CONESTOGA-ROVERS & ASSOCIATES

651 Colby Drive, Waterloo, Ontario, N2V 1C2
Telephone: (519) 884-0510 Fax: (519) 884-0525
www.CRAworld.com

June 4, 2014 Reference No. 082415

Mr. Robert Eno
Environmental Protection Division of the Department of Environment
Government of Nunavut
P.O. Box 1000, Stn. 1300
Iqaluit, NU X0A 0H0
Canada

Dear Mr. Eno:

Re: Tier 3 Risk-Based Approach Criteria
Rationale Document for Development of Risk-based Concentrations (RBCs) for Soil and Groundwater
Iqaluit International Airport Improvement Project (Site)

On behalf of Sintra Inc. (Sintra), Conestoga-Rovers & Associates (CRA) is pleased to provide this rationale document for the development of Tier 3 Risk-Based Approach Criteria for the Iqaluit International Airport (Site). CRA has prepared this document for the Environmental Protection Division (EPD) of the Department of the Environment of the Government of Nunavut (GN) for review and concurrence. CRA has developed risk-based concentrations (RBCs) for select soil and groundwater parameters based on Site-specific data obtained from the Site in 2013. Through the development of the RBCs, CRA reviewed the applicable exposure pathways at the Site to ensure that the risk- based criteria remained protective of all human and/or ecological receptors that could potentially be in contact with the soil and groundwater at the Site. The RBCs were developed in accordance with the GN's Guideline for Contaminated Site Remediation (GN, 2009)[1] and the Canada-Wide Standard for Petroleum Hydrocarbons in Scientific Rationale Supporting Technical Document (CCME, 2008)[2].

Upon receiving the EPD's concurrence on the Site-specific RBCs, Sintra will apply the RBCs to soil and groundwater data at the Site to facilitate Site development activities planned to commence in June 2014. A work plan detailing the management of impacted soil and groundwater throughout the Site development activities will be submitted to the EPD under separate cover.

1 Environmental Guideline for Contaminated Site Remediation, Department of Environment, GN, originally approved on April 1999. Revised January 2002 and March 2009.

2 Canada-Wide Standards for Petroleum Hydrocarbons (PHCs) in Soil: Scientific Rationale. Supporting Technical Document, Canadian Council of Ministers of Environment (CCME). January 2008.

## 1.0 Investigative Activities Completed in 2013

CRA advanced 36 test pits at the Site in July 2013. The soil and groundwater sample locations are shown on Figure 1. CRA collected 36 soil samples (surface[3] and subsurface) and two grab groundwater samples for analyses of volatile organic compounds (VOCs) (including benzene, toluene, ethylbenzene and xylenes [BTEX]), polycyclic aromatic hydrocarbons (PAHs), metals, petroleum hydrocarbons fractions (PHC F1-F4), polychlorinated biphenyls (PCBs) and general chemistry parameters. The soil and groundwater analytical data are provided in Tables 1 and 2, respectively. It should be noted that groundwater was only encountered at two of the 36 test pits advanced.

CRA compared the soil samples to the following standards:

1. **Canadian Council of Ministers of the Environment (CCME) Tier 1 Industrial Guidelines:** As presented in "Canadian Environmental Quality Guidelines Summary Tables, Soil Quality Guidelines for the Protection of Environmental and Human Health, Industrial Land Use", dated 1999, updated 2011 (CCME, 2011). CCME has recently updated their Soil Quality Guidelines (SQGs) for some PAHs, as presented in "Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health-Polycyclic Aromatic Hydrocarbons 2010" (CCME, 2010). CCME Tier 1 Industrial Guidelines were used to determine if soil impacts are present at the Site.
2. **EPD of the Department of Environment of the GN Tier 1 Criteria for PHC impacts in Surface Soil:** As presented in the "Environmental Guideline for Contaminated Site Remediation", Department of Environment, Government of Nunavut, dated April 1999, updated January 2002 and March 2009. The EPD developed this guidance document with reference to the CCME document "Canada-Wide Standards for Petroleum Hydrocarbons (PHC) in Soil", dated 2001, updated in 2008. The PHC standards are consistent between the two guidance documents. The surface soil depth relates to any soil sample collected less than 1.5 m bgs. The GN Tier 1 Criteria were used to determine if soil impacts are present at the Site.

[3] Surface soil is soil less than 1.5 metres below ground surface (m bgs)

CRA compared the groundwater samples to the following standards:

1. **CCME Water Quality Guidelines:** As presented in "Canadian Environmental Quality Guidelines Summary Tables, Water Quality Guidelines for the Protection of Aquatic Life, Freshwater", dated 1999, updated 2012 (CCME, 2012). CCME does not have any guidelines for groundwater. CRA has used the short and long term guidelines for comparison purposes, and as an initial screening of the groundwater data. The CCME Water Quality Guidelines for the Protection of aquatic Life were developed using freshwater toxicity data, which are conservative for a groundwater condition. The freshwater toxicity data do not take into account a dilution factor (i.e., groundwater entering into a freshwater body), and as such, CRA developed RBCs for the groundwater at the Site. The development of the RBCs is discussed further below.
2. **Ontario's Ministry of Environment (MOE) Table 3 Standards:** As presented in "Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Ontario Environmental Protection Act, Table 3: Full Depth Generic Site Condition Standards in a Non-Potable Ground Water Condition", dated April 15, 2011, (MOE, 2011). MOE Table 3 Standards for industrial/commercial/community property use for coarse-textured soil were applied. In the absence of CCME Water Quality Guidelines for groundwater conditions, CRA used the MOE standards for comparison purposes.

Locations where soil and groundwater samples contained concentrations of contaminants greater than the above-noted standards are presented on Figure 1.

The Site development activities contemplate the use of arsenic, naphthalene and PHC-impacted soil within secure areas of the project works. CRA developed RBCs to validate the acceptable use of the arsenic, naphthalene and PHC-impacted soil with application of appropriate risk management measures (RMMs). The RMMs are described in the technical memorandum summarizing the development rationale of the soil RBCs, provided in Attachment 1.

Groundwater was encountered at two of the 36 test pits advanced in 2013. PAH parameters were detected at concentrations greater than the comparative groundwater standards noted above at one location. CRA has developed RBCs for these PAH parameters to validate the acceptability of ground discharge of treated PAH-impacted groundwater during Site development activities. The technical memorandum summarizing the development rationale of the groundwater RBCs is provided in Attachment 2.

The following sections provide a summary of the development of the Site-specific RBCs.

## 2.0 Exposure Pathways

The current use and anticipated future use of the Site is commercial. The receptors that may come in contact with the identified contamination on Site include:

- Commercial workers
- Construction workers
- Trespassers (include persons visiting the airport property)
- Potential aquatic and terrestrial wildlife

The exposure scenarios contemplated while developing the RBCs were:

***Human receptors:***

- Direct exposure to soil and groundwater (i.e., through dermal contact or incidental ingestion of contaminants)
- Inhalation of contaminants (soil and groundwater)

***Ecological receptors:***

- Bioaccumulation, bio concentration, and direct toxicity to species as a result of soil and groundwater contamination on Site.

### 2.1 Soil RBCs

Soil samples collected from the Site in 2013 identified the presence of PHCs, arsenic, and naphthalene at concentrations greater than the CCME Tier 1 Industrial Guidelines that are protective of direct contact with soil (human and ecological receptors) and protective of aquatic ecological receptors from exposure to impacted soil leaching to groundwater with eventual discharge to a water body (CCME, 2010; 2011). Soil RBCs have been identified/calculated for parameters that exceeded the CCME Tier 1 Industrial Guidelines in soil proposed to be used within secure areas of the project works.

As discussed in the rationale document provided in Attachment 1, the maximum naphthalene concentration detected in a soil sample collected from the Site was less than the calculated soil RBC, and as such, no RMMs are required for the use of this soil during the Site development activities. The maximum soil concentrations detected for arsenic and PHC F2 and PHC F3 are greater than the calculated soil RBCs, and as such RMMs must be implemented when using arsenic and PHC-impacted soil in Site development activities.

As noted above, CRA will provide EPD with a detailed work plan outlining the RMMs that will be used at the Site under a separate cover.

## 2.2 Groundwater RBCs

Current groundwater standards do not address the construction/utility worker and plants to soil organism exposure pathways. CRA calculated groundwater RBCs for all of the parameters that were detected in the groundwater samples collected with the exception of select elements and nutrients. Elements and nutrients such as aluminum, calcium, iron, magnesium, potassium, silicon, sodium, strontium, sulfur, and titanium were not considered in this evaluation as they are naturally occurring and toxicity data is not available.

Groundwater RBCs were calculated for the parameters summarized below:

| | | |
|---|---|---|
| Tetrachloroethene | Benzo(k)fluoranthene | Arsenic |
| 2-Methylnaphthalene | Chrysene | Boron |
| Acenaphthene | Dibenzo(a,h)anthracene | Cobalt |
| Acenaphthylene | Fluoranthene | Copper |
| Acridine | Fluorene | Lead |
| Anthracene | Indeno(1,2,3-cd)pyrene | Mercury |
| Benzo(a)anthracene | Naphthalene | Molybdenum |
| Benzo(a)pyrene | Perylene | Nickel |
| Benzo(b)fluoranthene | Phenanthrene | Selenium |
| Benzo(e)pyrene | Pyrene | Uranium |
| Benzo(g,h,i)perylene | Total PCBs | |

CONESTOGA-ROVERS & ASSOCIATES

June 4, 2014 Reference No. 082415



All groundwater parameters listed above were detected at concentrations less than the calculated groundwater RBCs with the exception of benzo(a)anthracene and indeno(1,2,3-cd)pyrene. RMMs must be followed while managing groundwater containing concentrations of contaminants greater than the calculated RBCs during the Site development activities.

CRA respectfully requests that the EPD review the RBCs developed for the Site and approve their application during Site development activities scheduled to commence in June 2014. CRA will provide EPD with the proposed RMMs in a Soil and Groundwater Management Work Plan for review and approval. The work plan will summarize the handling and management activities of impacted soil and groundwater potentially encountered during the Site development activities.

If you have any questions or comments regarding the development of the RBCs, please do not hesitate to contact the undersigned.

We look forward to hearing from you.

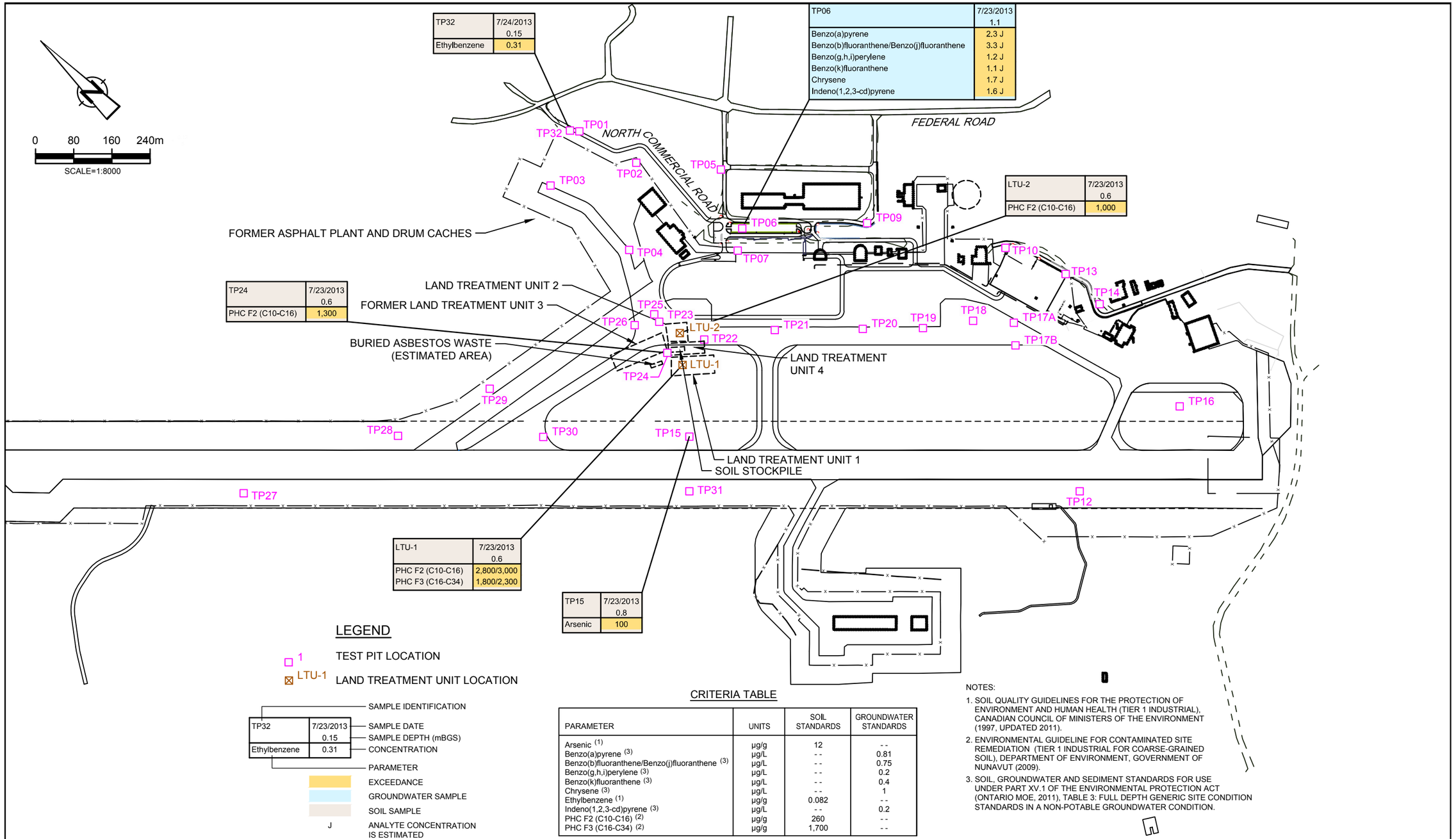
Yours truly,

CONESTOGA-ROVERS & ASSOCIATES

Lindsay Shepherd, P.Eng.

HS/mg/1
Encl.

cc: Michel Boulianne, Sintra
Greg Ferraro, CRA




## LEGEND

- TEST PIT LOCATION (1)
- LAND TREATMENT UNIT LOCATION (LTU-1)

TP32 | 7/23/2013 | 0.15 | Ethylbenzene | 0.31

- SAMPLE IDENTIFICATION
- SAMPLE DATE
- SAMPLE DEPTH (mBGS)
- CONCENTRATION
- PARAMETER
- EXCEEDANCE
- GROUNDWATER SAMPLE
- SOIL SAMPLE
- J — ANALYTE CONCENTRATION IS ESTIMATED

## CRITERIA TABLE

| PARAMETER | UNITS | SOIL STANDARDS | GROUNDWATER STANDARDS |
|---|---|---|---|
| Arsenic (1) | µg/g | 12 | - - |
| Benzo(a)pyrene (3) | µg/L | - - | 0.81 |
| Benzo(b)fluoranthene/Benzo(j)fluoranthene (3) | µg/L | - - | 0.75 |
| Benzo(g,h,i)perylene (3) | µg/L | - - | 0.2 |
| Benzo(k)fluoranthene (3) | µg/L | - - | 0.4 |
| Chrysene (3) | µg/L | - - | 1 |
| Ethylbenzene (1) | µg/g | 0.082 | - - |
| Indeno(1,2,3-cd)pyrene (3) | µg/L | - - | 0.2 |
| PHC F2 (C10-C16) (2) | µg/g | 260 | - - |
| PHC F3 (C16-C34) (2) | µg/g | 1,700 | - - |

NOTES:

1. SOIL QUALITY GUIDELINES FOR THE PROTECTION OF ENVIRONMENT AND HUMAN HEALTH (TIER 1 INDUSTRIAL), CANADIAN COUNCIL OF MINISTERS OF THE ENVIRONMENT (1997, UPDATED 2011).
2. ENVIRONMENTAL GUIDELINE FOR CONTAMINATED SITE REMEDIATION (TIER 1 INDUSTRIAL FOR COARSE-GRAINED SOIL), DEPARTMENT OF ENVIRONMENT, GOVERNMENT OF NUNAVUT (2009).
3. SOIL, GROUNDWATER AND SEDIMENT STANDARDS FOR USE UNDER PART XV.1 OF THE ENVIRONMENTAL PROTECTION ACT (ONTARIO MOE, 2011), TABLE 3: FULL DEPTH GENERIC SITE CONDITION STANDARDS IN A NON-POTABLE GROUNDWATER CONDITION.

figure 1

# SOIL AND GROUNDWATER EXCEEDANCES
# IQALUIT INTERNATIONAL AIRPORT
*Iqaluit, Nunavut*

CPA

82415-00(ENO001)GN-WA001 MAY 21/2014

**TABLE 1**

**ANALYTICAL RESULTS - SOIL SAMPLES**
**DEVELOPMENT OF RISK-BASED CONCENTRATIONS**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| ***Sample Location:*** | | | | ***LTU-1*** | ***LTU-1*** | ***LTU-2*** | ***TP01*** | ***TP02*** | ***TP02*** |
|---|---|---|---|---|---|---|---|---|---|
| ***Sample Date:*** | | | | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** |
| ***Sample Depth:*** | | | | ***0.6*** | ***0.6*** | ***0.6*** | ***0.9*** | ***1.5*** | ***1.5*** |
| ***Parameters*** | ***Units*** | ***CCME Industrial a*** | ***RBCs b*** | | ***Duplicate*** | | | | ***Duplicate*** |
| ***Volatile Organic Compounds (VOCs)*** | | | | | | | | | |
| 1,1,1,2-Tetrachloroethane | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1,1-Trichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1,2,2-Tetrachloroethane | µg/g | 50 | - | ND(0.35) | ND(0.23) | ND(0.060) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1,2-Trichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1-Dichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1-Dichloroethene | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dibromoethane (Ethylene dibromide) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dichlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dichloropropane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,3-Dichlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,4-Dichlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 2-Butanone (Methyl ethyl ketone) (MEK) | µg/g | - | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| 4-Methyl-2-pentanone (Methyl isobutyl ketone) (MIBK) | µg/g | - | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| Acetone | µg/g | - | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| Benzene | µg/g | 0.030 | - | ND(0.0060) | ND(0.0060) | ND(0.0060) | ND(0.0060) | ND(0.0060) | ND(0.0060) |
| Bromodichloromethane | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Bromoform | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Bromomethane (Methyl bromide) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Carbon tetrachloride | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Chlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Chloroform (Trichloromethane) | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| cis-1,2-Dichloroethene | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| cis-1,3-Dichloropropene | µg/g | - | - | ND(0.030) | ND(0.030) | ND(0.030) | ND(0.030) | ND(0.030) | ND(0.030) |
| Dibromochloromethane | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Dichlorodifluoromethane (CFC-12) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Ethylbenzene | µg/g | 0.082 | - | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) |
| Hexane | µg/g | 6.5 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| m&p-Xylenes | µg/g | - | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| Methyl tert butyl ether (MTBE) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Methylene chloride | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| o-Xylene | µg/g | - | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| Styrene | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Tetrachloroethene | µg/g | 0.6 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Toluene | µg/g | 0.37 | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| trans-1,2-Dichloroethene | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| trans-1,3-Dichloropropene | µg/g | - | - | ND(0.040) | ND(0.040) | ND(0.040) | ND(0.040) | ND(0.040) | ND(0.040) |
| Trichloroethene | µg/g | 0.01 | - | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) |
| Trichlorofluoromethane (CFC-11) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Vinyl chloride | µg/g | - | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| Xylenes (total) | µg/g | 11 | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| ***Polycyclic Aromatic Hydrocarbons (PAHs)*** | | | | | | | | | |
| 1-Methylnaphthalene | µg/g | - | - | ND(0.050) | 0.36 | ND(0.020) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| 2-Methylnaphthalene | µg/g | - | - | 0.028 | ND(0.20) | ND(0.010) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Acenaphthene | µg/g | - | - | ND(0.040) | ND(0.10) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Acenaphthylene | µg/g | - | - | ND(0.050) | 0.057 | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Anthracene | µg/g | 32 | - | 0.038 | 0.35 | 0.0054 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Benzo(a)anthracene | µg/g | - | - | 0.28 | 1.4 | 0.011 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Benzo(a)pyrene | µg/g | 72 | - | 0.31 | 1.6 | 0.018 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Benzo(b)fluoranthene/Benzo(j)fluoranthene | µg/g | 10 | - | 0.21 | 0.80 | 0.031 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Benzo(g,h,i)perylene | µg/g | - | - | 0.28 | 1.3 | 0.016 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Benzo(k)fluoranthene | µg/g | 10 | - | 0.028 | 0.059 | 0.0089 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Chrysene | µg/g | - | - | 0.39 | 2.0 | 0.011 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Dibenz(a,h)anthracene | µg/g | 10 | - | ND(0.025) | 0.062 | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Fluoranthene | µg/g | 180 | - | 0.20 | 0.85 | 0.011 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Fluorene | µg/g | - | - | ND(0.040) | 0.20 | 0.0082 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Indeno(1,2,3-cd)pyrene | µg/g | 10 | - | 0.087 | 0.36 | 0.012 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Naphthalene | µg/g | 22 | 22 | ND(0.20) | 0.16 | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Phenanthrene | µg/g | 50 | - | 0.14 | 3.2 | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Pyrene | µg/g | 100 | - | 1.3 | 5.9 | 0.059 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| ***Metals*** | | | | | | | | | |
| Antimony | µg/g | 40 | - | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) |
| Arsenic | µg/g | 12 | 26 | 1.8 | 1.9 | 2.7 | 3.5 | 1.5 | 1.5 |
| Barium | µg/g | 2000 | - | 21 | 24 | 29 | 52 | 13 | 11 |
| Beryllium | µg/g | 8 | - | ND(0.20) | ND(0.20) | ND(0.20) | 0.46 | ND(0.20) | ND(0.20) |
| Boron (hot water soluble) | µg/g | - | - | 0.15 | 0.12 | 0.089 | 0.21 | ND(0.050) | ND(0.050) |
| Cadmium | µg/g | 22 | - | ND(0.10) | ND(0.10) | ND(0.10) | 0.12 | ND(0.10) | ND(0.10) |
| Chromium | µg/g | 87 | - | 17 | 19 | 21 | 34 | 19 | 9.2 |
| Chromium VI (hexavalent) | µg/g | 1.4 | - | ND(0.2) | ND(0.2) | ND(0.2) | ND(0.2) | ND(0.2) | ND(0.2) |
| Cobalt | µg/g | 300 | - | 4.3 | 4.6 | 5.5 | 12 | 6.4 | 4.4 |
| Copper | µg/g | 91 | - | 9.1 | 9.7 | 70 | 24 | 9.7 | 9.0 |
| Lead | µg/g | - | - | 13 | 15 | 17 | 6.6 | 3.6 | 2.2 |
| Mercury | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Molybdenum | µg/g | 40 | - | 0.56 | 0.74 | 0.72 | 2.2 | 0.69 | ND(0.50) |
| Nickel | µg/g | 50 | - | 6.8 | 7.5 | 8.9 | 15 | 6.9 | 5.7 |
| Selenium | µg/g | 2.9 | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| Silver | µg/g | 40 | - | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) |
| Sulfur | µg/g | NV | - | 110 | 130 | 160 | 870 | ND(50) | ND(50) |
| Thallium | µg/g | 1 | - | ND(0.050) | ND(0.050) | ND(0.050) | 0.076 | ND(0.050) | ND(0.050) |
| Tin | µg/g | 300 | - | ND(5.0) | ND(5.0) | ND(5.0) | ND(5.0) | ND(5.0) | ND(5.0) |
| Uranium | µg/g | 300 | - | 0.48 | 0.35 | 0.40 | 1.0 | 0.36 | 0.23 |
| Vanadium | µg/g | 130 | - | 39 | 39 | 44 | 67 | 46 | 19 |
| Zinc | µg/g | 360 | - | 35 | 36 | 39 | 110 | 30 | 29 |
| ***Polychlorinated Biphenyls (PCBs)*** | | | | | | | | | |
| Total PCBs | µg/g | 33 | - | 0.046 | 0.044 | ND(0.010) | ND(0.020) | ND(0.010) | ND(0.010) |
| ***Petroleum Hydrocarbons*** | | | | | | | | | |
| Petroleum hydrocarbons F1 (C6-C10) | µg/g | - | - | ND(50) | 59 | 17 | ND(10) | ND(10) | ND(10) |
| Petroleum hydrocarbons F1 (C6-C10) - less BTEX [2] | µg/g | 320 | - | ND(50) | 59 | 17 | ND(10) | ND(10) | ND(10) |
| Petroleum hydrocarbons F2 (C10-C16) [2] | µg/g | 260 | 260 | **2800** | **3000** | **1000** | ND(10) | ND(10) | ND(10) |
| Petroleum hydrocarbons F3 (C16-C34) [2] | µg/g | 1700 | 1700 | **1800** | **2300** | 1500 | ND(50) | ND(50) | ND(50) |
| Petroleum hydrocarbons F4 (C34-C50) [2] | µg/g | 3300 | - | 740 | 1200 | 750 | ND(50) | ND(50) | ND(50) |
| Gravimetric heavy hydrocarbons (F4G) | µg/g | - | - | - | - | - | - | - | - |
| ***General Chemistry*** | | | | | | | | | |
| Cyanide (free) | µg/g | - | - | 0.03 | 0.02 | 0.02 | 0.04 | ND(0.01) | ND(0.01) |
| pH, lab | s.u. | 6-8 | - | 7.03 | 7.02 | 7.07 | 5.45 | 6.98 | 6.79 |
| Moisture | % | - | - | 8.0 | 7.9 | 8.0 | 33 | 3.5 | 3.3 |

