2.0 STUDY BACKGROUND

2.1 SITE DESCRIPTION

CAM-F is a former DEW line site located at 68°33' N, 83°19' W on the Melville Peninsula between Foxe Basin and Committee Bay. The main station is situated on a hill approximately 2 km north of the west arm of Sarcpa Lake from which the site derives its name. The site was an intermediate DEW Line site until 1963 (see Figure 1). In 1977 the site was converted to a scientific research station under the support of the Science Institute of the Northwest Territories and DIAND. Terrain at CAM-F is characterized by rolling tundra highland with gravely till deposits, several lakes and numerous rivers.

2.2 STUDY AREAS

The study area was defined as the area including and surrounding the investigated areas at CAM-F. The site consists of a Main Station Area, two Dump Sites and a former Construction Camp.

Infrastructure at the site included a module building train; warehouse and garage; Inuit house (dormitory); petroleum, oil, lubricant (POL) pumphouse; quonset hut; collapsed communications antenna; POL tanks; drum storage pads, sewage outfall; vehicle pile, generator site, former construction camp, shop site and two dump sites.

2.3 PREVIOUS REPORTS

In July 1988, soil and swab sampling was conducted at CAM-F DEW Line Station (D. Jessiman, 1998). The sampling program was initiated by PCB sampling conducted the previous year, which lead to the discovery of possible PCB contaminated soils around the module train and dump, and PCB contaminated paint in the module train. The scientific research station was closed until a more detailed PCB sampling program was completed. Results above non-detect values ranged from 1.0 and 13 ppm. PCB results from swab sampling ranged from 3.7 to 1000 total μg Aroclor 1254. As a result of the PCB levels, the research station remained closed

In 1994, the Environmental Sciences Group of Royal Roads Military College (RRMC) completed a report entitled "Environmental Study of Abandoned DEW Line Sites" (RRMC, 1994) in which a detailed surface soil, water, and vegetation sampling program was completed for DEW line sites across the Canadian north. Soil contamination exceeding DEW Line Clean-up Criteria (DCC) was identified at various locations throughout the CAM-F site for PCBs, cadmium, lead, and zinc (RRMC 1994). DEW Line Clean-up Criteria (DCC) were developed specially for remediation of Department of National Defence DEW Line Sites. Samples analyzed for polycyclic aromatic hydrocarbons (PAHs), although detectable, did not exceed criteria.

In 1996, Queen's University and UMA Engineering conducted extensive investigations as well as remedial work on Dump A, at CAM-F (Queens, 1997). Site investigations included debris removal from Dump A and the excavation of contaminated soils, delineation of all other contaminated area, topographic survey of the work areas, sampling and analysis of paint chips from building and barrel contents and the development of site cleanup specifications, drawings and preparations of cost estimates. Delineatory investigations of contaminated areas were conducted and contaminated soil volumes were calculated. Investigation of hazardous and non-hazardous materials was also conducted. The preliminary design and recommendations for the cleanup of CAM-F was also discussed.

In 1997, another team from Queens University was on site to complete the cleanup of CAM-F so that it meets legal compliance regards to PCB and asbestos in soil and building materials. (Queens, 1998)

Representatives from Queen's University, Environment Canada and the Igloolik Research Centre visited the site in 1999 (Queens, 1999). The site visit was to inspect the waste oil storage are, the Wrangler bags containing Tier II PCB soils, complete minor repairs to the warehouse roof and to conduct limited sampling of Dump A to ensure all soils were below CEPA levels. The waste oil storage was found to be in good condition, the Wrangler boxes were undamaged and the warehouse roof was successfully repaired. Results from the soil sampling showed PCB levels below the CEPA criteria.

The current study undertakes a quantitative human and ecological risk assessment of the CAM-F site. It is supported by new contaminant data for the site, based on a Phase III Environmental Site Assessment (Earth Tech 2004), which included analysis for hydrocarbons, PAHs, PCBs, and inorganic element in soils. In addition, a limited number of analyses for lake and river sediments, lake water and fish were collected. A restricted number of background soil samples were also collected. The ERA considers a broad range of ecological receptors and incorporates the new data, while also retaining the previously collected data for CAM-F and surrounding areas. The HHRA also evaluates both Phase II and the newly generated Phase III data supplied and described by Earth Tech (2004).

2.4 INUIT TRADITIONAL LAND USE

In 1998, Gartner Lee Limited and Cantox Inc. conducted a risk assessment for the FOX-C DEW Line site and argued that due to the northern location of the site and the probable use of the site by Inuit for traditional purposes, the conventional land use categories (residential, parkland, commercial, and industrial) must be expanded to incorporate an additional land use, which they term "Traditional Land Use". The parameters of this land use were developed after consultation with residents of the Eastern Arctic, the Quikiqtaaluk Corporation and DIAND.

The current assessment adopted the Traditional Land Use for the CAM-F site, as set out by Gartner Lee and Cantox (1998). The traditional land use designation consists of Inuit families residing on the land, in tents for periods up to 3 months. It was assumed that during this period the Inuit engage in traditional hunting, fishing and gathering activities. It was also assumed that all time spent on site will be in the non-snow covered months, which resulted in the most extensive exposure scenario for the human receptors. Detailed exposure values are discussed in Section 4.3, and in the Gartner Lee and Cantox risk assessment (1998).

