerals for many biological processes. These elements are: calcium, magnesium, phosphorus, potassium and sodium. These elements are physiologically regulated as nutrients by humans and other organisms. Ambient environmental exposure to these elements in soil would not result in internal doses that will result in the occurrence of adverse effects to humans.

Manitoba Conservation included an analysis for zirconium in soil samples; however, environmental quality guidelines or toxicity reference values have not been established for this element. In addition, zirconium was below the detection limit (<1 µg/g) in nearly half of all samples analyzed and is not considered to be significant element of smelter emissions. Therefore, zirconium was excluded from the COC screening process.

Concentrations of boron measured as part of the Manitoba Conservation study represent total concentrations, whereas the values reported by Jacques Whitford represent hot water soluble (HWS) concentrations. Given that soil guidelines that are protective of human health are based on total boron concentrations, the results of the Jacques Whitford study were converted to total concentrations assuming that the HWS fraction represents 5% of the total concentration as recommended by OMOE (1996) and Gupta (1979). The calculated maximum total boron concentration was used in the COC screening process for the selection of COC in soil.

The release of sulphur from the HBMS smelter will influence levels in soil through deposition, however, exposure to sulphur in soil through oral or dermal pathways, or through the consumption of locally derived food items, is generally not of significant concern. Sulphur is known to be a respiratory irritant and is therefore, most likely to cause health issues *via* direct inhalation in ambient air. Regulatory agencies such as Health Canada, the CCME, the Ontario Ministry of the Environment (OMOE), and the U.S. EPA have not developed soil quality guidelines for sulphur. Therefore, sulphur was excluded from the COC screening process for the selection of COC in soil.

Table 3-2 Maximum Concentrations of Elements Measured in Soil within the Manitoba Conservation and Jacques Whitford Soil Studies

Element	***Maximum Measured Concentration (µg/g)***					
	Manitoba Conservation (n=318)	***Jacques Whitford Study***				***Overall Max***
		Channing (n=18)	***Creighton (n=68)***	***East Flin Flon (n=141)***	***West Flin Flon (n=107)***	
Aluminum	36,600	-	-	-	-	36,600
Antimony	11.2	1.2	5.9	1.8	5.4	11.2
Arsenic	454	35.7	314	49.7	237	454
Barium	239	213	750	237	1,640	1,640
Beryllium	3	0.7	0.8	1.2	1.5	3
Boron	62	(3.7) 74	(3.6) 72	(7.8) 156	(19) 380	380
Cadmium	88.5	20.7	31.8	33.5	70.8	88.5
Chromium	245	71	57	76.8	95.3	245
Cobalt	45	20.6	29.1	17.4	24	45
Copper	5,620	700	1,800	2,050	7,810	7,810
Iron	77,600	-	-	-	-	77,600
Lead	1,990	266	1,490	552	820	1,990
Manganese	996	-	-	-	-	996
Mercury	898	7	38.8	32	971	971
Molybdenum	8	2	9	4	9	9
Nickel	93	37.2	33.1	58.9	55.2	93
Selenium	260	4	20.4	12	286	286
Silver	7.5	1	3	2.9	5.2	7.5
Strontium	157	-	-	-	-	157
Thallium	2.7	0.49	0.81	1.51	0.86	2.7
Tin	77	4	7	9	20	77
Titanium	1,650	-	-	-	-	1,650
Vanadium	85	75.1	61.5	84	90.6	90.6
Zinc	16,500	5,680	4,660	8,240	21,200	21,200

\- Indicates that the analysis did not include this element

( ) Value in brackets represents the hot water soluble (HWS) concentration for boron. This value has been converted to a total boron concentration assuming that the HWS concentration represents 5% of the total concentration.

3.2.3 Selection of Screening Criteria

As part of their 2006 soils study, Manitoba Conservation (2007) completed a screening process to indicate which chemicals may be found at concentrations that would warrant their further assessment within an HHRA. This screening process included a Spearman correlation analysis to describe the relationships between concentrations of chemicals in analyzed soil, and in particular, to see which chemicals were positively inter-correlated with known constituents of the smelter emissions. This analysis, along with historical emissions records, resulted in further consideration of twelve chemicals (antimony, arsenic, cadmium, copper, lead, mercury, molybdenum, selenium, silver, sulphur, thallium, and zinc) within this screening process. Concentrations of these chemicals in soil were compared to the CCME soil guidelines for residential/parkland properties or CCME interim remediation criteria when guidelines were not available. Additional consideration was given to soil concentrations considered to be representative of minimally-impacted or non-impacted soils as measured in Bakers Narrows Provincial Park and Cranberry Portage, respectively.

A similar chemical screening process was undertaken within the current Problem Formulation by initially comparing the maximum concentrations of elements measured in soil to human health-based soil quality guidelines to identify those chemicals to be carried forward for further assessment. Following this comparison, the percentage of samples found in excess of the soil quality guidelines was considered as well as concentrations of certain chemicals relative to regional background concentrations. The selection of health-based criteria was based on the following hierarchy:

1. **Canadian Council of Ministers of the Environment (CCME, 2007): Canadian Soil Quality Guidelines for the Protection of Human Health**

   The Canadian Council of Ministers of the Environment (CCME) has developed guidelines for substances in soil that are designed to approximate a “no- to low” effect level based on a chemical’s toxicity and environmental fate and behaviour (CCME, 2006). The CCME indicates that these guidelines are intended as general guidance only and that site-specific conditions should be considered when applying these values. The CCME has developed two components to their guidelines to be protective of human health and the environment. Given that the focus of the HHRA is to assess exposure and risks to humans, the human health component of the guidelines was selected as the screening criterion. The CCME has developed human health guidelines that are protective of receptors under a number of different property uses. For the current assessment, guidelines developed for residential/parkland properties were conservatively selected for comparison to all soil samples. Given the conservative nature of these guidelines, chemicals that are not found in any soils in excess of these values are not likely to result in the occurrence of adverse health effects and do not need to be retained as COC. Details on the basis and derivation of the CCME human health soil quality guidelines are provided in CCME (2006).

2. Ontario Ministry of the Environment (OMOE) Site Condition Standards

For chemicals lacking CCME (2007) human health guidelines, the lowest human health-based soil guidelines provided by the OMOE was selected (OMOE, 1996). Under Ontario Regulation 153/04, the OMOE has developed soil standards that are designed to be protective of human and environmental health under a number of different land use categories. As with the CCME guidelines, there are separate human and environmental component values within each standard. For the current screening process, the S-1 component value for residential/parkland/institutional land use was selected. The S-1 category addresses sites with a high exposure potential, such as a residential scenario, where a child has direct contact with soil while playing. For non-carcinogens, the S-1 risk-based soil concentrations are based on a child (1 to 6 years) receptor. For carcinogens, the S-1 concentrations are based on a composite receptor exposed over a 30 year duration. Further details are available in OMOE (1996).