**TABLE 1**

**ANALYTICAL RESULTS - SOIL SAMPLES**
**DEVELOPMENT OF RISK-BASED CONCENTRATIONS**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| ***Sample Location:*** | | | | ***TP03*** | ***TP04*** | ***TP05*** | ***TP06*** | ***TP07*** | ***TP09*** |
|---|---|---|---|---|---|---|---|---|---|
| ***Sample Date:*** | | | | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** |
| ***Sample Depth:*** | | | | ***1.3*** | ***2.1*** | ***1.45*** | ***1.1*** | ***1.25*** | ***3.5*** |
| ***Parameters*** | ***Units*** | ***CCME Industrial a*** | ***RBCs b*** | | | | | | |
| ***Volatile Organic Compounds (VOCs)*** | | | | | | | | | |
| 1,1,1,2-Tetrachloroethane | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1,1-Trichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1,2,2-Tetrachloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1,2-Trichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1-Dichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1-Dichloroethene | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dibromoethane (Ethylene dibromide) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dichlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dichloropropane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,3-Dichlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,4-Dichlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 2-Butanone (Methyl ethyl ketone) (MEK) | µg/g | - | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| 4-Methyl-2-pentanone (Methyl isobutyl ketone) (MIBK) | µg/g | - | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| Acetone | µg/g | - | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| Benzene | µg/g | 0.030 | - | ND(0.0060) | ND(0.0060) | ND(0.0060) | ND(0.0060) | ND(0.0060) | ND(0.0060) |
| Bromodichloromethane | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Bromoform | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Bromomethane (Methyl bromide) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Carbon tetrachloride | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Chlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Chloroform (Trichloromethane) | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| cis-1,2-Dichloroethene | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| cis-1,3-Dichloropropene | µg/g | - | - | ND(0.030) | ND(0.030) | ND(0.030) | ND(0.030) | ND(0.030) | ND(0.030) |
| Dibromochloromethane | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Dichlorodifluoromethane (CFC-12) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Ethylbenzene | µg/g | 0.082 | - | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) |
| Hexane | µg/g | 6.5 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| m&p-Xylenes | µg/g | - | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| Methyl tert butyl ether (MTBE) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Methylene chloride | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| o-Xylene | µg/g | - | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| Styrene | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Tetrachloroethene | µg/g | 0.6 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Toluene | µg/g | 0.37 | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| trans-1,2-Dichloroethene | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| trans-1,3-Dichloropropene | µg/g | - | - | ND(0.040) | ND(0.040) | ND(0.040) | ND(0.040) | ND(0.040) | ND(0.040) |
| Trichloroethene | µg/g | 0.01 | - | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) |
| Trichlorofluoromethane (CFC-11) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Vinyl chloride | µg/g | - | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| Xylenes (total) | µg/g | 11 | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| ***Polycyclic Aromatic Hydrocarbons (PAHs)*** | | | | | | | | | |
| 1-Methylnaphthalene | µg/g | - | - | ND(0.010) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.050) | ND(0.0050) |
| 2-Methylnaphthalene | µg/g | - | - | ND(0.010) | ND(0.0050) | ND(0.0050) | 0.0057 | ND(0.050) | ND(0.0050) |
| Acenaphthene | µg/g | - | - | ND(0.010) | ND(0.0050) | ND(0.0050) | 0.011 | ND(0.050) | ND(0.0050) |
| Acenaphthylene | µg/g | - | - | ND(0.010) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.050) | ND(0.0050) |
| Anthracene | µg/g | 32 | - | ND(0.010) | ND(0.0050) | ND(0.0050) | 0.013 | ND(0.050) | ND(0.0050) |
| Benzo(a)anthracene | µg/g | - | - | 0.047 | ND(0.0050) | ND(0.0050) | 0.028 | ND(0.050) | ND(0.0050) |
| Benzo(a)pyrene | µg/g | 72 | - | 0.039 | ND(0.0050) | ND(0.0050) | 0.025 | ND(0.050) | ND(0.0050) |
| Benzo(b)fluoranthene/Benzo(j)fluoranthene | µg/g | 10 | - | 0.055 | ND(0.0050) | ND(0.0050) | 0.031 | ND(0.050) | ND(0.0050) |
| Benzo(g,h,i)perylene | µg/g | - | - | 0.027 | ND(0.0050) | ND(0.0050) | 0.015 | ND(0.050) | ND(0.0050) |
| Benzo(k)fluoranthene | µg/g | 10 | - | 0.020 | ND(0.0050) | ND(0.0050) | 0.012 | ND(0.050) | ND(0.0050) |
| Chrysene | µg/g | - | - | 0.034 | ND(0.0050) | ND(0.0050) | 0.023 | ND(0.050) | ND(0.0050) |
| Dibenz(a,h)anthracene | µg/g | 10 | - | ND(0.010) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.050) | ND(0.0050) |
| Fluoranthene | µg/g | 180 | - | 0.11 | ND(0.0050) | ND(0.0050) | 0.054 | 0.072 | ND(0.0050) |
| Fluorene | µg/g | - | - | ND(0.010) | ND(0.0050) | ND(0.0050) | 0.0095 | ND(0.050) | ND(0.0050) |
| Indeno(1,2,3-cd)pyrene | µg/g | 10 | - | 0.025 | ND(0.0050) | ND(0.0050) | 0.015 | ND(0.050) | ND(0.0050) |
| Naphthalene | µg/g | 22 | 22 | 0.013 | ND(0.0050) | ND(0.0050) | 0.017 | 0.075 | ND(0.0050) |
| Phenanthrene | µg/g | 50 | - | 0.032 | ND(0.0050) | ND(0.0050) | 0.044 | 0.25 | ND(0.0050) |
| Pyrene | µg/g | 100 | - | 0.088 | ND(0.0050) | ND(0.0050) | 0.039 | 0.053 | ND(0.0050) |
| ***Metals*** | | | | | | | | | |
| Antimony | µg/g | 40 | - | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) |
| Arsenic | µg/g | 12 | 26 | 1.6 | 4.4 | 1.1 | 2.2 | 2.0 | 2.4 |
| Barium | µg/g | 2000 | - | 28 | 31 | 8.0 | 47 | 30 | 16 |
| Beryllium | µg/g | 8 | - | 0.20 | 0.24 | ND(0.20) | 0.33 | 0.22 | ND(0.20) |
| Boron (hot water soluble) | µg/g | - | - | 0.094 | ND(0.050) | ND(0.050) | 0.055 | 0.18 | 0.11 |
| Cadmium | µg/g | 22 | - | ND(0.10) | ND(0.10) | ND(0.10) | 0.11 | 0.10 | ND(0.10) |
| Chromium | µg/g | 87 | - | 17 | 23 | 17 | 30 | 18 | 22 |
| Chromium VI (hexavalent) | µg/g | 1.4 | - | ND(0.2) | ND(0.2) | ND(0.2) | ND(0.2) | ND(0.2) | ND(0.2) |
| Cobalt | µg/g | 300 | - | 5.1 | 7.3 | 4.8 | 7.7 | 6.9 | 8.2 |
| Copper | µg/g | 91 | - | 12 | 17 | 8.0 | 16 | 16 | 15 |
| Lead | µg/g | - | - | 10 | 6.5 | 2.8 | 6.5 | 9.1 | 4.4 |
| Mercury | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Molybdenum | µg/g | 40 | - | 0.60 | 0.83 | 0.61 | 0.68 | 0.69 | 0.84 |
| Nickel | µg/g | 50 | - | 7.4 | 12 | 5.5 | 14 | 9.2 | 9.0 |
| Selenium | µg/g | 2.9 | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| Silver | µg/g | 40 | - | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) |
| Sulfur | µg/g | NV | - | 100 | 150 | 82 | 130 | 190 | 86 |
| Thallium | µg/g | 1 | - | ND(0.050) | ND(0.050) | ND(0.050) | 0.099 | ND(0.050) | ND(0.050) |
| Tin | µg/g | 300 | - | ND(5.0) | ND(5.0) | ND(5.0) | ND(5.0) | ND(5.0) | ND(5.0) |
| Uranium | µg/g | 300 | - | 0.40 | 0.50 | 0.40 | 0.45 | 0.42 | 0.39 |
| Vanadium | µg/g | 130 | - | 35 | 50 | 38 | 52 | 38 | 49 |
| Zinc | µg/g | 360 | - | 52 | 53 | 26 | 95 | 56 | 34 |
| ***Polychlorinated Biphenyls (PCBs)*** | | | | | | | | | |
| Total PCBs | µg/g | 33 | - | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) |
| ***Petroleum Hydrocarbons*** | | | | | | | | | |
| Petroleum hydrocarbons F1 (C6-C10) | µg/g | - | - | ND(10) | ND(10) | ND(10) | ND(10) | ND(10) | ND(10) |
| Petroleum hydrocarbons F1 (C6-C10) - less BTEX [2] | µg/g | 320 | - | ND(10) | ND(10) | ND(10) | ND(10) | ND(10) | ND(10) |
| Petroleum hydrocarbons F2 (C10-C16) [2] | µg/g | 260 | 260 | ND(10) | ND(10) | ND(10) | ND(10) | ND(10) | ND(10) |
| Petroleum hydrocarbons F3 (C16-C34) [2] | µg/g | 1700 | 1700 | 110 | ND(50) | ND(50) | ND(50) | 190 | ND(50) |
| Petroleum hydrocarbons F4 (C34-C50) [2] | µg/g | 3300 | - | 82 | ND(50) | ND(50) | ND(50) | 170 | ND(50) |
| Gravimetric heavy hydrocarbons (F4G) | µg/g | - | - | - | - | - | - | 610 | - |
| ***General Chemistry*** | | | | | | | | | |
| Cyanide (free) | µg/g | - | - | 0.01 | 0.01 | ND(0.01) | ND(0.01) | 0.02 | ND(0.01) |
| pH, lab | s.u. | 6-8 | - | 7.54 | 7.54 | 7.96 | 7.39 | 7.34 | 7.99 |
| Moisture | % | - | - | 6.3 | 10 | 9.5 | 8.8 | 10 | 2.5 |

**TABLE 1**

**ANALYTICAL RESULTS - SOIL SAMPLES**
**DEVELOPMENT OF RISK-BASED CONCENTRATIONS**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| ***Sample Location:*** | | | | ***TP10*** | ***TP12*** | ***TP13*** | ***TP14*** | ***TP15*** | ***TP16*** |
|---|---|---|---|---|---|---|---|---|---|
| ***Sample Date:*** | | | | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** |
| ***Sample Depth:*** | | | | ***1.65*** | ***0.6*** | ***1.35*** | ***0.8*** | ***0.8*** | ***0.65*** |
| ***Parameters*** | ***Units*** | ***CCME Industrial a*** | ***RBCs b*** | | | | | | |
| ***Volatile Organic Compounds (VOCs)*** | | | | | | | | | |
| 1,1,1,2-Tetrachloroethane | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1,1-Trichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1,2,2-Tetrachloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1,2-Trichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1-Dichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1-Dichloroethene | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dibromoethane (Ethylene dibromide) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dichlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dichloropropane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,3-Dichlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,4-Dichlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 2-Butanone (Methyl ethyl ketone) (MEK) | µg/g | - | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| 4-Methyl-2-pentanone (Methyl isobutyl ketone) (MIBK) | µg/g | - | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| Acetone | µg/g | - | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| Benzene | µg/g | 0.030 | - | ND(0.0060) | ND(0.0060) | ND(0.0060) | ND(0.0060) | ND(0.0060) | ND(0.0060) |
| Bromodichloromethane | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Bromoform | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Bromomethane (Methyl bromide) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Carbon tetrachloride | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Chlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Chloroform (Trichloromethane) | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| cis-1,2-Dichloroethene | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| cis-1,3-Dichloropropene | µg/g | - | - | ND(0.030) | ND(0.030) | ND(0.030) | ND(0.030) | ND(0.030) | ND(0.030) |
| Dibromochloromethane | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Dichlorodifluoromethane (CFC-12) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Ethylbenzene | µg/g | 0.082 | - | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) |
| Hexane | µg/g | 6.5 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| m&p-Xylenes | µg/g | - | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| Methyl tert butyl ether (MTBE) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Methylene chloride | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| o-Xylene | µg/g | - | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| Styrene | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Tetrachloroethene | µg/g | 0.6 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Toluene | µg/g | 0.37 | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| trans-1,2-Dichloroethene | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| trans-1,3-Dichloropropene | µg/g | - | - | ND(0.040) | ND(0.040) | ND(0.040) | ND(0.040) | ND(0.040) | ND(0.040) |
| Trichloroethene | µg/g | 0.01 | - | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) |
| Trichlorofluoromethane (CFC-11) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Vinyl chloride | µg/g | - | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| Xylenes (total) | µg/g | 11 | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| ***Polycyclic Aromatic Hydrocarbons (PAHs)*** | | | | | | | | | |
| 1-Methylnaphthalene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.050) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| 2-Methylnaphthalene | µg/g | - | - | ND(0.0050) | ND(0.0050) | 0.059 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Acenaphthene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.050) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Acenaphthylene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.050) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Anthracene | µg/g | 32 | - | ND(0.0050) | ND(0.0050) | ND(0.050) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Benzo(a)anthracene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.050) | 0.0076 | ND(0.0050) | 0.0064 |
| Benzo(a)pyrene | µg/g | 72 | - | ND(0.0050) | ND(0.0050) | ND(0.050) | 0.0089 | ND(0.0050) | 0.0073 |
| Benzo(b)fluoranthene/Benzo(j)fluoranthene | µg/g | 10 | - | ND(0.0050) | ND(0.0050) | 0.062 | 0.014 | ND(0.0050) | 0.010 |
| Benzo(g,h,i)perylene | µg/g | - | - | ND(0.0050) | 0.0062 | ND(0.050) | 0.0088 | ND(0.0050) | 0.0066 |
| Benzo(k)fluoranthene | µg/g | 10 | - | ND(0.0050) | ND(0.0050) | ND(0.050) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Chrysene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.050) | 0.0077 | ND(0.0050) | 0.0063 |
| Dibenz(a,h)anthracene | µg/g | 10 | - | ND(0.0050) | ND(0.0050) | ND(0.050) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Fluoranthene | µg/g | 180 | - | ND(0.0050) | ND(0.0050) | 0.059 | 0.016 | ND(0.0050) | 0.014 |
| Fluorene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.050) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Indeno(1,2,3-cd)pyrene | µg/g | 10 | - | ND(0.0050) | ND(0.0050) | ND(0.050) | 0.0085 | ND(0.0050) | 0.0055 |
| Naphthalene | µg/g | 22 | 22 | ND(0.0050) | ND(0.0050) | 0.094 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Phenanthrene | µg/g | 50 | - | ND(0.0050) | ND(0.0050) | 0.077 | 0.0054 | ND(0.0050) | 0.0063 |
| Pyrene | µg/g | 100 | - | ND(0.0050) | ND(0.0050) | 0.081 | 0.012 | ND(0.0050) | 0.011 |
| ***Metals*** | | | | | | | | | |
| Antimony | µg/g | 40 | - | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) |
| Arsenic | µg/g | 12 | 26 | 1.2 | 2.2 | 1.5 | 1.6 | **100** | 1.7 |
| Barium | µg/g | 2000 | - | 14 | 16 | 21 | 15 | 24 | 20 |
| Beryllium | µg/g | 8 | - | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) |
| Boron (hot water soluble) | µg/g | - | - | 0.094 | 0.053 | 0.072 | 0.053 | ND(0.050) | 0.076 |
| Cadmium | µg/g | 22 | - | ND(0.10) | ND(0.10) | ND(0.10) | ND(0.10) | ND(0.10) | ND(0.10) |
| Chromium | µg/g | 87 | - | 13 | 28 | 15 | 11 | 20 | 17 |
| Chromium VI (hexavalent) | µg/g | 1.4 | - | ND(0.2) | ND(0.2) | ND(0.2) | ND(0.2) | ND(0.2) | ND(0.2) |
| Cobalt | µg/g | 300 | - | 4.9 | 5.2 | 4.2 | 3.3 | 5.3 | 4.3 |
| Copper | µg/g | 91 | - | 8.0 | 7.1 | 9.6 | 6.2 | 6.0 | 8.2 |
| Lead | µg/g | - | - | 4.5 | 20 | 9.8 | 3.1 | 2.8 | 4.1 |
| Mercury | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Molybdenum | µg/g | 40 | - | ND(0.50) | 0.81 | 0.52 | ND(0.50) | 0.65 | 0.57 |
| Nickel | µg/g | 50 | - | 6.3 | 9.1 | 7.0 | 5.5 | 11 | 6.3 |
| Selenium | µg/g | 2.9 | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| Silver | µg/g | 40 | - | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) |
| Sulfur | µg/g | NV | - | 53 | 100 | 83 | 63 | 120 | 140 |
| Thallium | µg/g | 1 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Tin | µg/g | 300 | - | ND(5.0) | ND(5.0) | ND(5.0) | ND(5.0) | ND(5.0) | ND(5.0) |
| Uranium | µg/g | 300 | - | 0.25 | 0.42 | 0.31 | 0.31 | 0.33 | 0.31 |
| Vanadium | µg/g | 130 | - | 30 | 62 | 31 | 23 | 55 | 32 |
| Zinc | µg/g | 360 | - | 29 | 29 | 36 | 28 | 35 | 40 |
| ***Polychlorinated Biphenyls (PCBs)*** | | | | | | | | | |
| Total PCBs | µg/g | 33 | - | ND(0.010) | ND(0.010) | 0.015 | ND(0.010) | ND(0.010) | ND(0.010) |
| ***Petroleum Hydrocarbons*** | | | | | | | | | |
| Petroleum hydrocarbons F1 (C6-C10) | µg/g | - | - | ND(10) | ND(10) | ND(10) | ND(10) | ND(10) | ND(10) |
| Petroleum hydrocarbons F1 (C6-C10) - less BTEX [2] | µg/g | 320 | - | ND(10) | ND(10) | ND(10) | ND(10) | ND(10) | ND(10) |
| Petroleum hydrocarbons F2 (C10-C16) [2] | µg/g | 260 | 260 | ND(10) | ND(10) | 110 | ND(10) | ND(10) | ND(10) |
| Petroleum hydrocarbons F3 (C16-C34) [2] | µg/g | 1700 | 1700 | ND(50) | ND(50) | 540 | ND(50) | ND(50) | ND(50) |
| Petroleum hydrocarbons F4 (C34-C50) [2] | µg/g | 3300 | - | ND(50) | ND(50) | 740 | ND(50) | ND(50) | ND(50) |
| Gravimetric heavy hydrocarbons (F4G) | µg/g | - | - | - | - | 2800 | - | - | - |
| ***General Chemistry*** | | | | | | | | | |
| Cyanide (free) | µg/g | - | - | ND(0.01) | ND(0.01) | 0.01 | 0.01 | 0.04 | 0.02 |
| pH, lab | s.u. | 6-8 | - | 7.69 | 7.81 | 7.57 | 7.24 | 5.90 | 7.44 |
| Moisture | % | - | - | 4.4 | 8.8 | 11 | 11 | 7.6 | 11 |

**TABLE 1**

**ANALYTICAL RESULTS - SOIL SAMPLES**
**DEVELOPMENT OF RISK-BASED CONCENTRATIONS**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| ***Sample Location:*** | | | | ***TP17A*** | ***TP17B*** | ***TP18*** | ***TP19*** | ***TP20*** | ***TP21*** |
|---|---|---|---|---|---|---|---|---|---|
| ***Sample Date:*** | | | | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** |
| ***Sample Depth:*** | | | | ***1.15*** | ***1.1*** | ***1.1*** | ***1.5*** | ***0.9*** | ***1.45*** |
| ***Parameters*** | ***Units*** | ***CCME Industrial a*** | ***RBCs b*** | | | | | | |
| ***Volatile Organic Compounds (VOCs)*** | | | | | | | | | |
| 1,1,1,2-Tetrachloroethane | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1,1-Trichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1,2,2-Tetrachloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1,2-Trichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1-Dichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1-Dichloroethene | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dibromoethane (Ethylene dibromide) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dichlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dichloropropane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,3-Dichlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,4-Dichlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 2-Butanone (Methyl ethyl ketone) (MEK) | µg/g | - | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| 4-Methyl-2-pentanone (Methyl isobutyl ketone) (MIBK) | µg/g | - | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| Acetone | µg/g | - | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| Benzene | µg/g | 0.030 | - | ND(0.0060) | ND(0.0060) | ND(0.0060) | ND(0.0060) | ND(0.0060) | ND(0.0060) |
| Bromodichloromethane | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Bromoform | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Bromomethane (Methyl bromide) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Carbon tetrachloride | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Chlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Chloroform (Trichloromethane) | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| cis-1,2-Dichloroethene | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| cis-1,3-Dichloropropene | µg/g | - | - | ND(0.030) | ND(0.030) | ND(0.030) | ND(0.030) | ND(0.030) | ND(0.030) |
| Dibromochloromethane | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Dichlorodifluoromethane (CFC-12) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Ethylbenzene | µg/g | 0.082 | - | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) |
| Hexane | µg/g | 6.5 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | 0.060 |
| m&p-Xylenes | µg/g | - | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| Methyl tert butyl ether (MTBE) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Methylene chloride | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| o-Xylene | µg/g | - | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| Styrene | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Tetrachloroethene | µg/g | 0.6 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Toluene | µg/g | 0.37 | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| trans-1,2-Dichloroethene | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| trans-1,3-Dichloropropene | µg/g | - | - | ND(0.040) | ND(0.040) | ND(0.040) | ND(0.040) | ND(0.040) | ND(0.040) |
| Trichloroethene | µg/g | 0.01 | - | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) |
| Trichlorofluoromethane (CFC-11) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Vinyl chloride | µg/g | - | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| Xylenes (total) | µg/g | 11 | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| ***Polycyclic Aromatic Hydrocarbons (PAHs)*** | | | | | | | | | |
| 1-Methylnaphthalene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | 0.079 |
| 2-Methylnaphthalene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | 0.13 |
| Acenaphthene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.010) |
| Acenaphthylene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.010) |
| Anthracene | µg/g | 32 | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | 0.0086 |
| Benzo(a)anthracene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | 0.013 |
| Benzo(a)pyrene | µg/g | 72 | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | 0.033 |
| Benzo(b)fluoranthene/Benzo(j)fluoranthene | µg/g | 10 | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | 0.0086 | 0.021 |
| Benzo(g,h,i)perylene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | 0.0051 | 0.045 |
| Benzo(k)fluoranthene | µg/g | 10 | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Chrysene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | 0.016 |
| Dibenz(a,h)anthracene | µg/g | 10 | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Fluoranthene | µg/g | 180 | - | 0.0056 | 0.0059 | ND(0.0050) | ND(0.0050) | 0.0083 | 0.029 |
| Fluorene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.050) |
| Indeno(1,2,3-cd)pyrene | µg/g | 10 | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | 0.0052 | 0.014 |
| Naphthalene | µg/g | 22 | 22 | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.010) | ND(0.10) |
| Phenanthrene | µg/g | 50 | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | 0.0058 | 0.045 |
| Pyrene | µg/g | 100 | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | 0.0077 | 0.054 |
| ***Metals*** | | | | | | | | | |
| Antimony | µg/g | 40 | - | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) |
| Arsenic | µg/g | 12 | 26 | 2.0 | 1.0 | ND(1.0) | ND(1.0) | 1.0 | 5.2 |
| Barium | µg/g | 2000 | - | 20 | 11 | 9.6 | 12 | 12 | 25 |
| Beryllium | µg/g | 8 | - | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) |
| Boron (hot water soluble) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | 0.065 | 0.11 | 0.093 |
| Cadmium | µg/g | 22 | - | ND(0.10) | ND(0.10) | ND(0.10) | ND(0.10) | ND(0.10) | ND(0.10) |
| Chromium | µg/g | 87 | - | 16 | 11 | 11 | 7.3 | 11 | 22 |
| Chromium VI (hexavalent) | µg/g | 1.4 | - | ND(0.2) | ND(0.2) | ND(0.2) | ND(0.2) | ND(0.2) | ND(0.2) |
| Cobalt | µg/g | 300 | - | 4.0 | 3.0 | 5.6 | 3.6 | 3.7 | 6.0 |
| Copper | µg/g | 91 | - | 6.6 | 6.8 | 8.4 | 7.2 | 7.2 | 15 |
| Lead | µg/g | - | - | 4.5 | 2.1 | 1.9 | 1.8 | 5.6 | 14 |
| Mercury | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Molybdenum | µg/g | 40 | - | 0.74 | ND(0.50) | 0.58 | ND(0.50) | ND(0.50) | 0.66 |
| Nickel | µg/g | 50 | - | 6.2 | 4.6 | 8.6 | 5.1 | 5.2 | 9.1 |
| Selenium | µg/g | 2.9 | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| Silver | µg/g | 40 | - | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) |
| Sulfur | µg/g | NV | - | 96 | ND(50) | 67 | 64 | 91 | 190 |
| Thallium | µg/g | 1 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Tin | µg/g | 300 | - | ND(5.0) | ND(5.0) | ND(5.0) | ND(5.0) | ND(5.0) | ND(5.0) |
| Uranium | µg/g | 300 | - | 0.32 | 0.23 | 0.18 | 0.29 | 0.22 | 0.42 |
| Vanadium | µg/g | 130 | - | 38 | 22 | 25 | 13 | 24 | 40 |
| Zinc | µg/g | 360 | - | 29 | 24 | 27 | 25 | 26 | 41 |
| ***Polychlorinated Biphenyls (PCBs)*** | | | | | | | | | |
| Total PCBs | µg/g | 33 | - | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | 0.016 |
| ***Petroleum Hydrocarbons*** | | | | | | | | | |
| Petroleum hydrocarbons F1 (C6-C10) | µg/g | - | - | ND(10) | ND(10) | ND(10) | ND(10) | 10 | ND(10) |
| Petroleum hydrocarbons F1 (C6-C10) - less BTEX [2] | µg/g | 320 | - | ND(10) | ND(10) | ND(10) | ND(10) | 10 | ND(10) |
| Petroleum hydrocarbons F2 (C10-C16) [2] | µg/g | 260 | 260 | ND(10) | ND(10) | ND(10) | ND(10) | 64 | 130 |
| Petroleum hydrocarbons F3 (C16-C34) [2] | µg/g | 1700 | 1700 | ND(50) | ND(50) | ND(50) | ND(50) | ND(50) | 630 |
| Petroleum hydrocarbons F4 (C34-C50) [2] | µg/g | 3300 | - | ND(50) | ND(50) | ND(50) | ND(50) | ND(50) | 180 |
| Gravimetric heavy hydrocarbons (F4G) | µg/g | - | - | - | - | - | - | - | - |
| ***General Chemistry*** | | | | | | | | | |
| Cyanide (free) | µg/g | - | - | 0.02 | ND(0.01) | ND(0.01) | ND(0.01) | ND(0.01) | 0.01 |
| pH, lab | s.u. | 6-8 | - | 7.23 | 7.85 | 7.91 | 7.87 | 7.77 | 7.47 |
| Moisture | % | - | - | 6.9 | 9.4 | 3.7 | 4.8 | 4.9 | 12 |

