CanNorth

Canada North Environmental Services Limited Partnership

A First Nation Environmental Services Company

DERIVATION OF REMEDIATION SOIL QUALITY GUIDELINES FOR ARSENIC FOR YELLOWKNIFE AND INUVIK

Final Report

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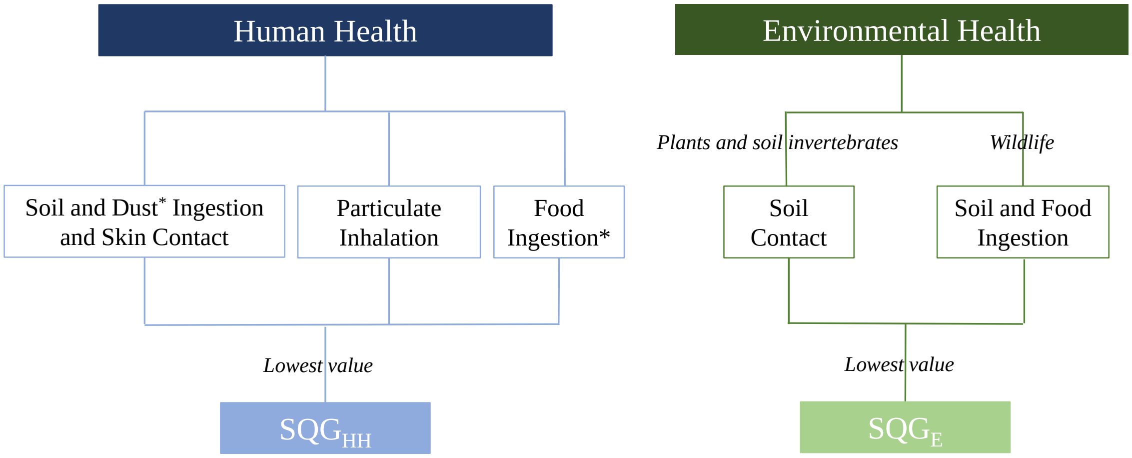
EXECUTIVE SUMMARY

The background arsenic concentrations in soil that are currently being applied in Yellowknife and Inuvik were developed in 2002 and 2011, respectively. The Department of Environment and Natural Resources (ENR) of the Government of the Northwest Territories (GNWT) has recently updated these background concentrations, which served as the first step in the revision of the existing arsenic soil quality guidelines (SQGs) for remediation in the Northwest Territories (NT) that were also derived in 2002 for Yellowknife and in 2011 for Inuvik. ENR is in the process of revising the SQGs for remediation to ensure updated information and new scientific data are incorporated into ENR's regulatory regime.

Canada North Environmental Services Inc. (CanNorth) was retained by ENR to update the arsenic SQGs for remediation in areas around Yellowknife and Inuvik based on the updated background arsenic in soil concentrations. Arsenic SQGs for site remediation were developed for Yellowknife and Inuvik using the CCME framework with the recently updated background arsenic concentrations in soil. Site-specific modifications were also considered, such as months of snow cover in a year and arsenic transfer from soil to plants. Guidelines were developed for two areas within 25 km of the City of Yellowknife based on being within or outside of the Yellowknife municipal boundaries and the Yellowknife Greenstone Belt (YGB), which has naturally elevated concentrations of arsenic in local, mineralized zones.

Guidelines specific to both human and environmental health were derived, consistent with the CCME framework. The human health guidelines were based on the protection of direct contact with soil and eating local vegetables. The ecological guidelines were based on the protection of plants and earthworms and wildlife. The lowest of the derived values for the various exposure pathways for human health and the environment were selected as the human health guideline and the environmental health guideline, respectively:



*Dust ingestion and skin contact and food ingestion were only evaluated for agricultural and residential/parkland land uses only

The human health guidelines are based on eating local vegetables for agricultural and residential/parkland land uses and soil ingestion and dermal contact for commercial and industrial land uses. The environmental health guidelines are based on protection of plants and earthworms. However, the derived environmental health guidelines are not specific to Yellowknife or Inuvik and are based on toxicity studies on sensitive plants and earthworms that are not native to the NT. Additionally, observations from plant samples collected from the Giant Mine site show that plants are growing well in areas with arsenic concentrations as high as 4,500 mg/kg, demonstrating the conservative nature of the environmental health guideline. It is recommended that the updated arsenic SQGs for the NT be based on the protection of human health, consistent with the previous arsenic in soil remediation guidelines.

The recommended NT arsenic SQGs for remediation are summarized in Table ES.1. The NT SQG for soil remediation for residential/parkland land use within Yellowknife and the YGB of 120 mg/kg is the same order of magnitude but lower than the current remediation guideline of 160 mg/kg. This is because the revised background arsenic concentration is lower than the previous value of 150 mg/kg. For the commercial and industrial land uses, the derived NT SQG of 163 mg/kg for Yellowknife is lower than the current guideline of 340 mg/kg. The SQGs for remediation within 25 km of the City of Yellowknife but outside of the municipal boundary and the YGB are lower due to the lower arsenic background concentration. Additionally the derived arsenic remediation guidelines are generally above the range of background concentrations considered for the two areas in Yellowknife.

For Inuvik, the derived NT SQGs for remediation for all land uses are set to the 90th percentile background concentration as the derived human health guidelines were within *the range of background concentrations. This is a similar approach as was used in setting the previous arsenic soil remediation guideline in Inuvik.*

Table ES.1 Proposed NT remediation soil quality guidelines for arsenic

Location	Land Use			
	Agricultural	Residential / Parkland	Commercial	Industrial
Soil Quality Guideline (mg/kg)				
Within Yellowknife and YGB	115	120	163	163
Outside Yellowknife and YGB[a]	42	47	90	90
Inuvik	100[b]	100[b]	100[b]	100[b]

[a] Within 25 km of the City of Yellowknife.
[b] Set equal to the 90^{th} percentile background concentration.

ACRONYMS

ATSDR	Agency for Toxic Substances and Disease Registry
BCF	Bioconcentration Factor
BF	Bioaccessibility Factor
CCME	Canadian Council of Ministers of the Environment
DMA	Dimethylarsinic Acid
DTED	Daily Threshold Effect Dose
EC_x	Effects Concentration affecting x% of the test population
ECL	Effects Concentration - Low
Eco-SSL	Ecological Soil Screening Level
ENR	Environment and Natural Resources
ESSD	Estimated Species Sensitivity Distribution
GMRP	Giant Mine Remediation Plan
GNWT	Government of Northwest Territories
HHRA	Human Health Risk Assessment
HHERA	Human Health and Ecological Risk Assessment
IARC	International Agency for Research on Cancer
IRIS	Integrated Risk Information System
LOAEL	Lowest Observed Adverse Effects Level
LOEC	Lowest Observed Effects Concentration
LOEL	Lowest Observed Effects Level
MATC	Maximum Acceptable Toxicant Concentration
MMA	Monomethylarsonic Acid
NOAEL	No Observed Adverse Effects Level
NOEC	No Observed Effects Concentration
NOEL	No Observed Effects Level
NT	Northwest Territories
SAB	Science Advisory Board
SQG	Soil Quality Guideline
TEC	Threshold Effects Concentration
TRV	Toxicity Reference Value
U.S. EPA	United States Environmental Protection Agency
UCLM	Upper Confidence Level of the Mean
WOE	Weight-of-Evidence
YGB	Yellowknife Greenstone Belt

1.0 INTRODUCTION

The Department of Environment and Natural Resources (ENR) of the Government of Northwest Territories (GNWT) has embarked on updating the existing soil quality guidelines (SQGs) for arsenic in the Northwest Territories (NT) which were derived in 2002 for Yellowknife (Risklogic 2002) and 2011 for Inuvik (Meridian 2011). ENR is revising the arsenic SQGs for remediation to ensure updated information and new scientific data are incorporated into ENR's regulatory regime.

The first step in the revision process was to update the background arsenic concentrations in soil in areas around Yellowknife (Stantec 2020a) and Inuvik (Stantec 2020b) from the background values that have been in place since 2002 (Risklogic 2002) and 2011 (Meridian 2011), respectively.

Canada North Environmental Services Inc. (CanNorth) was retained by ENR to update the NT SQGs for arsenic in areas around Yellowknife and Inuvik using these revised background concentrations.

The Canadian Council of Ministers of the Environment (CCME) has developed a national framework for the management of contaminated sites for the protection of environmental and human health effects. The framework relies on generic guidelines and site-specific objectives. A protocol was first published in 1996, and was subsequently updated in 2006 (CCME 1996, 2006). The generic guidelines are simple numerical values, based on generic scenarios, developed for different land uses and human and ecological receptors, and employ conservative assumptions. The generic guidelines may not be applicable for every site, requiring the development of site-specific objectives through modification (within limits) of the generic guideline based on site-specific conditions (CCME 2006).

In this work, SQGs for remediation for arsenic that are applicable to Yellowknife and Inuvik were developed using the CCME framework while taking into consideration the background arsenic soil concentrations in the area, site-specific modifications, and current guidance.

Specific to ecological protection, the CCME guidelines were derived based on the soil contact guideline (i.e., derived to be protective of soil invertebrates and plants). In addition to being below background soil arsenic concentrations for Yellowknife and Inuvik, the ecological toxicity data for arsenic that were relied on by CCME (1997) may be dated and also may not be representative of natural species which have adapted to living in areas with naturally elevated soil arsenic concentrations. In the present guideline derivation process, a literature review was completed in an effort to identify newer ecological toxicity data for arsenic in soil (primarily with respect to plants and/or soil invertebrates) and to identify any data that may be more relevant to the NT and/or other areas with naturally elevated soil arsenic concentrations.

2.0 BACKGROUND INFORMATION

2.1 Existing Guidelines

There are a number of existing guidelines for arsenic in soil across Canada. Table 2.1 provides a summary of values from various sources, including the CCME, British Columbia, Alberta, and Ontario. The current remediation arsenic guidelines derived for Yellowknife and Inuvik are also included (Risklogic 2002; Meridian 2011).