3. U.S. EPA Region III Risk-Based Concentrations (RBCs) or U.S. EPA Region IX Preliminary Remedial Goals (PRGs)

For chemicals lacking human health-based guidelines from the CCME or OMOE, the U.S. EPA Region III RBCs (2007) or U.S. EPA Region IX PRGs (2004) for soil under a residential land use were selected. Soil RBCs and PRGs are risk-based soil concentrations that are derived in a similar manner as OMOE (1996) risk-based concentrations. Details regarding the RBC values are provided at: http://www.epa.gov/reg3hwmd/risk/human/rbc/RBCoct07.pdf and for the PRG values at: http://www.epa.gov/Region9/waste/sfund/prg/index.htm. The criteria identified above from CCME and OMOE were derived by applying a 20% soil allocation factor, meaning that exposure to chemicals in soil can only account for 20% of the safe daily dose. Since the RBC and PRG values were developed based on the entire TRV being allocated to soil exposure, the RBC and PRG values were divided by a factor of 5. With respect to apportionment, this adjustment makes the PRGs similar to the CCME and OMOE values. Since the Region III RBCs were updated in 2007, these values were given priority over the Region IX PRGs from 2004,

Based on this hierarchy, the soil criteria selected for the COC screening are presented in Table 3-3.

Table 3-3 Summary of Selected Soil Screening Criteria

Element	***Soil Criterion (µg/g)***	***Source***
Aluminum	15,200	U.S. EPA Region IX
Antimony	13	OMOE
Arsenic	12	CCME
Barium	3,700	OMOE
Beryllium	32[a]	U.S. EPA Region III
Boron	3,200	U.S. EPA Region III and IX
Cadmium	14	CCME
Chromium	220	CCME
Cobalt	2,700	OMOE
Copper	1,100	CCME
Iron	11,000	U.S. EPA Region III
Lead	140	CCME
Manganese	320	U.S. EPA Region III
Mercury	6.6	CCME

Table 3-3 Summary of Selected Soil Screening Criteria

Element	*Soil Criterion (µg/g)*	*Source*
Molybdenum	170	OMOE
Nickel	310	OMOE
Selenium	80	CCME
Silver	98	OMOE
Strontium	9,400	U.S. EPA Region III and IX
Thallium	1.0	CCME
Tin	9,400	U.S. EPA Region III and IX
Titanium	20,000	U.S. EPA Region IX
Vanadium	470	OMOE
Zinc	16,000	OMOE

[a] The OMOE human health soil criterion of 0.37 µg/g for beryllium was not selected since this value is below the Ontario background concentration of 1.2 µg/g and was therefore excluded by the OMOE in the derivation of the final Site Condition Standard.

3.2.4 Screening of COC

The maximum concentrations of elements measured in soil (as presented in Table 3-2) were compared to the selected soil criteria (as presented in Table 3-3) as an initial step in determining the COC to be evaluated in the HHRA (Table 3-4). Also included in Table 3-4 is the percentage of samples in which each element was found in excess of the criteria. This was included as a secondary step in the screening process to evaluate the spatial extent of exceedances and to determine if an element is elevated across a sufficient portion of the study area to warrant its inclusion as a COC in the HHRA. Those chemicals that were not found in excess of the selected soil criterion in greater than 1% of all samples were not retained as COC.

For those chemicals that were found above the soil criterion in greater than 1% of all samples, the concentrations relative to those that are representative of background concentrations were considered. In a study completed by the U.S. Geological Survey (USGS) and the Geological Survey of Canada, concentrations of major and trace elements were measured in soil from two continental-scale transects of the United States and Canada to determine an unbiased geochemical status of all North American soils (Smith *et al*., 2005). This survey included the analysis of surface soils (*i.e*., top 5 cm) from 32 sites in Manitoba. The average of the samples collected from Manitoba were used to represent Manitoba background concentrations as presented for comparison in Table 3-4. Average soil concentrations measured at Cranberry Portage in the 2006 Manitoba Conservation soils study are also presented in Table 3-4, representative of regional background concentrations.

Table 3-4 Comparison of Maximum Soil Concentrations to the Selected Soil Screening Criteria

Element	*Soil Criterion (µg/g)*	*Maximum Concentration (µg/g)*	*Percentage of Samples in Excess of Standard*	*Manitoba Background Concentration (µg/g)*	*Regional Background Concentration (µg/g)*
Aluminum	15,200	**36,600**	11% (35 of 318)	56,000	12,100
Antimony	13	11.2	-	0.22	< 0.1
Arsenic	12	**454**	72% (467 of 652)	2.8	2.5
Barium	3,700	1640	-	530	59
Beryllium	32	3	-	1.2	< 1
Boron	3,200	380	-	NA	9
Cadmium	14	**88.5**	37% (242 of 652)	0.25	< 0.2
Chromium	220	**245**	0.31% (2 of 652)	40	42

Table 3-4 Comparison of Maximum Soil Concentrations to the Selected Soil Screening Criteria

Element	*Soil Criterion (µg/g)*	*Maximum Concentration (µg/g)*	*Percentage of Samples in Excess of Standard*	*Manitoba Background Concentration (µg/g)*	*Regional Background Concentration (µg/g)*
Cobalt	2,700	45	-	8.2	7
Copper	1,100	**7,810**	29% (190 of 652)	15	26
Iron	11,000	**77,600**	31% (200 of 652)	22,000	15,600
Lead	140	**1,990**	43% (279 of 652)	18	5
Manganese	320	**996**	16% (51 of 318)	500	194
Mercury	6.6	**971**	45% (296 of 652)	0.032	0.14
Molybdenum	170	9	-	0.55	0.2
Nickel	310	93	-	23	24
Selenium	80	**286**	2% (13 of 652)	0.52	0.2
Silver	98	7.5	-	0.93	< 0.1
Strontium	9,400	157	-	200	10
Thallium	1.0	**2.7**	0.46% (3 of 652)	0.38	0.1
Tin	9,400	77	-	1.2	< 5
Titanium	20,000	1,650	-	0.23	455
Vanadium	470	90.6	-	60	38
Zinc	16,000	**21,200**	0.31% (2 of 652)	57	39

Bolded values shaded in grey are in excess of the screening criterion.

Based on the initial comparison, the maximum measured concentration of twelve elements was found in excess of the corresponding soil criterion. However, given that only two samples, representing 0.31% of all samples, contained chromium or zinc in excess of the criterion, and three samples, representing 0.46% of all samples, contained thallium in excess of the criterion, these elements are not considered to be elevated across the study area at concentrations that have the potential to cause adverse human health effects. The occurrence of these exceedances is considered to be an anomaly and not representative of widespread conditions. As a result, chromium, zinc and thallium were not retained as COC for the HHRA.

Arsenic, cadmium, copper, lead, mercury, and selenium were all found in excess of the corresponding criterion within a significant percentage of samples and have all been identified as notable components of the HBMS smelter emissions. In addition, each of these elements was identified as having a strong positive inter-correlation by Manitoba Conservation (2007) and was recommended to be further assessed within an HHRA. Concentrations of these chemicals in soils sampled from the Flin Flon/Creighton-area are notably higher than concentrations considered to be representative of Provincial background concentrations as well as regional background concentrations measured at Bakers Narrows and Cranberry Portage.