3.0 DATA COMPILATION

3.1 SOURCES

The primary source of data for this risk assessment was supplied by Earth Tech Environmental Inc., who on behalf of PWGSC and DIAND, conducted the field investigation and sampling in August 2004. Environmental data consisted of soil, surface water and tissue samples collected from around the site. Detailed list of samples and their locations are presented by Earth Tech in their report (2004). In addition to the 2004 data collection, inorganic data was also used for vegetation and soil samples analyzed and presented by the Environmental Sciences Group at Royal Roads Military College (RRMC) in their 1994 report. Description of samples and sample locations can be found in that report (RRMC, 1994) and will not be detailed further herein.

3.2 SELECTION OF DATA

The soil and water sample data from the Phase II and Phase III sampling programs were screened for use in this risk assessment. For the purposes of the risk assessment for both human and ecological receptors, only soil samples that accurately reflect concentrations in the upper 10 to 30 cm from ground surface are relevant to potential exposures. The Phase II and Phase III data were screened on the basis of depth and any sample that did not intersect the surface and/or extended to a depth of greater than 0.3 m below ground surface (mbgs) was excluded. This was done to ensure that the data used were representative of surface soil and not heavily influenced by subsurface soil characteristics.

All surface water samples were considered to be valid inputs for the risk assessment.

3.2.1 Phase III Data

Data supplied and described in Earth Tech's report (2004). Data was sampled and analyzed in August 2004.

3.2.2 Phase II Data

RRMC's Environmental Sciences Group presented their data in a 1994 report. All the presented data was taken as part of their 1994 sampling of the CAM-F DEW line site.

3.3 DESCRIPTION AND STATISTICAL ANALYSIS OF DATA

Maximum concentrations of all chemicals were screened against generic criteria guidelines for either human or ecological assessments. If a chemical exceeded a guideline and if it was measured in both the Phase II and Phase III site assessments, the phase II data was manually appended to the existing phase III data set for statistical analysis.

Environmental data are generally log-normally distributed resulting in a skewed data set. This data was tested and found to closely resemble log normal distribution but still mostly failed Shapiro Wilk's Test for log normal distribution confirmation. This is likely to be a result of the non-random sample selection where only known "hot spots" or areas where significant contamination is known to exist were sampled. As a result, the data has outliers, samples with very high concentrations compared to other samples analyzed on-site. Nevertheless, the data is more representative of a log normal distribution than a normal distribution, therefore, data was log transformed to calculate the appropriate exposure point concentration (EPC) – 95% upper confidence limit (UCL) of the geometric mean for the ERA.

Typically the 95th percentile or UCL values would be used for the HHRA. However, maximum concentrations were used as per instructions from PWGSC. The rationale behind using maximum concentrations was to be protective of the fact that human receptors (especially the most sensitive – toddlers) may in fact play/use a single area where significant contamination exists. Ecological receptors will be more mobile, moving from location to location resulting in a less than maximum exposure scenario.

Therefore, maximum concentrations were used in the HHRA and the 95% UCL of the geometric mean was derived from the existing data sets and used in the ERA.

4.0 HUMAN HEALTH RISK ASSESSMENT

4.1 RISK ASSESSMENT FRAMEWORK

To guide the conduct of the human health and ecological risk assessments, a common framework was developed (illustrated in Figure 2). The steps in this flowchart are described briefly below:

Box 1 Compare maximum concentrations to guidelines.
Maximum concentrations sampled on site were compared to generic CCME and Ontario Ministry of the Environment (MOE) generic soil quality guidelines for residential/parkland land use or to DCC cleanup criteria.

Box 2 Maximum concentration greater than guideline?
If the maximum soil sample CoPC concentration from the data set was less than the appropriate generic guideline, either CCME or MOE, then the CoPC was not carried forward into this quantitative risk assessment

Box 3 Determine the EPC.
To remain conservative, the maximum CoPC concentration values were adopted as the EPCs for the human health risk assessment while the 95% upper confidence limit for and were used in the quantitative risk assessments to calculate potential risks and area-wide SSTLs.

Box 4 Is the EPC greater than the background soil concentration?
Only if the EPC is greater than the background soil concentration will the CoPC be carried forward to the risk assessment process.

Box 5 Conduct quantitative risk assessment
CoPCs that exceeded guidelines and background concentrations were carried forward into the risk assessment process. The risk assessment was conducted using EPCs. This process was conducted independently for each chemical on the site and for the HHRA and the ERA separately. In this way, the chemicals subjected to ecological risk assessment were not necessarily included in the human health risk assessment.

Box 6 Do the hazard quotients in the risk assessment exceed the target hazard quotient value?
When hazard quotients (HQs) exceed the target HQ value (0.2 for HHRA, 1.0 for ERA), there may be an inherent risk on site. Therefore, site specific target levels (SSTLs) or calculated soil concentrations where risk would be considered minor, would be calculated and remedial action could be taken to obtain those concentrations on site.