Table 2.1 Summary of available soil quality guidelines for arsenic

Location/ Jurisdiction	Land Use			
	Agricultural	Residential / Parkland	Commercial	Industrial
Soil Quality Guideline (mg/kg)				
CCME[a]	12	12	12	12
Yellowknife[b]	-	160	-	340
Inuvik[c]	-	120	120	120
British Columbia[d]	20	20 (low density) 40 (high density)	40	40
Alberta[e]	17	17	26	26
Ontario[f]	11	18	18	18

Note:
[a] CCME (Environment Canada 1999). Considers a background concentration of 10 mg/kg.
[b] Risklogic (2002). Considers a background concentration of 150 mg/kg.
[c] Meridian (2011). Set equal to the 90th percentile background concentration since the calculated human health-based guidelines of 92 mg/kg (residential) and 113 mg/kg (industrial/commercial) were below background.
[d] Schedule 3.1 (B.C. Reg. 13/2019, s. 12.). Considers a background concentration of 10 mg/kg. Guideline values shown only consider direct soil contact pathways. British Columbia also has a guideline for wild lands of 15 mg/kg for natural lands and 25 mg/kg for reverted lands.
[e] Alberta Environment and Parks (AEP 2019). Alberta Tier 1 Soil Remediation Guidelines. Considers a background concentration of 10 mg/kg. Alberta also has a guideline for natural areas of 17 mg/kg.
[f] Ontario Ministry of Environment, Conservation and Parks (MOE 2011). Table 2: Full Generic Site Condition Standards in a Potable Ground Water Condition (coarse-grained soil). Background set to 11 mg/kg in agricultural areas and 18 mg/kg in all other areas.

As seen from Table 2.1, the generic SQG for arsenic derived by the CCME (Environment Canada 1999) is 12 mg/kg for all land uses and considers a generic background arsenic concentration of 10 mg/kg across Canada. This guideline is based on the protection of human health for an adult receptor and assumes exposure to soil occurs year-round. The ecological protection values from the guideline derivation are 17 mg/kg for agricultural and residential/parkland land uses and 26 mg/kg for commercial and industrial land uses.

In 2002, Risklogic (2002) derived site-specific human health soil quality remediation objectives for Yellowknife for residential and industrial land uses of 160 mg/kg and 340 mg/kg, respectively, based on a background arsenic soil concentration of 150 mg/kg and protection of an adult receptor. Meridian (2011) derived human health guidelines of 92 mg/kg and 113 mg/kg for residential and industrial/commercial land uses, respectively, based on a mean background concentration of 53.7 mg/kg and protection of an adult receptor. Ultimately, the 90th percentile background concentration of 120 mg/kg was set as the SQG for all land uses in Inuvik.

The British Columbia SQGs for arsenic are based on an arsenic background soil concentration of 10 mg/kg and direct contact with soil. There are two different residential categories. Low density use refers to protection of plants for human consumption, recreational land use in terms of playgrounds, sports fields, picnic areas, and other land use that promotes frequent contact by children. The high density use does not consider those activities. The SQGs for commercial and industrial land uses are based on ecological protection as they are lower than the corresponding human health values of 150 mg/kg and 400 mg/kg, respectively.

The Alberta SQGs were derived using the CCME (2006) protocols and a background soil concentration of 10 mg/kg. The agricultural and residential/parkland values are 17 mg/kg and the industrial and commercial land use values are 26 mg/kg. The Alberta SQGs also have an additional land use category for natural lands, with SQG of 17 mg/kg.

In Ontario, there are two different arsenic background numbers used in the development of the arsenic SQGs: 11 mg/kg for agricultural areas and 18 mg/kg for all other areas. The Ontario SQGs are all based on background as seen in Table 2.1.

2.2 Naturally Elevated Arsenic in Soil

Arsenic is present in rock and soils with concentrations in soils reflecting the geology of the region as well as anthropogenic inputs. The generic SQG for arsenic from the CCME (Environment Canada 1999) has been derived based on a background arsenic soil concentration of 10 mg/kg, which is much lower than natural background levels of arsenic for Yellowknife and Inuvik (Risklogic 2002; Ollson 2000, 2003; Bromstad 2011; Kerr 2006; Stantec 2020a, 2020b; Meridian 2011).

Areas of Yellowknife are located within the Archean-aged Yellowknife Greenstone Belt (YGB; see Figure 2.1), located in the southeast corner of the Slave Province and extending north from Great Slave Lake for almost 50 km. The YGB is a geologic formation largely made up of volcanic rocks and mafic sills. It is known to be rich in gold deposits predominately hosted in arsenopyrite, leading to naturally elevated concentrations of arsenic in local, mineralized zones (Palmer et al. 2015; Cheung et al. 2020). The YGB is bounded to the west by younger rocks composed of granite and to the east by silica-bearing sedimentary rocks (INAC/GNWT 2010).

Numerous studies have been completed over the past 20 years to develop a background concentration of arsenic in soil that is reflective of the naturally elevated concentrations of arsenic within the YGB and surrounding area. In his graduate work, Ollson (2000, 2003) determined that the background range of arsenic concentrations in Yellowknife soils ranged from 3 mg/kg to 150 mg/kg. In developing site-specific human-health soil quality remediation objectives for Yellowknife, Risklogic (2002) used data available from the Geological Survey of Canada (GSC), as well as other data around Yellowknife to develop an average natural background concentration of arsenic of 150 mg/kg with an upper limit of normal (90^{th} percentile of the distribution) of 300 mg/kg. Later, Bromstad (2011) provides the following discussion "Kerr (2006) has determined regional background values for the Yellowknife area that are significantly lower than 150 ppm [150 mg/kg] (3 ppm - 79 ppm As depending on the underlying bedrock type)".

The data from Kerr (2006) as well as the information provided in the two theses by Ollson (2000, 2003) support the assertion that the average background arsenic concentration in soil for the Yellowknife area is less than 150 mg/kg, but higher than the default value of 10 mg/kg used by the CCME in deriving the generic SQG for arsenic.

In recent years, ENR has been working on updating the background arsenic concentration in soil for use in remedial action planning in Yellowknife within 25 km of the City of Yellowknife, taking into account the naturally elevated arsenic concentrations in the area, particularly within the YGB, as well as legacy anthropogenic impacts (i.e., referred to as ambient background or baseline). Stantec (2020a) has developed background datasets for arsenic in Yellowknife within 25 km of the City of Yellowknife, comprising data collected by the Geological Survey of Canada (GSC; Kerr 2001) and Jamieson et al. (2017). Beyond 25 km, the CCME (2001) background concentration of 10 mg/kg is applicable as indicated by Stantec (2019).

Palmer et al. (2021) used mineralogical analyses and geospatial methods to estimate a geochemical background arsenic concentration for unimpacted soils in the Yellowknife area. The results indicated that the geochemical background for arsenic for the region outside a 20 km radius of Yellowknife was in the range of 0.25 mg/kg to 15 mg/kg arsenic with upper concentrations in volcanic geology (YGB) of 30 mg/kg. Thus, the use of the

CCME background concentration of 10 mg/kg by ENR is supported by the Palmer et al. (2021) study.

In their background soil derivation, Stantec (2020a) only used data collected at depths of greater than 10 cm to reduce potential effects of aerial deposition from the former Giant and Con mines, which are located within the municipal boundaries of Yellowknife (see Figure 2.1). Samples collected directly on the Giant and Con Mine properties were not included in the analysis. The background concentrations for within 25 km of the City of Yellowknife are summarized in Table 2.2, which represent the 95% Upper Confidence Level of the Mean (95% UCLM) values. Since arsenic concentrations are naturally elevated as a result of the YGB, a higher background concentration is applicable for areas within the YGB and municipal boundary (see Figure 2.1). Outside of the YGB and municipal boundary, the background arsenic concentration is lower.

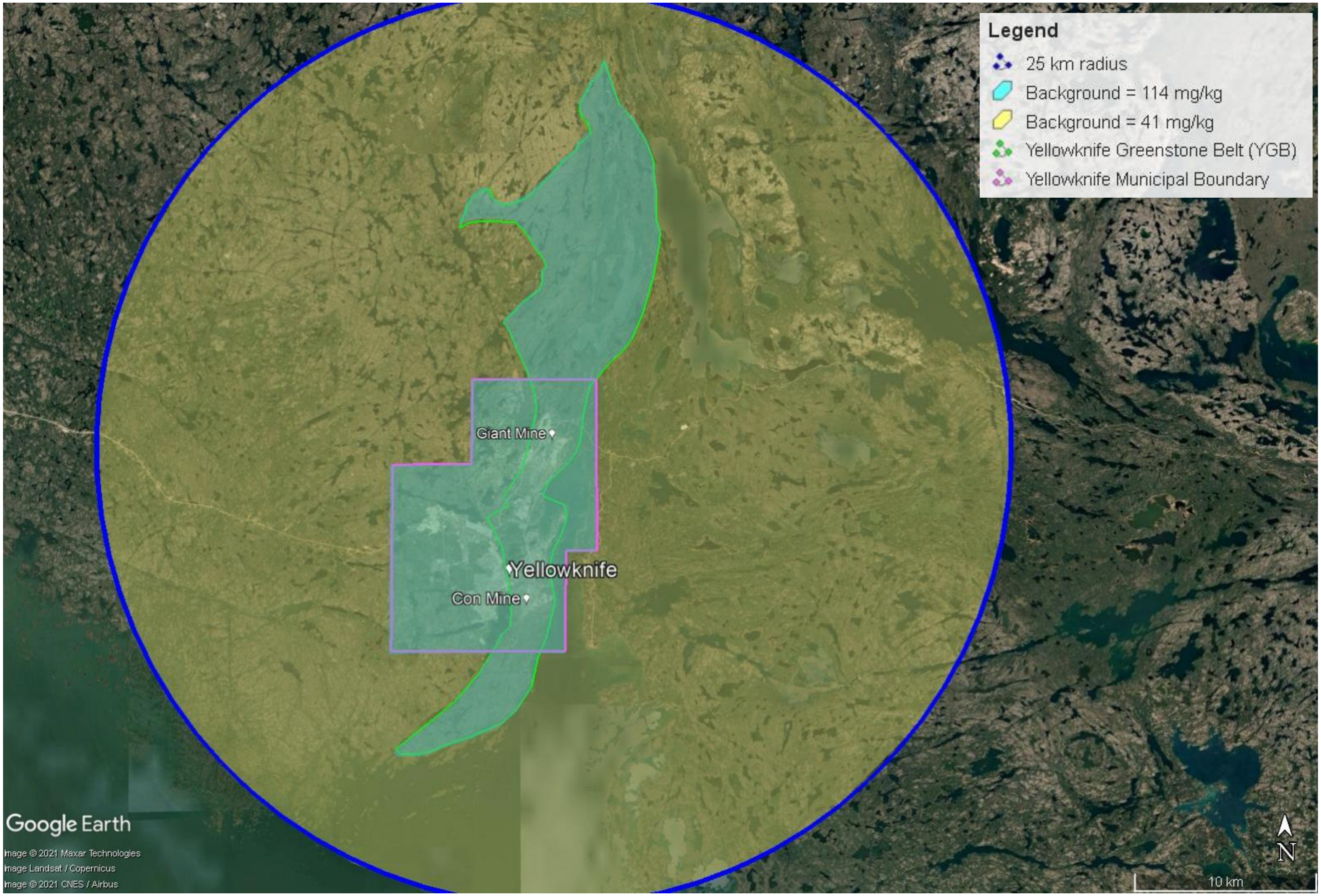
The YGB does not extend up to Inuvik; however, arsenic concentrations in the developed area of the town frequently exceed the CCME background concentration of 10 mg/kg due to the use of fill materials imported from local borrow pits and/or quarries where arsenic concentrations are naturally elevated. In deriving, the previous arsenic human health guideline for Inuvik, Meridian (2011) used a mean background arsenic concentration of 53.7 mg/kg (90th percentile of 120 mg/kg), based on data collected in 2011 for native tills obtained within Inuvik and nearby borrow pits. In 2017, Stantec (2020b) collected additional soil samples in areas within Inuvik and surrounding areas to infill the 2011 data collected by Meridian. Samples collected from the top 15 cm were classified as being from developed or undeveloped areas of Inuvik. Summary statistics were evaluated for each dataset separately, as well as combined to represent concentrations within the municipal boundary of Inuvik. The 95% UCLM of the combined dataset was selected to represent background within the municipal boundary of Inuvik (Stantec 2020b), as shown in Table 2.2 and is similar to the background value used by Meridian (2011).