Aluminum, manganese and iron were also found at concentrations in excess of the corresponding soil criterion within a significant percentage of samples. However, these elements are not regarded as major components of smelter emissions and are not correlated with known constituents. Further discussion is provided for these compounds below along with consideration of Provincial and regional background concentrations.

Aluminum

Aluminum was found at concentrations in excess of the soil criterion (15,200 µg/g) in 11% (or 35 of 318) of the samples. Based on the spearman correlation analysis completed by Manitoba Conservation (2007), concentrations of aluminum in soil were not correlated with any of the known or suspected elements of smelter emissions (*i.e.*, antimony, arsenic, cadmium, copper, lead, mercury, molybdenum, selenium, silver, sulphur, thallium, and zinc). This suggests that levels of aluminum in soils are not related to atmospheric emissions from the smelter. Although the maximum measured concentration of 36,600 µg/g was significantly higher than the soil criterion of 15,200 µg/g, the average concentration of 8,423 µg/g was well below the criterion and was similar to concentrations measured in Bakers Narrows (9,140, 8,450 and 8,990 µg/g) and in Cranberry Portage (13,800, 6,830 and 15,800 µg/g).

The results of the study completed by the USGS and the Geological Survey of Canada (Smith *et al*., 2005) found that the average concentration of aluminum measured in surface soils (*i.e.*, top 5 cm) from 32 sites in Manitoba was 56,000 µg/g, with a maximum of 71,000 µg/g, both of which are significantly higher than the corresponding average and maximum concentrations measured in soils from Flin Flon and Creighton (Table 3-5).

Table 3-5 Background Concentrations of Aluminum in Manitoba Surface Soils

Location		***Concentration of Aluminum (µg/g)***
Latitude	***Longitude***	
56.7	-99.9	66,500
49.5	-98.0	45,100
48.8	-97.9	48,900
49.7	-98.0	37,800
50.3	-97.9	40,300
49.7	-98.0	36,100
49.9	-98.0	45,400
51.7	-98.7	52,000
50.7	-98.1	39,600
49.7	-98.0	41,200
54.9	-98.7	64,700
51.1	-98.3	51,600
51.9	-98.8	56,700
52.7	-99.0	49,800
54.5	-99.0	62,500
56.3	-100.0	67,900
52.9	-99.1	30,900
55.3	-98.4	70,000
52.0	-98.8	60,800
52.5	-98.9	58,800
54.5	-99.1	53,700
51.9	-98.8	71,000
55.6	-98.0	67,400
52.5	-98.9	55,900
56.2	-100.0	65,300
54.5	-99.0	70,100
55.9	-99.7	62,900
53.3	-99.3	61,800
54.4	-99.1	53,100
52.5	-98.9	61,700
53.7	-99.3	59,700
55.9	-99.7	71,000
Average		**56,000**
Maximum		**71,000**

Given that Manitoba Conservation found that levels of aluminum in soil were not correlated with known constituents of smelter emissions, and that concentrations were generally lower than levels representative of background concentrations in Manitoba soils, aluminum was considered to be naturally elevated in the soils of Flin Flon and Creighton. Aluminum is not anticipated to be present in soils at levels that have the potential to cause adverse human health effects; therefore, aluminum was not retained as a COC for further evaluation in the HHRA.

Manganese

Manganese was found at concentrations in excess of the soil criterion (360 µg/g) in 16% (or 51 of 318) of the samples. Based on the spearman correlation analysis completed by Manitoba Conservation (2007), concentrations of manganese in soil were not correlated with any of the known or suspected elements of smelter emissions (*i.e.*, antimony, arsenic, cadmium, copper, lead, mercury, molybdenum, selenium, silver, sulphur, thallium, and zinc). This suggests that levels of manganese in soils are not related to atmospheric emissions from the smelter. Although the maximum measured concentration of 996 µg/g was significantly higher than the soil criterion of 320 µg/g, the average concentration of 222 µg/g was well below the criterion and was similar to concentrations measured in Bakers Narrows (197, 299 and 362 µg/g) and in Cranberry Portage (127, 217 and 238 µg/g).

The results of the study completed by the USGS and the Geological Survey of Canada (Smith *et al*., 2005) found that the average concentration of manganese measured in surface soils (*i.e.*, top 5 cm) from 32 sites in Manitoba was 500 µg/g, with a maximum of 2,470 µg/g, both of which are significantly higher than the corresponding average and maximum concentrations measured in soils from Flin Flon and Creighton (Table 3-6).

Table 3-6 Background Concentrations of Manganese in Manitoba Surface Soils

Location		***Concentration of Manganese (µg/g)***
Latitude	***Longitude***	
56.7	-99.9	312
49.5	-98.0	364
48.8	-97.9	2,470
49.7	-98.0	306
50.3	-97.9	600
49.7	-98.0	292
49.9	-98.0	552
51.7	-98.7	625
50.7	-98.1	540
49.7	-98.0	264
54.9	-98.7	518
51.1	-98.3	320
51.9	-98.8	487
52.7	-99.0	467
54.5	-99.0	271
56.3	-100.0	134
52.9	-99.1	79
55.3	-98.4	752
52.0	-98.8	477
52.5	-98.9	909
54.5	-99.1	199
51.9	-98.8	625
55.6	-98.0	485
52.5	-98.9	508
56.2	-100.0	339
54.5	-99.0	243
55.9	-99.7	294
53.3	-99.3	878

Table 3-6	**Background Concentrations of Manganese in Manitoba Surface Soils**	
Location		***Concentration of Manganese (µg/g)***
Latitude	***Longitude***	
54.4	-99.1	402
52.5	-98.9	665
53.7	-99.3	324
55.9	-99.7	232
Average		**500**
Maximum		**2,470**

Given that Manitoba Conservation found that levels of manganese in soil were not correlated with known constituents of smelter emissions, and that concentrations were generally lower than levels representative of background concentrations in Manitoba soils, manganese was considered to be naturally elevated in the soils of Flin Flon and Creighton. Manganese is not anticipated to be present in soils at levels that have the potential to cause adverse human health effects; therefore, manganese was not retained as a COC for further evaluation in the HHRA.

<u>Iron</u>

Iron was found at concentrations in excess of the soil criterion (11,000 µg/g) in 31% (or 200 of 652) of the samples. Based on the spearman correlation analysis completed by Manitoba Conservation (2007) on samples collected as part of their study, concentrations of iron in soil were not correlated with any of the known or suspected elements of smelter emissions. This suggests that levels of iron in soils are not related to atmospheric emissions from the smelter. Although the maximum measured concentration of 77,600 µg/g was significantly higher than the soil criterion of 11,000 µg/g, the average concentration of 15,288 µg/g was similar to concentrations measured in Bakers Narrows (12,100, 13,700, and 14,900 µg/g) and in Cranberry Portage (9,640, 16,800 and 20,500 µg/g). In addition, these concentrations were similar to those measured in Manitoba soils as part of the USGS soils study that can be considered to be representative of background concentrations (average of 22,000 µg/g and maximum of 51,500 µg/g) (Smith *et al*., 2005) (Table 3-7).