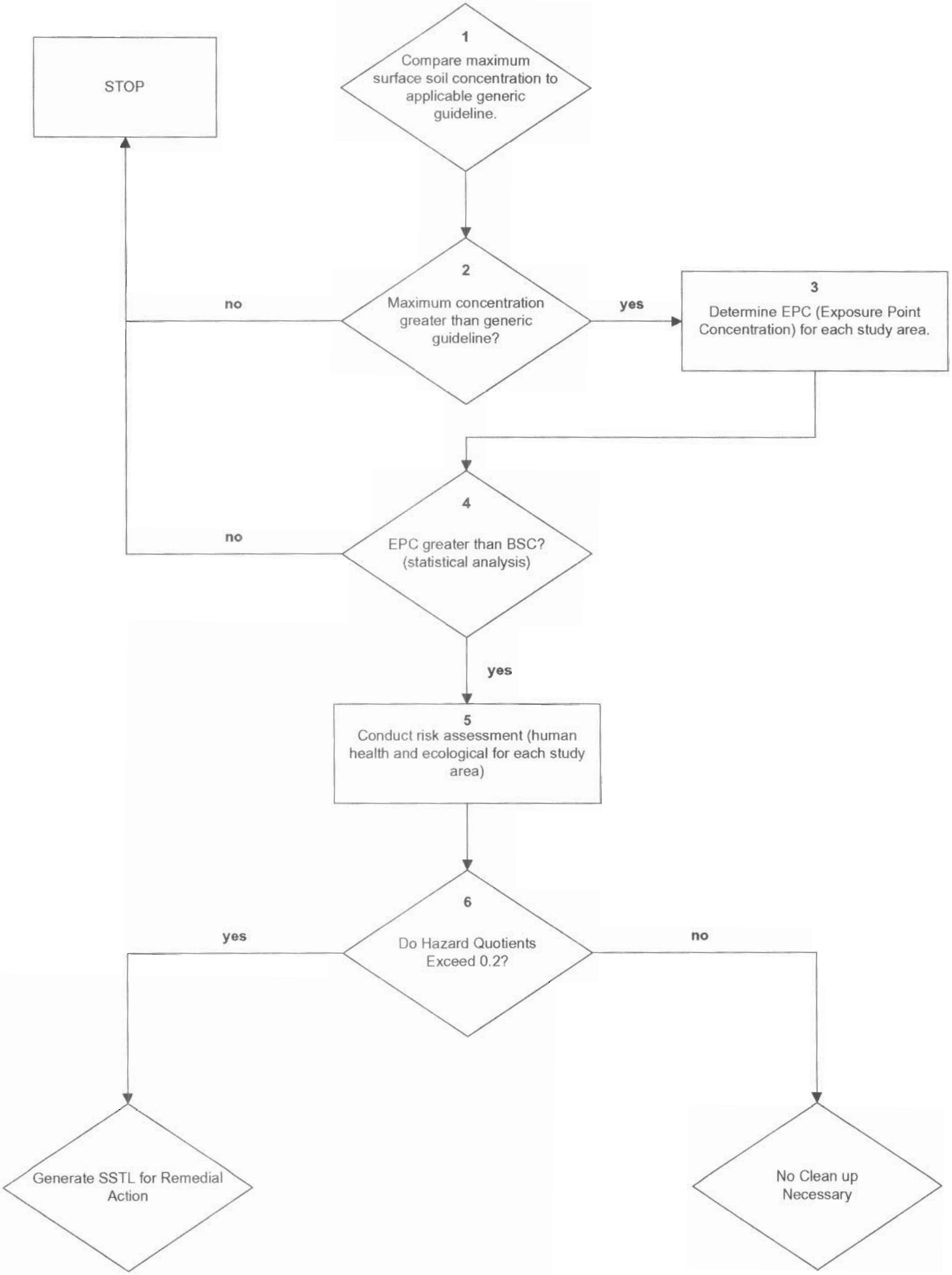


Figure 4 Risk Assessment Framework

4.2 RISK SCREENING

The screening of CoPC maximum concentrations against generic CCME and MOE guidelines and standards was undertaken by Earth Tech in the 2004 Phase III Site Assessment. The CoPCs identified include metals, benzene, toluene, ethylbenzene, xylene, (BTEX), total petroleum hydrocarbons, (TPH) and PAH parameters from Earth Tech's report (Earth Tech 2004).

Generic CCME and MOE soil quality guidelines may be based on either ecological or human health protection and provide a protective initial screening of the site data. For the human health risk assessment, the remaining CoPCs are then screened specifically against human health based generic guidelines. Because the HHRA includes an exposure scenario for Inuit camping at the site, residential/parkland values have been adopted for the screening. In order of preference, these guidelines are taken from CCME (2002), MOE (1996), or the US EPA (2003). The maximum CoPC values were also screened against the Defense Construction Canada (DCC) DEW Line Soil Clean-up Criteria, to provide a comparison to criteria used on Department of National Defence DEW Lines sites.

4.2.1 Hazard Identification

The results of the human health screening for the upper site and the lower site are presented in Table 1.