**TABLE 1**

**ANALYTICAL RESULTS - SOIL SAMPLES**
**DEVELOPMENT OF RISK-BASED CONCENTRATIONS**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| ***Sample Location:*** | | | | ***TP22*** | ***TP23*** | ***TP24*** | ***TP24*** | ***TP25*** | ***TP26*** |
|---|---|---|---|---|---|---|---|---|---|
| ***Sample Date:*** | | | | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** |
| ***Sample Depth:*** | | | | ***1.6*** | ***1.5*** | ***0.6*** | ***1.6*** | ***1*** | ***0.95*** |
| ***Parameters*** | ***Units*** | ***CCME Industrial a*** | ***RBCs b*** | | | | | | |
| ***Volatile Organic Compounds (VOCs)*** | | | | | | | | | |
| 1,1,1,2-Tetrachloroethane | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1,1-Trichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1,2,2-Tetrachloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.11) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1,2-Trichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1-Dichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,1-Dichloroethene | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dibromoethane (Ethylene dibromide) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dichlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,2-Dichloropropane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,3-Dichlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 1,4-Dichlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| 2-Butanone (Methyl ethyl ketone) (MEK) | µg/g | - | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| 4-Methyl-2-pentanone (Methyl isobutyl ketone) (MIBK) | µg/g | - | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| Acetone | µg/g | - | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| Benzene | µg/g | 0.030 | - | ND(0.0060) | ND(0.0060) | ND(0.0060) | ND(0.0060) | ND(0.0060) | ND(0.0060) |
| Bromodichloromethane | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Bromoform | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Bromomethane (Methyl bromide) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Carbon tetrachloride | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Chlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Chloroform (Trichloromethane) | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| cis-1,2-Dichloroethene | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| cis-1,3-Dichloropropene | µg/g | - | - | ND(0.030) | ND(0.030) | ND(0.030) | ND(0.030) | ND(0.030) | ND(0.030) |
| Dibromochloromethane | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Dichlorodifluoromethane (CFC-12) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Ethylbenzene | µg/g | 0.082 | - | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) |
| Hexane | µg/g | 6.5 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| m&p-Xylenes | µg/g | - | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| Methyl tert butyl ether (MTBE) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Methylene chloride | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| o-Xylene | µg/g | - | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| Styrene | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Tetrachloroethene | µg/g | 0.6 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Toluene | µg/g | 0.37 | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| trans-1,2-Dichloroethene | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| trans-1,3-Dichloropropene | µg/g | - | - | ND(0.040) | ND(0.040) | ND(0.040) | ND(0.040) | ND(0.040) | ND(0.040) |
| Trichloroethene | µg/g | 0.01 | - | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) |
| Trichlorofluoromethane (CFC-11) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Vinyl chloride | µg/g | - | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| Xylenes (total) | µg/g | 11 | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) |
| ***Polycyclic Aromatic Hydrocarbons (PAHs)*** | | | | | | | | | |
| 1-Methylnaphthalene | µg/g | - | - | ND(0.0050) | ND(0.0050) | 0.025 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| 2-Methylnaphthalene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.025) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Acenaphthene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.025) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Acenaphthylene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.025) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Anthracene | µg/g | 32 | - | ND(0.0050) | ND(0.0050) | ND(0.025) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Benzo(a)anthracene | µg/g | - | - | ND(0.0050) | ND(0.0050) | 0.031 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Benzo(a)pyrene | µg/g | 72 | - | ND(0.0050) | ND(0.0050) | 0.063 | 0.0054 | ND(0.0050) | ND(0.0050) |
| Benzo(b)fluoranthene/Benzo(j)fluoranthene | µg/g | 10 | - | ND(0.0050) | ND(0.0050) | 0.10 | 0.0076 | ND(0.0050) | ND(0.0050) |
| Benzo(g,h,i)perylene | µg/g | - | - | ND(0.0050) | ND(0.0050) | 0.067 | 0.0056 | ND(0.0050) | ND(0.0050) |
| Benzo(k)fluoranthene | µg/g | 10 | - | ND(0.0050) | ND(0.0050) | 0.031 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Chrysene | µg/g | - | - | ND(0.0050) | ND(0.0050) | 0.028 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Dibenz(a,h)anthracene | µg/g | 10 | - | ND(0.0050) | ND(0.0050) | ND(0.025) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Fluoranthene | µg/g | 180 | - | ND(0.0050) | ND(0.0050) | 0.045 | 0.0068 | ND(0.0050) | ND(0.0050) |
| Fluorene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.025) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Indeno(1,2,3-cd)pyrene | µg/g | 10 | - | ND(0.0050) | ND(0.0050) | 0.052 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Naphthalene | µg/g | 22 | 22 | ND(0.0050) | ND(0.0050) | ND(0.10) | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Phenanthrene | µg/g | 50 | - | ND(0.0050) | ND(0.0050) | 0.039 | ND(0.0050) | ND(0.0050) | ND(0.0050) |
| Pyrene | µg/g | 100 | - | ND(0.0050) | ND(0.0050) | 0.14 | 0.0098 | ND(0.0050) | ND(0.0050) |
| ***Metals*** | | | | | | | | | |
| Antimony | µg/g | 40 | - | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) |
| Arsenic | µg/g | 12 | 26 | 2.8 | 2.0 | 2.0 | 5.2 | 1.8 | 1.9 |
| Barium | µg/g | 2000 | - | 31 | 18 | 25 | 13 | 21 | 21 |
| Beryllium | µg/g | 8 | - | 0.24 | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) |
| Boron (hot water soluble) | µg/g | - | - | 0.069 | ND(0.050) | 0.25 | 0.064 | 0.091 | 0.057 |
| Cadmium | µg/g | 22 | - | ND(0.10) | ND(0.10) | ND(0.10) | ND(0.10) | ND(0.10) | ND(0.10) |
| Chromium | µg/g | 87 | - | 22 | 15 | 19 | 27 | 16 | 16 |
| Chromium VI (hexavalent) | µg/g | 1.4 | - | ND(0.2) | ND(0.2) | ND(0.2) | ND(0.2) | ND(0.2) | ND(0.2) |
| Cobalt | µg/g | 300 | - | 6.6 | 4.0 | 4.6 | 5.1 | 4.1 | 5.7 |
| Copper | µg/g | 91 | - | 15 | 7.9 | 10 | 11 | 8.2 | 13 |
| Lead | µg/g | - | - | 9.3 | 2.1 | 23 | 3.7 | 2.4 | 3.0 |
| Mercury | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Molybdenum | µg/g | 40 | - | 0.66 | 0.76 | 0.60 | 0.73 | 0.62 | 0.57 |
| Nickel | µg/g | 50 | - | 9.9 | 5.8 | 7.3 | 7.1 | 6.4 | 7.1 |
| Selenium | µg/g | 2.9 | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| Silver | µg/g | 40 | - | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) |
| Sulfur | µg/g | NV | - | 320 | 78 | 160 | 140 | 120 | 93 |
| Thallium | µg/g | 1 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Tin | µg/g | 300 | - | ND(5.0) | ND(5.0) | ND(5.0) | ND(5.0) | ND(5.0) | ND(5.0) |
| Uranium | µg/g | 300 | - | 0.52 | 0.32 | 0.35 | 0.25 | 0.39 | 0.32 |
| Vanadium | µg/g | 130 | - | 49 | 30 | 36 | 63 | 30 | 35 |
| Zinc | µg/g | 360 | - | 42 | 23 | 40 | 28 | 26 | 28 |
| ***Polychlorinated Biphenyls (PCBs)*** | | | | | | | | | |
| Total PCBs | µg/g | 33 | - | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) |
| ***Petroleum Hydrocarbons*** | | | | | | | | | |
| Petroleum hydrocarbons F1 (C6-C10) | µg/g | - | - | ND(10) | ND(10) | ND(50) | ND(10) | ND(10) | ND(10) |
| Petroleum hydrocarbons F1 (C6-C10) - less BTEX [2] | µg/g | 320 | - | ND(10) | ND(10) | ND(50) | ND(10) | ND(10) | ND(10) |
| Petroleum hydrocarbons F2 (C10-C16) [2] | µg/g | 260 | 260 | 13 | ND(10) | **1300** | ND(10) | ND(10) | ND(10) |
| Petroleum hydrocarbons F3 (C16-C34) [2] | µg/g | 1700 | 1700 | 52 | ND(50) | 1300 | ND(50) | ND(50) | ND(50) |
| Petroleum hydrocarbons F4 (C34-C50) [2] | µg/g | 3300 | - | ND(50) | ND(50) | 730 | ND(50) | ND(50) | ND(50) |
| Gravimetric heavy hydrocarbons (F4G) | µg/g | - | - | - | - | - | - | - | - |
| ***General Chemistry*** | | | | | | | | | |
| Cyanide (free) | µg/g | - | - | 0.02 | ND(0.01) | 0.01 | ND(0.01) | ND(0.01) | ND(0.01) |
| pH, lab | s.u. | 6-8 | - | 7.27 | 7.68 | 7.25 | 7.80 | 7.64 | 7.87 |
| Moisture | % | - | - | 14 | 12 | 7.7 | 12 | 12 | 4.1 |

**TABLE 1**

**ANALYTICAL RESULTS - SOIL SAMPLES**
**DEVELOPMENT OF RISK-BASED CONCENTRATIONS**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| ***Sample Location:*** | | | | ***TP27*** | ***TP28*** | ***TP29*** | ***TP30*** | ***TP31*** | ***TP32*** |
|---|---|---|---|---|---|---|---|---|---|
| ***Sample Date:*** | | | | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** | ***7/23/2013*** |
| ***Sample Depth:*** | | | | ***0.6*** | ***1.2*** | ***1*** | ***0.6*** | ***1.2*** | ***0.15*** |
| ***Parameters*** | ***Units*** | ***CCME Industrial a*** | ***RBCs b*** | | | | | | |
| ***Volatile Organic Compounds (VOCs)*** | | | | | | | | | |
| 1,1,1,2-Tetrachloroethane | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| 1,1,1-Trichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| 1,1,2,2-Tetrachloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| 1,1,2-Trichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| 1,1-Dichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| 1,1-Dichloroethene | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| 1,2-Dibromoethane (Ethylene dibromide) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| 1,2-Dichlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| 1,2-Dichloroethane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| 1,2-Dichloropropane | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| 1,3-Dichlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| 1,4-Dichlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| 2-Butanone (Methyl ethyl ketone) (MEK) | µg/g | - | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(1.5) |
| 4-Methyl-2-pentanone (Methyl isobutyl ketone) (MIBK) | µg/g | - | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(1.5) |
| Acetone | µg/g | - | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(1.5) |
| Benzene | µg/g | 0.030 | - | ND(0.0060) | ND(0.0060) | ND(0.0060) | ND(0.0060) | ND(0.0060) | ND(0.018) |
| Bromodichloromethane | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| Bromoform | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| Bromomethane (Methyl bromide) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| Carbon tetrachloride | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| Chlorobenzene | µg/g | 10 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| Chloroform (Trichloromethane) | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| cis-1,2-Dichloroethene | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| cis-1,3-Dichloropropene | µg/g | - | - | ND(0.030) | ND(0.030) | ND(0.030) | ND(0.030) | ND(0.030) | ND(0.090) |
| Dibromochloromethane | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| Dichlorodifluoromethane (CFC-12) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| Ethylbenzene | µg/g | 0.082 | - | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | **0.31** |
| Hexane | µg/g | 6.5 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| m&p-Xylenes | µg/g | - | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | 2.3 |
| Methyl tert butyl ether (MTBE) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| Methylene chloride | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| o-Xylene | µg/g | - | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | 1.2 |
| Styrene | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| Tetrachloroethene | µg/g | 0.6 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| Toluene | µg/g | 0.37 | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | 0.22 |
| trans-1,2-Dichloroethene | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| trans-1,3-Dichloropropene | µg/g | - | - | ND(0.040) | ND(0.040) | ND(0.040) | ND(0.040) | ND(0.040) | ND(0.12) |
| Trichloroethene | µg/g | 0.01 | - | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.030) |
| Trichlorofluoromethane (CFC-11) | µg/g | - | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.15) |
| Vinyl chloride | µg/g | - | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.060) |
| Xylenes (total) | µg/g | 11 | - | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | ND(0.020) | 3.5 |
| ***Polycyclic Aromatic Hydrocarbons (PAHs)*** | | | | | | | | | |
| 1-Methylnaphthalene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | 0.14 |
| 2-Methylnaphthalene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | 0.22 |
| Acenaphthene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.10) |
| Acenaphthylene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.10) |
| Anthracene | µg/g | 32 | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.10) |
| Benzo(a)anthracene | µg/g | - | - | ND(0.0050) | ND(0.0050) | 0.015 | ND(0.0050) | ND(0.0050) | ND(0.10) |
| Benzo(a)pyrene | µg/g | 72 | - | ND(0.0050) | ND(0.0050) | 0.038 | ND(0.0050) | ND(0.0050) | ND(0.10) |
| Benzo(b)fluoranthene/Benzo(j)fluoranthene | µg/g | 10 | - | ND(0.0050) | ND(0.0050) | 0.015 | ND(0.0050) | ND(0.0050) | ND(0.10) |
| Benzo(g,h,i)perylene | µg/g | - | - | ND(0.0050) | ND(0.0050) | 0.071 | ND(0.0050) | ND(0.0050) | ND(0.10) |
| Benzo(k)fluoranthene | µg/g | 10 | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.10) |
| Chrysene | µg/g | - | - | ND(0.0050) | ND(0.0050) | 0.020 | ND(0.0050) | ND(0.0050) | ND(0.10) |
| Dibenz(a,h)anthracene | µg/g | 10 | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.10) |
| Fluoranthene | µg/g | 180 | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.10) |
| Fluorene | µg/g | - | - | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.10) |
| Indeno(1,2,3-cd)pyrene | µg/g | 10 | - | ND(0.0050) | ND(0.0050) | 0.018 | ND(0.0050) | ND(0.0050) | ND(0.10) |
| Naphthalene | µg/g | 22 | 22 | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | ND(0.0050) | 0.19 |
| Phenanthrene | µg/g | 50 | - | ND(0.0050) | ND(0.0050) | 0.0061 | ND(0.0050) | ND(0.0050) | ND(0.10) |
| Pyrene | µg/g | 100 | - | ND(0.0050) | ND(0.0050) | 0.044 | ND(0.0050) | ND(0.0050) | ND(0.10) |
| ***Metals*** | | | | | | | | | |
| Antimony | µg/g | 40 | - | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | 0.23 |
| Arsenic | µg/g | 12 | 26 | 1.4 | 1.5 | 2.3 | 2.4 | 1.3 | 1.8 |
| Barium | µg/g | 2000 | - | 25 | 23 | 42 | 24 | 23 | 94 |
| Beryllium | µg/g | 8 | - | ND(0.20) | 0.25 | 0.26 | 0.28 | ND(0.20) | 0.23 |
| Boron (hot water soluble) | µg/g | - | - | 0.075 | 0.062 | 0.11 | ND(0.050) | 0.059 | 0.38 |
| Cadmium | µg/g | 22 | - | ND(0.10) | ND(0.10) | ND(0.10) | ND(0.10) | ND(0.10) | 0.13 |
| Chromium | µg/g | 87 | - | 18 | 19 | 23 | 33 | 14 | 18 |
| Chromium VI (hexavalent) | µg/g | 1.4 | - | ND(0.2) | ND(0.2) | ND(0.2) | ND(0.2) | ND(0.2) | ND(0.2) |
| Cobalt | µg/g | 300 | - | 4.3 | 4.5 | 6.1 | 5.7 | 4.0 | 5.2 |
| Copper | µg/g | 91 | - | 7.6 | 9.4 | 14 | 6.7 | 8.0 | 22 |
| Lead | µg/g | - | - | 2.4 | 2.8 | 3.7 | 3.2 | 2.9 | 17 |
| Mercury | µg/g | 50 | - | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) | ND(0.050) |
| Molybdenum | µg/g | 40 | - | 0.65 | ND(0.50) | 1.1 | 1.3 | 0.61 | 0.71 |
| Nickel | µg/g | 50 | - | 6.9 | 7.7 | 10 | 9.5 | 6.0 | 9.7 |
| Selenium | µg/g | 2.9 | - | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) | ND(0.50) |
| Silver | µg/g | 40 | - | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) | ND(0.20) |
| Sulfur | µg/g | NV | - | 58 | 88 | 230 | 220 | 75 | 1100 |
| Thallium | µg/g | 1 | - | ND(0.050) | ND(0.050) | 0.055 | ND(0.050) | ND(0.050) | ND(0.050) |
| Tin | µg/g | 300 | - | ND(5.0) | ND(5.0) | ND(5.0) | ND(5.0) | ND(5.0) | ND(5.0) |
| Uranium | µg/g | 300 | - | 0.33 | 0.32 | 0.54 | 0.39 | 0.41 | 1.3 |
| Vanadium | µg/g | 130 | - | 48 | 38 | 46 | 86 | 44 | 31 |
| Zinc | µg/g | 360 | - | 29 | 30 | 46 | 37 | 29 | 57 |
| ***Polychlorinated Biphenyls (PCBs)*** | | | | | | | | | |
| Total PCBs | µg/g | 33 | - | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.010) | ND(0.030) |
| ***Petroleum Hydrocarbons*** | | | | | | | | | |
| Petroleum hydrocarbons F1 (C6-C10) | µg/g | - | - | ND(10) | ND(10) | ND(10) | ND(10) | ND(10) | ND(30) |
| Petroleum hydrocarbons F1 (C6-C10) - less BTEX [2] | µg/g | 320 | - | ND(10) | ND(10) | ND(10) | ND(10) | ND(10) | ND(30) |
| Petroleum hydrocarbons F2 (C10-C16) [2] | µg/g | 260 | 260 | ND(10) | ND(10) | ND(10) | ND(10) | ND(10) | 21 |
| Petroleum hydrocarbons F3 (C16-C34) [2] | µg/g | 1700 | 1700 | ND(50) | ND(50) | 150 | ND(50) | ND(50) | 1500 |
| Petroleum hydrocarbons F4 (C34-C50) [2] | µg/g | 3300 | - | ND(50) | ND(50) | 140 | ND(50) | ND(50) | 1300 |
| Gravimetric heavy hydrocarbons (F4G) | µg/g | - | - | - | - | 400 | - | - | 2700 |
| ***General Chemistry*** | | | | | | | | | |
| Cyanide (free) | µg/g | - | - | 0.02 | 0.03 | 0.02 | 0.02 | 0.01 | 0.07 |
| pH, lab | s.u. | 6-8 | - | 7.42 | 5.96 | 7.54 | 5.96 | 7.13 | 5.96 |
| Moisture | % | - | - | 6.0 | 10 | 12 | 12 | 5.6 | 61 |

**TABLE 1**

**ANALYTICAL RESULTS - SOIL SAMPLES**
**DEVELOPMENT OF RISK-BASED CONCENTRATIONS**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

Notes:

a Canadian Council of Ministers of the Environment (CCME) Tier 1 Industrial Guidelines: As presented in "Canadian Environmental Quality Guidelines Summary Tables, Soil Land Industrial Use", Quality Guidelines for the Protection of Environmental and Human Health, dated 1999, updated 2011 (CCME, 2011). CCME has recently updated their Soil Quality Guidelines (SQGs) for some polycyclic aromatic hydrocarbons (PAHs), as presented in Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health- Polycyclic Aromatic Hydrocarbons 2010 (CCME, 2010).

b Site-specific Risk-Based Concentrations (RBCs) were developed by CRA in 2013 (Reference Appendix A)

1 Environment Protection Department (EPD) of the Department of Environment of the GN Tier 1 Criteria for PHC impacts in Surface Soil: As presented in the "Environmental Guideline for Contaminated Site Remediation", Department of Environment, Government of Nunavut, dated April 1999, updated January 2002 and March 2009. The EPD developed this guidance document with reference to the CCME document "Canada-Wide Standards for Petroleum Hydrocarbons (PHC) in Soil", dated 2001, updated in 2008. The PHC standards are consistent between the two guidance documents. The surface soil depth relates to any soil sample collected less than 1.5 metres below ground surface (m BGS).