Table 3-7	**Background Concentrations of Iron in Manitoba Surface Soils**	
Location		***Concentration of Iron (µg/g)***
Latitude	***Longitude***	
56.7	-99.9	23,300
49.5	-98.0	13,300
48.8	-97.9	21,600
49.7	-98.0	10,200
50.3	-97.9	17,100
49.7	-98.0	9,400
49.9	-98.0	18,700
51.7	-98.7	25,300
50.7	-98.1	17,000
49.7	-98.0	13,600
54.9	-98.7	31,000
51.1	-98.3	21,900
51.9	-98.8	15,400
52.7	-99.0	19,800
54.5	-99.0	17,200
56.3	-100.0	6,900
52.9	-99.1	6,600
55.3	-98.4	40,900
52.0	-98.8	21,800

Table 3-7 Background Concentrations of Iron in Manitoba Surface Soils

Location		***Concentration of Iron (µg/g)***
Latitude	***Longitude***	
52.5	-98.9	34,800
54.5	-99.1	9,000
51.9	-98.8	16,500
55.6	-98.0	43,300
52.5	-98.9	20,800
56.2	-100.0	26,900
54.5	-99.0	51,500
55.9	-99.7	37,000
53.3	-99.3	26,100
54.4	-99.1	14,900
52.5	-98.9	26,000
53.7	-99.3	27,400
55.9	-99.7	27,100
Average		**22,000**
Maximum		**51,500**

Given that Manitoba Conservation found that levels of iron in soil were not correlated with known constituents of smelter emissions, and that concentrations were generally lower than levels representative of background concentrations in Manitoba soils, iron was considered to be naturally elevated in the soils of Flin Flon and Creighton. Iron is not anticipated to be present in soils at levels that have the potential to cause adverse human health effects; therefore, iron was not retained as a COC for further evaluation in the HHRA.

3.2.5 Summary of COC Selection

The selection of the elements to be retained as COC for evaluation in the HHRA considered all soil measurements for Flin Flon and Creighton taken as part of the 2006 Manitoba Conservation surface soils study and the 2007 Jacques Whitford residential soil sampling program. These studies included the analysis of several elements that are considered to be essential nutrients or minerals (*e.g.*, calcium, sodium, potassium) that are naturally found in abundance in native soils. Given that they are not related to smelter emissions and are regulated by living organisms as necessary components for biological processes, they were not further considered in the COC screening process.

The maximum concentrations of the remaining elements as found within these studies were identified for comparison to conservative soil criteria that are designed to be protective of human health during prolonged exposure under a residential land use. The selection of the criteria followed a hierarchy which gave priority to human health-based values provided by the CCME, then the OMOE, and then the U.S. EPA Region III or Region IX. This initial comparison indicated that the maximum concentration of twelve elements was in excess of the corresponding soil criterion. The frequency of the exceedances, the correlation of elements with known constituents of smelter emissions, and consideration of concentrations representative of regional background levels were all additional factors that were considered in subsequent stages of the screening process.

The following six elements were found to be elevated across a significant portion of the study area and have all been positively inter-correlated as constituents of the smelter emissions:

- Arsenic;
- Cadmium;
- Copper;
- Lead;
- Mercury; and,
- Selenium.

These elements were retained as COC for detailed quantitative evaluation in the HHRA.

3.3 Receptor Characterization

A human receptor is a hypothetical person (*i.e.,* an infant, toddler, child, teen, or adult) who may reside, spend leisure time and/or work in the area being investigated and is, or could potentially be, exposed to the chemicals identified as being of concern. General physical and behavioural characteristics specific to the receptor type (*e.g.*, body weight, breathing rate, food consumption rate, *etc*.) are used to approximate the amount of chemical exposure received by each receptor. The HHRA must be sufficiently comprehensive to ensure that those receptors with the greatest potential for exposure to COC, and those that have the greatest sensitivity, or potential for developing adverse effects from these exposures, are included. With this in mind, the selection of hypothetical receptors, with somewhat exaggerated life style habits (to ensure a conservative assessment), should be developed for consideration in the HHRA. Due to differences in physiological characteristics and activity patterns between children and adults, the exposures received by a child and an adult will be different. Consequently, the potential risks estimated for the same COC will differ depending on the receptor chosen for evaluation.

For chemicals considered to be carcinogenic, it is common to assess exposure over a lifetime, as development of cancer is a long-term process that may take many years to manifest itself. For this reason, a special type of receptor called a “lifetime” or “composite” receptor is selected for evaluation of potential carcinogenic risks. This receptor is a “composite” of all relevant life stages for which exposure will be evaluated. Health risks associated with exposure to carcinogenic compounds are usually expressed as an estimate of excess or incremental lifetime cancer risk (ILCR) for a population resulting from exposure to a particular source. Thus, risks associated with carcinogenic compounds are predicted using the average daily dose over a human receptor’s entire life span. In order to allow a comprehensive assessment of COC, all five age classes recommended by Health Canada (2006) will be evaluated in the HHRA:

i. Infant (0 to 6 months);
ii. Preschool child or toddler (7 months to 4 years);
iii. Child (5 years to 11 years);
iv. Adolescent or teen (12 to 19 years); and,
v. Adult (20 years and over).

For carcinogenic COC, a composite receptor will typically be the most relevant for assessment of lifetime carcinogenic risks. For non-carcinogens, the toddler is typically the most sensitive receptor for estimating exposure and risk as a result of an elevated soil ingestion rate during this life stage.

In order to evaluate potential exposures, it is necessary to characterize the physiological and behavioural characteristics of each receptor group. Several published resources were considered in the selection of these parameters, including:

- *Federal Contaminated Sites Risk Assessment in Canada. PART I: Guidance on Human Health Risk Preliminary Quantitative Risk Assessment (PQRA).* (Health Canada, 2006);
- *Procedures for the Use of Risk Assessment under Part XV.1 of the Environmental Protection Act*. (OMOE, 2005);
- *Compendium of Canadian Human Exposure Factors for Risk Assessment. O'Connor Associates Environmental Inc. 1155-2720 Queensview Dr., Ottawa, Ontario.* (Richardson, 1997);
- *Human Health Risk Assessment for Priority Substances: Canadian Environmental Protection Act: ISBN 0-662-22126-5;* Health Canada, (1994);
- *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final. EPA/540//R/99/005. July, 2004*. (U.S. EPA, 2004a);
- *Short Sheet: Overview of the IEUBK Model for Lead in Children. Office of Solid Waste and Emergency Response. U.S. Environmental Protection Agency. Washington D.C.* (U.S. EPA, 2004b); and,
- *The U.S. EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities*. (U.S. EPA, 2005).

These sources have been used in numerous HHRAs that have been critically reviewed and accepted by regulatory agencies across Canada and the United States. Both the Compendium of Canadian Human Exposure Factors for Risk Assessment (Richardson, 1997) and Health Canada (2006) rely on data from published and reliable Canadian sources, such as Health Canada, Statistics Canada, and the Canadian Fitness and Lifestyles Research Institute. Where insufficient data are available in these sources to appropriately characterize relevant activity patterns and/or behavioural/physiological characteristics of a certain receptor group, other appropriate sources such as the U.S. EPA Exposure Factors Handbook (U.S. EPA, 1997) were used to supplement the receptor parameter dataset. In addition to the published resources listed above, site-specific information gathered as part of past and current programs including the local food consumption survey were used to characterize receptor parameters.