Soils

As indicated in Table 1, and based upon the human health screening described in Box 5 of Figure 1, the maximum soil concentrations of arsenic, boron, chromium, cobalt, mercury, molybdenum, nickel, selenium, silver, vanadium and zinc at CAM-F are less than their corresponding human health-based soil quality guidelines. Therefore, these metals were not considered further in the HHRA.

The maximum concentrations of antimony and beryllium in soils were greater than the MOE human health based criterion and thus were carried forward as CoPCs in the HHRA. Likewise, the maximum concentrations of barium, cadmium and lead in soils were greater than the CCME human health based criterion and they were also carried forward. The maximum concentration of tin exceeded the interim CCME guideline and was included. Although the maximum concentration of copper in soils was less than both the CCME and MOE health based criteria, it exceeded the DCC DEW Line cleanup criteria, and so was carried forward into the HHRA.

Table 1 Human Health Soil Screening for CAM-F

Top Site Soils CoPCs	Phase III Max Conc. (mg/kg)	Phase II Max[a] Conc. (mg/kg)	No. of Samples	CCME Human Health (mg/kg)	MOE Human Health (mg/kg)	Other Human Health (mg/kg)	DCC Criteria Tier I (mg/kg)	DCC Criteria Tier II (mg/kg)	No. of Samples Exceeding Guidelines	% of Samples Exceeding Guidelines
Inorganics										
Antimony	**19.5**		63		**13**				**2**	3.17
Arsenic	2.70	1.70		12	13			30		
Barium	**735**		63	**500**	3700				**1**	1.59
Beryllium	**0.55**		63		**0.37**				**2**	3.17
Boron	3.80					7000 [d]				
Cadmium	10.0	**19.2**	119	**14**	14			5		
Chromium	41.8	93	119	220				250		
Cobalt	10.5	11.2			2700			50		
Copper	**842**	**940**	119	1100	1100			**100**	**3**	2.52
Lead	130	**800**	119	**140**			200	500	**9**	7.56
Mercury	0.710			6.6	13			2		
Molybdenum	0.6				170					
Nickel	25.3	28.0			310			100		
Selenium	1.0				320					
Silver	0.45				98					
Tin	**53**		63			**50** [b]			**1**	1.59
Vanadium	50.4				470					
Zinc	1280	5740	119		16000			500		
Organics										
Benzene	0.1	BD			35					
Toluene	3.63	BD		0.8	6100					
Ethylbenzene	0.003	BD			2300					
Total Xylenes	47.7	BD		5	61000					
F1 C6-C10	1390	BD		15000						
F2 C10-C16	**13300**	BD		**8000**					**3**	10.71
F3 C16-C34	**18300**	BD		**18000**					**1**	3.57

Top Site Soils CoPCs	Phase III Max Conc. (mg/kg)	Phase II Max[a] Conc. (mg/kg)	No. of Samples	CCME	MOE	Other Human Health (mg/kg)	DCC Criteria Tier I (mg/kg)	DCC Criteria Tier II (mg/kg)	No. of Samples Exceeding Guidelines	% of Samples Exceeding Guidelines
				Human Health (mg/kg)	Human Health (mg/kg)					
F4 C34-C50	**68000**	BD		**25000**					2	7.14
Total PCBs	**25.2**	c				1.3[b]	1	5	7	16.28
Acenaphthene	0.97	BD			1400					
Acenaphthylene	BD	BD			1000					
Anthracene	BD	BD			5300					
Benzo(a)anthracene	BD	BD				120[e]				
Benzo(a)pyrene	BD	BD		0.7						
Benzo(b)fluoranthene	BD	BD				12[e]				
Benzo(k)fluoranthene	BD	BD				12[e]				
Benzo(g,h,i)perylene	BD	BD				120[e]				
Chrysene	0.150	BD		1.5		12[e]				
Dibenzo(a,h) anthracene	BD	BD				1.2[e]				
Fluoranthene	BD	BD			910					
Fluorene	0.840	BD			910					
Indeno(1,2,3-c,d)pyrene	BD	BD			12					
Naphthalene	5.10	BD			1300					
Phenanthrene	1.05	BD				120[e]				
Pyrene	0.08	BD			680					

a - 1994 Reimer et al.
b - interim CCME guideline 1991
c - data from Phase III not usable for comparison due to differences in analytical determination
d - U.S. EPA Region III Risk Based Concentration (RBC) Table, 2003.
e - OMOE 1996. Table B Soil Remediation Criteria - Non-Potable Groundwater Situation, Coarse Textured Soils, Residential Parkland, Human health based criteria.
BD – below detection limit
Shaded boxes - criteria used to screen for risk assessment.

Although the maximum concentration of the F1 fraction of petroleum hydrocarbon in soils was below the Canada Wide Standard (CWS) criterion, the maximum concentrations of the F2, F3 and F4 fractions were greater than their CWS criteria, and therefore were carried forward as CoPCs in the HHRA.