Table 2.2 Background arsenic soil concentrations

Location	Background Soil Concentration (mg/kg)
Within the Yellowknife municipal boundary and YGB[a]	114
Outside the Yellowknife municipal boundary and YGB[a]	41
Inuvik[b]	50

Note: YGB – Yellowknife Greenstone Belt.
[a] Background concentrations as derived by Stantec (2020a) for within 25 km of the City of Yellowknife.
[b] Background concentrations as derived by Stantec (2020b).

Figure 2.1 Application of background arsenic soil concentrations within 25 km of the City of Yellowknife



3.0 FATE AND BEHAVIOUR

3.1 Arsenic in the Environment

In its elemental form, arsenic (As) is a steel gray metal-like substance that is found naturally in the earth's crust. Arsenic can occur in oxidation states as arsine (-3), arsenic metal (0), arsenite (+3 or trivalent arsenic), and arsenate (+5, or pentavalent arsenic), although it is usually found as inorganic arsenic sulphide or as metal arsenates and arsenides. It is rarely found in its elemental form. Organic arsenic compounds such as monomethylarsonic acid (MMA), dimethylarsinic acid (DMA), and arsenobetaine can also form, but are typically less toxic than inorganic arsenic compounds. Arsenic occurs as a minor constituent in complex ores that are mined, such as the gold ore that was historically mined and processed at the Giant and Con Mine sites. The anthropogenic form of arsenic most frequently released to the environment is arsenic(III)oxide (Environment Canada 1999), recovered from dusts and residues associated with roasting of ores. At Giant, the roasting of As-bearing ore created emissions of sulfur dioxide (SO_2) and arsenic vapour, that condensed to arsenic trioxide (As_2O_3) dust when released to the atmosphere (Palmer et al. 2021).

Arsenic is also released to the environment through other anthropogenic activities, such as through its use in wood preservatives, agricultural chemicals, glass manufacturing, nonferrous alloys, etc. Most (80%) of the anthropogenic releases to the environment are ultimately released to soil, where it is found primarily in its pentavalent form (Environment Canada 1999).

In groundwater and sediment, natural arsenic is present mainly as inorganic As(III) and As(V) species. Surface water contains largely As(V) and to a lesser extent As(III) species. Groundwater concentrations are generally higher than found in associated surface waters. Naturally occurring concentrations in surface water are typically low, with high concentrations generally being the result of anthropogenic activities. In air, natural atmospheric emissions of arsenic through biological methylation and volatilization following weather processes are approximately 50% greater worldwide than anthropogenic emissions. Arsenic has also been detected in most foodstuffs consumed by humans, but the proportion of inorganic arsenic varies (Environment Canada 1999).

Exposure pathways for arsenic in humans typically include air, water, food, and soil via inhalation and ingestion as well as dermal contact. Each exposure pathway can involve exposure to different forms of arsenic with different bioavailabilities. For example, inorganic arsenic in drinking water is more bioavailable than organic arsenic in fish.

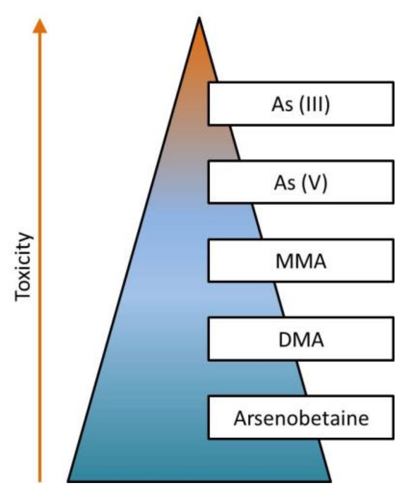
The absorption of arsenic compounds via oral exposure is largely dependent on its solubility in water, while the absorption of arsenic compounds via inhalation is dependent both on solubility and particle size. Dermal absorption of arsenic compounds is not well characterized, but it is thought to be lot less significant than other exposure routes.

3.2 Toxic Forms of Arsenic

Trivalent arsenic (3+) is generally more toxic than pentavalent arsenic (5+) due to its affinity for sulfhydryl groups of biomolecules (e.g., thiol groups in enzymes). Pentavalent arsenic toxicity results from its interference with oxidative phosphorylation in cells by substituting for P (phosphate) in adenosine triphosphate (ATP) synthesis, which results in a deactivation of intracellular energy storage (Jang et al. 2016). The problem with arsenic toxicity is the formation of by-products of oxidation of arsenate, which are arsenite, MMA, and DMA, which does not allow for a clear dose-response curve. While the methylation of arsenate helps in the removal of arsenic from the body, it has been shown to increase the levels of these three toxicants.

Research has shown that all four forms of arsenic (3+, 5+, DMA, MMA) have adverse effects at the cell metabolism level by damaging cell DNA or by reacting with critical sulfhydryl containing enzymes; however, it is unclear how to correlate data obtained from animal studies to actual human effects (Hughes et al. 2011). Arsenic and its metabolites are believed to have adverse influences at the cell level. Organic arsenic compounds, such as arsenobetaine, are found in fish and shellfish. This form of arsenic is generally assumed to be the least toxic of the arsenic species (DEFRA/EA 2002). Figure 3.1 shows a schematic of the relative toxicities of the arsenic species.

Figure 3.1 Schematic of the relative toxicities of arsenic species



3.3 Metabolism

Inorganic arsenic metabolism is quite complex and leads to the formation of various arsenic species that are very different in toxicity, tissue distribution, and rate of elimination. Inorganic arsenic, in both the trivalent and pentavalent oxidation states, can easily be absorbed within the gastrointestinal tract. In low-to-moderate exposure situations, absorbed pentavalent arsenic is largely reduced to trivalent arsenic in the blood (Vahter 2002). Hepatocytes mainly absorb trivalent arsenic (Lerman et al. 1983) and metabolize it to MMA and DMA, both of which may exist in the trivalent and pentavalent oxidation states. Thus, human tissues, blood, and urine contain a mixture of arsenic metabolites that vary in toxicity.

Cell- and animal-model systems provide evidence that the trivalent species of inorganic arsenic, MMA, and DMA are far more toxic than the less reactive pentavalent species. For example, MMA(III) has been shown to be particularly cytotoxic in human cell cultures (Styblo et al. 2000). It is unclear as to the extent to which DMA(V) can be reduced to the more toxic DMA(III); however, there is some evidence that DMA(III) is also found in human biologic samples (Valenzuela et al. 2005). Thus, the retention of arsenic in tissues is influenced by a host of factors, particularly methylation capacity. Tissues vary extensively in their arsenic methylation efficiency (Kobayashi et al. 2007), which probably affects their susceptibility to arsenic toxicity.

The ability to metabolize inorganic arsenic varies widely in humans, as shown by the widely varying proportions of inorganic arsenic, MMA, and DMA in urine and blood. It seems that women are more efficient than men in converting inorganic arsenic to DMA, particularly during pregnancy (Vahter et al. 2006). Also, children appear to methylate arsenic similar to adults (Wasserman et al. 2004). There is evidence from epidemiologic studies in populations exposed to high arsenic concentrations in drinking water in Taiwan, Argentina, and Bangladesh that shows that individuals who can efficiently convert inorganic arsenic to DMA are at lower risk for arsenic-induced disease than those who cannot convert arsenic as efficiently.

The form of arsenic impacts on the rate at which arsenic is excreted from the body. Some of the inorganic arsenic is mainly excreted via urine as the form of arsenic ingested. After methylation, it is also excreted as MMA and DMA. Between 50% and 90% of blood arsenic is cleared from the body in two to four days (NRC 1977). The remainder is cleared 10 to 100 times more slowly.

4.0 GUIDELINE DERIVATION

The revised NT arsenic SQGs for remediation for Yellowknife and Inuvik were derived to generally be consistent with current guidance from the CCME (2006). According to the CCME protocol for SQG derivation, the generic SQGs are derived for the protection of human and ecological receptors for four land use scenarios: agricultural, residential/parkland, commercial, and industrial (CCME 2006). For each land use, SQGs are developed for key human and ecological receptors based on exposure pathways that would be expected to sustain normal activities on these lands. The most restrictive guideline (i.e., lowest value) is then chosen as the recommended SQG for a particular land use that protects both human health and the environment. The SQGs for agricultural land use can also be applied to natural areas as a conservative approach unless site-specific scenarios are considered (CCME 2006).

4.1 Human Health

To derive SQGs for the protection of human health, the methodology from the CCME (2006) was used as a starting point, but was updated to reflect current science, to align with assumptions made in previous derivations (Risklogic 2002; Meridian 2011), and to consider the recent human health risk assessments (HHRAs) that have been completed for the Yellowknife area (CanNorth 2018, 2021).

4.1.1 Approach

The CCME (2006) outlines a procedure for deriving a final SQG for human health (SQG_{HH}) with consideration of exposure from different pathways. These pathways and their rationale for inclusion or exclusion in the current derivation of the NT SQGs for Yellowknife and Inuvik are summarized in Table 4.1. The CCME selects the lowest of the calculated values of the applicable pathways as the final SQG_{HH}. In the case of the NT SQGs, the applicable pathways are direct contact and consumption of vegetables from local gardens.