**1.0** Exceeds RBC and requires risk management measures.

\- No value

**TABLE 2**

**ANALYTICAL RESULTS - GROUNDWATER SAMPLES**
**DEVELOPMENT OF RISK-BASED CONCENTRATIONS**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| ***Sample Location:*** | | | | | | ***TP06*** | ***TP12*** |
|---|---|---|---|---|---|---|---|
| ***Sample Date:*** | | | | | | ***7/23/2013*** | ***7/23/2013*** |
| ***Parameters*** | ***Units*** | ***CCME [1] Short Term a*** | ***CCME [1] Long Term b*** | ***MOE Table 3 c*** | ***RBCs d*** | | |
| ***Volatile Organic Compounds (VOCs)*** | | | | | | | |
| 1,1,1,2-Tetrachloroethane | µg/L | - | - | 3.3 | - | ND(0.50) | ND(0.50) |
| 1,1,1-Trichloroethane | µg/L | - | - | 640 | - | ND(0.20) | ND(0.20) |
| 1,1,2,2-Tetrachloroethane | µg/L | - | - | 3.2 | - | ND(0.50) | ND(0.50) |
| 1,1,2-Trichloroethane | µg/L | - | - | 4.7 | - | ND(0.50) | ND(0.50) |
| 1,1-Dichloroethane | µg/L | - | - | 320 | - | ND(0.20) | ND(0.20) |
| 1,1-Dichloroethene | µg/L | - | - | 1.6 | - | ND(0.20) | ND(0.20) |
| 1,2-Dibromoethane (Ethylene dibromide) | µg/L | - | - | 0.25 | - | ND(0.20) | ND(0.20) |
| 1,2-Dichlorobenzene | µg/L | - | 0.7 | 4600 | - | ND(0.50) | ND(0.50) |
| 1,2-Dichloroethane | µg/L | - | 100 | 1.6 | - | ND(0.50) | ND(0.50) |
| 1,2-Dichloropropane | µg/L | - | - | 16 | - | ND(0.20) | ND(0.20) |
| 1,3-Dichlorobenzene | µg/L | - | 150 | 9600 | - | ND(0.50) | ND(0.50) |
| 1,4-Dichlorobenzene | µg/L | - | 26 | 8 | - | ND(0.50) | ND(0.50) |
| 2-Butanone (Methyl ethyl ketone) (MEK) | µg/L | - | - | 470000 | - | ND(10) | ND(10) |
| 4-Methyl-2-pentanone (Methyl isobutyl ketone) (MIBK) | µg/L | - | - | 140000 | - | ND(5.0) | ND(5.0) |
| Acetone | µg/L | - | - | 130000 | - | ND(10) | ND(10) |
| Benzene | µg/L | - | 370 | 44 | - | ND(0.20) | ND(0.20) |
| Bromodichloromethane | µg/L | - | - | 85000 | - | ND(0.50) | ND(0.50) |
| Bromoform | µg/L | - | - | 380 | - | ND(1.0) | ND(1.0) |
| Bromomethane (Methyl bromide) | µg/L | - | - | 5.6 | - | ND(0.50) | ND(0.50) |
| Carbon tetrachloride | µg/L | - | 13.3 | 0.79 | - | ND(0.20) | ND(0.20) |
| Chlorobenzene | µg/L | - | 1.3 | 630 | - | ND(0.20) | ND(0.20) |
| Chloroform (Trichloromethane) | µg/L | - | 1.8 | 2.4 | - | ND(0.20) | ND(0.20) |
| cis-1,2-Dichloroethene | µg/L | - | - | 1.6 | - | ND(0.50) | ND(0.50) |
| cis-1,3-Dichloropropene | µg/L | - | - | - | - | ND(0.30) | ND(0.30) |
| Dibromochloromethane | µg/L | - | - | 82000 | - | ND(0.50) | ND(0.50) |
| Dichlorodifluoromethane (CFC-12) | µg/L | - | - | 4400 | - | ND(1.0) | ND(1.0) |
| Ethylbenzene | µg/L | - | 90 | 2300 | - | ND(0.20) | ND(0.20) |
| Hexane | µg/L | - | - | 51 | - | ND(1.0) | ND(1.0) |
| m&p-Xylenes | µg/L | - | - | - | - | ND(0.20) | ND(0.20) |
| Methyl tert butyl ether (MTBE) | µg/L | - | 10000 | 190 | - | ND(0.50) | ND(0.50) |
| Methylene chloride | µg/L | - | 98.1 | 610 | - | ND(2.0) | ND(2.0) |
| o-Xylene | µg/L | - | - | - | - | ND(0.20) | ND(0.20) |
| Styrene | µg/L | - | 72 | 1300 | - | ND(0.50) | ND(0.50) |
| Tetrachloroethene | µg/L | - | 110 | 1.6 | 396 | 0.58 | ND(0.20) |
| Toluene | µg/L | - | 2 | 18000 | - | ND(0.20) | ND(0.20) |
| trans-1,2-Dichloroethene | µg/L | - | - | 1.6 | - | ND(0.50) | ND(0.50) |
| trans-1,3-Dichloropropene | µg/L | - | - | - | - | ND(0.40) | ND(0.40) |
| Trichloroethene | µg/L | - | 21 | 1.6 | - | ND(0.20) | ND(0.20) |
| Trichlorofluoromethane (CFC-11) | µg/L | - | - | 2500 | - | ND(0.50) | ND(0.50) |
| Vinyl chloride | µg/L | - | - | 0.5 | - | ND(0.20) | ND(0.20) |
| Xylenes (total) | µg/L | - | - | 4200 | - | ND(0.20) | ND(0.20) |
| ***Polycyclic Aromatic Hydrocarbons (PAHs)*** | | | | | | | |
| 2-Methylnaphthalene | µg/L | - | - | 1800 | 164 | 0.066 J | 0.12 J |
| Acenaphthene | µg/L | - | 5.8 | 600 | 2048 | 0.31 J | ND(0.02) J |
| Acenaphthylene | µg/L | - | - | 1.8 | 1029 | 0.032 J | ND(0.02) J |
| Acridine | µg/L | - | 4.4 | - | 353 | 0.14 J | ND(0.02) J |
| Anthracene | µg/L | - | 0.012 | 2.4 | 321 | 0.36 J | ND(0.02) J |
| Benzo(a)anthracene | µg/L | - | 0.018 | 4.7 | 1.0 | **2.1 J[d]** | 0.03 J |
| Benzo(a)pyrene | µg/L | - | 0.015 | 0.81 | 6.6 | 2.3 J | 0.08 J |
| Benzo(b)fluoranthene/Benzo(j)fluoranthene | µg/L | - | - | 0.75 | 39 | 3.3 J | 0.12 J |
| Benzo(b)pyridine (Quinoline) | µg/L | - | 3.4 | - | - | ND(0.02) J | ND(0.05) J |
| Benzo(c)phenanthrene | µg/L | - | - | - | - | ND(0.3) J | ND(0.02) J |
| Benzo(e)pyrene | µg/L | - | - | - | 6.6 | 2.0 J | 0.30 J |
| Benzo(g,h,i)perylene | µg/L | - | - | 0.2 | 6.4 | 1.2 J | 0.17 J |
| Benzo(k)fluoranthene | µg/L | - | - | 0.4 | 150 | 1.1 J | 0.03 J |
| Chrysene | µg/L | - | - | 1 | 22 | 1.7 J | 0.07 J |
| Dibenz(a,h)anthracene | µg/L | - | - | 0.52 | 2.6 | 0.37 J | ND(0.02) J |
| Fluoranthene | µg/L | - | 0.04 | 130 | 501 | 3.3 J | 0.09 J |
| Fluorene | µg/L | - | 3 | 400 | 733 | 0.25 J | ND(0.02) J |
| Indeno(1,2,3-cd)pyrene | µg/L | - | - | 0.2 | 0.096 | **1.6 J[d]** | 0.07 J |
| Naphthalene | µg/L | - | 1.1 | 1400 | 43 | 0.11 J | 0.08 J |
| Perylene | µg/L | - | - | - | 257143 | 0.54 J | ND(0.02) J |
| Phenanthrene | µg/L | - | 0.4 | 580 | 362 | 1.6 J | 0.06 J |
| Pyrene | µg/L | - | 0.025 | 68 | 52 | 2.8 J | 0.15 J |
| Total benzo(a)pyrene equivalents | µg/L | - | - | - | 3.9 | 3.6 J | 0.12 J |

**TABLE 2**

**ANALYTICAL RESULTS - GROUNDWATER SAMPLES**
**DEVELOPMENT OF RISK-BASED CONCENTRATIONS**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| ***Sample Location:*** | | | | | | ***TP06*** | ***TP12*** |
|---|---|---|---|---|---|---|---|
| ***Sample Date:*** | | | | | | ***7/23/2013*** | ***7/23/2013*** |
| ***Parameters*** | ***Units*** | ***CCME [1] Short Term*** | ***CCME [1] Long Term*** | ***MOE Table 3*** | ***RBCs*** | | |
| ***Metals*** | | | | | | | |
| Aluminum (dissolved) | µg/L | - | 100 | - | - | 31 / ND(40) | 61 / 270 |
| Antimony (dissolved) | µg/L | - | - | 20000 | - | ND(0.6) | ND(0.6) |
| Arsenic (dissolved) | µg/L | - | 5 | 1900 | 689 | 0.33 | ND(0.2) |
| Barium (dissolved) | µg/L | - | - | 29000 | - | ND(10) | ND(10) |
| Beryllium (dissolved) | µg/L | - | - | 67 | - | ND(1) | ND(1) |
| Boron (dissolved) | µg/L | 29000 | 1500 | 45000 | 7237 | 32 | 35 |
| Cadmium (dissolved) | µg/L | - | - | 2.7 | - | ND(0.013) / ND(0.013) | ND(0.0058) / ND(0.0058) |
| Calcium (dissolved) | µg/L | - | - | - | - | 65000 | 39000 |
| Chromium (dissolved) | µg/L | - | - | 810 | - | ND(1) / ND(10) | ND(1) / ND(10) |
| Chromium VI (hexavalent) (dissolved) | µg/L | - | 1 | 140 | - | ND(1) | ND(1) |
| Cobalt (dissolved) | µg/L | - | - | 66 | 430 | 0.36 | ND(0.3) |
| Copper (dissolved) | µg/L | - | 2 | 87 | 2595 | 2.5 | 3.2 |
| Iron (dissolved) | µg/L | - | 300 | - | - | ND(60) | 120 |
| Lead (dissolved) | µg/L | - | 1 | 25 | 434 | 0.24 | ND(0.2) |
| Lithium (dissolved) | µg/L | - | - | - | - | ND(20) | ND(20) |
| Magnesium (dissolved) | µg/L | - | - | - | - | 6400 | 5700 |
| Manganese (dissolved) | µg/L | - | - | - | - | ND(4) | ND(4) |
| Mercury | µg/L | - | 0.026 | 0.29 | 0.42 | 0.06 | 0.17 |
| Molybdenum (dissolved) | µg/L | - | 73 | 9200 | 1993 | 1 | 4.6 |
| Nickel (dissolved) | µg/L | - | 25 | 490 | 768 | 0.81 | 0.54 |
| Phosphorus (dissolved) | µg/L | - | - | - | - | ND(100) | ND(100) |
| Potassium (dissolved) | µg/L | - | - | - | - | 1500 | 4600 |
| Selenium (dissolved) | µg/L | - | 1 | 63 | 478 | 0.26 | ND(0.2) |
| Silicon (dissolved) | µg/L | - | - | - | - | 2700 | 3200 |
| Silver (dissolved) | µg/L | - | 0.1 | 1.5 | - | ND(0.1) | ND(0.1) |
| Sodium (dissolved) | µg/L | - | - | 2300000 | - | 7400 | 52000 |
| Strontium (dissolved) | µg/L | - | - | - | - | 120 | 98 |
| Sulfur (dissolved) | µg/L | - | - | - | - | 3100 | 1600 |
| Thallium (dissolved) | µg/L | - | 0.8 | 510 | - | ND(0.2) | ND(0.2) |
| Tin (dissolved) | µg/L | - | - | - | - | ND(1) | ND(1) |
| Titanium (dissolved) | µg/L | - | - | - | - | ND(1) | 1 |
| Uranium (dissolved) | µg/L | 33 | 15 | 420 | 248 | 0.53 | 1.1 |
| Vanadium (dissolved) | µg/L | - | - | 250 | - | ND(1) | ND(1) |
| Zinc (dissolved) | µg/L | - | 30 | 1100 | - | ND(3) | ND(3) |
| ***Polychlorinated Biphenyls (PCBs)*** | | | | | | | |
| Aroclor-1016 (PCB-1016) | µg/L | - | - | - | - | ND(0.01) | ND(0.01) |
| Aroclor-1221 (PCB-1221) | µg/L | - | - | - | - | ND(0.01) | ND(0.01) |
| Aroclor-1232 (PCB-1232) | µg/L | - | - | - | - | ND(0.01) | ND(0.01) |
| Aroclor-1242 (PCB-1242) | µg/L | - | - | - | - | ND(0.01) | ND(0.01) |
| Aroclor-1248 (PCB-1248) | µg/L | - | - | - | - | ND(0.01) | ND(0.01) |
| Aroclor-1254 (PCB-1254) | µg/L | - | - | - | - | ND(0.01) | ND(0.01) |
| Aroclor-1260 (PCB-1260) | µg/L | - | - | - | - | 0.03 | ND(0.01) |
| Aroclor-1262 (PCB-1262) | µg/L | - | - | - | - | ND(0.01) | ND(0.01) |
| Aroclor-1268 (PCB-1268) | µg/L | - | - | - | - | ND(0.01) | ND(0.01) |
| Total PCBs | µg/L | - | 0.001 | 7.8 | 0.39 | 0.03 | ND(0.01) |
| ***Petroleum Hydrocarbons*** | | | | | | | |
| Petroleum hydrocarbons F1 (C6-C10) | µg/L | - | - | 750 | - | ND(25) | ND(25) |
| Petroleum hydrocarbons F1 (C6-C10) - less BTEX | µg/L | - | - | 750 | - | ND(25) | ND(25) |
| Petroleum hydrocarbons F2 (C10-C16) | µg/L | - | - | 150 | - | ND(100) | ND(100) |
| Petroleum hydrocarbons F3 (C16-C34) | µg/L | - | - | 500 | - | ND(200) | ND(200) |
| Petroleum hydrocarbons F4 (C34-C50) | µg/L | - | - | 500 | - | ND(200) | ND(200) |
| ***General Chemistry*** | | | | | | | |
| Cyanide (total) | µg/L | - | 5 | 66 | - | ND(2) | ND(2) |
| pH, lab | s.u. | - | 6.5-9 | - | - | 7.91 | 7.92 |

Notes:

| | |
|---|---|
| 1 | Canadian Environmental Quality Guidelines Summary Tables, Water Quality Guidelines for the Protection of Aquatic, Freshwater, dated 1999, updated 2012. |
| a | Short Term Guidelines |
| b | Long Term Guidelines |
| c | Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act, Table 3: Full Depth Generic Site Condition Standards in a Non-Potable Ground Water Condition (coarse-textured soils), dated April 15, 2011 |
| d | Site-specific Risk-Based Concentrations (RBCs) were developed by CRA in 2013 (Reference Appendix B) |
| **1.0** | Exceeds noted standard. |
| J | Value is estimated. |
| ND(0.01) | Value was not detected above the laboratory detection limit in brackets. |

# Attachment 1

**Memorandum- Development of Soil Risk-Based Concentrations**

CONESTOGA-ROVERS & ASSOCIATES

651 Colby Drive, Waterloo, Ontario, Canada N2V 1C2
Telephone: (519) 884-0510 Fax: (519) 884-0525
www.CRAworld.com

# MEMORANDUM

TO: Lindsay Shepherd

VN

FROM: Nicole Knezevich/Vincent Nero/kf/2

REF. NO.: 082415

DATE: August 29, 2013
REVISED: May 14, 2014

**RE: Development of Soil Risk-Based Concentrations**
**Iqaluit International Airport**
**Iqaluit, Nunavut**

## 1.0 INTRODUCTION

Conestoga-Rovers & Associates (CRA) has prepared this memorandum to present the development of Risk-Based Concentrations (RBCs) for soil for the Iqaluit International Airport located in Iqaluit, Nunavut (Property or Site). These soil RBCs are considered to be protective of human and/or ecological receptors that may potentially be in contact with soil at the Site. Where soil concentrations are greater than the soil RBCs, the impacted soil could be remediated, or managed in such a way to prevent detrimental exposure from occurring.

## 2.0 DEVELOPMENT OF SOIL RBCs

This section presents the methodology for the development of soil RBCs that are protective of human and ecological receptors.

RBCs were identified/calculated for the parameters identified in Section 2.1, and for the following potential exposure pathways:

- Commercial worker direct contact (incidental ingestion and dermal contact) with soil– Section 2.2
- Commercial worker inhalation of vapours (indoor air)– Section 2.3
- Construction/utility worker direct contact (incidental ingestion, dermal contact, and ambient air inhalation) with soil – Section 2.4
- Trespasser direct contact (incidental ingestion, dermal contact, and ambient air inhalation) with soil – Section 2.4
- Plants and soil organisms direct contact with soil – Section 2.5

## 2.1 SOIL PARAMETERS

Soil samples collected from the Site during test pitting activities (July 2013) and during decommissioning of a land treatment unit (July 2011), identified the presence of petroleum hydrocarbons (PHCs), arsenic, and naphthalene at concentrations greater than the Canadian Council of Ministers of the Environment (CCME)

Tier 1 Industrial Guidelines that are protective of direct contact with soil (human and ecological receptors) and protective of aquatic ecological receptors from exposure to impacted soil leaching to groundwater with eventual discharge to a waterbody (CCME, 2010; 2011). Soil RBCs have been identified/calculated for parameters that exceeded the CCME Tier 1 Industrial Guidelines in soil proposed to be used within secure areas of the project works.

Soil RBCs were identified/calculated for the parameters summarized below:

- Arsenic
- Naphthalene
- PHC F2
- PHC F3

## 2.2 COMMERCIAL WORKER DIRECT CONTACT WITH SOIL

The RBCs for the commercial worker direct contact (incidental ingestion and dermal contact) with soil were obtained directly from CCME (1997; 2008; 2010). For arsenic, the soil quality guideline for human health for commercial land use (CCME, 1997), which is based on a soil ingestion guideline value, was applied after being adjusted to an incremental cancer risk of 1.0E-05 (Health Canada, 2012a). As CCME (2010) has not derived soil quality guidelines for human health for direct contact (ingestion, inhalation, and dermal exposure) for non-carcinogenic PAHs, no value was available for naphthalene. For PHC F2 and F3, the Direct Contact (ingestion and dermal contact) Tier 1 Levels for coarse-grained soil and commercial land use (CCME, 2008) were applied.

## 2.3 COMMERCIAL WORKER INHALATION OF VAPOURS (INDOOR AIR)

For PHC F2, the Vapour Inhalation (indoor) Tier 1 Level for coarse-grained soil and commercial land use was applied as the RBC for the commercial worker inhalation of vapours via indoor air. As CCME (2010) has not derived soil quality guidelines for human health for protection of indoor air quality for non-carcinogenic PAHs, no value was available for naphthalene. As arsenic and PHC F3 are not considered to be volatile this exposure pathway is not applicable. Therefore, no soil RBCs were applied for arsenic and PHC F3 for the inhalation of vapours via indoor air.

## 2.4 CONSTRUCTION/UTILITY WORKER AND TRESPASSER

As there are no CCME soil guidelines available for the construction/utility worker or trespasser, RBCs were developed for these receptors. The construction/utility worker is assumed to be an adult conducting ground intrusive activities (i.e., during maintenance of a subsurface utility) at the Site for 8 hours/day, 6 days/week for 13 weeks/year. The construction/utility worker could potentially be exposed to soil through incidental ingestions and dermal contact with exposed skin on the hands, arms, and legs. In addition, inhalation of volatile parameters in ambient air emitted from soil or parameters within windblown particulates could also occur during work completed in the immediate vicinity of the excavation.

The trespasser is assumed to be a teenager trespassing on the Site for 2 hours/day, 2 days/week for 35 weeks/year. The trespasser may be exposed to soil through incidental ingestion and dermal contact

through exposed skin on the hands, arms, and legs. The trespasser may also be exposed to volatile compounds in the ambient air or parameters within windblown particles.

The RBCs developed for the construction/utility worker and trespasser incidental ingestion, dermal contact, and inhalation exposure to soil were derived based on the following equations. For each parameter, two risk-based concentrations were initially developed if toxicity data was available: one protective of carcinogenic health impacts and a second protective of non-carcinogenic health impacts. The RBC for each particular exposure pathway was determined to be the lower value between carcinogenic and non-carcinogenic health impacts.

Carcinogenic Endpoint:

$$RBC_{soil} = \frac{TR \times ATc}{EF \times ED \times (((CSF \times IR \times CF \times RAFo)/BW) + (CSF \times SA \times AF \times CF \times RAFd)/BW) + (URF \times ET \times (VF \text{ or } PEF)))))}$$

Non-Carcinogenic Endpoint:

$$RBC_{soil} = \frac{THQ \times ATnc}{EF \times ED \times ((((1/RfD) \times IR \times CF \times RAFo)/BW) + ((1/RfD) \times SA \times AF \times CF \times RAFd)/BW) + ((1/RfC) \times ET \times (VF \text{ or } PEF)))))}$$

Where:

$RBC_{soil}$ = Risk-Based Concentration in soil based on oral, dermal, and inhalation exposure (mg/kg)
$TR$ = Target Cancer Risk
$THQ$ = Target Hazard Quotient
$BW$ = Body Weight (kg)
$CF$ = Conversion factor (kg/mg)
$CSF$ = Cancer Slope Factor - dermal - chemical-specific $(mg/kg/day)^{-1}$
$URF$ = Inhalation Unit Risk Factor – chemical-specific $(mg/m^3)^{-1}$
$RfD$ = Reference Dose Factor - dermal - chemical-specific (mg/kg/day)
$RfC$ = Reference Concentration – inhalation – chemical-specific $(mg/m^3)$
$IR$ = Ingestion rate (mg/day)
$RAFo$ = Relative Absorption Factor – Oral (% /100)
$SA$ = Surface Area Exposed $(cm^2)$
$AF$ = Adherence Factor $(mg/cm^2)$
$RAFd$ = Relative Absorption Factor – Dermal (% /100)
$ET$ = Exposure Time – inhalation (hours/24 hours)
$VF$ = Volatilization Factor – inhalation - chemical-specific $(L/m^3)$
$EF$ = Exposure Frequency (days/year)
$ED$ = Exposure Duration (years)
$ATc$ = Averaging Time – carcinogen (days)
$ATnc$ = Averaging Time - non-carcinogen (days)
$PEF$ = Particulate Emission Factor $(kg/m^3)$

The receptor-specific exposure assumptions for the construction/utility worker and trespasser applied in the derivation of the soil RBCs are summarized in the table below.

| *Parameter* | *Receptor Characteristics* | | *Reference* |
|---|---|---|---|
| | *Construction/Utility Worker* | *Trespasser* | |
| Ingestion Rate (IR) | 100 mg/day | 20 mg/day | Health Canada, 2012a |
| Relative Absorption Factor – Oral | Chemical-specific | | Health Canada, 2010 |
| Surface Area Exposed - adult | 5,000 $cm^2$/day (1) | 4,400 $cm^2$/day (2) | Health Canada, 2012a |
| Adherence Factor | 0.1 mg/$cm^2$ (hands)<br>0.01 mg/$cm^2$ (rest of body) | | Health Canada, 2012a |
| Relative Absorption Factor – Dermal | Chemical-specific | | Health Canada, 2010 |
| Exposure Frequency (EF) | 78 days/year (3) | 70 days/year (4) | Professional Judgment |
| Exposure Duration (ED) | 1 year (5) | 8 years | Professional Judgment; Health Canada, 2012a |
| Exposure Time (ET)– Inhalation | 8 hours/24 hours | 2 hours/24 hours (6) | Health Canada, 2012a; Professional Judgment |
| Body Weight (BW) | 70.7 kg | 59.7 kg | Health Canada, 2012a |
| Conversion Factor (CF) | 1.0E-06 kg/mg | | -- |
| Averaging Time (cancer) (ATc) | 21,900 days (7) | 29,200 days (8) | Health Canada, 2012a |
| Averaging Time (non-cancer) (ATnc) | 365 days | 2,920 days | Health Canada, 2012a |
| Particulate Emission Factor (PEF) | 2.50E-07 kg/$m^3$ | 7.60E-10 kg/$m^3$ | Health Canada, 2012a |
| Volatilization Factor (VF) | Chemical-specific | | Refer to Tables 2 and 4 |

Notes:

(1) Skin surface area includes hands (890 $cm^2$), lower arms (2500/2 $cm^2$), and lower legs (5720/2 $cm^2$).
(2) Skin surface area includes hands (800 $cm^2$), lower arms (2230/2 $cm^2$), and lower legs (4970/2 $cm^2$).
(3) Professional Judgment; 6 days per week for 13 weeks per year.
(4) Professional Judgment; 2 days per week for 35 weeks per year.
(5) Professional Judgment; assumes construction campaign to occur over a 1-year period.
(6) Professional Judgment; assumes that the trespasser would be at the Site 2 hours per day.
(7) Averaging time is for the duration of adulthood (60 years).
(8) Averaging time is the lifetime expectancy (80 years).