Maximum soil concentrations of BTEX and PAHs were all less than their respective human health based criteria, and were therefore not carried forward. Total Aroclor polychlorinated biphenyl's (PCBs) were higher than the interim CCME guideline criteria and since PCBs are of special concern to human health in the arctic, were carried forward in the HHRA

The soil CoPCs from the upper site carried into the HHRA include:

- *antimony;*
- *barium;*
- *beryllium;*
- *cadmium;*
- *copper;*
- *lead;*
- *tin;*
- *total PCBs;*
- *TPH F2 fraction;*
- *TPH F3 fraction; and,*
- *TPH F4 fraction.*

Surface Water

Surface water samples were taken from Sarcpa lake. Table 2 presents the results of the screening for all parameters that were above the analysis detection limits. A full table of results is available in the Phase III Site assessment (Earth Tech, 2004). None of the maximum CoPC concentrations were greater than available drinking water guideline criteria. A number of parameters, including lithium, silicon, sulphur, strontium, and titanium do not have published health based drinking water criteria, and so no benchmark against which to evaluate the concentrations found in the surface water. Because neither the CCME, MOE or US EPA has derived drinking water criteria for these parameters, they are assumed to have a low inherent toxicity and not to pose a risk to human health. Additionally, the concentrations are deemed to be sufficiently low that surface water is not considered a contaminated medium, and was not carried forward into the HHRA.

However, where parameters were identified as CoPCs based on soil concentrations and were also detected in surface water, surface water was treated as an additional source medium and surface water ingestion and dermal contact were included in the total dose for that parameter.

Table 2 Human Health Surface Water Screening

Surface Water CoPCs	Phase III Max	Screening Criteria: CCME[1] Human Health[1] MAC (ug/L)	IMAC (ug/L)	MOE[2] Drinking Water	EPA[3] Drinking Water	EPA[3] Other
Inorganics						
Aluminum	76					50
Antimony	0.30	6		6		
Barium	10.0	1000		1000		
Boron	11.0			5000		
Chromium (total)	0.50	50		50		
Copper	2.0			23		1000
Iron (dissolved)	20					300
Lithium	7.00					
Silicon	450					
Sulphur	4590					
Strontium	51.0					
Titanium	4.00					
Vanadium	0.500			200		
Zinc	5.00			1100		5000
Organics						
Total PCBs	BD			0.2		

1. CCME. 1999. Community Water Supplies. Updated 2002.
2. MOE. 2004. Soil, Groundwater and Sediment Standards for Use under Part XV.1 of the Environmental Protection Act. Table 2 – Full Depth Generic Site Condition Standards in a Potable Groundwater Condition.
3. EPA. 2004. 2004 Edition of the Drinking Water Standards and Health Advisories.

BD – Below Detection Limit

4.2.2 Wild Game

Additional exposure to CoPCs from the site can occur through ingestion of contaminated wild game and fish. Because CAM-F is a site that may be used as a recreation area for Inuit visitors, and would serve as a base for hunting and fishing activities, wild game and fish meat must be considered as a further source of CoPCs.

While concentrations of CoPCs can be, and have been measured in water, soils and plants, it is necessary to estimate the concentrations of CoPCs occurring in the meat of other biological components. The process by which the uptake of CoPCs from soil to plants, and from soil to animals, are estimated is explained in detail in Section 5.4.2.

4.2.2.1 Wild Game

Because wild game is not restricted to just the CAM-F site uptakes have been calculated based on the proportion of time spent at the site based on the area of their range. A composite CoPC meat concentration was then calculated for two wild game species, the caribou and the arctic hare. CoPCs were not screened in for the HHRA based on caribou or hare meat concentration; the exposure via wild game is only assessed for CoPCs previously identified for the site.

Table 3 summarizes the calculated concentrations of CoPCs in caribou meat, while Table 4 presents a summary of the CoPC concentrations in Arctic hare. The results of detailed calculations are provided in Tables 24 and 25, respectively.

Table 3 Summary of modeled CoPC Concentration in Caribou Meat

CoPC	Concentration in Caribou Meat (mg/kg)
Antimony	6.25E-04
Barium	1.26E-02
Beryllium	1.04E-04
Cadmium	8.65E-04
Copper	4.43E-01
Lead	3.31E-03
Tin	7.71E-02
TPH F2 Fraction	4.28E-02
TPH F3 Fraction	3.47E-01
TPH F4 Fraction	6.43E-02
Total PCBs	1.18E-03

Table 4 Summary of Modeled CoPC Concentration in Arctic Hare Meat

CoPC	Concentration in Arctic Hare Meat (mg/kg)
Antimony	1.86E-02
Barium	1.22E+00
Beryllium	5.53E-04
Cadmium	6.14E-02
Copper	3.59E+00
Lead	7.80E-01
Tin	4.99E-01
TPH F2 Fraction	4.28E-02
TPH F3 Fraction	3.47E-01
TPH F4 Fraction	6.43E-02
Total PCBs	1.15E-3

4.2.2.2 Lake Trout

The bioaccumulation of PCBs in fish is of particular concern throughout the Canadian north. Due to this particular concern, lake trout samples were taken from Sarcpa lake and the samples were analyzed to determine the levels of PCBs in their flesh

Because of the particular concern regarding the intake of PCBs from fish, PCBs in fish flesh were carried forward into the HHRA, and the risk associated with ingestion was assessed. However, it should be noted that PCBs were also carried forward as CoPCs based on soil and surface water concentrations, which were greater than CCME and MOE guidelines. A confounding input of PCBs into the fish environment will be through global transport of PCBs to the arctic environment.