Table 4.1 Summary of pathways considered in deriving the human health guidelines

Pathway	Considered?	Rationale
Direct contact (SQG_{DH})	Yes	People in Yellowknife and Inuvik may have direct contact with soil, including ingestion, skin contact, and inhalation of particulates. Additionally, this pathway is required by the CCME to derive a final guideline value. Although the CCME does not consider direct contact (ingestion, skin contact) with indoor dust, it was included for agricultural and residential land uses since it was determined to be a significant pathway of exposure from the Giant Mine Remediation Plan Human Health and Ecological Risk Assessment (GMRP HHERA; CanNorth 2018).
Protection of potable groundwater (SQG_{PW})	No	Due to the permafrost, groundwater wells cannot be advanced.
Protection of indoor air quality (SQG_{IAQ})	No	Arsenic is not volatile and will not migrate from soil to indoor air.
Produce, milk, and meat check (SQG_{FI})	Produce only	While there are some backyard gardens for personal use and some community gardens that supply local markets, there are no livestock or dairy farms in Yellowknife or Inuvik.
Off-site migration check (SQG_{OM-HH})	No	Check mechanism only for industrial land use to protect adjacent more sensitive land uses. The derivation of this value is complicated by the elevated background. CCME (2006) found that it is generally much higher than the agricultural protection value therefore this component was not included.

In the CCME procedure, direct contact with indoor dust (ingestion and skin contact) is not considered. It was, however, included by Risklogic (2002) and Meridian (2011) and has been included in the current derivation for agricultural and residential land uses in Yellowknife and Inuvik since this pathway was determined to be a significant source of exposure in the Giant Mine Remediation Plan Human Health and Ecological Risk Assessment (GMRP HHERA; CanNorth 2018). The methodology and assumptions used for estimating exposure via this pathway was, however, updated from those used by Risklogic (2002) and Meridian (2011) to be consistent with Health Canada guidance (Wilson & Meridian 2011).

Risklogic (2002) evaluated exposure from the direct contact pathways separately, deriving soil guideline values for ingestion, dermal contact, and inhalation and then selecting the lowest value as the final SQG_{HH}. As per current CCME guidance, these pathways are evaluated together to derive one overall value for direct contact so long as the mechanism of toxicity is the same for each exposure pathway (CCME 2006). This approach was used by Meridian (2011). In the current guideline derivation for Yellowknife and Inuvik, ingestion of and dermal contact with soil and dust were evaluated together; however, inhalation was evaluated separately, using toxicity data specific to inhalation exposure (see discussion below and Table 4.3).

Risklogic (2002) derived an overall ingestion value that was inclusive of soil, dust, and garden produce. In the current guideline derivation for Yellowknife and Inuvik, consumption of vegetables has been separated from soil and dust ingestion as a check mechanism, as per the CCME (2006) procedure. Meridian (2011) did not evaluate exposure from consumption of vegetables.

In the current guideline derivation for Yellowknife and Inuvik, NT SQGs were derived for four land uses, including agricultural/wildlands, residential, industrial, and commercial. A lifetime receptor was considered for the agricultural and residential land uses since arsenic is known to cause cancer. This lifetime receptor represents a combination of all life stages (infant, toddler, child, adolescent, adult, and Elder) and is considered to be appropriate since a person needs to be exposed to arsenic for a very long time before a cancer develops. This lifetime receptor was calculated assuming 6 months as an infant, 4.5 years as a toddler, 7 years as a child, 8 years as a teen, 50 years as an adult, and 10 years as an Elder, for a total of 80 years of exposure. For the industrial and commercial land uses, an adult worker was considered. The NT SQGs were derived based on Health Canada's negligible incremental lifetime cancer risk level of one-in-one hundred thousand people (1 in 100,000). This was the same cancer risk level used by Risklogic (2002) and Meridian (2011).

Guidelines were developed for two different areas of Yellowknife within 25 km of the City of Yellowknife (i.e., within and outside of Yellowknife and the YGB), using the location-specific arsenic soil background concentrations derived by Stantec (2020a, 2020b) and shown in Table 2.2.

4.1.2 Toxicity of Arsenic to Humans

Inorganic arsenic and its metabolites have many targets of toxicity and carcinogenicity. The International Agency for Research on Cancer (IARC 2012) lists the lung, urinary bladder, and skin as known targets for arsenic toxicity and the prostate, liver, and kidney as three probable targets for carcinogenicity. The Agency for Toxic Substances and Disease Registry (ATSDR 2016) provides a detailed discussion of the various toxicity endpoints for arsenic. The focus of this discussion is on the endpoints used in the derivation of the TRVs by both Health Canada and the United States Environmental Protection Agency (U.S. EPA).

4.1.2.1 Effects on Humans

Arsenic is a known skin carcinogen. There is a well-established dose-response relationship with skin lesions and arsenic in drinking water. The ATSDR (2007) based its chronic minimal risk level of 0.0003 mg/kg-d on skin lesions. Skin lesions have been noted to occur at concentrations as low as 10 µg/L in cross-sectional (Ahsan et al. 2006) and prospective cohort (Argos et al. 2011) studies from exposure in Bangladesh.

Arsenic exposure via drinking water has also been linked to lung cancer in humans. Associations have been observed in highly exposed populations in Taiwan, Japan, Chile, Argentina, and the United States (Guo 2004; IARC 2004, 2012).

Arsenic is also known to cause bladder cancer (IARC 2004, 2012) based on ecologic studies of highly exposed populations in Taiwan, Chile, and Argentina. These studies indicated higher mortality from bladder cancers in exposed populations than in non-exposed populations. A case-control study in Chile (Steinmaus et al. 2013) found evidence of a dose-related increase in bladder-cancer incidence, which establishes a causal relationship between arsenic exposure and bladder cancer.

4.1.2.2 Toxicity Reference Values – Inorganic Arsenic

The U.S. EPA published a toxicological summary of inorganic arsenic in 1988 and started to update the assessment in 2003. In 2005, a draft arsenic assessment related to the carcinogenic effects of oral exposure to inorganic arsenic was released for public comment and review by the U.S. EPA's Science Advisory Board (SAB). The SAB provided recommendations in 2007, and in 2010 the U.S. EPA released a revised draft inorganic arsenic assessment focusing on carcinogenic effects. In 2011, the SAB provided comments and the U.S. EPA is currently working to develop an updated assessment focused on both cancer and non-cancer effects. The preliminary assessment of materials associated with the toxicity of arsenic was released in 2019 and no progress has been reported after this date. Therefore, the current toxicity reference values (TRVs) available in the Integrated Risk Information System (IRIS) database from the U.S. EPA (2021; last updated 1995) are still being used in risk assessments.

Health Canada derived TRVs based on the carcinogenic nature of arsenic in 2010 (Health Canada 2010) and have not provided an update on these values for arsenic since that time.

Oral Exposure

The IRIS database (U.S. EPA 2021; last updated 1995) provides an oral slope factor of 1.5 $(mg/kg\text{-}d)^{-1}$ for skin cancer based on a cross-sectional study of Taiwanese people exposed to drinking water (Tseng et al. 1968; Tseng 1977). Based on the same studies, Health Canada (2004) has previously derived an oral slope factor of 2.8 $(mg/kg\text{-}d)^{-1}$. In 2010, Health Canada considered new data that have become available that suggest that the risk of internal cancers due to ingestion of drinking water is greater than previously believed. The cancer risk models based on the Taiwanese data have been updated (Morales et al. 2000) and an evaluation was completed by Health Canada of the cancer potency indices for liver, lung, and bladder cancers. An oral slope factor of 1.8 $(mg/kg\text{-}d)^{-1}$ was derived (Health Canada 2010).

Health Canada has previously suggested that the approach of the Joint FAO/WHO Expert Committee on Food Additives (JECFA) and the European Food Safety Authority (EFSA) be considered for risk assessments for the Giant Mine. JECFA (FAO and WHO 2011) derived a low-end Benchmark Dose Level ($BMDL_{0.5}$) for a 0.5% increased incidence of lung cancer using a range of assumptions to estimate exposure from drinking water and food with differing concentrations of arsenic. The $BMDL_{0.5}$ was determined to be 3 µg/kg-d (range of 2 to 7 µg/kg-d based on the range of estimated dietary exposure). For a "negligible" risk value of 1×10^{-5}, the risk specific dose is determined to be 0.006 µg/kg-d based on linear extrapolation which is similar using a slope factor of 1.8 $(mg/kg\text{-}d)^{-1}$.

Table 4.2 provides a summary of the oral carcinogenic endpoints. The value of 1.8 $(mg/kg\text{-}d)^{-1}$ from Health Canada for liver, lung, and bladder cancers was selected for use in the current guideline derivation for Yellowknife and Inuvik. As there are no TRVs for dermal exposure, they were set equal to that for oral exposure as is common practice in risk assessment (Health Canada 2012).

Table 4.2 Carcinogenic oral exposure limits for arsenic

TRV $(mg/kg\text{-}d)^{-1}$	Basis	Effects	Source
1.8	-Poisson model fit (Morales et al. 2000). -Based on upper range of mean unit risks. -Exposure from drinking water.	Liver, lung and bladder cancers	Health Canada (2010)
1.5	-Time-and-dose-related formulation of the multistage model. -Exposure from drinking water (Tseng et al. 1968; Tseng 1977).	Skin cancer in humans	U.S. EPA (2021; last updated 1995)
2.8	-Based on tumourigenic dose, TD_{05} (total intake that corresponds to 5% increase in incidence or mortality due to tumours associated with exposure). -TD_{05} of 0.018 mg/kg-d, derived from TC_{05} of 840 µg/L (Health Canada 1996) using a body weight of 70.7 kg and water ingestion rate of 1.5L/d -$SF_o = 0.05/TD_{05}$.	Skin cancer in humans	Health Canada (2004)

Note: Shading indicates value that was used in the current derivation.

Inhalation Exposure

Health Canada (2010) provides an inhalation unit risk of 6.4 $(mg/m^3)^{-1}$. This was derived by Environment Canada/Health Canada (EC/HC 1993) in which three different TD_{05} values were presented (7.83 µg/m^3, 10.2 µg/m^3, and 50.5 µg/m^3) based on three occupational studies of smelter workers at the Tacoma, Anaconda, and Ronnskar smelters. The unit risk was obtained by dividing the most conservative value of 7.83 µg/m^3 into 0.05 (Health Canada 1996).

The IRIS database (U.S. EPA 2021; last updated 1995) provides an inhalation unit risk of 4.3 $(mg/m^3)^{-1}$. This is based on occupational studies of male workers at the Anaconda smelter in Montana and at the Tacoma ASARCO smelter in Washington who showed an increased risk of developing lung cancer following inhalation exposure to arsenic. The extrapolation method used to generate the slope factor was the absolute-risk linear model, and a geometric mean of the different unit risks from each study was used to derive the unit risk.