Receptor characteristics reflective of a Central Tendency Estimate (CTE) were selected for use in the HHRA. A list of parameters and assumptions describing the physiological and behavioural characteristics of each receptor evaluated in the HHRA are provided in the following tables (Tables 3-8 to 3-12).

Table 3-8 Receptor Characteristics and Assumptions for the Infant Receptor

Description	***Units***	***Value***	***Statistic***	***Reference/Comment***
Exposure duration	yr	0.5	-	Health Canada (2006)
Exposure frequency – residential	days/yr	182	-	Health Canada (2006)
Body weight	kg	8.2	Arithmetic mean	Richardson (1997); Health Canada (2006)
Breathing rate	m^3/day	2.1	Arithmetic mean	Richardson (1997); Health Canada (2006)
Water intake rate	L/day	0.3	Arithmetic mean	Richardson (1997); Health Canada (2006)
Soil/dust intake rate	g/day	0.02	-	Health Canada (2006)
Surface area – hands	cm^2	320	Arithmetic mean	Richardson (1997); Health Canada (2006)

Table 3-8 Receptor Characteristics and Assumptions for the Infant Receptor

Description	*Units*	*Value*	*Statistic*	*Reference/Comment*
Surface area – arms	cm^2	550	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – legs	cm^2	910	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – whole body	cm^2	3620	Arithmetic mean	Richardson (1997)
Market Basket Food Consumption Rates				
Meat and Eggs	g/day	15	Arithmetic mean	Richardson (1997)
Cereals and Grains	g/day	37	Arithmetic mean	Richardson (1997)
Milk and Dairy	g/day	468	Arithmetic mean	Richardson (1997)
Fish and Shellfish	g/day	0	-	Richardson (1997)
Fats and Oils	g/day	0	-	Richardson (1997)
Formula	g/day	113	Arithmetic mean	Richardson (1997)
Fruits and Juices	g/day	99	Arithmetic mean	Richardson (1997)
Other vegetables	g/day	22	Arithmetic mean	Richardson (1997)
Nuts and Seeds	g/day	0	-	Richardson (1997)
Root Vegetables	g/day	8.8	Arithmetic mean	Richardson (1997)
Sugars and Sweets	g/day	30	Arithmetic mean	Richardson (1997)
Local Food Consumption Rates				
Fish	g/day	0	-	Assumed
Blueberries	g/day	0.61	Mean + SE	U.S. EPA (1997)
Wild Game (fraction of market basket meat and eggs)	unitless	0	-	Assumed
Home Garden Root Vegetables (fraction of market basket rate)	unitless	0.018	Mean	U.S. EPA (1997)
Home Garden Other Vegetables (fraction of market basket rate)	unitless	0.062	Mean	U.S. EPA (1997)

Table 3-9 Receptor Characteristics and Assumptions for the Toddler Receptor

Description	*Units*	*Value*	*Statistic*	*Reference/Comment*
Exposure duration	yr	4.5	-	Health Canada (2006)
Exposure frequency –residential	days/yr	365	-	Health Canada (2006)
Swim events per year - recreational	events/yr	30	90th percentile	U.S. EPA (2003); based on the 90th percentile swim events per month from U.S. EPA (1997) for 3 months per year
Duration of swim event - recreational	hrs/event	2.3	50th percentile	U.S. EPA (2003); recommended exposure duration for long-term exposure for children 5-11 from U.S. EPA (1997)
Body weight	kg	16.5	Arithmetic mean	Richardson (1997); Health Canada (2006)
Breathing rate	m^3/day	9.3	Arithmetic mean	Richardson (1997); Health Canada (2006)
Water intake rate	L/day	0.6	Arithmetic mean	Richardson (1997); Health Canada (2006)
Water ingestion while swimming	L/hrs	0.05	-	U.S. EPA (1989)

Table 3-9 Receptor Characteristics and Assumptions for the Toddler Receptor

Description	***Units***	***Value***	***Statistic***	***Reference/Comment***
Soil/dust intake rate	g/day	0.08	-	Health Canada (2006)
Surface area – hands	cm^2	430	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – arms	cm^2	890	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – legs	cm^2	1,690	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – whole body	cm^2	6,130	Arithmetic mean	Richardson (1997)
Market Basket Food Consumption Rates				
Meat and Eggs	g/day	77	Arithmetic mean	Richardson (1997)
Cereals and Grains	g/day	167	Arithmetic mean	Richardson (1997)
Milk and Dairy	g/day	579	Arithmetic mean	Richardson (1997)
Fish and Shellfish	g/day	4.7	Arithmetic mean	Richardson (1997)
Fats and Oils	g/day	21	Arithmetic mean	Richardson (1997)
Formula	g/day	3.3	Arithmetic mean	Richardson (1997)
Fruits and Juices	g/day	179	Arithmetic mean	Richardson (1997)
Other vegetables	g/day	48	Arithmetic mean	Richardson (1997)
Nuts and Seeds	g/day	2.79	Arithmetic mean	Richardson (1997)
Root Vegetables	g/day	79	Arithmetic mean	Richardson (1997)
Sugars and Sweets	g/day	46	Arithmetic mean	Richardson (1997)
Local Food Consumption Rates				
Fish	g/day	11	-	Local Food Survey
Blueberries	g/day	1.2	Mean + SE	U.S. EPA (1997)
Wild Game (fraction of market basket meat and eggs)	unitless	0.1	-	Local Food Survey
Home Garden Root Vegetables (fraction of market basket rate)	unitless	0.018	Mean	U.S. EPA (1997)
Home Garden Other Vegetables (fraction of market basket rate)	unitless	0.062	Mean	U.S. EPA (1997)

Table 3-10 Receptor Characteristics and Assumptions for the Child Receptor

Description	***Units***	***Value***	***Statistic***	***Reference***
Exposure duration	yr	7.0	-	Health Canada (2006)
Exposure frequency – residential	days/yr	365	-	Health Canada (2006)
Swim events per year - recreational	events/yr	30	90th percentile	U.S. EPA (2003); based on the 90th percentile swim events per month from U.S. EPA (1997) for 3 months per year
Duration of swim event - recreational	hrs/event	2.3	50th percentile	U.S. EPA (2003); recommended exposure duration for long-term exposure for children 5-11 from U.S. EPA (1997)