As with surface water, where parameters were identified as CoPCs based on soil concentrations and were also detected in fish flesh, fish was treated as an additional source medium and fish ingestion was included in the total dose for that parameter.

Table 5 presents the maximum measured CoPC concentrations in lake trout flesh. All fish analysis data can be found in the Earth Tech report (2004).

Table 5 Summary of CoPC Concentrations in Lake Trout

CoPC	Concentration in Lake Trout (mg/kg)
Antimony	nd
Barium	0.1
Beryllium	nd
Cadmium	nd
Copper	0.53
Lead	nd
Tin	2.4
TPH F2 Fraction	na
TPH F3 Fraction	na
TPH F4 Fraction	na
Total PCBs	0.022

nd – non detect
na – not analysed for.

4.2.3 Receptor Identification

Existing and intended land use is an important factor in evaluating the potential exposures and estimating risk. This risk assessment is directed toward the following potential end use of the land:

- Intermittent use of the general area for recreational and hunting purposes.

Therefore the potential human "receptors", or people who may be most affected by the potential hazards are people hunting on the land. For the purposes of this assessment, the human receptor is characterized as an adult or child with no extreme sensitivities. Carcinogenic and non-carcinogenic chemicals are evaluated differently as illustrated below:

	RESIDENTIAL EXPOSURE
NON-CARCINOGENIC CHEMICALS	Most sensitive receptor modelled as a toddler aged six months to four years old.
CARCINOGENIC CHEMICAL	Receptor assumed to visit the site yearly from birth to 75 years lifetime. Exposures averaged over five age groups: (0 to 6 months) + (6 months to 4 yrs) + (5 to 11 yrs) + (12 to 19 yrs) + (20 to 75yrs).

The above assumptions regarding receptors are the most protective approaches for the intended land uses. Important characteristics of the receptors (including body weight, soil ingestion rate, etc.) considered in the analysis are presented Section 4.3.

4.2.4 Exposure Pathway Assessment

The exposure assessment evaluated the likelihood that the potential hazards would come into contact with the potential receptors. The likelihood of exposure was determined through consideration of the properties of individual hazards that control chemical mobility, and the various pathways through which the hazard could move to contact the receptor, or through which the receptor could move to contact with the hazard. The exposure analysis also considers the possible mechanisms through which a hazard could be introduced to a human receptor (i.e., ingestion, dermal contact, inhalation).

4.2.5 Potential Transport Pathways

The principal pathways through which environmental hazards can typically contact a receptor include:

- direct contact (with soil, dust, liquid product phase hazards, or water);
- transport of liquid product phase contaminants;
- transport in groundwater;
- transport in surface water;
- air borne transport (as dust); and
- transport as a vapour.

4.2.6 Potential Exposure Mechanisms

The mechanisms by which receptors typically become exposed to hazards include:

- inhalation;
- ingestion;
- dermal contact; and
- uptake by plants/animals.

4.2.7 Human Receptor Exposure Scenarios

The exposure scenarios which have been considered for human receptors include:

- ingestion/dermal contact with soil;
- inhalation/ingestion/dermal contact with dust;
- ingestion of vegetation or garden produce grown in contaminated soil or irrigated with contaminated groundwater;
- ingestion of wild game (e.g., Caribou, hares) caught by hunting on the land in the CAM-F site area;
- ingestion/dermal contact with surface water;
- ingestion/dermal contact with groundwater; or
- inhalation of vapours.

Jacques Whitford evaluated the likelihood that the identified human receptors could be exposed to the identified hazards through the various exposure scenarios using a qualitative method. The likelihood of exposure is considered and evaluated in terms of the following series of definitions, presented in Table 6.

The relevant exposure pathways are summarized in Table 7. Table 7 includes the qualitative evaluation of each pathway and a justification for the likelihood of exposure assigned. The likelihood of exposure includes consideration of the duration and frequency of exposure to each potential hazard and to the relative concentrations to which the receptor is likely to be exposed. Those hazard-exposure-receptor combinations considered to have the highest likelihood to contribute a health risk are carried forward for further quantitative analysis.

Table 6 Exposure Definitions

Likelihood of Exposure	Definition
Very Unlikely	Level of exposure that could result in adverse effects is not expected.
Unlikely	Level of exposure that could result in adverse effects would probably not occur.
Possible	Level of exposure that could result in adverse effects might be expected.
Likely	Level of exposure that could result in adverse effects is expected. Exceedance of this exposure level might be expected.