The California Environmental Protection Agency (CalEPA 2009) derived an inhalation unit risk of 3.3 $(mg/m^3)^{-1}$ for lung tumour incidence using a relative risk model adjusted for interaction with tobacco smoking on data from a human occupational exposure study by Enterline et al. (1987). (CDHS 1990)

The World Health Organization (WHO 2000) provide a unit risk of 1.5 $(mg/m^3)^{-1}$, derived from an estimated cancer risk of $1.5x10^{-3}$ for lifetime exposure to arsenic at a concentration of 1 μg/m^3 in air. The value was estimated by pooling risk estimates from studies conducted on workers at various smelters (Viren and Silvers 1994).

Table 4.3 provides a summary of the carcinogenic inhalation exposure limits for arsenic. The inhalation unit risk of 6.4 (mg/m^3)$^{-1}$ from Health Canada (2010) was selected for use in the current guideline derivation for Yellowknife and Inuvik.

Table 4.3 Carcinogenic inhalation exposure limits for arsenic

TRV (mg/m^3)$^{-1}$	Basis	Effects	Source
6.4	-Based on tumourigenic concentration, TC_{05} (concentration that corresponds to 5% increase in incidence or mortality due to tumours associated with exposure). -TC_{05} of 0.0078 mg/m^3 (EC/HC 1993; Health Canada 1996). -UR = 0.05/TC_{05}.	Lung cancer	Health Canada (2010)
4.3	-occupational inhalation exposure (Brown and Chu 1983a, 1983b, 1982; Lee-Feldstein 1983; Higgins 1982; Enterline and Marsh 1982). -Geometric mean of geometric means from two datasets.	Lung cancer	U.S. EPA (2021; last updated 1995)
3.3	-Human occupational exposure study (Enterline and Marsh 1982); relative risk model, adjusted for interaction with tobacco smoking (CDHS 1990).	Lung tumor incidence	CalEPA (2009)
1.5	-Cancer risk of 1.5 x 10^{-3} for lifetime exposure to concentration of 1 μg/m^3 (URi=risk/concentration). -Estimated by pooling risk estimates from studies on various smelters (Viren and Silvers 1994).	Lung cancer	WHO (2000)

Note: Shading indicates value that was used in the current derivation.

4.1.3 Methodology

This section provides a summary of the equations and values used in deriving the NT SQGs for each of the relevant pathways summarized in Table 4.1. The values used in the equations in the following section are summarized in Table 4.4. Detailed calculations are provided in Appendix B.

The following assumptions were used in deriving the guideline values:

- People were assumed to have potential direct contact with soil for five months of the year (no snow cover); exposure from indoor dust (skin contact and ingestion) was considered year-round for the agricultural and residential land uses.
- Receptor characteristics were preferentially obtained from Health Canada (2012), with the exception of dust ingestion (Wilson et al. 2013) and dust dermal contact

(Wilson & Meridian 2011) values. Dust contact was evaluated for hands only since clothes provide protection to other areas of the body and hands are the most likely to be in contact with indoor dust. This is consistent with the recent HHRAs for the Yellowknife area (CanNorth 2018, 2021).

- For skin contact with soil, the exposed skin surface area was assumed to be the hands and arms for the agricultural and residential land uses. This is consistent with the recent HHRAs for the Yellowknife area (CanNorth 2018, 2021). For the industrial and commercial land uses, the exposed skin surface area was assumed to be limited to the hands and face, with the face representing 3.5% of total body skin surface area (Liu et al. 2008). This is consistent with the worker exposure evaluation that CanNorth completed in 2020 (CanNorth 2021).
- In the derivation of the generic SQG, the CCME uses a soil ingestion rate of 20 mg/d for the adult for all land uses; in the current derivation, a soil ingestion rate of 50 mg/d was used for industrial and commercial land uses to capture the higher soil ingestion that may occur for workers during remediation or other soil works. The soil ingestion rate represents the upper percentile value which is the average of the 95th percentile value of soil and dust ingestion studies in adults (U.S. EPA 2017) and is assumed to represent the range of soil ingestion rates within an industrial or commercial land use.
- Indoor dust was assumed to be 70% of outdoor soil, as per the default U.S. EPA value (1998). This was the same assumption used in recent HHRAs for the Yellowknife area (CanNorth 2018, 2021).
- A soil to plant bioconcentration factor (BCF) for garden produce of 0.002 kg dw soil per kg ww produce was used, derived from measured data from a 2001 study on risks from consumption of garden produce in Yellowknife (ESG 2001). The derivation of this value is detailed in Appendix A.

Table 4.4 Summary of human receptor characteristics

Symbol	Characteristic	Units	Worker	Composite [a]		Details
			Industrial / Commercial	Agricultural	Residential	
BW	Body weight	kg	70.7	62.9	62.9	Health Canada (2012)
SIR	Soil ingestion rate	kg/d	$5.0x10^{-5}$	$2.3x10^{-5}$	$2.3x10^{-5}$	Health Canada (2012) for the agricultural and residential land uses; upper percentile for dust and soil exposure for an adult for industrial and commercial land uses (U.S. EPA 2017).
DIR	Dust ingestion rate	kg/d	0	$7.4x10^{-6}$	$7.4x10^{-6}$	Health Canada (2018)
F_{dust}	Fraction of soil that is dust	-	0.7	0.7	0.7	U.S. EPA (1998)
PM_{10}	Particulate concentration (10 µm in diameter or less)	kg/m^3	$1.0x10^{-7}$	$1.0x10^{-7}$	$1.0x10^{-7}$	Ontario Ministry of Environment, Conservation and Parks (MOE 2011)
F_{dep}	Fraction of inhaled PM_{10} deposited to respiratory system	-	0.6	0.6	0.6	Ontario Ministry of Environment, Conservation and Parks (MOE 2011)
DCR_{soil}	Soil dermal contact rate	kg/d	$9.5x10^{-4}$	$1.1x10^{-3}$	$1.1x10^{-3}$	$=[(SA_{hands} \times SL_{hands}) + (SA_{other} \times SL_{other})] \times EV$
SA_{hands}	*Skin Surface Area - hands*	cm^2	890	825	825	Health Canada (2012)
SA_{other}	*Skin Surface Area - other*	cm^2	617	2281	2281	Arms for composite; 3.5% of total body (i.e., face) for worker (Liu et al. 2008)
SA_{body}	*Skin Surface Area - whole body*	cm^2	17640	16032	16032	Health Canada (2012)
SL_{hands}	*Soil loading - hands*	kg/cm^2/event	$1.0x10^{-6}$	$1.0x10^{-6}$	$1.0x10^{-6}$	Health Canada (2012)
SL_{other}	*Soil loading - other*	kg/cm^2/event	$1.0x10^{-7}$	$1.0x10^{-7}$	$1.0x10^{-7}$	Health Canada (2012)
EV	*Soil dermal contact events per day*	event/d	1	1	1	Health Canada (2012)
DCR_{dust}	Dust dermal contact rate	kg/d	$1.8x10^{-4}$	$1.7x10^{-4}$	$1.7x10^{-4}$	$=[(SA_{hands} \times DL_{hands}) + (SA_{other\_d} \times DL_{other})] \times EV_d$
SA_{hands}	*Skin Surface Area - hands*	cm^2	890	825	825	Health Canada (2012)
SA_{other_d}	*Skin Surface Area - other*	cm^2	0	0	0	Assume dust contact with hands only
DL_{hands}	*Dust loading - hands*	kg/cm^2/event	$2.0x10^{-7}$	$2.0x10^{-7}$	$2.0x10^{-7}$	Health Canada (Wilson & Meridian 2011)
DL_{other}	*Dust loading - other*	kg/cm^2/event	$3.0x10^{-8}$	$3.0x10^{-8}$	$3.0x10^{-8}$	Health Canada (Wilson & Meridian 2011)
EV_d	*Dust dermal contact events per day*	event/d	1	1	1	Assumed equal to soil dermal contact events
FIR	Food (produce) ingestion rate	kg ww/d	0	0.31	0.31	$= FIR_{RV} + FIR_{OV}$
FIR_{RV}	*Root vegetable consumption rate*	kg ww/d	0	0.18	0.18	Health Canada (2012)
FIR_{OV}	*Other vegetable consumption rate*	kg ww/d	0	0.13	0.13	Health Canada (2012)
F_{food}	Fraction of food (produce) that is homegrown	-	0	0.50	0.10	CCME (2006)
BCF	Soil to garden produce bioconcentration factor	kg dw soil/ kg ww produce	0.002	0.002	0.002	Derived from data from garden produce study (ESG 2001); see Appendix A
ET1	Months outdoors per year/12 months per year	-	0.42	0.42	0.42	Site-specific; five months per year (no snow cover)
ET2	Months indoors per year/12 months per year	-	0	0.58	0.58	Year-round
ET3	Hours per day exposed/24 hours per day	-	0.42	0.06	0.06	Outdoors 1.5 hours per day for composite, 10 hours per day for worker (Health Canada 2012)
ET4	Days per week exposed/7 days per week	-	0.71	1.0	1.0	7 days per week for composite, 5 days per week for worker (Health Canada 2012)
ED	Exposure duration	years	35	80	80	Health Canada (2012)
AT	Averaging time	years	60	80	80	Health Canada (2012); years as an adult/Elder for worker

Note:
[a] Composite receptor averaged over lifetime, using receptor characteristics specific to each life stage (infant, toddler, child, teen, adult, Elder). See Appendix B for details.