Table 3-10 Receptor Characteristics and Assumptions for the Child Receptor

Description	*Units*	*Value*	*Statistic*	*Reference*
Body weight	kg	32.9	Arithmetic mean	Richardson (1997); Health Canada (2006)
Breathing rate	m^3/day	14.5	Arithmetic mean	Richardson (1997); Health Canada (2006)
Water intake rate	L/day	0.8	Arithmetic mean	Richardson (1997); Health Canada (2006)
Water ingestion while swimming	L/hrs	0.05	-	U.S. EPA (1989)
Soil/dust intake rate	g/day	0.02	-	Health Canada (2006)
Surface area – hands	cm^2	590	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – arms	cm^2	1,480	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – legs	cm^2	3,070	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – whole body	cm^2	10,140	Arithmetic mean	Richardson (1997)
Market Basket Food Consumption Rates				
Meat and Eggs	g/day	115	Arithmetic mean	Richardson (1997)
Cereals and Grains	g/day	264	Arithmetic mean	Richardson (1997)
Milk and Dairy	g/day	591	Arithmetic mean	Richardson (1997)
Fish and Shellfish	g/day	10	Arithmetic mean	Richardson (1997)
Fats and Oils	g/day	37	Arithmetic mean	Richardson (1997)
Formula	g/day	0	-	Richardson (1997)
Fruits and Juices	g/day	197	Arithmetic mean	Richardson (1997)
Other vegetables	g/day	80	Arithmetic mean	Richardson (1997)
Nuts and Seeds	g/day	7.27	Arithmetic mean	Richardson (1997)
Root Vegetables	g/day	132	Arithmetic mean	Richardson (1997)
Sugars and Sweets	g/day	66	Arithmetic mean	Richardson (1997)
Local Food Consumption Rates				
Fish	g/day	22	-	Local Food Survey
Blueberries	g/day	2.4	Mean + SE	U.S. EPA (1997)
Wild Game (fraction of market basket meat and eggs)	unitless	0.13	-	Local Food Survey
Home Garden Root Vegetables (fraction of market basket rate)	unitless	0.018	Mean	U.S. EPA (1997)
Home Garden Other Vegetables (fraction of market basket rate)	unitless	0.062	Mean	U.S. EPA (1997)

Table 3-11 Receptor Characteristics and Assumptions for the Teen Receptor

Description	*Units*	*Value*	*Statistic*	*Reference/Comment*
Exposure duration	yr	8.0	-	Health Canada (2006)
Exposure frequency – residential	days/yr	365	-	Health Canada (2006)

Table 3-11 Receptor Characteristics and Assumptions for the Teen Receptor				
Description	***Units***	***Value***	***Statistic***	***Reference/Comment***
Swim events per year - recreational	events/yr	30	90th percentile	U.S. EPA (2003); based on the 90th percentile swim events per month from U.S. EPA (1997) for 3 months per year
Duration of swim event - recreational	hrs/event	1.7	50th percentile	U.S. EPA (2003); recommended exposure duration for long-term exposure for children 12-17 from U.S. EPA (1997)
Body weight	kg	59.7	Arithmetic mean	Richardson (1997); Health Canada (2006)
Breathing rate	m^3/day	15.8	Arithmetic mean	Richardson, 1997; recommended by Health Canada (2006)
Water intake rate	L/day	1.0	Arithmetic mean	Richardson (1997); Health Canada (2006)
Water ingestion while swimming	L/hrs	0.05	-	U.S. EPA (1989)
Soil/dust intake rate	g/day	0.02	-	Health Canada (2006)
Surface area – hands	cm^2	800	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – arms	cm^2	2,230	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – legs	cm^2	4,970	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – whole body	cm^2	15,470	Arithmetic mean	Richardson (1997)
Market Basket Food Consumption Rates				
Meat and Eggs	g/day	158	Arithmetic mean	Richardson (1997)
Cereals and Grains	g/day	280	Arithmetic mean	Richardson (1997)
Milk and Dairy	g/day	545	Arithmetic mean	Richardson (1997)
Fish and Shellfish	g/day	12	Arithmetic mean	Richardson (1997)
Fats and Oils	g/day	49	Arithmetic mean	Richardson (1997)
Formula	g/day	0	-	Richardson (1997)
Fruits and Juices	g/day	163	Arithmetic mean	Richardson (1997)
Other vegetables	g/day	95	Arithmetic mean	Richardson (1997)
Nuts and Seeds	g/day	7.52	Arithmetic mean	Richardson (1997)
Root Vegetables	g/day	185	Arithmetic mean	Richardson (1997)
Sugars and Sweets	g/day	71	Arithmetic mean	Richardson (1997)
Local Food Consumption Rates				
Fish	g/day	40	-	Local Food Survey
Blueberries	g/day	4.4	Mean + SE	U.S. EPA (1997)
Wild Game (fraction of market basket meat and eggs)	unitless	0.17	-	Local Food Survey
Home Garden Root Vegetables (fraction of market basket rate)	unitless	0.018	Mean	U.S. EPA (1997)
Home Garden Other Vegetables (fraction of market basket rate)	unitless	0.062	Mean	U.S. EPA (1997)

Table 3-12 Receptor Characteristics and Assumptions for the Adult Receptor

Description	*Units*	*Value*	*Statistic*	*Reference/Comment*
Exposure duration	yr	60	-	Health Canada (2006)
Exposure frequency - residential	days/yr	365	-	Health Canada (2006)
Exposure frequency - commercial	days/yr	240	Mean	Health Canada (2006)
Exposure frequency - commercial	hrs/day	10	Mean	Health Canada (2006)
Swim events per year - recreational	events/yr	30	90th percentile	U.S. EPA (2003); based on the 90th percentile swim events per month from U.S. EPA (1997) for 3 months per year
Duration of swim event - recreational	hrs/event	1.3	50th percentile	U.S. EPA (2003); recommended exposure duration for long-term exposure for adults from U.S. EPA (1997)
Body weight	kg	70.7	Arithmetic mean	Richardson (1997); Health Canada (2006)
Breathing rate	m^3/day	15.8	Arithmetic mean	Richardson (1997); Health Canada (2006)
Water intake rate	L/day	1.5	Arithmetic mean	Richardson (1997); Health Canada (2006)
Water ingestion while swimming	L/hrs	0.05	-	U.S. EPA (1989)
Soil/dust intake rate	g/day	0.02	-	Health Canada (2006)
Surface area – hands	cm^2	890	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – arms	cm^2	2,500	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – legs	cm^2	5,720	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – whole body	cm^2	17,640	Arithmetic mean	Richardson (1997)
Market Basket Food Consumption Rates				
Meat and Eggs	g/day	158	Arithmetic mean	Richardson (1997)
Cereals and Grains	g/day	219	Arithmetic mean	Richardson (1997)
Milk and Dairy	g/day	265	Arithmetic mean	Richardson (1997)
Fish and Shellfish	g/day	16	Arithmetic mean	Richardson (1997)
Fats and Oils	g/day	44	Arithmetic mean	Richardson (1997)
Formula	g/day	0	-	Richardson (1997)
Fruits and Juices	g/day	168	Arithmetic mean	Richardson (1997)
Other vegetables	g/day	109	Arithmetic mean	Richardson (1997)
Nuts and Seeds	g/day	2.93	Arithmetic mean	Richardson (1997)
Root Vegetables	g/day	153	Arithmetic mean	Richardson (1997)
Sugars and Sweets	g/day	58	Arithmetic mean	Richardson (1997)
Local Food Consumption Rates				
Fish	g/day	48	-	Local Food Survey
Blueberries	g/day	5.2	Mean + SE	U.S. EPA (1997)
Wild Game (fraction of market basket meat and eggs)	unitless	0.20	-	Local Food Survey
Home Garden Root Vegetables (fraction of market basket rate)	unitless	0.018	Mean	U.S. EPA (1997)