Table 1 presents the derivation of the pathway-specific RBCs for the construction/utility worker direct contact (incidental ingestion, dermal contact, and inhalation) exposure to soil, which have been summarized in Section 3.0. Table 3 presents the derivation of the pathway-specific RBCs for the trespasser direct contact (incidental ingestion, dermal contact, and inhalation) exposure to soil.

The inhalation of compounds within vapour originating from soil is modelled through the use of a VF to estimate ambient air concentrations based on the soil concentration. The VF is chemical-specific and was calculated using the approach presented by USEPA (2002). Chemical specific properties were obtained from CCME (2008; 2010), with MOE (2011) used as a secondary source. The VFs used in the calculation of

inhalation exposure to soil in ambient air for the construction/utility worker and the trespasser are presented in Tables 2 and 4, respectively.

The toxicity values used in the calculation of the soil RBCs included cancer slope factors (CSFs) and unit risk factors (URFs) for carcinogenic effects, and chronic reference doses (RfDs) and reference concentrations (RfCs) for non-carcinogenic effects. All toxicity values were obtained from Health Canada (2010) and CCME (2008) for the PHCs. For naphthalene, a proposed residential indoor air quality guideline was applied as the RfC (Health Canada, 2012b). The human health RBCs are calculated using an acceptable cancer risk target level ($10^{-5}$, or one in a hundred thousand) and non-cancer hazard target level (0.2 or 0.5 for PHCs) (Health Canada, 2012a; CCME, 2008).

## 2.5 PLANTS AND SOIL ORGANISMS

The RBCs for the ecological receptors direct soil contact were obtained directly from CCME (1997; 2008; 2010). For arsenic, the soil quality guideline for environmental health for commercial land use (CCME, 1997) was applied. For PHC F2 and F3, Ecological Soil Contact Tier 1 Levels for coarse-grained surface soil from CCME (2008) were applied. For naphthalene, the provisional soil quality guideline for the protection of environmental health (CCME, 2010) was applied.

## 3.0 SUMMARY OF SOIL RBCs

The soil RBCs are presented in Table 5 and summarized in the table below. The final soil RBC represents the lower of the pathway-specific RBCs calculated for the human health receptors (commercial worker, construction worker, and trespasser) and the ecological receptors. The maximum soil concentration of each parameter was compared to the final RBC.

| *Parameter* | *Human Health RBC (µg/g)* | *Ecological RBC (µg/g)* | *Final Soil RBC (1) (µg/g)* | *Maximum Soil Concentration (mg/kg)* | *Risk Management Measures Required* |
|---|---|---|---|---|---|
| **Arsenic** | **31** | **26** | **26** | **100** | **Yes** |
| Naphthalene | 1,951 | 22 | 22 | 0.26 | No |
| **PHC F2** | **1,700** | **260** | **260** | **3,000** | **Yes** |
| **PHC F3** | **23,000** | **1,700** | **1,700** | **2,300** | **Yes** |

Notes:

**Bold**, Maximum soil concentration exceeds the final soil RBC

(1) Final RBC is the lowest of the human and ecological RBCs.

The maximum concentration of arsenic, PHC F2, and PHC F3 exceed the final soil RBCs, as a result, the impacted soil must be managed in such a way to prevent detrimental exposure from occurring through the following pathways:

- Commercial worker direct contact (incidental ingestion and dermal contact) with soil
- Commercial worker inhalation of vapours (indoor air)
- Plants and soil organisms direct contact with soil

## 4.0 RISK MANAGEMENT MEASURES

In 2011, a land treatment unit (LTU) was partially decommissioned at the Iqaluit Airport. PHC-impacted soil from the LTU was excavated and relocated into two adjacent LTUs, also containing PHC-impacted soil. Recent test pitting activities also identified the presence of arsenic-impacted soil adjacent to the airport runway. Proposed improvements to the airport include the construction of a taxiway through the area where the partially decommissioned and existing LTUs are located and installation of a utility corridor adjacent to the runway. As such, the LTUs must be decommissioned and the arsenic and PHC-impacted soil must be managed. It is proposed that the arsenic and PHC-impacted soil will be used as fill during the airport improvement activities. However, as several parameters exceed their respective final soil RBCs, the soils must be managed to prevent exposure from occurring.

Soil Management

If these impacted soils are excavated and temporarily stockpiled pending future re-use, these impacted soils will need to be managed to prevent exposure. In these instances, excavated impacted soils should be placed in a designated area. The stockpiles should be located away from publicly accessible areas, other than those of a very temporary nature (less than 48 hours). Stockpiled soils should be covered for dust control and to prevent impact to storm water runoff. Stockpiled soils should be placed on a liner, if practical, to prevent leaching to the subsurface. It is also recommended that fencing be placed around these stockpiled soils and signs put up to prevent unauthorized access.

Soil Cover

Arsenic, PHC F2, and PHC F3 exceeded the pathway specific RBCs for commercial workers and ecological receptors for direct contact with soil. As a result, soil excavated from the vicinity of TP15, LTU-1, LTU-2, TP24, LTU-BOTTOM 6, LUT-BOTTOM 8, LTU-WEST 1, and LTU-EAST 1 could be reused at the Site as long as they are maintained under a soil cover. This soil cover may consist of a hard cap, such as asphalt or concrete (i.e., taxi pavement or runways) or a clean fill cap.

Inhalation of Vapours (Indoor Air)

PHC F2 exceeded the pathway specific RBC for the commercial worker inhalation of vapours via indoor air. As a result, soil excavated from the vicinity of LTU-2 should not be used as fill under a building or within 30 metres of any building.

## 5.0 REFERENCES

CCME, 1997. Canadian soil quality guidelines for the protection of environmental and human health: Arsenic (inorganic). Updated In: 1999.

CCME, 2008. Canada-Wide Standards for Petroleum Hydrocarbons (PHCs) in Soil: Scientific Rationale. Supporting Technical Document. January 2008.

CCME, 2010. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health – Polycyclic Aromatic Hydrocarbons.

CCME, 2011. Canadian Environmental Quality Guidelines for the Protection of Environmental and Human Health, Summary Tables – Soil, Land Industrial Use.

Health Canada, 2010. Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, Version 2.0, September 2010.

Health Canada, 2012a. Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0, September 2012.

Health Canada, 2012b. Public Consultation on Proposed Residential Indoor Air Quality Guideline for Naphthalene. December 2012.

Biogenie, 2012. Land Treatment Unit Decommissioning, Iqaluit Airport.

MOE, 2011. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario, April 15, 2011.

USEPA, 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. Office of Emergency and Remedial Response. OSWER 9355.4-24, December 2002.

**TABLE 1**

**DERIVATION OF RISK-BASED CONCENTRATIONS IN SOIL - CONSTRUCTION/UTILITY WORKER ORAL, DERMAL, AND INHALATION EXPOSURE**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| | CSF | | URF | RfD | | RfC | | Relative Absorption Factor | | | Construction/ Utility Worker RBCs | | | Risk-Based Concentrations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | oral | dermal | inhalation | oral | dermal | inhalation | | Oral | Dermal | VF | Cancer | Non-Cancer | | $RBC_{soil}$ (1) |
| *Parameters* | *1/(mg/kg-d)* | *1/(mg/kg-d)* | *1/(mg/kg-d)* | *(mg/kg-d)* | *(mg/kg-d)* | *($mg/m^3$)* | | *(%/100)* | *(%/100)* | *($kg/m^3$)* | *(mg/kg)* | *(mg/kg)* | | *(mg/kg)* |
| ***Metals*** | | | | | | | | | | | | | | |
| Arsenic | 1.80E+00 | 1.80E+00 | 6.40E+00 | -- | -- | -- | | 1 | 0.03 | NA | 8.83E+02 | NV | | 883 |
| ***PAHs*** | | | | | | | | | | | | | | |
| Naphthalene | -- | -- | -- | 2.00E-02 | 2.00E-02 | 1.00E-02 | (2) | 1 | 0.148 | 1.51E-04 | NV | 6.28E+03 | | 6,283 |
| ***PHCs*** | | | | | | | | | | | | | | |
| PHC F2 | | | | | | | | | | | | 9.27E+04 | (3) | 92,670 |
| Aliphatic (C10-C12) | -- | -- | -- | 1.00E-01 | 1.0E-01 | 1.00E+00 | | 1 | 0.2 | 6.05E-04 | NV | 1.15E+05 | | |
| Aliphatic (C12-C16) | -- | -- | -- | 1.00E-01 | 1.0E-01 | 1.00E+00 | | 1 | 0.2 | 2.84E-04 | NV | 1.23E+05 | | |
| Aromatic (C10-C12) | -- | -- | -- | 4.00E-02 | 4.0E-02 | 2.00E-01 | | 1 | 0.2 | 2.07E-04 | NV | 4.78E+04 | | |
| Aromatic (C12-C16) | -- | -- | -- | 4.00E-02 | 4.0E-02 | 2.00E-01 | | 1 | 0.2 | 9.05E-05 | NV | 5.03E+04 | | |
| PHC F3 | | | | | | | | | | | | 1.86E+05 | (3) | 185,752 |
| Aliphatic (C16-C21) | -- | -- | -- | 2.00E+00 | 2.00E+00 | -- | | 1 | 0.2 | NA | NV | 2.63E+06 | | |
| Aliphatic (C21-C34) | -- | -- | -- | 2.00E+00 | 2.00E+00 | -- | | 1 | 0.2 | NA | NV | 2.63E+06 | | |
| Aromatic (C16-C21) | -- | -- | -- | 3.00E-02 | 3.00E-02 | -- | | 1 | 0.2 | NA | NV | 3.94E+04 | | |
| Aromatic (C21-C34) | -- | -- | -- | 3.00E-02 | 3.00E-02 | -- | | 1 | 0.2 | NA | NV | 3.94E+04 | | |

Notes:

-- = Not Available
NA = Not Applicable
NV = No Value
(1) The selected RBC is the lower of the carcinogenic-based concentration and the non-carcinogenic-based concentration.
(2) Proposed residential indoor air quality guideline for naphthalene (Health Canada, 2012a).
(3) RBCs for PHC Fractions are determined from the relationship $C_{soil}$ Fraction i = $1/\Sigma(MF_{subfractionj}/C_{gw\ subfractionj})$, where $MF_{subfractionj}$ is the mass fraction of each sub-fraction within Fraction i (CCME, 2008; Table B.4).

Construction/ Utility Worker Exposure Assumptions

| | | | |
|---|---|---|---|
| Risk-Based Concentration in Soil (mg/kg) | $RBC_{soil}$ | calculated | |
| Target Risk Level (unitless) | TR | 1.0E-05 | Health Canada, 2012b |
| Target Hazard Level (unitless) | THQ | 0.2 | Health Canada, 2012b |
| Target Hazard Level for PHCs (unitless) | THQ | 0.5 | CCME, 2008 |
| Cancer Slope Factor (per mg/kg-day) | CSF | chemical-specific | Health Canada, 2010 |
| Reference Dose Factor (mg/kg-day) | RfD | chemical-specific | Health Canada, 2010; CCME, 2008 |
| Unit Risk Factor ($1/(mg/m^3)$) | URF | chemical-specific | Health Canada, 2010 |
| Reference Concentration ($mg/m^3$) | RfC | chemical-specific | Health Canada, 2010; CCME, 2008 |
| Ingestion Rate (mg/day) | IR | 100 | Health Canada, 2012b |
| Relative Absorption Factor - Oral (%/100) | RAFo | chemical-specific | Health Canada, 2010 |
| Surface Area Exposed ($cm^2$/day) | SA | 5,000 | Health Canada, 2012b; Skin surface area includes hands (890 cm2), lower arms (2500/2 cm2), and lower legs (5720/2 cm2) |

**TABLE 1**

**DERIVATION OF RISK-BASED CONCENTRATIONS IN SOIL - CONSTRUCTION/UTILITY WORKER ORAL, DERMAL, AND INHALATION EXPOSURE**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| | | | |
|---|---|---|---|
| Adherence Factor ($mg/cm^2$) | AF | 0.1; 0.01 | Health Canada, 2012b; Adherence factor for hands is 0.1 mg/cm2; adherence factor for rest of the body is 0.01 mg/cm2. |
| Relative Absorption Factor - Dermal (%/100) | RAFd | chemical-specific | Health Canada, 2010 |
| Exposure Time (hrs/day) | ET | 8/24 | Health Canada, 2012b |
| Exposure Frequency (days/year) | EF | 78 | Professional Judgement; 6 days per week for 13 weeks per year |
| Exposure Duration (years) | ED | 1 | Professional Judgement; assumes construction campaign to occur over a 1-year period. |
| Body Weight (kg) | BW | 70.7 | Health Canada, 2012b |
| Conversion Factor (kg/mg) | CF | 1.0E-06 | |
| Averaging Time - carc. (days) | ATc | 21,900 | Health Canada, 2012b |
| Averaging Time - noncarc. (days) | ATnc | 365 | Health Canada, 2012b |
| Particulate Emission Factor ($kg/m^3$) | PEF | 2.50E-07 | Health Canada, 2012b |
| Volatilization Factor ($kg/m^3$) | VF | chemical-specific | Refer to Table 2 |

Exposure Equations

Carcinogenic Endpoints:

$$RBC_{soil} = \frac{TR \times ATc}{EF \times ED \times [(CSF \times IR \times CF \times RAFo)/BW + (CSF \times SA \times AF \times CF \times RAFd)/BW + (URF \times ET \times (PEFor\ VF))]}$$

Non-Carcinogenic Endpoints:

$$RBC_{soil} = \frac{THQ \times ATnc}{EF \times ED \times [((1/RfD) \times IR \times CF \times RAFo)/BW + ((1/RfD) \times SA \times AF \times CF \times RAFd)/BW + ((1/RfC) \times ET \times (PEF\ or\ VF))]}$$

References:

CCME, 2008. Canada-Wide Standards for Petroleum Hydrocarbons (PHCs) in Soil: Scientific Rationale. Supporting Technical Document. January 2008.

Health Canada, 2010: Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, Version 2.0, September 2010.

Health Canada, 2012a. Public Consultation on Proposed Residential Indoor Air Quality Guideline for Naphthalene. December, 2012.

Health Canada, 2012b: Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0, September 2012.

**TABLE 2**

**DERIVATION OF VOLATILIZATION FACTOR (VF) FOR SOIL - CONSTRUCTION/UTILITY WORKER INHALATION EXPOSURE**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

$$VF = (Q/C) \times 1/F_D \times ((3.14 \times D_a \times T)^{1/2}) \times 10^{-4} / (2 \times db \times D_a)$$

$$Da = ((Pa^{10/3} \times Di \times H + Pw^{10/3} \times Dw) / n^2)/(db \times Kd + Pw + Pa \times H)$$

$$Q/C_{sa} = A \times EXP [ (\ln A_s - B)^2 / C]$$

$$F_D = 0.1852+(5.3537/t_c)+(-9.6318/t_c^2)$$

| *Input Parameters* | *Reference* | *Parameters* | | | | |
|---|---|---|---|---|---|---|
| | | Naphthalene | F2 Aliphatic (C10-C12) | F2 Aliphatic (C12-C16) | F2 Aromatic (C10-C12) | F2 Aromatic (C12-C16) |
| **VF/ volatilization factor ($kg/m^3$) =** | | **1.51E-04** | **6.05E-04** | **2.84E-04** | **2.07E-04** | **9.05E-05** |
| **VF/ volatilization factor ($m^3/kg$) =** | Equation 5-14, USEPA, 2002 | **6.61E+03** | **1.65E+03** | **3.53E+03** | **4.82E+03** | **1.10E+04** |
| Da/ apparent diffusivity ($cm^2/s$) = | Equation 5-14, USEPA, 2002 | 1.16E-05 | 1.86E-04 | 4.09E-05 | 2.19E-05 | 4.17E-06 |
| Q/C/ inverse of the mean conc. at center of square source ($g/m^2$-s per $kg/m^3$) = | Equation 5-15, USEPA, 2002 | 14.31 | 14.31 | 14.31 | 14.31 | 14.31 |
| A/ constant (unitless) = | USEPA, 2002 | 2.4538 | 2.4538 | 2.4538 | 2.4538 | 2.4538 |
| B/ constant (unitless) = | USEPA, 2002 | 17.566 | 17.566 | 17.566 | 17.566 | 17.566 |
| C/ constant (unitless) = | USEPA, 2002 | 189.0426 | 189.0426 | 189.0426 | 189.0426 | 189.0426 |
| $A_s$/ areal extent of site surface soil contamination (acres) = | USEPA, 2002 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| $F_D$/ dispersion correction factor (unitless) = | Equation E-16, USEPA, 2002 | 0.186 | 0.186 | 0.186 | 0.186 | 0.186 |
| Pa/ air-filled soil porosity ($L_{air}/L_{soil}$) = | CCME, 2008; coarse-grained soil | 0.241 | 0.241 | 0.241 | 0.241 | 0.241 |
| Di/ diffusivity in air ($cm^2/s$) = | CCME, 2008; MOE, 2011 | 5.90E-02 | 5.00E-02 | 5.00E-02 | 5.00E-02 | 5.00E-02 |
| H/ dimensionless Henry's law constant = | CCME, 2008; MOE, 2011 | 1.80E-02 | 1.20E+02 | 5.20E+02 | 1.40E-01 | 5.30E-02 |
| Pw/ water-filled soil porosity ($L_{water}/L_{soil}$) = | CCME, 2008; coarse-grained soil | 0.119 | 0.119 | 0.119 | 0.119 | 0.119 |
| Dw/ diffusivity in water ($cm^2/s$) = | MOE, 2011 | 7.50E-06 | 6.00E-06 | 6.00E-06 | 6.00E-06 | 6.00E-06 |
| n/ total soil porosity ($L_{pore}/L_{soil}$) = | CCME, 2008; coarse-grained soil | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 |
| db/ dry soil bulk density ($g/cm^3$) = | CCME, 2008; coarse-grained soil | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 |
| Kd/ soil-water partition coefficient ($cm^3/g$) = | USEPA, 2002 (Kd = Koc x foc) | 3.54E+00 | 1.26E+03 | 2.51E+04 | 1.26E+01 | 2.51E+01 |
| Koc/ soil organic carbon-water partition coefficient ($cm^3/g$) = | CCME, 2008; 2010 | 7.08E+02 | 2.51E+05 | 5.01E+06 | 2.51E+03 | 5.01E+03 |
| foc/ organic carbon content of soil ($g/g$) = | CCME, 2008 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |
| $t_c$/ exposure interval (hrs) = | Site-Specific | 8.76E+03 | 8.76E+03 | 8.76E+03 | 8.76E+03 | 8.76E+03 |
| T/ exposure interval (s) = | Site-Specific | 3.15E+07 | 3.15E+07 | 3.15E+07 | 3.15E+07 | 3.15E+07 |
| Conversion Factor/ $10^{-4}$ ($m^2/cm^2$) = | USEPA, 2002 | 1.00E-04 | 1.00E-04 | 1.00E-04 | 1.00E-04 | 1.00E-04 |

References:

CCME, 2008. Canada-Wide Standard for Petroleum Hydrocarbons (PHC) in Soil: Scientific Rationale, Supporting Technical Document. January 2008.

CCME, 2010. Canadian Soil Quality Guidelines - Carcinogenic and Other Polycyclic Aromatic Hydrocarbons (PAHs), Environmental and Human Health Effects, Scientific Criteria Document.

MOE, 2011: Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario, Appendix B, April 15, 2011.

USEPA, 2002: Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites, Office of Emergency and Remedial Response, OSWER 9355.4-24, December 2002.

**TABLE 3**

**DERIVATION OF RISK-BASED CONCENTRATIONS IN SOIL - TRESPASSER ORAL, DERMAL, AND INHALATION EXPOSURE**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| *Chemicals of Potential Concern* | *CSF* | | *URF* | *RfD* | | *RfC* | | *Relative Absorption Factor* | | *VF* | *Trespasser (Teen) RBC* | | | *Risk-Based Concentration* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *oral* | *dermal* | *inhalation* | *oral* | *dermal* | *inhalation* | | *Oral* | *Dermal* | | *Cancer* | *Non-Cancer* | | *RBC $_{soil}$ (1)* |
| | *1/(mg/kg-d)* | *1/(mg/kg-d)* | *1/(mg/kg-d)* | *(mg/kg-d)* | *(mg/kg-d)* | *(mg/m$^3$)* | | *(%/100)* | *(%/100)* | *(kg/m$^3$)* | *(mg/kg)* | *(mg/kg)* | | *(mg/kg)* |
| ***Metals*** | | | | | | | | | | | | | | |
| Arsenic | 1.80E+00 | 1.80E+00 | 6.40E+00 | -- | -- | -- | | 1 | 0.03 | NA | 7.36E+02 | NV | | 736 |
| ***PAHs*** | | | | | | | | | | | | | | |
| Naphthalene | -- | -- | -- | 2.00E-02 | 2.00E-02 | 1.00E-02 | (2) | 1 | 0.148 | 6.04E-05 | NV | 1.95E+03 | | 1,951 |
| ***PHCs*** | | | | | | | | | | | | | | |
| PHC F2 | | | | | | | | | | | | 1.10E+05 | (2) | 109,704 |
| Aliphatic (C10-C12) | -- | -- | -- | 1.00E-01 | 1.0E-01 | 1.00E+00 | | 1 | 0.2 | 2.42E-04 | NV | 9.52E+04 | | |
| Aliphatic (C12-C16) | -- | -- | -- | 1.00E-01 | 1.0E-01 | 1.00E+00 | | 1 | 0.2 | 9.02E-05 | NV | 1.77E+05 | | |
| Aromatic (C10-C12) | -- | -- | -- | 4.00E-02 | 4.0E-02 | 2.00E-01 | | 1 | 0.2 | 6.60E-05 | NV | 5.72E+04 | | |
| Aromatic (C12-C16) | -- | -- | -- | 4.00E-02 | 4.0E-02 | 2.00E-01 | | 1 | 0.2 | 2.88E-05 | NV | 8.66E+04 | | |
| PHC F3 | | | | | | | | | | | | 5.10E+05 | (2) | 509,848 |
| Aliphatic (C16-C21) | -- | -- | -- | 2.00E+00 | 2.00E+00 | -- | | 1 | 0.2 | NA | NV | 7.21E+06 | | |
| Aliphatic (C21-C34) | -- | -- | -- | 2.00E+00 | 2.00E+00 | -- | | 1 | 0.2 | NA | NV | 7.21E+06 | | |
| Aromatic (C16-C21) | -- | -- | -- | 3.00E-02 | 3.00E-02 | -- | | 1 | 0.2 | NA | NV | 1.08E+05 | | |
| Aromatic (C21-C34) | -- | -- | -- | 3.00E-02 | 3.00E-02 | -- | | 1 | 0.2 | NA | NV | 1.08E+05 | | |

Notes:

-- = Not Available

NA = Not Applicable

NV = No Value

(1) The selected RBC is the lower of the carcinogenic-based concentration and the non-carcinogenic-based concentration.

(2) Proposed residential indoor air quality guideline for naphthalene (Health Canada, 2012a).

(3) RBCs for PHC Fractions are determined from the relationship $C_{soil}$ Fraction i = $1/\Sigma(MF_{subfractionj}/C_{gw\ subfractionj})$, where $MF_{subfractionj}$ is the mass fraction of each sub-fraction within Fraction i (CCME, 2008; Table B.4).