4.1.3.1 Soil and Dust Ingestion and Dermal Contact

The SQG based on the soil and dust ingestion and dermal contact pathways ($SQG_{DH\text{-}IDC}$) was calculated according to equation 1:

$$SQG_{DH-IDC} = \frac{\frac{Risk}{SF_0} \times BW}{ET_4 \times \{RAF_{ing} \times (SIR \times ET_1 + DIR \times F_{dust} \times ET_2) + RAF_d \times (DCR_{soil} \times ET_1 + DCR_{dust} \times F_{dust} \times ET_2)\} \times \frac{ED}{AT}} + BSC \quad (1)$$

Where:

$SQG_{DH\text{-}SDI}$	=	Soil quality guideline for human health based on ingestion of soil and dust (mg/kg)
Risk	=	Acceptable level of risk (-) {1x10^{-5}, as per Health Canada (2012)}
SF_o	=	Oral slope factor (mg/(kg-d)$^{-1}$) {see Table 4.2}
BW	=	Body weight (kg) {see Table 4.4}
ET_4	=	Days per week exposed/7 day per week (-) {see Table 4.4}
RAF_{ing}	=	Relative absorption factor for soil/dust ingestion (-) {see below}
SIR	=	Soil ingestion rate (kg/d) {see Table 4.4}
ET_1	=	Months outdoors per year/12 months per year (-) {see Table 4.4}
DIR	=	Dust ingestion rate (kg-d) {see Table 4.4}
F_{dust}	=	Fraction of soil that is dust (-) {see Table 4.4}
ET_2	=	Months indoors per year/12 months per year (-) {see Table 4.4}
RAF_d	=	Relative absorption factor for skin (-) {see below}
DCR_{soil}	=	Soil dermal contact rate (kg/d) {see Table 4.4}
DCR_{dust}	=	Dust dermal contact rate (kg/d) {see Table 4.4}
ED	=	Exposure duration (years) {see Table 4.4}
AT	=	Averaging time (years) {see Table 4.4}
BSC	=	Background soil concentration (mg/kg) {see Table 2.2}

When site-specific information is not available, Health Canada (2010) and CCME (Environment Canada 1999) use a value of 1 for the absorption of soil following ingestion (RAF_{ing}). For Yellowknife and Inuvik, a site-specific value of 0.36 has been applied. This value was derived in support of the GMRP HHERA (CanNorth 2018). This same value was used for bioaccessibility in indoor dust.

For dermal contact with soil and dust, a relative absorption factor (RAF_d) of 0.03 was applied, consistent with Health Canada (2010).

4.1.3.2 Particulate Inhalation

The SQG based on particulate (dust) inhalation (SQG_{DH-PI}) was calculated according to equation 2:

$$SQG_{DH-PI} = \frac{\frac{Risk}{UR}}{PM_{10} \times F_{dep} \times RAF_{inh} \times ET_1 \times ET_3 \times ET_4 \times \frac{ED}{AT}} + BSC \qquad (2)$$

Where:

SQG_{DH-PI}	=	Soil quality guideline for human health based on particulate inhalation (mg/kg)
Risk	=	Acceptable level of risk (-) {1x10^{-5}, as per Health Canada (2012)}
UR	=	Inhalation unit risk ((mg/m^3)$^{-1}$) {see Table 4.3}
PM_{10}	=	Particulate concentration in air (10 µm in diameter or less) {see Table 4.4}
F_{dep}	=	Fraction of inhaled PM_{10} deposited to respiratory system (-) {see Table 4.4}
RAF_{inh}	=	Relative absorption factor for lung (-) {assumed equal to 1}
ET_1	=	Months outdoors per year/12 months per year (-) {see Table 4.4}
ET_3	=	Hours per day exposed/24 hours per day (-) {see Table 4.4}
ET_4	=	Days per week exposed/7 day per week (-) {see Table 4.4}
ED	=	Exposure duration (years) {see Table 4.4}
AT	=	Averaging time (years) {see Table 4.4}
BSC	=	Background soil concentration (mg/kg) {see Table 2.2}

4.1.3.3 Food Ingestion

The SQG based on the food (produce) ingestion pathway (SQG_{FI}) was calculated according to equation 3:

$$SQG_{FI} = \frac{\frac{Risk}{SF_0} \times BW}{RAF_{f-ing} \times BCF \times FIR \times F_{food} \times \frac{ED}{AT}} + BSC \qquad (3)$$

Where:

SQG_{FI}	=	Soil quality guideline for human health based on food (produce) ingestion (mg/kg)
Risk	=	Acceptable level of risk (-) {1x10^{-5}, as per Health Canada (2012)}
SF_o	=	Oral slope factor (mg/(kg-d)$^{-1}$) {see Table 4.2}

BW	=	Body weight (kg) {see Table 4.4}
$RAF_{f\text{-}ing}$	=	Relative absorption factor for food ingestion (-) {see below}
BCF	=	Soil to garden produce bioconcentration factor (kg dw soil/kg ww produce) {see Table 4.4}
FIR	=	Food ingestion rate (kg/d) {see Table 4.4}
F_{food}	=	Fraction of food (produce) that is homegrown (-) {see Table 4.4}
ED	=	Exposure duration (years) {see Table 4.4}
AT	=	Averaging time (years) {see Table 4.4}
BSC	=	Background soil concentration (mg/kg) {see Table 2.2}

For produce, it is assumed that only the bioaccessible fraction of arsenic is taken up by the plant from soil so that all the arsenic ingested is absorbed ($RAF_{f\text{-}ing}$ of 1).

4.1.4 Values Protective of Human Health

The derived human health values for different land uses in each of the two different areas in Yellowknife as well as Inuvik for the various exposure pathways are summarized in Table 4.5. As seen in the table, the particulate inhalation exposure pathway is the least restrictive pathway (i.e., highest arsenic in soil concentrations). For the agricultural and residential/parkland land uses, the consumption of local vegetables represents the most restrictive exposure pathway (i.e., lowest arsenic in soil concentrations), followed closely by soil and dust ingestion and skin contact. For the industrial and commercial land uses, the soil ingestion and skin contact pathway results in the lowest soil concentrations. The final values for human health (SQG_{HH}) are selected as the lowest of the values for the various pathways (i.e., the limiting pathway), which is food (local vegetables) ingestion (SQG_{FI}) for agricultural and residential land uses and soil ingestion and skin contact ($SQG_{DH\text{-}IDC}$) for commercial and industrial land uses.

Table 4.5 Summary of human health soil quality guidelines for arsenic

Pathway	Background (mg/kg)	Land Use			
		Agricultural	Residential/ Parkland	Commercial	Industrial
SQG_{HH} (mg/kg)					
Within Yellowknife and YGB	114	**115**	**120**	**163**	**163**
Outside Yellowknife and YGB[a]	41	**42**	**47**	**90**	**90**
Inuvik	50	**51**	**56**	**99**	**99**
SQG_{DH-IDC} (Soil and Dust Ingestion and Dermal Contact) (mg/kg)					
Within Yellowknife and YGB	114	130	130	*163*	*163*
Outside Yellowknife and YGB[a]	41	57	57	*90*	*90*
Inuvik	50	66	66	*99*	*99*
SQG_{DH-PI} (Particulate Inhalation) (mg/kg)					
Within Yellowknife and YGB	114	1114	1114	474	474
Outside Yellowknife and YGB[a]	41	1041	1041	401	401
Inuvik	50	1050	1050	410	410
SQG_{FI} (Food [Produce] Ingestion) (mg/kg)					
Within Yellowknife and YGB	114	*115*	*120*	-	-
Outside Yellowknife and YGB[a]	41	*42*	*47*	-	-
Inuvik	50	*51*	*56*	-	-

Note: *Italics* denote limiting pathway; dash indicates a guideline/check value that is not part of the exposure scenario for this land use and therefore is not calculated.
[a] Within 25 km of the City of Yellowknife.

4.1.5 Sensitivity Analysis

Several assumptions were made in deriving the NT SQG_{HH} for Yellowknife and Inuvik as summarized in Section 4.1.3. Of these assumptions, the ones that could result in changing the values are the soil ingestion rates, produce ingestion rates, and percent produce that is considered to be grown in the area. All the other assumptions, when adjusted within the expected range, have a marginal effect on the resulting SQG_{HH}.

Default soil ingestion rates from Health Canada (2012) were used for the composite receptor when deriving the SQG_{DH-IDC} for agricultural and residential/parkland land use. It is broadly acknowledged among professional risk assessors that the assumed rates of soil ingestion currently used for risk assessment significantly overestimate actual exposure from this environmental medium. Wilson et al. (2013) has derived alternative soil ingestion rates, using receptor characteristics supported by Health Canada (2012), that are separate from dust ingestion rates and can be developed into an hourly rate or adjusted on a site-specific basis. The deterministic estimates of soil ingestion rates from Wilson et al. (2013) are lower, with average values for the elder, adult, teen, child, and toddler of 1.5 mg/d, 1.6 mg/d, 1.4 mg/d, 21 mg/d, and 14 mg/d, respectively.

For industrial and commercial land uses, a soil ingestion rate of 50 mg/d was used based on U.S. EPA (2017). This is higher than the default value used the CCME for these land uses. The Ontario Ministry of the Environment, Conservation and Parks (MOE 2011) provides an even higher soil ingestion rate for a subsurface worker of 100 mg/d.

The effect of using different soil ingestion rates on the resulting guidelines for ingestion and direct contact is seen in Table 4.6. A change in the soil ingestion rate for agricultural and residential/parkland land uses does not affect the $SQG_{DH\text{-}IDC}$. A change in the $SQG_{DH\text{-}IDC}$ is observed for industrial and commercial land uses where there is no accounting for exposure from dust. However, it only represents approximately a 9% change in the $SQG_{DH\text{-}IDC}$.

Table 4.6 Effect of soil ingestion rate on soil quality guideline for ingestion and direct contact pathways

Location	**$SQG_{DH\text{-}IDC}$ (Soil and Dust Ingestion and Dermal Contact) (mg/kg)**				
	Agricultural/ Residential/Parkland		**Industrial/Commercial**		
	Health Canada (2012)	**Wilson et al. (2013)**	***50 mg/d***	**100 mg/d**	**20 mg/d**
Within Yellowknife and YGB	*130*	128	*163*	149	177
Outside Yellowknife and YGB[a]	*57*	55	*90*	76	104
Inuvik	*66*	64	*99*	85	113

Note: Health Canada (2012) values were used in the derivation and are 80 mg/d for the toddler and 20 mg/d for all other life stages; Wilson et al. (2013) values are 1.5 mg/d, 1.6 mg/d, 1.4 mg/d, 21 mg/d, and 14 mg/d for the Elder, adult, teen, child, and toddler, respectively; *italics* denote values used in the current derivation.

[a] Within 25 km of the City of Yellowknife.

For the SQG from food (produce) ingestion (SQG_{FI}), the effect of using values for food ingestion rate and percent vegetables (produce) obtained locally that are not consistent with default CCME or Health Canada values are summarized in Table 4.7. As seen from the table, the consideration of how many vegetables are obtained locally does not materially change the SQG_{FI} for the agricultural land use. For the residential/parkland land use, the change in the amount of produce obtained locally results in approximately a 4% change in the SQG_{FI}. Similarly, the change in how much vegetables are consumed only changes the SQG_{FI} in the order of 2% to 9%.

The results of the sensitivity analysis demonstrates that a change in any of the assumptions used in the assessment within an expected range does not have any substantial effect in the resulting NT SQG_{HH}.