Table 3-12 Receptor Characteristics and Assumptions for the Adult Receptor

Description	*Units*	*Value*	*Statistic*	*Reference/Comment*
Home Garden Other Vegetables (fraction of market basket rate)	unitless	0.062	Mean	U.S. EPA (1997)

Food intake rates as provided by Richardson (1997) were based on a 24-hour recall study collected during the 1972 to 1973 National Food Consumption Survey (NFCS). These values represent the arithmetic mean intake rates for “eaters only”, meaning that those that did not report eating items within a given food group were excluded from the derivation of the mean intake rate. Use of the eater’s only intake rates for all food categories can result in a significant overestimation of the total daily food intake rate because it does not account for the condition that on days when a significant amount of a few food items are consumed, there will likely be lower intake rates (or zero intake) for other food items. Therefore, the eater’s only intake rates were adjusted to represent per capita intake rates by multiplying these values by the fraction of the total people surveyed that reported consuming foods in each category. The market basket food consumption rates presented in Tables 3-8 to 3-12 are the adjusted rates.

3.4 Identification of Exposure Pathways

People can come into contact with chemicals in their environment in a variety of ways, depending on their daily activities and land use patterns. The means by which a person comes into contact with a chemical in an environmental medium are referred to as *exposure pathways*. The means by which a chemical enters the body from the environmental medium are referred to as *exposure routes*. There are three major exposure routes through which chemicals can enter the body: inhalation; ingestion; and dermal absorption (*i.e.*, uptake through the skin). For each of these major exposure routes, there are a number of potential sources of chemical exposure or exposure pathways:

- Inhalation of air containing COC and absorption through the lungs;
- Ingestion of soil, dust, drinking water, garden produce, food; and,
- Dermal absorption from soil, dust and water contact with skin.

Exposure pathways may require direct contact between receptors and media of concern (*e.g.*, incidental ingestion of soil), or may be indirect requiring the movement of the chemical from one environmental medium to another (*e.g.,* the uptake and/or transfer of a chemical from soil into home garden vegetables which are then ingested by an individual).

Based upon the available information associated with the study area, the above considerations, and professional judgment, the exposure pathways that were assessed in this study are summarized below and illustrated in the Conceptual Model in Figure 3-2.

<u>Inhalation exposure pathways</u>

- Direct inhalation of COC in outdoor air; and,
- Direct inhalation of COC in indoor air.

<u>Dermal exposure pathways</u>

- Dermal contact with COC in outdoor soil;
- Dermal contact with COC in indoor dust; and,
- Dermal contact with COC in surface water.

Ingestion exposure pathways

- Ingestion of COC in outdoor soil;
- Ingestion of COC in indoor dust;
- Ingestion of COC *via* consumption of home garden vegetables;
- Ingestion of COC *via* consumption of local wild blueberries;
- Ingestion of COC *via* consumption of local fish and wild game;
- Ingestion of COC *via* incidental surface water ingestion while swimming;
- Ingestion of COC present in typical market basket items (*i.e*., groceries);
- Ingestion of COC in drinking water derived from Flin Flon and Creighton area water resources;
- Ingestion of COC in sediment while swimming; and,
- Ingestion of COC in snow.

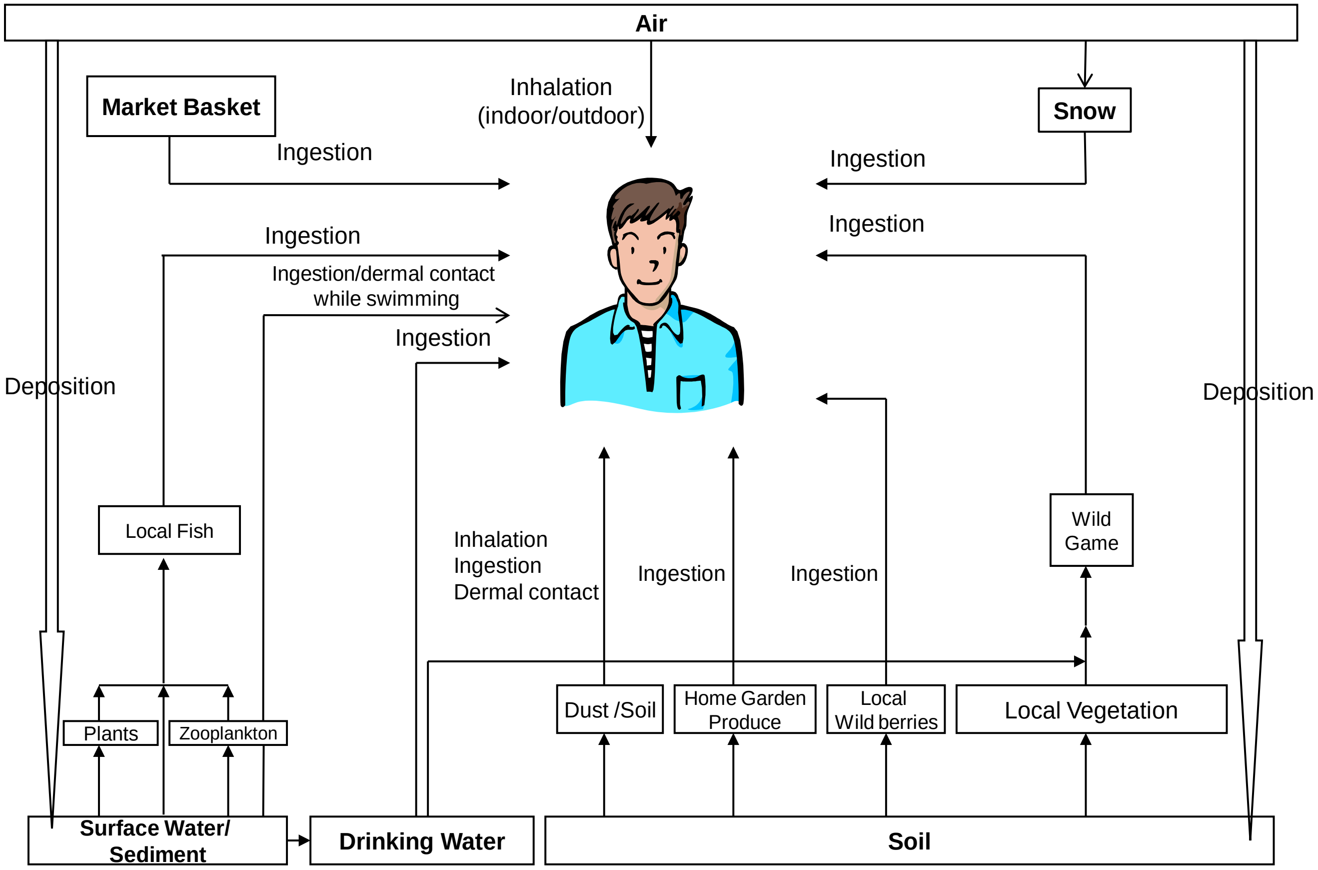

Figure 3-2 Conceptual Model for the HHRA

3.5 Identification of Exposure Scenarios

A key requirement of any HHRA is the ability to evaluate changing levels of exposure under a variety of different scenarios. Exposure scenarios describe the situations and conditions in which receptors may be exposed to COC in environmental media. In developing an exposure scenario, a variety of factors are considered including: potential for human access to specific areas or environmental media; physical activities / behavioural patterns; time spent in contact with exposure media (*e.g.*, soil); other potential sources of exposure to COC; lifestyle factors (*e.g.,* wild berry consumption, fishing, and other uses of natural resources); and the potential of sensitive sub-populations or sensitive locations within the community (*e.g.,* children at schools, playgrounds; elderly at nursing homes).