Trespasser Exposure Assumptions

| | | | |
|---|---|---|---|
| Risk-Based Concentration in Soil (mg/kg) | $RBC_{soil}$ | calculated | |
| Target Risk Level (unitless) | TR | 1.0E-05 | Health Canada, 2012b |
| Target Hazard Level (unitless) | THQ | 0.2 | Health Canada, 2012b |
| Target Hazard Level for PHCs (unitless) | THQ | 0.5 | CCME, 2008 |
| Cancer Slope Factor (per mg/kg-day) | CSF | chemical-specific | Health Canada, 2010 |
| Reference Dose Factor (mg/kg-day) | RfD | chemical-specific | Health Canada, 2010; CCME, 2008 |
| Unit Risk Factor (1/(mg/m$^3$)) | URF | chemical-specific | Health Canada, 2010 |

**TABLE 3**

**DERIVATION OF RISK-BASED CONCENTRATIONS IN SOIL - TRESPASSER ORAL, DERMAL, AND INHALATION EXPOSURE**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| | | | | |
|---|---|---|---|---|
| Reference Concentration ($mg/m^3$) | RfC | chemical-specific | Health Canada, 2010; CCME, 2008 | |
| Ingestion Rate (mg/day) - Teen | IR | 20 | Health Canada, 2012b | |
| Relative Absorption Factor - Oral (%/100) | RAFo | chemical-specific | Health Canada, 2010b | |
| Surface Area Exposed ($cm^2$/day) - Teen | SA | 4,400 | Health Canada, 2012b | Skin surface area to include hands (800 $cm^2$), lower arms (2230/2 $cm^2$) and lower legs (4970/2 $cm^2$). |
| Adherence Factor ($mg/cm^2$) | AF | 0.1; 0.01 | Health Canada, 2012b | Adherence factor for hands is 0.1 $mg/cm^2$; adherence factor for rest of the body is 0.01 $mg/cm^2$. |
| Relative Absorption Factor - Dermal (%/100) | RAFd | chemical-specific | Health Canada, 2010 | |
| Exposure Time (hrs/day) | ET | 2/24 | Professional Judgment; 2 hours per day | |
| Exposure Frequency (days/year) | EF | 70 | Professional Judgment; 2 days per week for 35 weeks per year | |
| Exposure Duration (years) - Teen | ED | 8 | Health Canada, 2012b | |
| Body Weight (kg) - Teen | BW | 59.7 | Health Canada, 2012b | |
| Conversion Factor (kg/mg) | CF | 1.0E-06 | | |
| Averaging Time - carc. (days) | ATc | 29,200 | Health Canada, 2012b | |
| Averaging Time - noncarc. (days) | ATnc | 2,920 | Health Canada, 2012b | |
| Particulate Emission Factor ($kg/m^3$) | PEF | 7.60E-10 | Health Canada, 2012b | |
| Volatilization Factor ($kg/m^3$) | VF | chemical-specific | Refer to Table 4 | |

Exposure Equations

Carcinogenic Endpoints:

$$RBC_{soil} = \frac{TR \times ATc}{EF \times ED \times [(CSF \times IR \times CF \times RAFo)/BW + (CSF \times SA \times AF \times CF \times RAFd)/BW + (URF \times ET \times (VF \text{ or } PEF))]}$$

Non-Carcinogenic Endpoints:

$$RBC_{soil} = \frac{THQ \times ATnc}{EF \times ED \times [((1/RfD) \times IR \times CF \times RAFo)/BW + ((1/RfD) \times SA \times AF \times CF \times RAFd)/BW + ((1/RfC) \times ET \times (VF \text{ or } PEF))]}$$

References:

Health Canada, 2010: Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, Version 2.0, September 2010.

Health Canada, 2012a. Public Consultation on Proposed Residential Indoor Air Quality Guideline for Naphthalene. December, 2012.

Health Canada, 2012: Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0, September 2012.

MOE, 2011: Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario, Table 2.23: Toxicological Reference Values (TRVs) for Derivation of Human Health Soil & Groundwater Standards, April 15, 2011.

**TABLE 4**

**DERIVATION OF VOLATILIZATION FACTOR (VF) FOR SOIL - TRESPASSER INHALATION EXPOSURE**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

**VF: Soil-to-Air Volatilization Factor**

$$VF = Q/C \times \frac{(3.14 \times D_A \times T)^{1/2}}{(2 \times \rho_b \times D_A)} \times 10^{-4} (m^2/cm^2)$$

| | | | | *Reference* | *Units* | *Parameters* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | *Naphthalene* | *F2 Aliphatic (C10 - C12)* | *F2 Aliphatic (C12 - C16)* | *F2 Aromatic (C10 - C12)* | *F2 Aromatic (C12 - C16)* |
| | **VF** | | **soil-to-air volatilization factor** | | kg/m³ | **6.04E-05** | **2.42E-04** | **9.02E-05** | **6.60E-05** | **2.88E-05** |
| Where: | **VF** | **=** | **soil-to-air volatilization factor** | Equation 4-8, USEPA, 2002 | m³/kg | **1.65E+04** | **4.13E+03** | **1.11E+04** | **1.52E+04** | **3.47E+04** |
| | $Q/C_{vol}$ | = | inverse of mean conc - centre of square source | Equation D-3, USEPA, 2002 | (g/m²-sec)/(kg/m³) | 68.18 | 68.18 | 85.63 | 85.63 | 85.63 |
| | $D_A$ | = | apparent diffusivity | Equation 4-8, USEPA, 2002 | cm²/s | 1.16E-05 | 1.86E-04 | 4.09E-05 | 2.19E-05 | 4.17E-06 |
| | T | = | exposure interval | Site Specific | s | 2.52E+08 | 2.52E+08 | 2.52E+08 | 2.52E+08 | 2.52E+08 |
| | $r_b$ | = | soil dry bulk density | CCME, 2008; coarse-grained soil | g/cm³ | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 |

**$Q/C_{vol}$: Inverse of Mean Conc - Centre of Square Source**

$$Q/C_{vol} = A \times \exp\frac{(\ln Area - B)^2}{C}$$

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Where: | "A" | = | constant | USEPA, 2002 | | 11.911 | 11.911 | 12.8612 | 12.8612 | 12.8612 |
| | Area | = | areal extent of the site or contamination | USEPA, 2002 | acres | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| | "B" | = | constant | USEPA, 2002 | | 18.4385 | 18.4385 | 20.5164 | 20.5164 | 20.5164 |
| | "C" | = | constant | USEPA, 2002 | | 209.7845 | 209.7845 | 237.2798 | 237.2798 | 237.2798 |

**$D_A$: Apparent Diffusivity**

$$D_A = \frac{\left[\left(\Theta_a^{10/3} D_i H' + \Theta_w^{10/3} D_w\right) n^2\right]}{\rho_b K_d + \Theta_w + \Theta_a H'}$$

| | | | | | *Units* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Where: | $D_A$ | = | apparent diffusivity | Equation 4-8, USEPA, 2002 | cm²/s | 1.16E-05 | 1.86E-04 | 4.09E-05 | 2.19E-05 | 4.17E-06 |
| | $Q_a$ | = | air-filled porosity | CCME, 2008; coarse-grained soil | unitless | 0.241 | 0.241 | 0.241 | 0.241 | 0.241 |
| | $Q_w$ | = | water-filled porosity | CCME, 2008; coarse-grained soil | unitless | 0.119 | 0.119 | 0.119 | 0.119 | 0.119 |
| | n | = | total soil porosity | CCME, 2008; coarse-grained soil | unitless | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 |
| | $r_b$ | = | soil dry bulk density | CCME, 2008; coarse-grained soil | g/cm³ | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 |
| | H' | = | dimensionless Henry's Law Constant | CCME, 2008; MOE, 2011 | unitless | 1.80E-02 | 1.20E+02 | 5.20E+02 | 1.40E-01 | 5.30E-02 |
| | $D_i$ | = | diffusivity of chemical x in air | CCME, 2008; MOE, 2011 | cm²/s | 5.90E-02 | 5.00E-02 | 5.00E-02 | 5.00E-02 | 5.00E-02 |
| | $D_w$ | = | diffusivity of chemical x in water | MOE, 2011 | cm²/s | 7.50E-06 | 6.00E-06 | 6.00E-06 | 6.00E-06 | 6.00E-06 |
| | $K_d$ | = | soil-water partition coefficient | USEPA, 2002 | cm³/g | 3.54E+00 | 1.26E+03 | 2.51E+04 | 1.26E+01 | 2.51E+01 |

**Kd: Soil-Water Partition Coefficient**

$$K_d = K_{oc} \times f_{oc}$$

| | | | | | *Units* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Where: | $K_d$ | = | soil-water partition coefficient | USEPA, 2002 | cm³/g | 3.54E+00 | 1.26E+03 | 2.51E+04 | 1.26E+01 | 2.51E+01 |
| | $K_{oc}$ | = | soil organic carbon-water partition coefficient | CCME, 2008 | cm³/g | 7.08E+02 | 2.51E+05 | 5.01E+06 | 2.51E+03 | 5.01E+03 |
| | $f_{oc}$ | = | organic content of soil | CCME, 2008 | g/g | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |

References:

CCME, 2008. Canada-Wide Standard for Petroleum Hydrocarbons (PHC) in Soil: Scientific Rationale, Supporting Technical Document. January 2008.

MOE, 2011: Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario, Appendix B, April 15, 2011.

USEPA, 2002: Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites, Office of Emergency and Remedial Response, OSWER 9355.4-24, December 2002.

**TABLE 5**

**SUMMARY OF SOIL RISK-BASED CONCENTRATIONS**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| | *RBCs Per Exposure Pathway (Table Reference)* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Human RBCs* | | | | *Ecological RBCs* | | | | |
| *Parameter* | *Commerical Worker Direct Contact with Soil (Ingestion and Dermal) (1)* | *Construction Worker Direct Contact with Soil (Ingestion, Dermal, and Inhalation) (Table 1)* | *Trespasser Direct Contact with Soil (Ingestion, Dermal, and Inhalation) (Table 3)* | *Vapour Inhalation (Indoor Air) (1)* | *Ecological Soil Contact (1)* | *Final Soil RBC Value* (2) | *Maximum Soil Concentration (mg/kg)* | *Risk Management Measures Required* | *Proposed Risk Management Measure (3)* |
| **Metals** | | | | | | | | | |
| Arsenic | **31 (4)** | 883 | 736 | NA | **26** | 26 | 100 | Yes | A |
| **PAHs** | | | | | | | | | |
| Naphthalene | NV | 6,283 | 1,951 | NV | 22 (5) | 22 | 0.26 | No | -- |
| **PHCs** | | | | | | | | | |
| PHC F2 | 10,000 | 92,670 | 109,704 | **1,700** | **260** | 260 | 3,000 | Yes | A, B |
| PHC F3 | 23,000 | 185,752 | 509,848 | NA | **1,700** | 1,700 | 2,300 | Yes | A |

Notes:
NV, no value
NA, not applicable as parameter is not considered to be volatile
**Bold**, the maximum soil concentration exceeds the pathway specific RBC
The maximum soil concentration exceeds the final soil RBC value.

(1) Direct contact with soil risk-based concentrations were obtained from CCME (1997) for arsenic, CCME (2010) for PAHs, and CCME (2008) for PHCs. For PHCs, coarse-grained soil Tier 1 Values were applied.

(2) The final RBC value is the lowest of the human and ecological RBC values.

(3) Risk Management Measure:
--: no risk management measure required
A: Soil Cover - to protect commerical workers and terrestrial ecological receptors (Locations of exceedance: TP15, LTU-1, LTU-2, TP24, LTU-BOTTOM 6, LTU-BOTTOM 8, LTU-WEST 1, LTU-EAST 1)
B: Vapour inhalation (indoor air) - impacted soils cannot be used as fill underneath or within 30 metres of any future building (Locations of exceedance: LTU-2)

(4) CCME soil ingestion guideline adjusted for an incremental lifetime cancer risk of 1.0E-05.

(5) Provisional soil quality guideline for the protection of environmental health (CCME, 2010).

***Sources:***

CCME, 1997. Canadian soil quality guidelines for the protection of environmental and human health: Arsenic (inorganic). Updated In: 1999.
CCME, 2008. Canada-Wide Standards for Petroleum Hydrocarbons (PHCs) in Soil: Scientific Rationale. Supporting Technical Document. January 2008.
CCME, 2010. Canadian Soil Quality Guidelines - Carcinogenic and Other Polycyclic Aromatic Hydrocarbons (PAHs), Environmental and Human Health Effects, Scientific Criteria Document.

# Attachment 2

**Memorandum- Development of Groundwater Risk-Based Concentrations**

CONESTOGA-ROVERS & ASSOCIATES

651 Colby Drive, Waterloo, Ontario, Canada N2V 1C2
Telephone: (519) 884-0510 Fax: (519) 884-0525
www.CRAworld.com

# MEMORANDUM

| | | | |
|---|---|---|---|
| TO: | Heidi Steinberg | REF. NO.: | 082415 |
| FROM: | Tina LePage/Vincent Nero/Nicole Knezevich/jh/1 | DATE: | September 9, 2013 |
| **RE:** | **Development of Groundwater Risk-Based Concentrations<br>Iqaluit International Airport<br>Iqaluit, Nunavut** | | |

## 1.0 INTRODUCTION

Conestoga-Rovers & Associates (CRA) has prepared this memorandum to present the development of Risk-Based Concentrations (RBCs) for groundwater for the Iqaluit International Airport located in Iqaluit, Nunavut (Property or Site). These groundwater RBCs are considered to be protective of human and/or ecological receptors that may potentially be in contact with groundwater at the Site. Where groundwater concentrations are greater than the groundwater RBCs, the impacted groundwater could be remediated, or managed in such a way to prevent detrimental exposure from occurring.

## 2.0 DEVELOPMENT OF GROUNDWATER RBCs

This section presents the methodology for the development of groundwater RBCs that are protective of human and ecological receptors.

RBCs were calculated for the parameters identified in Section 2.1, and for the following potential exposure pathways:

- Construction/utility worker direct contact (incidental ingestion, dermal contact, and ambient air inhalation) with groundwater during subsurface activities that reach the water table – Section 2.2
- Commercial worker inhalation of vapours (indoor air) within a building that is above the groundwater impacts – Section 2.3
- Plants and soil organisms direct contact with groundwater from directly discharging impacted groundwater at the surface – Section 2.4

## 2.1 GROUNDWATER PARAMETERS

There were two grab groundwater samples collected at the Site. Current groundwater Standards do not address the construction/utility worker and plants to soil organism exposure pathways indicated above. Therefore, groundwater RBCs were calculated for all of the parameters that were detected in the groundwater samples. However, naturally occurring elements and nutrients (aluminum, calcium, iron, magnesium, potassium, silicon, sodium, strontium, sulfur, and titanium) were not considered in the

evaluation as they are naturally occurring elements and nutrients that typically have no available toxicity data.

Groundwater RBCs were calculated for the parameters summarized below:

- Tetrachloroethene
- 2-Methylnaphthalene
- Acenaphthene
- Acenaphthylene
- Acridine
- Anthracene
- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(e)pyrene
- Benzo(g,h,i)perylene
- Benzo(k)fluoranthene
- Chrysene
- Dibenzo(a,h)anthracene
- Fluoranthene
- Fluorene
- Indeno(1,2,3-cd)pyrene
- Naphthalene
- Perylene
- Phenanthrene
- Pyrene
- Total PCBs
- Arsenic
- Boron
- Cobalt
- Copper
- Lead
- Mercury
- Molybdenum
- Nickel
- Selenium
- Uranium

Groundwater RBCs for the construction/utility worker were not derived for individual carcinogenic polycyclic aromatic hydrocarbons (PAHs). Human health effects from exposure to carcinogenic PAHs were addressed through the development of the groundwater RBC for Benzo(a)pyrene [B(a)P] total potency equivalents (TPE).

## 2.2 CONSTRUCTION/UTILITY WORKER

The RBCs developed for the construction/utility worker incidental ingestion, dermal contact, and inhalation exposure to groundwater were derived based on the following equations. For each parameter, two risk-based concentrations were initially developed if toxicity data was available: one protective of carcinogenic health impacts and a second protective of non-carcinogenic health impacts. The RBC for each particular exposure pathway was determined to be the lower value between carcinogenic and non-carcinogenic health impacts.

Carcinogenic Endpoint:

$$RBC_{gw} = \frac{TR \times ATc}{EFa \times EFb \times ED \times ((CSF \times IR/BW) + (CSF \times SA \times DAevent \times CF)/BW + (URF \times FT \times VF))}$$

Non-Carcinogenic Endpoint:

$$RBC_{gw} = \frac{THQ \times ATnc}{EFa \times EFb \times ED \times (((1/RfD) \times IR/BW) + ((1/RfD) \times SA \times DAevent \times CF)/BW) + ((1/RfC) \times FT \times VF)))}$$

Where:

$RBC_{gw}$ = Risk-Based Concentration in groundwater based on oral, dermal, and inhalation exposure (mg/L)

***TR*** = Target Cancer Risk
***THQ*** = Target Hazard Quotient
***BW*** = Body Weight (kg)
***CSF*** = Cancer Slope Factor - dermal - chemical-specific $(mg/kg/day)^{-1}$
***URF*** = Inhalation Unit Risk Factor – chemical-specific $(mg/m^3)^{-1}$
***RfD*** = Reference Dose Factor - dermal - chemical-specific (mg/kg/day)
***RfC*** = Reference Concentration – inhalation – chemical-specific $(mg/m^3)$
***IR*** = Ingestion rate (L/day)
***SA*** = Surface Area of skin exposed $(cm^2)$
$DA_{event}$ = Dermal Absorbed per Event – chemical-specific $(mg/cm^2\text{-event})$
***FT*** = Fraction of Time Exposed – inhalation (hours/24 hours) (accounts for the portion of the workday that a worker would be in the excavation and would inhale VOCs emitted from groundwater to ambient air at the base of the excavation)
***CF*** = Conversion Factor $(1.0E\text{-}03\ L/cm^3)$
***VF*** = Volatilization Factor – inhalation - chemical-specific $(L/m^3)$
***EFa*** = Exposure Frequency (weeks/year)
***EFb*** = Exposure Frequency (days/week)
***ED*** = Exposure Duration (years)
***ATc*** = Averaging Time – carcinogen (days)
***ATnc*** = Averaging Time - non-carcinogen (days)

The dose absorbed per unit area per event ($DA_{event}$) equation for calculating dermal exposure to groundwater (USEPA, 2004) is:

For Organic Parameters:

$$\textbf{If } t_{event} \le t^*\textbf{, then } DA_{event} = 2 \times FA \times K_p \times \sqrt{\frac{6 \times \tau_{event} \times t_{event}}{\pi}},$$

$$\textbf{If } t_{event} > t^*\textbf{, then } DA_{event} = FA \times K_p \times \left[ \frac{t_{event}}{1+B} + 2 \times \tau_{event} \times \left( \frac{1 + 3 \times B + 3 \times B^2}{(1+B)^2} \right) \right]$$

For Inorganic Parameters:

$$DA_{event} = K_p \times C \times t_{event}$$

Where:

***FA*** = Fraction absorbed water (dimensionless)
$K_p$ = Dermal permeability coefficient of compound in water (cm/hr)
$t_{event}$ = Event duration (hr/event)
$\tau_{event}$ = Lag time per event (hr/event)
$t^*$ = Time to reach steady state (hr) = $2.4 \times \tau_{event}$
***B*** = Dimensionless ratio of permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (dimensionless)

The receptor-specific exposure assumptions for the construction/utility worker applied in the derivation of the groundwater RBCs are summarized in the table below.

| *Parameter* | *Receptor Characteristics* | *Reference* |
|---|---|---|
| | *Construction/Utility Worker* | |
| Ingestion Rate (IR) | 0.15 litres/day | Health Canada, 2012 (1) |
| Exposure Frequency (EFa) | 13 weeks/year | Professional Judgment (2) |
| Exposure Frequency (EFb) | 6 days/week | Professional Judgment (2) |
| Exposure Duration (ED) | 1 years | Professional Judgment (3) |
| Fraction of Time Exposed (FT)– Inhalation | 8 hours/24 hours | Professional Judgment (4) |
| Exposure Time | 2 hours/day | Professional Judgment (5) |
| Event Frequency (EV) | 1 event/day | USEPA, 2004 |
| Body Weight (BW) | 70.7 kg | Health Canada, 2012 |
| Surface Area Exposed | 5,000 $cm^2$ | Health Canada, 2012 (6) |
| Conversion Factor | 0.001 $L/cm^3$ | -- |
| Dermal Absorbed per Event | Chemical-specific | Refer to Table 2 |
| Averaging Time (cancer) (ATc) | 21,900 days | Health Canada, 2012 (7) |
| Averaging Time (non-cancer) (ATnc) | 365 days | Health Canada, 2012 |
| Volatilization Factor (VF) - groundwater | Chemical-specific | Refer to Table 3 |

Notes:

(1) The incidental ingestion rate of 0.15 L/day was derived from the MOE drinking water intake rate of 1.5 L/day for an adult resident. Because the workers are not using the groundwater as a drinking water source, but instead may have only occasional limited contact, a factor of 10 was applied to arrive at the reasonable incidental ingestion rate of 0.15 L/day.

(2) Professional Judgment; assumes the construction/utility worker would be in contact with groundwater during subsurface activities for a period of 6 days per week and 13 weeks per year.

(3) Assumes construction campaign to occur over a 1-year period.

(4) Professional Judgment; based on an 8-hour work day.

(5) Professional Judgment; it is assumed that the construction/utility worker would have direct dermal contact with groundwater for 2 hours/day.

(6) Skin surface area includes hands (890 $cm^2$), lower arms (2500/2 $cm^2$), and lower legs (5720/2 $cm^2$)

(7) Averaging time is for the duration of adulthood (60 years).

The inhalation of compounds within vapour originating from groundwater is modelled through the use of a VF to estimate ambient air concentrations based on the groundwater concentration. The VF is chemical-specific and was calculated using the approach presented by USEPA (1999).

Table 1 presents the derivation of the pathway-specific RBCs for the construction/utility worker direct contact (incidental ingestion, dermal contact, and inhalation) exposure to groundwater, which have been summarized in Section 3.0. Table 2 presents the calculation of the DAevent used in the calculation of dermal exposure to groundwater. Table 3 presents the calculation of the VF used in the calculation of

inhalation exposure to groundwater. The derivation of the groundwater RBC for lead is based on USEPA's Adult Lead Model and is presented in Table 4

The toxicity values used in the calculation of the groundwater RBCs included cancer slope factors (CSFs) and unit risk factors (URFs) for carcinogenic effects, and chronic reference doses (RfDs) and reference concentrations (RfCs) for non-carcinogenic effects. All toxicity values were obtained from Health Canada (2010), with MOE (2011) applied as a secondary source. The human health RBCs are calculated using the acceptable cancer risk target level ($10^{-5}$, or one in a hundred thousand) and non-cancer hazard target level (0.2) (Health Canada, 2012).

There are no available toxicity values for acridine, phenanthrene, and perylene and therefore, RBCs could not be developed for these parameters.

### 2.3 COMMERCIAL WORKER

The groundwater RBCs developed for the commercial worker inhalation of vapours (indoor air) were derived based on the following equation. Groundwater to indoor air RBCs were only developed for identified parameters considered volatile which included: tetrachloroethene, acenaphthene, acenaphthylene, 2-methylnaphthalene, naphthalene, and mercury. The remaining parameters are high molecular weight PAHs and metals that are not likely an issue for the vapour intrusion exposure pathway.

$$RBC_{gw} = [((RBC_{ia} / \alpha) \times T) \times H] / CF$$

Where:

- $RBC_{gw}$ = Risk-Based Concentration in groundwater based on inhalation exposure (µg/L)
- $RBC_{ia}$ = Risk-Based Concentration in indoor air based on inhalation exposure (µg/m$^3$)
- $\alpha$ = Default soil vapour attenuation factor
- $T$ = Vadose zone temperature in Kelvin
- $H$ = Compound-specific dimensionless Henry's Law constant equal to $R/H_L$, where $H_L$ is the dimensioned Henry's Law constant (atmospheres cubic metres per mole [atm m$^3$/mol]) and R is the Universal Gas Law constant ($8.206 \times 10^{-3}$ atmospheres cubic metres per mole Kelvin [atm m$^3$/mol K]). The Henry's Law constants were adjusted to an average vadose zone temperature of 0°C based on professional judgment.
- $CF$ = Units conversion factor of 1,000 L/m$^3$.

The indoor air RBCs ($RBC_{ia}$) used to derive the groundwater RBCs for the inhalation of vapours (indoor air) were calculated using the equations below.

For each parameter, two RBCs were initially developed if toxicity data was available: one protective of carcinogenic health impacts and a second protective of non-carcinogenic health impacts. The RBC for each particular exposure pathway was determined to be the lower value between carcinogenic and non-carcinogenic health impacts.

Carcinogenic Endpoint:

$$RBC_{ia} = \frac{TR \times ATc}{EFa \times EFb \times FT \times ED \times URF}$$

Non-Carcinogenic Endpoint:

$$RBC_{ia} = \frac{THQ \times ATnc}{EFa \times EFb \times ED \times (1/RfC)}$$

Where:

$RBC_{ia}$ = Risk-Based Concentration in indoor air based on inhalation exposure ($\mu g/m^3$)
$TR$ = Target Cancer Risk
$THQ$ = Target Hazard Quotient
$URF$ = Inhalation Unit Risk Factor – chemical-specific $(mg/m^3)^{-1}$
$RfC$ = Reference Concentration – inhalation – chemical-specific ($mg/m^3$)
$FT$ = Fraction of Time Exposed – inhalation (hours/24 hours)
$EFa$ = Exposure Frequency (weeks/year)
$EFb$ = Exposure Frequency (days/week)
$ED$ = Exposure Duration (years)
$ATc$ = Averaging Time – carcinogen (days)
$ATnc$ = Averaging Time – non-carcinogen (days)

The receptor-specific exposure assumptions for the commercial worker applied in the derivation of the groundwater RBCs protective of indoor air are summarized in the table below.

| *Parameter* | *Receptor Characteristics* | *Reference* |
|---|---|---|
| | *Commercial Worker* | |
| Exposure Frequency (EFa) | 52 weeks/year | Health Canada, 2012 |
| Exposure Frequency (EFb) | 5 days/week | Health Canada, 2012 |
| Exposure Duration (ED) | 35 years | Health Canada, 2012 |
| Fraction of Time Exposed (FT)– Inhalation | 8 hours/24 hours | Health Canada, 2012 |
| Averaging Time (AT) – carcinogen | 21,900 days | Health Canada, 2012 |
| Averaging Time (AT) – non-carcinogen | 12,775 days | Health Canada, 2012 |

Groundwater within the excavated test pits at the Site was encountered at depths less than 1 metre below ground surface. Given the shallow depth to groundwater, a default attenuation factor of 0.004 was applied, consistent with the default attenuation factor applied by MOE (2011) for industrial/commercial buildings.