Table 7 Potential Exposure Scenarios – Inuit Visitor

Exposure Pathway Description	Likelihood of Exposure	Carried Forward for Quantitative Analysis	Justification
Ingestion of soil Dermal contact with soil Inhalation of soil particles	Likely	Yes	Surface soil samples collected during the soil sampling program 2004 were impacted by antimony, barium, beryllium, cadmium, copper, lead, tin, petroleum hydrocarbons and Total PCBs exceeding human health screening guidelines, as described in Section 4.2.1.
Inhalation of soil vapours	Unlikely	No	Neither the inorganic CoPCs nor the TPH F2 to F4 fractions found on site are considered volatile, therefore the inhalation of vapours pathway is considered negligible.
Ingestion of sediment Dermal contact with sediment Inhalation of sediment particles/vapours	Unlikely	No	There is little likelihood that receptors would come into direct contact with sediment considering the cold water temperatures.
Ingestion of surface water Dermal contact with surface water	Unlikely	Yes	Surface water was not considered a source medium for contaminants, however where CoPCs were identified in soil, and were detected in the surface water, surface water was considered an additional exposure pathway.
Inhalation of surface water vapours	Unlikely	No	No volatile CoPCs were identified in surface water, therefore vapour inhalation was not considered a valid pathway.
Ingestion of ground water Dermal contact with ground water Inhalation of ground water particles/vapours	Very Unlikely	No	Groundwater was not used as a source for either drinking or showering and therefore was not considered a valid pathway.
Ingestion of vegetation	Very Unlikely	No	Due to the climate, significant harvest vegetation was not expected.
Ingestion of wild game	Likely	Yes	Visiting Inuit receptors were expected to hunt and consume wild game on the site.
Ingestion of wild fish	Likely	Yes	Visiting Inuit receptors were expected to catch and consume fish from the site.

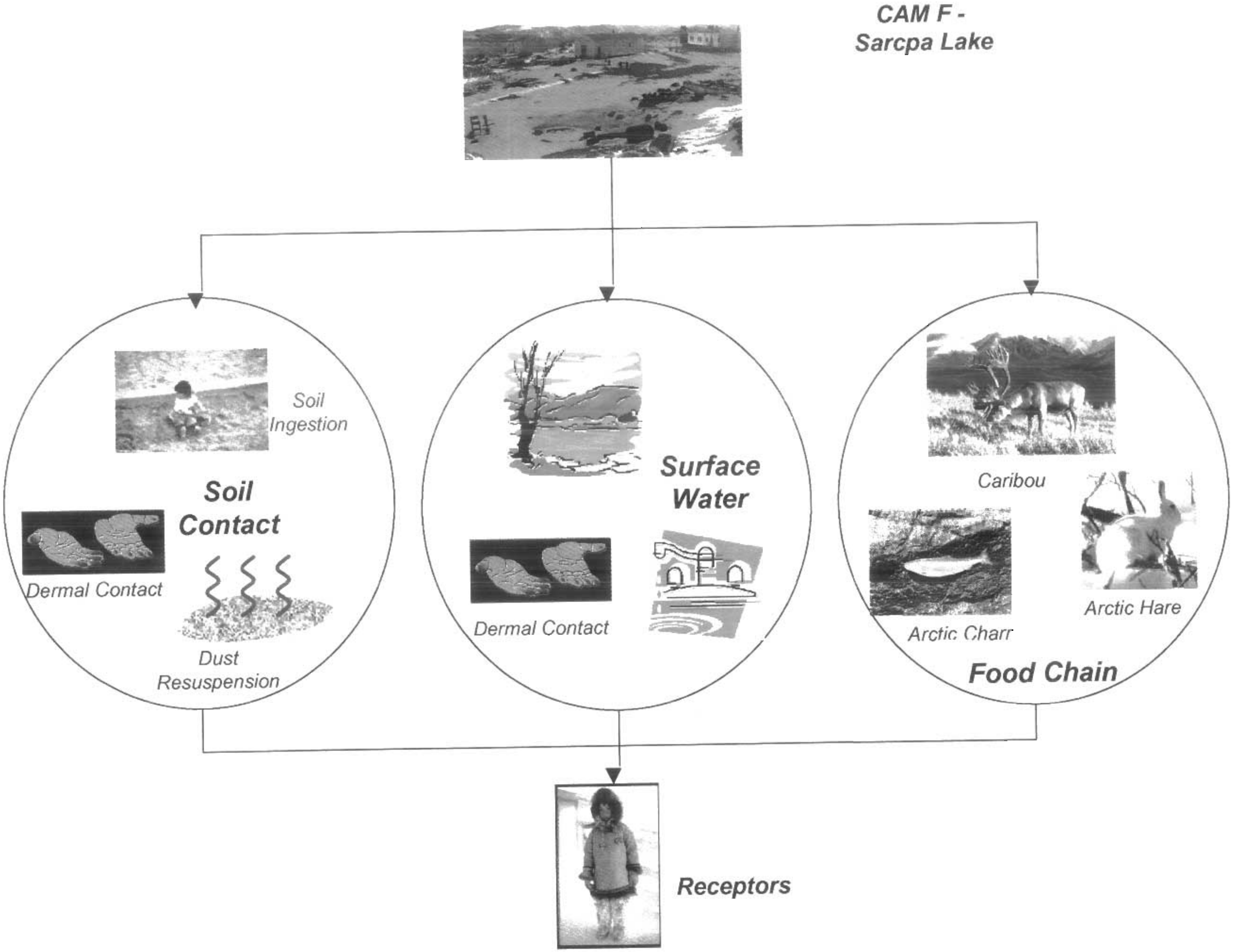
4.2.8 Qualitative Risk Assessment

Based on the qualitative risk screening presented above, the conceptual model (Figure 3) that formed the basis for the calculation of potential risk:

- A toddler aged six months to four years is exposed to surface soil contaminated with non-carcinogenic antimony, barium, beryllium, cadmium, copper, lead, tin, total PCBs and TPH F2, F3 and F4 fractions by inadvertent ingestion / dermal contact / dust inhalation, ingestion of wild game (caribou and arctic hare) and lake trout, and by ingestion and dermal contact with surface water.