In general, while all receptors may potentially be subject to the same, or similar, set of exposure pathways and environmental concentrations, the magnitude of exposure experienced by an individual *via* those pathways is, to some extent, dependent on the behavioural and physical characteristics of that individual.

For the current assessment, exposure scenarios were developed based on the likelihood that particular activities and behaviour patterns would be applicable to certain groups or subpopulations. These hypothetical scenarios are deliberately selected to be conservative in nature which ensures that potential exposures to COC and the resultant risks are neither overlooked nor underestimated.

Residential Scenario

This scenario considered residents of four distinct communities within the Flin Flon-Creighton area:

- East Flin Flon (designated as the area bordered by highway 10 on the east and north, Ross Lake on the West, and the southern edge of residential streets to the south);
- West Flin Flon (designated as the area bordered by Ross Lake on the east, highway 10 on the west, the northern edge of residential streets to the north, and the Flin Flon City limits to the south);
- Channing; and,
- Creighton.

As a result of the proximity of these communities to the HBMS complex and the influence of the predominant wind directions in this area, residents of these separate communities may be exposed to significantly different levels of COC in various environmental media. When available, the HHRA used environmental media concentrations reflective of the unique conditions of each of these communities. This included community-specific measurements of COC in outdoor soil, indoor dust, ambient air, and drinking water.

The primary focus of the residential scenarios was on those “stay-at-home” receptors (*e.g.,* infants, preschool children and adults that care for them, retired persons, *etc*.), since they may receive the highest exposures to residential soils/dusts. Based on recommendations from Health Canada (2006), these receptors were conservatively assumed to spend 100% of their time at home (*i.e.*, 24 hours per day, 365 days per year). This scenario is also considered to be protective of properties used for daycares and retirement homes, as well as schools and parks.

In addition to predicting exposure and risks for receptors in each of the five age classes within each of the four COI, health-based soil concentrations were also derived to be protective of receptors under a residential exposure scenario. These provisional trigger concentrations (PTCs) can be applied on a property-by-property basis to determine which homes may have concentrations of COC in soil that may require risk management or further consideration such as biomonitoring of residents. Further discussion of PTCs is provided in Section 3.6. The residential PTCs are recommended for residential properties as well as properties used for daycares, retirement homes, schools and parks.

Residential Typical Background Scenario

This scenario estimated exposure of residents of a typical northern Manitoba/Saskatchewan community that has not been impacted by any point source of emissions (*i.e.*, regional background) to the COC identified in the Flin Flon-Creighton area. Exposure parameters and assumptions were selected to mimic those described for the above described residential scenario but used environmental media concentrations reflective of regional background levels. This included an estimate of exposure resulting from the consumption of food products obtained from a typical North American supermarket. The data used in the residential typical background scenario are described in Section 4.1.2.

Outdoor Commercial/Industrial Worker Scenario

This scenario considered adults who work exclusively outdoors throughout the year. Based on recommendations from Health Canada (2006), these receptors were assumed to spend 10 hours per day, 5 days per week, 48 weeks per year at work. Receptors were assumed to spend 10 hours per day outdoors during which they will be in direct contact (*i.e.*, oral and dermal exposure) with impacted outdoor soil and exposed to outdoor air. This scenario also included exposure *via* consumption of market basket foods and municipal drinking water.

The commercial worker scenario was assessed using the 95% UCLM soil concentrations measured within the Manitoba Conservation (2007) soils study for public lands. Environmental media concentrations for air and drinking water were the EPCs derived for the community of West Flin Flon.

Additional Recreational Pathways

Under a supplemental recreational assessment, it was assumed that receptors may spend a significant portion of the summer months swimming in local lakes. Exposure to COC was assumed to occur *via* incidental ingestion of surface water and sediment, as well as dermal contact of surface water with all skin. Within this assessment, the maximum concentrations of COC measured in surface water and the 95% UCLM concentrations in sediment in lakes sampled as part of the local Fish Study (Stantec, 2009) were used to predict exposure while swimming. The ingestion of snow receiving deposited air emissions was also evaluated as a relevant exposure pathway for children.

3.6 Derivation of PTCs

Risk assessments typically employ the 95% upper confidence limit on the arithmetic mean (UCLM) to characterize the EPC of a given exposure unit (U.S. EPA, 2001). The sample mean is based on a collection of samples from the exposure unit and therefore, uncertainty exists as to whether the sample mean is a true reflection of the population mean. As a result, the 95% UCLM can be thought of as an estimate of the true population mean for a given exposure unit.

In this case, the exposure units were defined as the communities under assessment in the HHRA. The underlying assumption used when developing the chronic residential exposure scenarios was that individuals would move randomly within each community and, therefore, over time, come into contact with the 95% UCLM soil concentration within a given community (or exposure unit). In reality, individuals do not move in a random fashion within their community, but rather exhibit predictable spatial patterns in their movements. For example, many individuals will tend to spend the majority of their time between home and work or school. Therefore, the evaluation of risks on the basis of average EPCs (assuming random movement) in an area-wide risk assessment may underestimate risks for some receptors. As a result, in addition to predicting risks using the community-based EPCs, soil provisional trigger concentrations (PTCs) were derived for each COC to be protective of residential receptors. These PTCs can then be used to determine on a property-by-property basis, which properties contain concentrations that have the potential to cause unacceptable risks.

A PTC can be defined as the average COC soil concentration within an exposure unit (EU) that corresponds to an acceptable level of risk (U.S. EPA, 2001). In other words, the PTC is the EPC in soil within a given EU (*i.e.*, a residential property) which would yield an acceptable level of risk. Exceedances of the PTC do not necessarily indicate that conditions exist in which unacceptable health risks will occur, but rather that there is less certainty regarding the related risk level.

The U.S. EPA (2001) recommends the use of iterative forward calculation methods when generating PTCs with non-linear parameters. The current assessment included the estimation of indoor dust concentrations based on a potentially non-linear relationship with concentrations in outdoor soil. Therefore, the iterative forward calculation method outlined by the U.S. EPA (2001) was used to generate PTCs for this study. This method involves collecting data from multiple model runs. Each run uses a different EPC in soil. The calculation is conducted until the EPC corresponding to an HQ value of 1.0 is determined. This EPC represents the PTC that corresponds to an acceptable level of risk.

The PTCs are derived to determine if further consideration is required, and if warranted, to help focus the efforts of a biomonitoring program on those areas or properties that may be of the greatest concern. Should a biomonitoring program be completed, the results will be used to further evaluate risk levels.

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