Table 4.7 Effect of produce ingestion assumptions on soil quality guideline

Location	SQG_{FI} (Food [Produce] Ingestion) (mg/kg)					
	Agricultural			Residential/ Parkland		
Percent produce homegrown	***0.5***	**1**	**0.1**	***0.1***	**0.5**	**0.05**
Within Yellowknife and YGB	*115*	115	116	*120*	115	125
Outside Yellowknife and YGB[a]	*42*	42	43	*47*	42	52
Inuvik	*51*	51	52	*56*	51	61
Produce ingestion rate (kg/d)	***0.31***	**1**	**0.1**	***0.31***	**1**	**0.1**
Within Yellowknife and YGB	*115*	114	117	*120*	116	131
Outside Yellowknife and YGB[a]	*42*	41	44	*47*	43	58
Inuvik	*51*	50	53	*56*	52	67

Note: *Italics* denote values used in the current derivation.
[a] Within 25 km of the City of Yellowknife.

4.1.6 Comparison to Other Guidelines

As discussed previously, the current guideline values for human health were derived following the CCME (2006) procedure with the following modifications:

- a lifetime (composite) receptor was used to derive the guideline values for residential and agricultural land uses;
- direct contact with dust (ingestion and dermal contact) was considered year-round for the residential and agricultural land uses;
- direct contact with soil was assumed to occur for only five months a year when the ground is not covered in snow;
- a site-specific background arsenic concentration in soil was used;
- exposure from particulate inhalation was evaluated separately from ingestion and dermal contact pathways; and
- a higher soil ingestion rate of 50 mg/d was used for the industrial and commercial land uses as opposed to the CCME value of 20 mg/d.

Guideline values for human health from other jurisdictions tend to follow the CCME procedure as well, although there are some modifications as summarized in Table 4.8. Some of the key differences include:

- The British Columbia guidelines for soil pathways are based solely on inadvertent soil ingestion; unlike the CCME protocol, there is no consideration of dermal contact with soil, inhalation of soil particulates, or food ingestion. There is also no consideration of exposure to dust (BC MOECCS 2021).

- Soil ingestion rates used are generally consistent with Health Canada (2012), but for high-density residential and commercial sites, it is assumed that people would come into contact with much smaller amounts of soil and therefore reduce the soil ingestion rates by 50% (BC MOECCS 2021). This is in contrast to what has been done in the derivation for Yellowknife and Inuvik, where the soil ingestion rate for an adult for industrial and commercial land use has been increased from 20 mg/d to 50 mg/d to account for possible higher contact with dirt while working.
- Ontario considers a lifetime (composite) receptor for residential land use for carcinogenic substances as was done in the current derivation for Yellowknife and Inuvik; other jurisdictions consider an adult for all land uses. Ontario uses a negligible risk level of $1x10^{-6}$ compared to the value of $1x10^{-5}$ adopted by Health Canada.
- British Columbia and Ontario do not directly consider background in the calculation of the pathway-specific guidelines, but rather use background as a check mechanism to ensure the final guideline is not below background.
- Exposure to dust and food ingestion are not evaluated by British Columbia, Alberta, or Ontario.

It is interesting that CCME guidance and other jurisdictions do not consider dust exposure, while this was determined to be a significant pathway of exposure in the Yellowknife area in the GMRP HHERA (CanNorth 2018). It is also interesting to note that produce ingestion is not evaluated by other jurisdictions, while this has been identified as the limiting pathway in the current derivation for agricultural and residential land uses. Ontario (MOE 2011) discusses that garden produce was not included as there is a high degree of uncertainty with respect to assumptions required (uptake factors, consumption amount, changed due to food preparation, etc.). Lastly, most jurisdictions use a background arsenic soil concentration that is similar to or equal to the value from the CCME, which is lower than the updated background arsenic concentrations for Yellowknife and Inuvik (Stantec 2020a, 2020b).

Table 4.8 Summary of key similarities and differences in derivation of soil quality guidelines for arsenic from various jurisdictions

Parameter	CanNorth (current derivation for Yellowknife and Inuvik)	CCME[1]	Yellowknife (Risklogic 2002)	Inuvik (Meridian 2011)	British Columbia	Ontario	Alberta
Risk Level	10^{-5}	10^{-5} and 10^{-6}	10^{-5}	10^{-5}	10^{-5}	10^{-6}	10^{-5}
Background Soil Concentration	Within YK and YGB: 114 mg/kg Outside YK and YGB: 41 mg/kg Inuvik: 50 mg/kg	10 mg/kg	150 mg/kg	53.7 mg/kg (90th percentile background concentration of 120 mg/kg set as guideline)	10 mg/kg (not used in derivation directly; used as a check to ensure guideline is not below background)	11 mg/kg in agricultural areas 18 mg/kg in all other areas (not used in derivation directly; used as a check)	10 mg/kg
Land Uses	Agricultural (ag) Residential/parkland (res/park) Industrial (ind) Commercial (comm)	Agricultural (ag) Residential/parkland (res/park) Industrial (ind) Commercial (comm)	Residential (res) Industrial (ind)	Residential/parkland (res/park) Industrial (ind) Commercial (comm)	Agricultural (ag) Low (single family) and high (urban) density residential (res) Commercial (comm) Industrial (ind) Urban parkland (park) Natural and reverted wildlands (wild)	Agricultural (ag) Residential/parkland/institutional (res/park/ins) Industrial/commercial (ind/comm)	Agricultural (ag) Residential/parkland (res/park) Industrial (ind) Commercial (comm) Natural area (nat)
Life stages	Composite (ag, res) Adult (ind, comm)	Adult	Adult	Adult	Adult	Composite (res/park/ins) Adult (ind/comm)	Adult
Pathways	Soil and dust ingestion + dermal contact Particulate inhalation Food (produce) ingestion	Soil ingestion (current CCME guidance also includes soil dermal contact, particulate inhalation, and food ingestion, but arsenic guideline was derived prior to this guidance)	Soil, dust, and produce ingestion Soil and dust dermal contact Particulate inhalation	Soil and dust ingestion + soil and dust dermal contact + particulate inhalation	Soil ingestion	Soil ingestion + dermal contact Particulate inhalation (for subsurface worker for ind/comm land use only)	Soil ingestion + dermal contact + particulate inhalation
Oral slope factor	1.8 $(mg/kg\text{-}d)^{-1}$	1.8 $(mg/kg\text{-}d)^{-1}$	2.8 $(mg/kg\text{-}d)^{-1}$	1.8 $(mg/kg\text{-}d)^{-1}$	1.5 $(mg/kg\text{-}d)^{-1}$	1.5 $(mg/kg\text{-}d)^{-1}$	2.8 $(mg/kg\text{-}d)^{-1}$
Inhalation unit risk	6.4 $(mg/m^3)^{-1}$	Not considered	Not considered	Not considered	Not considered	1.5 $(mg/m^3)^{-1}$	Not considered
Fraction dust	Assumed to be 70% of outdoor soil; dust-specific exposure parameters	Not evaluated	Assumed to be 30% of outdoor soil; no dust-specific exposure parameters	Assumed to be 50% of outdoor soil; dust-specific exposure parameters	Not evaluated	Not evaluated	Not evaluated
Soil ingestion rate	80 mg/d for ag, res/park (toddler) 20 mg/d for ag, res/park (all other life stages) 50 mg/d for ind, comm	20 mg/d	20 mg/d	20 mg/d	20 mg/d for all land uses, except for 10 mg/d for commercial and high density residential	200 mg/d for toddler (ag, res/park/ins) 50 mg/d for all other life stages (ag, res/park/ins) 100 mg/d for worker (ind/comm)	20 mg/d
Relative absorption factor	0.36 (ingestion of soil, dust) 0.03 (dermal contact with soil, dust) 1 (inhalation) 1 (food ingestion)	1 (ingestion of soil)	1 (ingestion of soil, dust) 0.02 (dermal contact with soil , dust) 0.09 (inhalation) 1 (food ingestion)	1 (ingestion of soil, dust) 0.03 (dermal contact with soil, dust) 0.9 (inhalation)	0.6 (ingestion of soil)	0.5 (ingestion of soil) 0.03 (dermal contact with soil) 1 (inhalation)	1 (ingestion of soil) 0.03 (dermal contact with soil) 1 (inhalation)
Skin surface area	Hands and arms for soil (ag, res) Hands for dust (ag, res) Hands and face for soil (ind, comm)	Not evaluated (2006 guidance evaluates using hands and arms for all land uses)	Hands and arms (for all land uses, for soil and dust)	Hands and arms (for all land uses, for soil and dust)	Not evaluated	Weighted average considering varying exposed skin surface area during the year	Hands and arms (for all land uses)
Exposure time	5 month per year outdoors 12 months per year indoors (ag, res/park) 1.5 hours per day outdoors (ag, res/park) 10 hours per day (ind, comm) 7 days per week (ag, res/park) 5 days per week (ind, comm)	Year-round exposure, 24 hours per day (2006 guidance adjusts for ind, comm)	5 month per year outdoors 7 months per year indoors (res) 1.42 hours per day outdoors (ag, res) 10 hours per day (ind) 7 days per week (ag, res) 5 days per week (ind)	24 hours per day outdoors (res/park) 10 hours per day outdoors (ind, comm) 22.6 hours per day indoors (res/park) 8.6 hours per day indoors (ind, comm) 7 days per week (res/park) 5 days per week (ind, comm)	48 to 52 weeks per year (26 for wild) 24 hours per day (12 for comm, park; 8 for ind) 7 days per week (5 for ind, comm)	24 hours per day (9.8 for ind/comm) 39 weeks per year 7 days per week (5 for ind/comm)	24 hours per day (ag, res/park) 10 hours per day (ind, comm) 52 weeks per year (48 for ind, comm) 7 days per week (5 for ind, comm)

Note: [1] CCME guideline value for human health of 12 mg/kg was derived prior to 2006 protocol and thus is based on soil ingestion only.

4.2 Environmental Health

The environmental health component of the guideline (SQG_E) was derived generally following the procedure that is outlined by CCME (2006), using site-specific considerations. The approach to the derivation of the environmental components is described briefly below.

4.2.1 Approach

The CCME (2006) outlines a procedure for deriving a SQG for environmental health with consideration of several different pathways. These pathways and their rationale for inclusion or exclusion in the current guideline derivation for Yellowknife and Inuvik are summarized in Table 4.9. As seen from the table, the only exposure pathways to be considered in the environmental health derivation are the soil contact with plants and invertebrates and the wildlife food ingestion pathway. The lowest of the calculated values for the applicable pathways is selected as the final SQG_E.