The toxicity values used in the calculation of the groundwater RBCs included cancer slope factors (CSFs) and unit risk factors (URFs) for carcinogenic effects, and chronic reference doses (RfDs) and reference concentrations (RfCs) for non-carcinogenic effects. All toxicity values were obtained from Health Canada (2010), with MOE (2011) and USEPA Integrated Risk Information System (IRIS) database applied as secondary sources. The human health RBCs are calculated using the acceptable cancer risk target level ($10^{-5}$, or one in a hundred thousand) and non-cancer hazard target level (0.2) (Health Canada, 2012).

There are no available inhalation toxicity values for 2-methylnaphthalene, therefore, an RBC could not be developed for this parameter.

Table 5 presents the derivation of the groundwater RBCs for the commercial worker inhalation of vapours in indoor air (from groundwater), which have been summarized in Section 3.0. Table 6 presents the derivation of the indoor air RBCs that were used to derive the groundwater RBCs protective of the commercial worker inhalation of vapours (indoor air) from groundwater.

## 2.4 PLANTS AND SOIL ORGANISMS

The RBCs developed for plants and soil organisms direct contact exposure to groundwater were derived based on the following equation (FCSAP, 2012).

$$RBC_{gw} = SPV \times \frac{pb}{\theta w + (koc \times foc \times pb) + (H' \times \theta a)}$$

Where:

$RBC_{gw}$ = Groundwater protection value (µg/L)
$SPV$ = Soil protection value (mg/kg)
$pb$ = Soil bulk density
$\theta w$ = Soil moisture-filled porosity
$koc$ = Organic carbon partitioning coefficient (L/kg)
$foc$ = Fraction of organic carbon
$H'$ = Dimensionless Henry's law constant
$\theta a$ = Soil vapour-filled porosity

Soil protection values (SPV) obtained from CCME (2013), MOE (2011), and USEPA (2007) were used in the calculation of the groundwater RBCs. All soil properties were obtained from FCSAP (2012).

There are no available toxicity values for benzo(e)pyrene therefore, benzo(a)pyrene was applied as a surrogate.

Table 7 presents the derivation of the pathway-specific RBCs for plants and soil organisms direct contact exposure to groundwater, which have been summarized in Section 3.0.

## 3.0 SUMMARY OF GROUNDWATER RBCs

The groundwater RBCs are presented in Table 8 and summarized in the table below. The final groundwater RBC represents the lower of the pathway-specific RBCs calculated for the construction/utility worker, commercial worker, and plants/soil organisms. The maximum groundwater concentration of each parameter was compared to the pathway-specific and final groundwater RBCs.

| *Parameter* | *Pathway-specific Groundwater RBC (µg/L)* | | | *Final Groundwater RBC (1) (µg/L)* | *Maximum Groundwater Concentration (µg/L)* |
|---|---|---|---|---|---|
| | *Construction/Utility Worker (Direct Contact)* | *Commercial Worker (Vapour Inhalation)* | *Plants and Soil Organisms (Direct Contact)* | | |
| Tetrachloroethene | 954 | 396 | 22,638 | 396 | 0.58 |
| 2-Methylnaphthalene | 164 | NV | 1,939 | 164 | 0.12 |
| Acenaphthene | 2,435 | 29,799 | 2,048 | 2,048 | 0.31 |
| Acenaphthylene | 2,344 | 38,284 | 1,029 | 1,029 | 0.032 |
| Acridine | NV | NA | 353 | 353 | 0.14 |
| Anthracene | 6,832 | NA | 321 | 321 | 0.36 |
| **Benzo(a)anthracene** | (2) | NA | **1.0** | **1.0** | **2.1** |
| Benzo(a)pyrene | (2) | NA | 6.6 | 6.6 | 2.3 |
| Benzo(b)fluoranthene | (2) | NA | 39 | 39 | 3.3 |
| Benzo(e)pyrene | (2) | NA | 6.6 | 6.6 | 2.0 |
| Benzo(g,h,i)perylene | (2) | NA | 6.4 | 6.4 | 1.2 |
| Benzo(k)fluoranthene | (2) | NA | 150 | 150 | 1.1 |
| Chrysene | (2) | NA | 22 | 22 | 1.7 |
| Dibenzo(a,h)anthracene | (2) | NA | 2.6 | 2.6 | 0.37 |
| Fluoranthene | 501 | NA | 863 | 501 | 3.3 |
| Fluorene | 1,245 | NA | 733 | 733 | 0.25 |
| **Indeno(1,2,3-cd)pyrene** | (2) | NA | **0.096** | **0.096** | **1.6** |
| Naphthalene | 43 | 276 | 6,089 | 43 | 0.11 |
| Perylene | NV | NA | 257,143 | 257,143 | 0.54 |
| Phenanthrene | NV | NA | 362 | 362 | 1.6 |
| Pyrene | 423 | NA | 52 | 52 | 2.8 |
| B(a)P TPE | 3.9 | NA | NA | 3.9 | 3.6 |
| Arsenic | 689 | NA | 894 | 689 | 0.33 |
| Boron | 7,237 | NA | NV | 7,237 | 35 |
| Cobalt | 430 | NA | 6,656 | 430 | 0.36 |
| Copper | 37,633 | NA | 2,595 | 2,595 | 3.2 |
| Lead | 434 | NA | 667 | 434 | 0.24 |
| Mercury | 1.2 | 0.42 | 960 | 0.42 | 0.17 |
| Molybdenum | 9,511,643 | NA | 1,993 | 1,993 | 4.6 |
| Nickel | 4,788 | NA | 768 | 768 | 0.81 |
| Selenium | 2,274,523 | NA | 478 | 478 | 0.26 |
| Uranium | 248 | NA | 4,444 | 248 | 1.1 |
| Total PCBs | 0.39 | NA | 21 | 0.39 | 0.03 |

Notes:

**Bold** Maximum groundwater concentration exceeds the final RBC.

B(a)P TPE – benzo(a)pyrene total potency equivalents.

NA Not applicable.

NV No value.
(1) Final RBC is the lowest of the human and ecological RBCs.
(2) Human health effects from exposure to carcinogenic PAHs have been addressed through the development of the groundwater RBC for B(a)P TPE.

As indicated in the table above, the maximum groundwater concentrations of benzo(a)anthracene and indeno(1,2,3-cd)pyrene exceed their respective final groundwater RBCs. As a result, the impacted groundwater must be managed in such a way to prevent detrimental exposure from occurring through the following pathway:

- Plants and soil organisms direct contact with groundwater

Overland Discharge of Groundwater

Benzo(a)anthracene and indeno(1,2,3-cd)pyrene exceeded the pathway specific RBCs for plants and soil organisms direct contact with groundwater. Therefore, it is not recommended that impacted groundwater encountered during subsurface activities be discharged at the surface to protect any plants and soil organisms.

## 4.0 REFERENCES

Health Canada, 2010. Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, Version 2.0, September 2010.

Health Canada, 2012. Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0, September 2012.

FCSAP, 2012. Guidance Document on Federal Interim Groundwater Quality Guidelines for Federal Contaminated Sites, Federal Contaminated Sites Action Plant, November 2012.

MOE, 2011. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario, April 15, 2011.

USEPA, 1999. Memorandum dated July 29, 1999 regarding the derivation of a volatilization factor to estimate upper bound exposure point concentration for workers in trenches flooded with ground water off-gassing volatile organic chemicals.

USEPA, 2004. USEPA Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual, (Part E, Supplemental Guidance for Dermal Risk Assessment), Final, July.

USEPA, 2007. Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs), Interim Final, OSWER Directive 9285.7-78. June.

**TABLE 1**

**DERIVATION OF RISK-BASED CONCENTRATIONS (RBCs) FOR GROUNDWATER - CONSTRUCTION/UTILITY WORKER ORAL, DERMAL, AND INHALATION EXPOSURE**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| | *Toxicity Values (1)* | | | | | | *Construction/ Utility Worker* | | *Risk-Based Concentrations (2)* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *CSF* | *URF* | *RfD* | *RfC* | | | *TR* | *THQ* | | |
| *Parameter* | *oral/dermal* | *inhalation* | *oral/dermal* | *inhalation* | *DAevent* | *VF* | *Adult* | *Adult* | $RBC_{gw}$ | |
| | *1/(mg/kg-d)* | *1/(mg/m$^3$)* | *(mg/kg-d)* | *(mg/m$^3$)* | *(cm/event)* | *(L/m$^3$)* | *(mg/L)* | *(mg/L)* | *(mg/L)* | *(µg/L)* |
| ***VOCs*** | | | | | | | | | | |
| Tetrachloroethene | 2.10E-03 | 2.60E-04 | 1.40E-02 | 3.60E-01 | 1.2E-01 | 1.9E-01 | 7.22E+01 | 9.54E-01 | 9.54E-01 | 954 |
| ***PAHs*** | | | | | | | | | | |
| 2-Methylnaphthalene | -- | -- | 4.00E-03 | -- | 2.9E-01 | NA | NV | 1.64E-01 | 1.64E-01 | 164 |
| Acenaphthene | -- | -- | 6.00E-02 | -- | 3.0E-01 | NA | NV | 2.44E+00 | 2.44E+00 | 2,435 |
| Acenaphthylene | -- | -- | 6.00E-02 | -- | 3.1E-01 | NA | NV | 2.34E+00 | 2.34E+00 | 2,344 |
| Acridine | -- | -- | -- | -- | 1.1E-01 | NA | NV | NV | NV | NV |
| Anthracene | -- | -- | 3.00E-01 | -- | 5.5E-01 | NA | NV | 6.83E+00 | 6.83E+00 | 6,832 |
| Fluoranthene | -- | -- | 4.00E-02 | -- | 1.0E+00 | NA | NV | 5.01E-01 | 5.01E-01 | 501 |
| Fluorene | -- | -- | 4.00E-02 | -- | 4.0E-01 | NA | NV | 1.25E+00 | 1.25E+00 | 1,245 |
| Naphthalene | -- | -- | 2.00E-02 | 3.70E-03 | 1.4E-01 | 1.9E-01 | NV | 4.26E-02 | 4.26E-02 | 43 |
| Perylene | -- | -- | -- | -- | 5.3E+00 | NA | NV | NV | NV | NV |
| Phenanthrene | -- | -- | -- | -- | 5.6E-01 | NA | NV | NV | NV | NV |
| Pyrene | -- | -- | 3.00E-02 | -- | 9.1E-01 | NA | NV | 4.23E-01 | 4.23E-01 | 423 |
| B(a)P TPE | 2.30E+00 | 3.10E-02 | -- | -- | 4.4E+00 | NA | 3.86E-03 | NV | 3.86E-03 | 3.9 |
| ***Metals*** | | | | | | | | | | |
| Arsenic | 1.80E+00 | 2.70E+01 | -- | -- | 2.0E-03 | NA | 6.89E-01 | NV | 6.89E-01 | 689 |
| Boron | -- | -- | 1.75E-02 | -- | 2.0E-03 | NA | NV | 7.24E+00 | 7.24E+00 | 7,237 |
| Cobalt | -- | -- | 1.00E-03 | 5.00E-04 | 8.0E-04 | NA | NV | 4.30E-01 | 4.30E-01 | 430 |
| Copper | -- | -- | 9.10E-02 | -- | 2.0E-03 | NA | NV | 3.76E+01 | 3.76E+01 | 37,633 |
| Lead | -- | -- | -- | -- | 2.0E-04 | NA | NV | NV | 4.34E-01 | 434 (a) |
| Mercury | -- | -- | 3.00E-04 | 9.00E-05 | 2.0E-03 | 1.7E-01 | NV | 1.20E-03 | 1.20E-03 | 1.2 |
| Molybdenum | -- | -- | 2.30E+01 | 1.20E-02 | 2.0E-03 | NA | NV | 9.51E+03 | 9.51E+03 | 9,511,643 |
| Nickel | -- | -- | 1.10E-02 | 1.80E-05 | 4.0E-04 | NA | NV | 4.79E+00 | 4.79E+00 | 4,788 |
| Selenium | -- | -- | 5.50E+00 | -- | 2.0E-03 | NA | NV | 2.27E+03 | 2.27E+03 | 2,274,523 |
| Uranium | -- | -- | 6.00E-04 | 3.00E-04 | 2.0E-03 | NA | NV | 2.48E-01 | 2.48E-01 | 248 |
| ***PCBs*** | | | | | | | | | | |
| Total PCBs | -- | -- | 1.30E-04 | 5.00E-04 | 4.3E+00 | NA | NV | 3.95E-04 | 3.95E-04 | 0.39 |

Notes :

-- Not Available
NA Not Applicable
NV No Value
B(a)P TPE = benzo(a)pyrene total potency equivalents

**TABLE 1**

**DERIVATION OF RISK-BASED CONCENTRATIONS (RBCs) FOR GROUNDWATER - CONSTRUCTION/UTILITY WORKER ORAL, DERMAL, AND INHALATION EXPOSURE**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

(1) The toxicity values were obtained from Health Canada (2010). MOE (2011) was applied as a secondary source.

(2) The selected RBC is the lower of the carcinogenic-based concentration and the non-carcinogenic-based concentration.
(a) Refer to Table 4

(3) The incidental ingestion rate of 0.15 L/day was derived from the MOE drinking water intake rate of 1.5 L/day for an adult resident. Because the workers are not using the groundwater as a drinking water source, but instead may have only occasional limited contact, a factor of 10 was applied to arrive at the reasonable incidental ingestion rate of 0.15 L/day.

(4) Professional Judgment; assumes the construction/utility worker would be in contact with groundwater during subsurface activities for a period of 6 days per week and 13 weeks per year.

(5) Assumes construction campaign to occur over a 1-year period.

(6) Professional Judgment; it is assumed that the construction/utility worker would have direct dermal contact with groundwater for 2 hours/day.

(7) Professional Judgment; based on an 8-hour work day.

(8) Skin surface area includes hands (890 $cm^2$), lower arms (2500/2 $cm^2$), and lower legs (5720/2 $cm^2$)

(9) Averaging time is for the duration of adulthood (60 years).

Construction/ Utility Worker Exposure Assumptions

| | | | |
|---|---|---|---|
| Risk-Based Concentration in Groundwater (mg/L) | $RBC_{gw}$ | calculated | |
| Target Risk Level (unitless) | TR | 1.0E-05 | Health Canada, 2012 |
| Target Hazard Level (unitless) | THQ | 0.2 | Health Canada, 2012 |
| Cancer Slope Factor (per mg/kg-day) | CSF | chemical-specific | Health Canada, 2010; refer to Footnote (1) |
| Reference Dose Factor (mg/kg-day) | RfD | chemical-specific | Health Canada, 2010; refer to Footnote (1) |
| Unit Risk Factor (1/(mg/$m^3$)) | URF | chemical-specific | Health Canada, 2010; refer to Footnote (1) |
| Reference Concentration (mg/$m^3$) | RfC | chemical-specific | Health Canada, 2010; refer to Footnote (1) |
| Ingestion Rate (L/day) | IR | 0.15 | Health Canada, 2012 (3) |
| Event Frequency (event/day) | EV | 1 | USEPA, 2004 |
| Exposure Frequency (weeks/year) | EFa | 13 | Professional Judgement (4) |
| Exposure Frequency (days/week) | EFb | 6 | Professional Judgement (4) |
| Exposure Duration (years) | ED | 1 | Professional Judgement (5) |
| Exposure Time (hrs/day) | ET | 2 | Professional Judgement (6) |
| Fraction Time Exposed (unitless) | FT | 8/24 | Professional Judgement (7) |
| Body Weight (kg) | BW | 70.7 | Health Canada, 2012 |
| Surface Area Exposed ($cm^2$) | SA | 5,000 | Health Canada, 2012 (8) |
| Conversion Factor (L/$cm^3$) | CF | 0.001 | |
| Dermal Absorbed per Event (cm/event) | DAevent | chemical-specific | Refer to Table 2 |
| Averaging Time - carc. (days) | ATc | 21,900 | Health Canada, 2012 (9) |
| Averaging Time - noncarc. (days) | ATnc | 365 | Health Canada, 2012 |
| Volatilization Factor (L/$m^3$) | VF | chemical-specific | Refer to Table 3 |

**TABLE 1**

**DERIVATION OF RISK-BASED CONCENTRATIONS (RBCs) FOR GROUNDWATER - CONSTRUCTION/UTILITY WORKER ORAL, DERMAL, AND INHALATION EXPOSURE**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

Exposure Equations

Carcinogenic Endpoints:

$$RBC_{gw} = \frac{TR \times ATc}{EFa \times EFb \times ED \times ((CSF \times IR)/BW + (CSF \times SA \times DAevent \times CF)/BW + (URF \times FT \times VF))}$$

Non-Carcinogenic Endpoints:

$$RBC_{gw} = \frac{THQ \times ATnc}{EFa \times EFb \times ED \times (((1/RfD) \times IR)/BW \times ((1/RfD) \times SA \times DAevent \times CF)/BW + ((1/RfC) \times FT \times VF))}$$

References:

Health Canada, 2012. Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0, September 2012.

Health Canada, 2010. Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, Version 2.0, September 2010.

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USEPA, 2004: Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment), EPA/540/R/99/005, July 2004.

**TABLE 2**

**DERIVATION OF DAevent FOR GROUNDWATER - CONSTRUCTION/ UTILITY WORKER DERMAL EXPOSURE**

**IQALUIT INTERNATIONAL AIRPORT**

**IQALUIT, NUNAVUT**

DAevent (cm/event) - Organics= ET <= t* =

$2 \times FA \times PC \times SQRT(6 \times \tau_{event} \times ET / PI)$

ET > t* =

$FA \times PC \times (ET/(1+B)+2 \times \tau_{event} \times ((1+3B+3B^2)/(1+B)^2)$

$t^* = 2.4 \times \tau_{event}$

DAevent (cm/event) - Inorganics= PC x ET

| *Parameter* | *PC* | *Ref* | *FA* | *Ref* | *MW* | $\tau_{event}$ | $D_{sc}$ | *b* | *c* | *t** | *ET (1)* | *B* | *DA event (2)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *cm/hr* | | *unitless* | | *g/mole* | *hr/event* | *$cm^2$/hr* | *unitless* | *unitless* | *hr* | *hr/event* | *dimensionless* | *cm/event* |
| ***VOCs*** | | | | | | | | | | | | | |
| Tetrachloroethene | 3.30E-02 | USEPA, 2004 | 1 | USEPA, 2004 | 166 | 8.93E-01 | 1.86E-07 | 4.12E-01 | 4.50E-01 | 2.14E+00 | 2 | 1.64E-01 | 1.22E-01 |
| ***PAHs*** | | | | | | | | | | | | | |
| 2-Methylnaphthalene | 9.10E-02 | USEPA, 2004 | 1 | USEPA, 2004 | 142 | 6.55E-01 | 2.54E-07 | 6.26E-01 | 6.52E-01 | 1.57E+00 | 2 | 4.17E-01 | 2.93E-01 |
| Acenaphthene | 8.41E-02 | USEPA, 2004 | 1 | USEPA, 2004 | 154 | 7.65E-01 | 2.18E-07 | 6.11E-01 | 6.39E-01 | 1.84E+00 | 2 | 4.01E-01 | 2.96E-01 |
| Acenaphthylene | 8.90E-02 | USEPA, 2004 | 1 | USEPA, 2004 | 152 | 7.45E-01 | 2.23E-07 | 6.31E-01 | 6.56E-01 | 1.79E+00 | 2 | 4.22E-01 | 3.09E-01 |
| Acridine | 2.80E-02 | USEPA, 2004 | 1 | USEPA, 2004 | 179 | 1.06E+00 | 1.58E-07 | 3.98E-01 | 4.35E-01 | 2.53E+00 | 2 | 1.44E-01 | 1.12E-01 |
| Anthracene | 1.38E-01 | USEPA, 2004 | 1 | USEPA, 2004 | 178 | 1.04E+00 | 1.60E-07 | 9.55E-01 | 9.04E-01 | 4.05E+00 | 2 | 7.09E-01 | 5.51E-01 |
| Fluoranthene | 2.20E-01 | USEPA, 2004 | 1 | USEPA, 2004 | 202.3 | 1.43E+00 | 1.17E-07 | 1.74E+00 | 1.35E+00 | 5.57E+00 | 2 | 1.20E+00 | 1.03E+00 |
| Fluorene | 1.07E-01 | USEPA, 2004 | 1 | USEPA, 2004 | 166 | 8.93E-01 | 1.86E-07 | 7.42E-01 | 7.48E-01 | 2.14E+00 | 2 | 5.30E-01 | 3.95E-01 |
| Naphthalene | 4.70E-02 | USEPA, 2004 | 1 | USEPA, 2004 | 128.2 | 5.48E-01 | 3.03E-07 | 4.43E-01 | 4.81E-01 | 1.32E+00 | 2 | 2.05E-01 | 1.40E-01 |
| Perylene | 8.20E-01 | USEPA, 2004 | 1 | USEPA, 2004 | 252 | 2.71E+00 | 6.15E-08 | 1.79E+01 | 5.06E+00 | 1.19E+01 | 2 | 5.01E+00 | 5.27E+00 |
| Phenanthrene | 1.40E-01 | USEPA, 2004 | 1 | USEPA, 2004 | 178 | 1.04E+00 | 1.60E-07 | 9.69E-01 | 9.13E-01 | 4.04E+00 | 2 | 7.20E-01 | 5.60E-01 |
| Pyrene | 1.95E-01 | USEPA, 2004 | 1 | USEPA, 2004 | 202 | 1.42E+00 | 1.17E-07 | 1.49E+00 | 1.23E+00 | 5.51E+00 | 2 | 1.06E+00 | 9.07E-01 |
| B(a)P TPE | 7.00E-01 | USEPA, 2004 | 1 | USEPA, 2004 | 250 | 2.64E+00 | 6.31E-08 | 1.33E+01 | 4.32E+00 | 1.15E+01 | 2 | 4.26E+00 | 4.44E+00 |
| ***Metals*** | | | | | | | | | | | | | |
| Arsenic | 1.00E-03 | USEPA, 2004 | -- | -- | -- | -- | -- | -- | -- | -- | 2 | -- | 2.00E-03 |
| Boron | 1.00E-03 | USEPA, 2004 | -- | -- | -- | -- | -- | -- | -- | -- | 2 | -- | 2.00E-03 |
| Cobalt | 4.00E-04 | USEPA, 2004 | -- | -- | -- | -- | -- | -- | -- | -- | 2 | -- | 8.00E-04 |
| Copper | 1.00E-03 | USEPA, 2004 | -- | -- | -- | -- | -- | -- | -- | -- | 2 | -- | 2.00E-03 |
| Lead | 1.00E-04 | USEPA, 2004 | -- | -- | -- | -- | -- | -- | -- | -- | 2 | -- | 2.00E-04 |
| Mercury | 1.00E-03 | USEPA, 2004 | -- | -- | -- | -- | -- | -- | -- | -- | 2 | -- | 2.00E-03 |

**TABLE 2**

**DERIVATION OF DAevent FOR GROUNDWATER - CONSTRUCTION/ UTILITY WORKER DERMAL EXPOSURE**

**IQALUIT INTERNATIONAL AIRPORT**

**IQALUIT, NUNAVUT**

DAevent (cm/event) - Organics= ET <= t* =

$2 \times FA \times PC \times SQRT(6 \times \tau_{event} \times ET / PI)$

ET > t* =

$FA \times PC \times (ET/(1+B)+2 \times \tau_{event} \times ((1+3B+3B^2)/(1+B)^2)$

$t^* = 2.4 \times \tau_{event}$

DAevent (cm/event) - Inorganics= PC x ET

| *Parameter* | *PC* | *Ref* | *FA* | *Ref* | *MW* | $\tau_{event}$ | $D_{sc}$ | *b* | *c* | *t** | *ET (1)* | *B* | *DA event (2)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *cm/hr* | | *unitless* | | *g/mole* | *hr/event* | $cm^2/hr$ | *unitless* | *unitless* | *hr* | *hr/event* | *dimensionless* | *cm/event* |
| **Metals (continued)** | | | | | | | | | | | | | |
| Molybdenum | 1.00E-03 | USEPA, 2004 | -- | -- | -- | -- | -- | -- | -- | -- | 2 | -- | 2.00E-03 |
| Nickel | 2.00E-04 | USEPA, 2004 | -- | -- | -- | -- | -- | -- | -- | -- | 2 | -- | 4.00E-04 |
| Selenium | 1.00E-03 | USEPA, 2004 | -- | -- | -- | -- | -- | -- | -- | -- | 2 | -- | 2.00E-03 |
| Uranium | 1.00E-03 | USEPA, 2004 | -- | -- | -- | -- | -- | -- | -- | -- | 2 | -- | 2.00E-03 |
| ***PCBs*** | | | | | | | | | | | | | |
| Total PCBs | 5.20E-01 | USEPA, 2004 | 1 | USEPA, 2004 | 292 | 4.53E+00 | 3.67E-08 | 8.94E+00 | 3.49E+00 | 1.94E+01 | 2 | 3.42E+00 | 4.33E+00 |

Notes:

(1) Professional Judgment; it is assumed that the construction/utility worker would have direct contact with groundwater for 2 hours/day out of an 8 hour work day.