- A person visits the site yearly from birth to 75 years of age and is exposed to carcinogenic beryllium and cadmium by dust inhalation and total PCBs by inadvertent ingestion / dermal contact / dust inhalation, ingestion of wild game (caribou and arctic hare) and lake trout, and by ingestion and dermal contact with surface water throughout their lifetime.

Figure 3 Site Conceptual Model



4.3 RECEPTOR CHARACTERISTICS

As discussed in Section 4.2.3, it is important that the most protective assumptions are made about the potential receptors. For the assessment of risk for antimony, barium, beryllium, cadmium, copper, lead, tin, total PCBs and the TPH F2, F3 and F4 fractions for exposure to site the most sensitive receptor was a toddler aged 6 months to 4 years old. In addition, a composite receptor was included in the assessment to examine the carcinogenic effects of beryllium, cadmium and total PCBs. A reasonable maximum exposure approach is adopted for a traditional land use of the sites in which it is assumed that the toddler will be present at the site for a conservative 90 days per year. It was also conservatively assumed that the human receptor is exposed to the most highly contaminated soil present on each particular site. This is a very conservative assumption since most contaminated spots are localized to small areas and the receptor would likely wander off those areas at least part of the time while on site. Nevertheless, for this HHRA and to be protective of human health, maximum exposure concentrations were assumed.

Receptor characteristics for the toddler and composite receptor are presented in Table 8 below:

Table 8 Summary of Receptor Characteristics

Characteristics		Values		Source
		Visitor Toddler	Visitor Composite	
Averaging Times and Constant Values				
AT_c	Averaging time – cancer (yrs)	n/a	75	Equal to exposure duration
AT_{nc}	Averaging time – non-cancer (yrs)	4.5	n/a	Equal to exposure duration
ED	Exposure duration (yrs)	4.5	75	CCME (2001)
EF_{lower}	Exposure Frequency – Lower Site (d)	90	90	Based on assumptions proposed in Gartner Lee Inc. (1998)
ET_{ing}	Exposure time – soil ingestion (hrs/d)	24	24	Based on full-time exposure to the site.
ET_{derm}	Exposure time – soil dermal contact (hrs/d)	24	24	Based on full-time exposure to the site.
ET_{inh}	Exposure time – soil particulate inhalation (hrs/d)	24	24	Based on full-time exposure to the site.
BW	Body weight (kg)	16.5	62.3	HC (2003)
Ingestion of Surface Soil				
IR_{soil}	Ingestion rate of surface soil (mg/hr)	3.33	0.98	HC (2003)
Dermal Contact with surface Soil				
SA_{body}	Exposed surface area - body (cm^2)	2580	7385	Richardson (1997)
Sa_{hand}	Exposed surface area - hand (cm^2)	430	821	Richardson (1997)
SAF_{body}	Soil adherence factor – body (mg/cm^2-d)	0.01	0.01	HC (2003)
SAF_{hand}	Soil adherence factor – hand (mg/cm^2-d)	0.10	0.10	HC (2003)

Characteristics		Values		Source
		Visitor Toddler	Visitor Composite	
Inhalation of Soil Particles				
IR_{air}	Inhalation rate (m^3/hr)	0.39	0.63	Richardson (1997)
Ingestion of Surface Water				
IR_{water}	Ingestion of surface water (L/d)	0.6	1.32	Richardson (1997)
Dermal Contact with Surface Water				
SA_{water}	Exposed surface area dermal water (cm^2)	430	821	Richardson (1997)
Ingestion of Wild Game				
IR_{game}	Ingestion rate of wild game (mg/d)	85000	233433	Richardson (1997)
F_{site}	Fraction of wild game that is from site (unitless)	1.00	1.00	Conservative site specific assumption
$F_{caribou}$	Fraction of wild game that is caribou (unitless)	0.90	0.90	Assumed based on professional judgement.
F_{hare}	Fraction of wild game that is hare (unitless)	0.10	0.10	Assumed based on professional judgement.
IR_{fish}	Ingestion rate of fish (mg/d)	95000	204233	Richardson (1997)
F_{site}	Fraction of fish that is from site (unitless)	1.00	1.00	Conservative site specific assumption

For non-threshold chemicals (carcinogens), in which any level of exposure is considered to have a potential for adverse health effects, exposures are not calculated within specific age groups (e.g., toddler) but are averaged over a lifetime. In accordance with the reasonable maximum exposure approach, it is assumed that a public visitor to the site grows up in Nunavut from birth to 75 years old. For the purposes of the risk characterization calculations, exposures are averaged over five age groups: (0 to 0.5 years) + (0.5 to 4 years) + (5 to 11 years) + (12 to 19 years) + (20 to 75 years). Receptor characteristics for each age group are presented in Table 9.