(2) Calculated using equations presented above and in USEPA (2004).

References:

USEPA, 2004: RAGs Volume 1, Human Health Evaluation Manual, Part E: Supplemental Guidance for Dermal Risk Assessment, EPA/540/R/99/005, July 2004.

**TABLE 3**

**DERIVATION OF VOLATILIZATION FACTOR (VF) FOR GROUNDWATER - CONSTRUCTION/ UTILITY WORKER INHALATION EXPOSURE**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| *Parameter* | *Molecular Weight, $MW_i$ (g/mol)* | *Henry's Law Constant, $H_i$ (1) (atm-$m^3$/mol)* | *Liquid Phase Coefficient, $k_{iL}$ (2) (cm/s)* | *Gas Phase Coefficient, $k_{iG}$ (3) (cm/s)* | *Overall Mass Transfer Coefficient, Ki (4) (cm/s)* | *Volatilization Factor, VF (5) ($L/m^3$)* |
|---|---|---|---|---|---|---|
| ***VOCs*** | | | | | | |
| Tetrachloroethene | 1.66E+02 | 1.84E-02 | 8.49E-04 | 3.83E-01 | 8.47E-04 | 1.88E-01 |
| ***PAHs*** | | | | | | |
| Naphthalene | 1.28E+02 | 4.99E-04 | 9.66E-04 | 4.17E-01 | 8.71E-04 | 1.93E-01 |
| ***Metals*** | | | | | | |
| Mercury | 2.01E+02 | 1.15E-02 | 7.72E-04 | 3.59E-01 | 7.68E-04 | 1.71E-01 |

| | |
|---|---|
| Temperature, T (K): | 288.15 |
| Ideal Gas Constant, R (atm-$m^3$/mole-K): | 0.000082 |
| Area of Trench, A ($m^2$): | 10 |
| Volume of Trench, V ($m^3$): | 20 |
| Depth of the trench, D, (m): | 2 |
| Width of the trench, W, (m): | 1 |
| Length of the trench, L, (m): | 10 |
| Wind speed 10 m above the water surface, u (m/s): | 0.45 |
| Air changes per hour, ACH ($hr^{-1}$): | 162 |
| Mixing factor (deviation from complete mixing in real conditions, k [unitless]): | 0.5 |
| Fraction of trench floor through which contaminant can enter, F (unitless): | 1 |
| Molecular weight of Oxygen, $MW_{Oi}$ (g/mol) | 16 |
| liquid□phase mass transfer coefficient for oxygen at 25°C, $k_L,O_2$ (cm/s). | 0.002 |
| Conversion Factor, $CF_1$ ( $cm^2/m^2$); | 10000 |
| Conversion Factor, $CF_2$ ( $L/cm^3$); | 0.001 |
| Conversion Factor, $CF_3$ ( sec/hr); | 3600 |

Notes:

(1) Henry's Law constants were obtained from AENV (2010) and MOE (2011).

(2) Calculated using the following equation:

$$k_{iL} = \left(\frac{MW_{O_2}}{MW_i}\right)^{0.5}\left(\frac{T}{298}\right)(k_L, O_2)$$

(3) Calculated using the following equation:

$$k_{iG} = \left(\frac{MW_{H_2O}}{MW_i}\right)^{0.335}\left(\frac{T}{298}\right)^{1.005}(k_{iG}, H_2O)$$

(4) Calculated using the following equation:

$$\frac{1}{K_i} = \frac{1}{k_{iL}} + \frac{RT}{H_i k_{iG}}$$

(5) Calculated using the following equation:

$$VF_i = \frac{(K_i \times A \times F \times CF_1 \times CF_2 \times CF_3)}{(k \times ACH \times V)}$$

**TABLE 4**

**RISK-BASED CONCENTRATION (RBC) FOR LEAD IN GROUNDWATER BASED ON THE ADULT LEAD MODEL**

**IQALUIT INTERNATIONAL AIRPORT**

**IQALUIT, NUNAVUT**

| *Model Parameters* | *Symbol* | *Units* | *Adult Worker* | *Ref* |
|---|---|---|---|---|
| Target Blood Lead (PbB) concentration in the fetus (95th percentile) | $PbB_{95fetal}$ | µg/dL | 5 | (1) |
| Baseline blood lead value | $PbB_{adult,0}$ | µg/dL | 1 | (2) |
| R (Mean ratio of fetal to maternal PbB) | $R_{fetal/maternal}$ | unitless | 0.9 | (3) |
| Individual geometric standard deviation | $GSD_i$ | unitless | 1.8 | (2) |
| Biokinetic slope factor | BKSF | µg/dL per µg/day | 0.4 | (3) |
| Water ingestion rate | $IR_W$ | L/d | 0.15 | (4) |
| Exposure Frequency | EF | days/yr | 78 | (4) |
| Absolute absorption fraction of lead in water | $AF_W$ | unitless | 0.2 | (3) |
| Averaging Time | AT | days/yr | 365 | (3) |

| | |
|---|---|
| **Risk-Based Concentration (RBC) - Groundwater (µg/L)** [5] | **4.34E+02** |

Notes:

(1) MOE, 2007. Ontario Air Standards for Lead and Lead Compounds, Standards Development Branch, June 2007.

(2) USEPA, 2009. Transmittal of Update of the Adult Lead Methodology's Default Baseline Blood Lead Concentration and Geometric Standard Deviation Parameters, dated June 26, 2009

(3) USEPA, 2003. Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil. EPA-540-R-03-001. January 2003.

(4) Health Canada, 2012. The incidental ingestion rate of 0.15 L/day was derived from the Health Canada drinking water intake rate of 1.5 L/day for an adult resident. Because the workers are not using groundwater as a drinking water source, but instead may have only occasional limited contact, a factor of 10 was applied to arrive at the reasonable incidental ingestion rate of 0.15 L/day.
EF = Professional Judgment; it is assumed that the construction/utility worker would be in direct contact with groundwater for a period of 5 days per week and 13 weeks per year.

(5) The RBC was calculated using the following formula:

$$RBC = \frac{((PbB_{95fetal}/(GSD_i^{1.645} \times R_{fetal/maternal}) - PbB_{adult,0})) \times AT}{(BKSF \times IR \times AF \times EF)}$$

**TABLE 5**

**CALCULATION OF RISK-BASED CONCENTRATIONS (RBCs) FOR GROUNDWATER BASED ON PROTECTION OF INDOOR AIR QUALITY - COMMERCIAL WORKER**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| | | | | *Risk-Based Concentrations for Groundwater, $RBC_{gw}$* | | |
|---|---|---|---|---|---|---|
| | *Chemical Properties (1)* | | *Default* | *Risk-Based Target Indoor* | *Soil Gas* | *Theoretical Groundwater* |
| | *Henry's Law* | | *Soil Vapour* | *Air Concentration* | *Criteria* | *Concentration* |
| *Contaminant of Concern* | *Constant, $H_L$* | | *Attenuation* | *$RBC_{ia}$ (3)* | *$C_{sg}$ (4)* | *$C'_{gw}$ (5)* |
| *(COC)* | *(atm m³/mol)* | | *Factor, α(2)* | *(µg/m³)* | *(µg/m³)* | *(µg/L)* |
| ***VOCs*** | | | | | | |
| Tetrachloroethene | 4.14E-03 | (0° C) | 4.00E-03 | 2.78E+02 | 6.94E+04 | 396 |
| ***PAHs*** | | | | | | |
| Acenaphthene | 1.30E-05 | (0° C) | 4.00E-03 | 6.56E+01 | 1.64E+04 | 29,799 |
| Acenaphthylene | 1.01E-06 | (0° C) | 4.00E-03 | 6.56E+00 | 1.64E+03 | 38,284 |
| 2-Methylnaphthalene | 4.14E-05 | (0° C) | 4.00E-03 | NC | NC | NC |
| Naphthalene | 6.68E-05 | (0° C) | 4.00E-03 | 3.12E+00 | 7.79E+02 | 276 |
| ***Metals*** | | | | | | |
| Mercury | 1.07E-03 | (0° C) | 4.00E-03 | 7.58E-02 | 1.90E+01 | 0.42 |

Notes:

(1) Henry's Law constants were obtained from AENV (2010) and MOE (2011). The Henry's Law constants were corrected for an average vadose zone temperature of 0°C based on professional judgement.

(2) As depth to groundwater is less than one metre the soil vapour attenuation factor, α, was fixed at an empirically-derived value of 0.004 for a commercial/industrial setting (MOE, 2011)

(3) Refer to Table 6 for acceptable indoor air concentrations.

(4) The Site-specific soil vapour criteria beneath the existing Site building is calculated from $C_{sg}=RBC_{ia} / \alpha$.

(5) The theoretical groundwater concentration determined from the soil vapour concentration assuming equilibrium conditions and Henry's Law; C'gw=Csg*[(T*R)/HL/CF] where T is the vadose temperature in degrees Kelvin, the universal gas constant R is 8.206E-05 atm $m^3$/mol K, and CF is a conversion factor of 1,000 L/m3.

References:

AENV, 2010: Alberta Tier 1 Soil and Groundwater Remediation Guidelines, Government of Alberta, December 2010.

MOE, 2011: Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario, April 15, 2011.

**TABLE 6**

**DERIVATION OF RISK-BASED CONCENTRATIONS FOR INDOOR AIR - COMMERCIAL WORKER INHALATION EXPOSURE**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| | | | *Commercial Worker* | | *Indoor Air* | |
|---|---|---|---|---|---|---|
| | | | *Carcinogen* | *Non-Carcinogen* | *Risk-Based* | |
| | *URF (1)* | *RfC (1)* | *TR* | *THQ* | *Concentration* | |
| *Contaminant of* | *inhalation* | *inhalation* | *Adult* | *Adult* | *RBC $_{ia}$ (2)* | |
| *Concern (COC)* | *1/(mg/m$^3$)* | *(mg/m$^3$)* | *(mg/m$^3$)* | *(mg/m$^3$)* | *(mg/m$^3$)* | *(µg/m$^3$)* |
| ***VOCs*** | | | | | | |
| Tetrachloroethene | 2.60E-04 | 3.60E-01 | 2.78E-01 | 3.03E-01 | 2.78E-01 | 2.78E+02 |
| ***PAHs*** | | | | | | |
| Acenaphthene | 1.10E-03 | -- | 6.56E-02 | NV | 6.56E-02 | 6.56E+01 |
| Acenaphthylene | 1.10E-02 | -- | 6.56E-03 | NV | 6.56E-03 | 6.56E+00 |
| 2-Methylnaphthalene | -- | -- | NV | NV | NC | NC |
| Naphthalene | -- | 3.70E-03 | NV | 3.12E-03 | 3.12E-03 | 3.12E+00 |
| ***Metals*** | | | | | | |
| Mercury | -- | 9.00E-05 | NV | 7.58E-05 | 7.58E-05 | 7.58E-02 |

Notes:

-- = Not Available
NV = No Value
NC = Not calculated
(1) The toxicity values were obtained from Health Canada (2010). MOE (2011) and the USEPA Integrated Risk Information System (IRIS) database were applied as a secondary source.
(2) The selected RBC is the lower of the carcinogenic-based concentration and the non-carcinogenic-based concentration.

Commercial Worker Assumptions

| | | | |
|---|---|---|---|
| Risk-Based Concentration in Indoor Air (mg/m$^3$) | $RBC_{ia}$ | calculated | |
| Target Risk Level (unitless) | TR | 1.0E-05 | Health Canada, 2012 |
| Target Hazard Level (unitless) | THQ | 0.2 | Health Canada, 2012 |
| Unit Risk Factor (per mg/m$^3$) | URF | chemical-specific | Health Canada, 2010; refer to Footnote (1) |
| Reference Concentration (mg/m$^3$) | RfC | chemical-specific | Health Canada, 2010; refer to Footnote (1) |
| Fraction Time Exposed (unitless) | FT | 8/24 | Health Canada, 2012 |
| Exposure Frequency (weeks/year) | EFa | 52 | Health Canada, 2012 |
| Exposure Frequency (days/week) | EFb | 5 | Health Canada, 2012 |
| Exposure Duration (years) | ED | 35 | Health Canada, 2012 |
| Averaging Time (days) - non-carcinogen | AT | 12,775 | Health Canada, 2012 |
| Averaging Time (days) - carcinogen | AT | 21,900 | Health Canada, 2012 |

Exposure Equations

Carcinogenic Endpoints: $$RBC_{ia} = \frac{TR \times AT}{EFa \times EFb \times FT \times ED \times URF}$$

Non-Carcinogenic Endpoints: $$RBC_{ia} = \frac{THQ \times AT}{EFa \times EFb \times FT \times ED \times (1/RfC)}$$

References:

Health Canada, 2010. Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, Version 2.0, September 2010.

MOE, 2011: Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario, April 15, 2011.

**TABLE 7**

**GROUNDWATER RISK-BASED CONCENTRATIONS FOR PROTECTION OF PLANTS AND SOIL ORGANISMS FROM DIRECT CONTACT**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| *Parameter* | *Soil Protection Value Soil Direct Contact Plants and Soil Organisms (mg/kg) (1)* | *Source* | *Organic Carbon Partition Coefficient (L/kg) (2)* | *Dimensionless Henry's Law Constant (H') (2)* | *Groundwater Protection Value Groundwater Direct Contact Plants and Soil Organisms (3) (mg/L)* | *(µg/L)* |
|---|---|---|---|---|---|---|
| **VOCs** | | | | | | |
| Tetrachloroethene | 34 | CCME, 2013 | 2.65E+02 | 7.54E-01 | 23 | 22,638 |
| **PAHs** | | | | | | |
| 2-Methylnaphthalene | 29 | USEPA, 2007 | 2.98E+03 | 2.12E-02 | 1.9 | 1,939 |
| Acenaphthene | 29 | USEPA, 2007 | 2.82E+03 | 6.56E-03 | 2 | 2,048 |
| Acenaphthylene | 29 | USEPA, 2007 | 5.62E+03 | 4.78E-04 | 1 | 1,029 |
| Acridine | 29 | USEPA, 2007 | 1.64E+04 | 1.62E-05 | 0.35 | 353 |
| Anthracene | 32 | CCME, 2013 | 2.00E+04 | 1.50E-03 | 0.32 | 321 |
| Benzo(a)anthracene | 1 | MOE, 2011 | 2.00E+05 | 1.42E-04 | 0.001 | 1 |
| Benzo(a)pyrene | 72 | CCME, 2013 | 2.19E+06 | 4.78E-05 | 0.0066 | 6.6 |
| Benzo(b)fluoranthene | 18 | USEPA, 2007 | 9.33E+04 | 4.68E-04 | 0.039 | 39 |
| Benzo(e)pyrene | 72 | CCME, 2013 | 2.19E+06 | 4.78E-05 | 0.0066 | 6.6 |
| Benzo(g,h,i)perylene | 13 | MOE, 2011 | 4.07E+05 | 5.97E-06 | 0.0064 | 6.4 |
| Benzo(k)fluoranthene | 15 | MOE, 2011 | 2.00E+04 | 3.51E-05 | 0.15 | 150 |
| Chrysene | 14 | MOE, 2011 | 1.26E+05 | 4.00E-03 | 0.022 | 22 |
| Dibenzo(a,h)anthracene | 18 | USEPA, 2007 | 1.38E+06 | 6.22E-07 | 0.0026 | 2.6 |
| Fluoranthene | 180 | CCME, 2013 | 4.17E+04 | 6.09E-04 | 0.86 | 863 |
| Fluorene | 18 | USEPA, 2007 | 4.90E+03 | 3.37E-03 | 0.73 | 733 |
| Indeno(1,2,3-cd)pyrene | 0.76 | MOE, 2011 | 1.58E+06 | 6.77E-05 | 0.000096 | 0.096 |
| Naphthalene | 22 | MOE, 2011 | 7.08E+02 | 2.04E-02 | 6.1 | 6,089 |
| Perylene | 18 | USEPA, 2007 | | | 257 | 257,143 |
| Phenanthrene | 12 | MOE, 2011 | 6.61E+03 | 9.86E-04 | 0.36 | 362 |
| Pyrene | 18 | USEPA, 2007 | 6.92E+04 | 4.66E-04 | 0.052 | 52 |
| **PCBs** | | | | | | |
| Total PCBs | 33 | CCME, 2013 | 3.09E+05 | 4.93E-03 | 0.021 | 21 |
| **Metals** | | | | | | |
| Arsenic | 26 | CCME, 2013 | 2.90E+01 | NA | 0.89 | 894 |
| Boron | NV | -- | 3.00E+00 | NA | NV | NV |
| Cobalt | 300 | CCME, 2013 | 4.50E+01 | NA | 6.7 | 6,656 |
| Copper | 91 | CCME, 2013 | 3.50E+01 | NA | 2.6 | 2,595 |
| Lead | 600 | CCME, 2013 | 9.00E+02 | NA | 0.67 | 667 |
| Mercury | 50 | CCME, 2013 | 5.20E+01 | NA | 0.96 | 960 |
| Molybdenum | 40 | CCME, 2013 | 2.00E+01 | NA | 2 | 1,993 |
| Nickel | 50 | CCME, 2013 | 6.50E+01 | NA | 0.77 | 768 |
| Selenium | 2.9 | CCME, 2013 | 6.00E+00 | NA | 0.48 | 478 |
| Uranium | 2,000 | CCME, 2013 | 4.50E+02 | NA | 4.4 | 4,444 |

**TABLE 7**

**GROUNDWATER RISK-BASED CONCENTRATIONS FOR PROTECTION OF PLANTS AND SOIL ORGANISMS FROM DIRECT CONTACT**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

Notes:

(1) Soil protection values were obtained from CCME (2013), MOE (2011), and USEPA (2007).
(2) Organic partition coefficient and dimensionless Henry's Law Constant were obtained from AENV (2010) and MOE (2011).
(3) Groundwater protection values were calculated using the following equation (FCSAP, 2012):
Note: there are no Koc values for metals, and therefore the value presented is the soil to water partition coefficient (Kd).

$$RBC_{gw} = SPV \times \frac{\rho b}{\theta w + (koc \times foc \times pb) + (H' \times \theta a)}$$

| | | | |
|---|---|---|---|
| Soil Bulk Density | ρb | 1.7 | FCSAP, 2012 |
| Soil Total Porosity | θt | 0.36 | FCSAP, 2012 |
| Soil Moisture-Filled Porosity | θw | 0.119 | FCSAP, 2012 |
| Soil Vapour-Filled Porosity | θa | 0.241 | FCSAP, 2012 |
| Fraction of Organic Carbon | foc | 0.005 | FCSAP, 2012 |

Note: metals are not volatile and therefore partitioning to air using Henry's Law Constant was not considered for these parameters

Sources:

AENV, 2010. Alberta Tier 1 Soil and Groundwater Remediation Guidelines, Alberta Environment, December 2010.
CCME, 2013. Canadian Environmental Quality Guidelines, Canadian Soil Quality Guidelines for the Protection of Human and Environmental Health, 1999, Accessed online, August 2013.
FCSAP, 2012. Guidance Document on Federal Interim Groundwater Quality Guidelines for Federal Contaminated Sites, Federal Contaminated Sites Action Plant, November 2012.
MOE, 2011. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario, April 15, 2011.
USEPA, 2007. Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs), Interim Final, OSWER Directive 9285.7-78. June.

**TABLE 8**

**SUMMARY OF GROUNDWATER RISK-BASED CONCENTRATIONS**
**IQALUIT INTERNATIONAL AIRPORT**
**IQALUIT, NUNAVUT**

| *Parameter* | *Calculated RBCs Per Exposure Pathway (Table Reference)* | | | *Final RBC Value* | *Maximum Groundwater Concentration* |
|---|---|---|---|---|---|
| | *Human RBCs* | | *Ecological RBCs* | | |
| | *Construction/Utility Worker* | *Commercial Worker* | *Plants and Soil Organisms* | (1) | *(2)* |
| | *(Table 1,4)* | *(Table 5)* | *(Table 7)* | | |
| **VOCs** | | | | | |
| Tetrachloroethene | 954 | 396 | 22,638 | 396 | 0.58 |
| **PAHs** | | | | | |
| 2-Methylnaphthalene | 164 | NV | 1,939 | 164 | 0.12 |
| Acenaphthene | 2,435 | 29,799 | 2,048 | 2,048 | 0.31 |
| Acenaphthylene | 2,344 | 38,284 | 1,029 | 1,029 | 0.032 |
| Acridine | NV | NA | 353 | 353 | 0.14 |
| Anthracene | 6,832 | NA | 321 | 321 | 0.36 |
| Benzo(a)anthracene | (2) | NA | **1.0** | 1.0 | **2.1** |
| Benzo(a)pyrene | (2) | NA | 6.6 | 6.6 | 2.3 |
| Benzo(b)fluoranthene | (2) | NA | 39 | 39 | 3.3 |
| Benzo(e)pyrene | (2) | NA | 6.6 | 6.6 | 2.0 |
| Benzo(g,h,i)perylene | (2) | NA | 6.4 | 6.4 | 1.2 |
| Benzo(k)fluoranthene | (2) | NA | 150 | 150 | 1.1 |
| Chrysene | (2) | NA | 22 | 22 | 1.7 |
| Dibenzo(a,h)anthracene | (2) | NA | 2.6 | 2.6 | 0.37 |
| Fluoranthene | 501 | NA | 863 | 501 | 3.3 |
| Fluorene | 1,245 | NA | 733 | 733 | 0.25 |
| Indeno(1,2,3-cd)pyrene | (2) | NA | **0.096** | 0.096 | **1.6** |
| Naphthalene | 43 | 276 | 6,089 | 43 | 0.11 |
| Perylene | NV | NA | 257,143 | 257,143 | 0.54 |
| Phenanthrene | NV | NA | 362 | 362 | 1.6 |
| Pyrene | 423 | NA | 52 | 52 | 2.8 |
| B(a)P TPE | 3.9 | NA | NA | 3.9 | 3.6 |
| **PCBs** | | | | | |
| Total PCBs | 0.39 | NA | 21 | 0.39 | 0.03 |
| **Metals** | | | | | |
| Arsenic | 689 | NA | 894 | 689 | 0.33 |
| Boron | 7,237 | NA | NV | 7,237 | 35 |
| Cobalt | 430 | NA | 6,656 | 430 | 0.36 |
| Copper | 37,633 | NA | 2,595 | 2,595 | 3.2 |
| Lead | 434 | NA | 667 | 434 | 0.24 |
| Mercury | 1.2 | 0.42 | 960 | 0.42 | 0.17 |
| Molybdenum | 9,511,643 | NA | 1,993 | 1,993 | 4.6 |
| Nickel | 4,788 | NA | 768 | 768 | 0.81 |
| Selenium | 2,274,523 | NA | 478 | 478 | 0.26 |
| Uranium | 248 | NA | 4,444 | 248 | 1.1 |

Notes:

NV No value
NA Not applicable
B(a)P TPE, benzo(a)pyrene total potency equivalents
**Bold**, The maximum groundwater concentration exceeds the pathway-specific RBC.
**45** Maximum groundwater concentration exceeds the final RBC.
(1) The final RBC value is the lower of the human and ecological RBC value.
(2) Human health effects from exposure to carcinogenic PAHs have been addressed through the development of the groundwater RBC for B(a)P TPE.