Table 4.9 Summary of pathways considered in deriving the environmental health guidelines

Pathway	Considered?	Rationale
Soil contact (SQG_{SC})	Yes	Plants and soil invertebrates may come in contact with arsenic in the soil.
Soil and food ingestion (SQG_I)	Yes	Wildlife may eat vegetation or prey and inadvertently eat soil from food.
Protection of freshwater life (SQG_{FL})	No	Not applicable on a generic basis for metals due to the uncertainty in the development of this value (e.g., the partitioning coefficient between soil and water can vary significantly depending on the site-specific conditions). (CCME 2006 Appendix A)
Livestock watering (SQG_{LW})	No	There are no livestock or dairy farms in Yellowknife or Inuvik.
Irrigation water (SQG_{IR})	No	Due to the permafrost, groundwater wells cannot be advanced.
Nutrient and energy cycling check (SQG_{NEC})	No	There is not enough information available to evaluate this pathway.
Off-site Migration Check (SQG_{OM-E})	No	Check mechanism only for industrial land use to protect adjacent more sensitive land uses. The derivation of this value is complicated by the elevated background. CCME (2006) found that it is generally much higher than the agricultural protection value therefore this component was not included.

4.2.2 Methodology

This section provides a summary of the approach for the soil contact pathway and the equations and values used in deriving the wildlife food ingestion pathway. Details are provided in Appendix C. The derivation of the SQG_E should result in soil concentrations that will provide a healthy functioning native ecosystem.

4.2.2.1 Soil Contact

The CCME preferred approach for deriving the soil contact value (SQG_{SC}) related to plants and invertebrates is a weight-of-evidence (WOE) approach using toxicity studies from the literature. The relevant endpoints selected in the literature studies should be related to growth, reproduction, and mortality. The WOE approach requires at least ten data points from at least three studies, and a minimum of two soil invertebrate and two crop/plant data points.

The first step in deriving the NT SQG_{SC} for Yellowknife and Inuvik was to compile a database of toxicity data for plants and soil invertebrates for exposure to arsenic in soil. This database included the information used by the CCME in the derivation of the 1999 SQG (Environment Canada 1999) and was augmented by data provided by the Ontario Ministry of the Environment, Conservation and Parks (MECP; formerly Ontario Ministry of the Environment (MOE 2011)), the Ecological Soil Screening Level (Eco-SSL) document for arsenic (U.S. EPA 2005a), and a search of the ECOTOX database (a publicly available knowledgebase providing single chemical environmental toxicity data on aquatic life, terrestrial plants, and wildlife hosted by the U.S. EPA).

A literature search was also conducted to determine if there was information available specifically for effects of arsenic on ecological receptors in cold climates; however, no papers were identified that were robust enough to be used in the derivation of the SQG_{SC}.

The compiled database is provided in Appendix C and includes data for 22 different plant species such as radish, lettuce, beans, tomatoes, cabbage, spinach, corn, oats as well as grasses, clover, barley and rice (none of which are native to the NT). There are five data points for earthworms (*Eisenia foetida*, which may not be present in the NT) based on three literature studies. As per the CCME, the preferred approach is to compile IC_{25} and EC_{25} data (i.e., effect concentration affecting 25% of the test population). For arsenic, only two EC_{25} values were available. Thus, as per the CCME procedure, the two EC_{25} values were augmented with a combined set of "effects" and "no observed effects" endpoints, including

EC_{50}, LC_{50}, no observed effects concentration/level and low observed effects concentration/level (NOEC/NOEL and LOEC/LOEL), and maximum acceptable toxicant concentration (MATC).

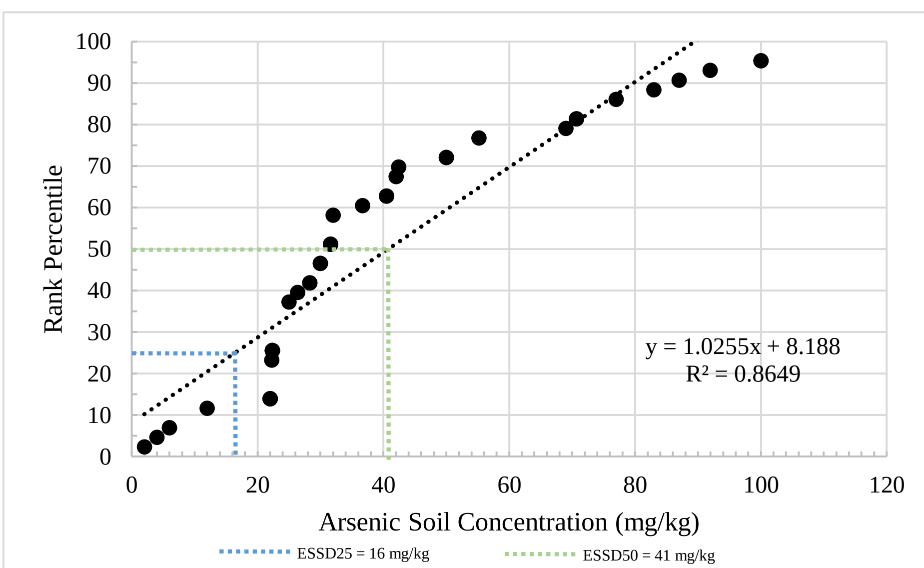
The derivation of the soil contact value involves the calculation of the threshold effects concentration (TEC) for agricultural and residential/parkland land uses, and the effects concentration – low (ECL) for commercial and industrial land uses:

$$\mathrm{SQG_{SC}} = \mathrm{TEC} = \frac{ESSD_{25}}{UF}\ (agricultural/residential/parkland) \qquad (4)$$

$$\mathrm{SQG_{SC}} = \mathrm{ECL} = ESSD_{50}\ (industrial/commercial)$$

In the above equations, either the 25th or 50th percentile of the estimated species sensitivity distribution ($ESSD_{25/50}$) is used, which is estimated from rank probability plots of the data. Thus, the compiled data were then ranked and rank percentiles were determined for each data point. The resulting rank probability plot of the complete database, shown in Appendix C, did not show a good fit of the data, especially for arsenic in soil concentrations greater than 100 mg/kg. Thus, revised rank percentiles were re-calculated for each data point up to and including an arsenic concentration of 100 mg/kg. The resulting rank probability plot of the truncated database is shown in Figure 4.1, which shows a much better fit of the data.

Figure 4.1 Rank probability plot of toxicity data for plants and earthworms up to an arsenic concentration of 100 mg/kg



As seen from Figure 4.1, the $ESSD_{25}$ arsenic soil concentration of the ranked data is 16 mg/kg. Thus, the SQG_{SC} for agricultural and residential/parkland land use is 16 mg/kg. This value is below the arsenic background concentrations for Yellowknife and Inuvik that were presented in Table 2.2 (Stantec 2020a, 2020b). Although there are only two EC_{25} values in the database and the only soil invertebrate represented is the earthworm, an additional uncertainty factor was not applied due to the large database of information.

The industrial and commercial SQG_{SC}, which is the $ESSD_{50}$ of the information provided in Figure 4.1, is an arsenic concentration of 41 mg/kg. This is equal to the background arsenic concentration within 25 km of Yellowknife, outside of the municipal boundary and YGB.

The SQG_{SC} presented here do not differ substantially from the CCME (Environment Canada 1999) values of 17 mg/kg (agricultural and residential/parkland) and 26 mg/kg (industrial and commercial) or Ontario (MOE 2011) values of 22 mg/kg (agricultural and residential/parkland) and 34 mg/kg (industrial and commercial), as similar studies have been used in the derivation.

Plant samples collected from the Giant Mine site as part of the GMRP HHERA (CanNorth 2018) demonstrated that healthy growth (i.e., no signs of disease, yellowing leaves, breakage or missing leaves) was observed in soils with arsenic concentrations up to 4,500 mg/kg. This site-specific information unfortunately cannot be used to derive a soil quality guideline but it demonstrates the extremely conservative nature of the NT SQG_{SC}.

4.2.2.2 Soil and Food Ingestion

The soil and food ingestion guideline (SQG_{I}) for wildlife was derived following the CCME (2006), which is calculated for the species that is considered to be most at threat from contaminated soil and food ingestion. The SQG_{I} was only derived for agricultural land use following the CCME approach. Other jurisdictions include consideration of soil and food ingestion for other land uses. This consideration would not affect the setting of a SQG_{E} for arsenic in Yellowknife and Inuvik since the derived SQG_{I} is above the plant and earthworm values provided in Section 4.2.2.1.

Toxicity of Arsenic to Wildlife

The U.S. EPA has developed risk-based ecological soil screening levels (Eco-SSLs) for a number of constituents, including arsenic (U.S. EPA 2005a). In the risk assessment community, these documents are currently considered to be the best source of toxicity data for metals. The data provided in the Eco-SSL database are based on no observed adverse effects levels and lowest observed adverse effects levels (NOAELs and LOAELs) from scientific studies. It is acknowledged that there is inherent uncertainty associated with the use of NOAEL or LOAEL values as TRVs as these values are not innately related to biologically relevant thresholds and do not provide information about the actual magnitude of effects in the reported studies; however, they have widespread use in the risk assessment community and the science is not currently available to change this approach to TRVs.

The Eco-SSL screening process for wildlife toxicity data included a review of dietary literature studies on oral exposure. Exposure durations that encompass multiple generations and/or critical life stages, and reported population relevant endpoints (U.S. EPA 2005b) were selected. Chronic exposure was generally attributed to an exposure duration encompassing a significant portion of a species lifespan. However exposure during sensitive lifestages, such as reproduction were also considered. Based on these critical life stages, reproductive studies with exposure durations as short as five days were considered in the derivation of the wildlife TRVs.

For arsenic, the U.S. EPA (2005a) compiled a dataset of 55 toxicological studies representing a variety of species (i.e., rats, mice, rabbits, guinea pigs, dogs, and goats) and endpoints (specifically reproduction, growth, survival). A TRV for mammalian wildlife of 1.04 mg/kg-d was derived, which represented a NOAEL for growth based on a toxicity study by Neiger and Osweiler (1989) where beagle dogs were exposed to sodium arsenite in food over an 8-week study period.

Derivation

Derivation of the SQG_I involves the estimation of the daily threshold effect dose (DTED) for the species most at risk at each level of the food web (i.e. primary, secondary, and tertiary consumers); since arsenic does not biomagnify, only the primary consumer is considered based on the CCME guidance. The SQG_I is then calculated based on the DTED, soil and food ingestion rates, body weight, bioavailability factor, and the bioaccumulation factor. By combining and rearranging the equations for soil and food ingestion, a SQG_I can be derived that will prevent primary consumers from being exposed to no more than 75% of the DTED from the ingestion of soil and plants:

$$\mathrm{SQG_I} = \frac{0.75 \times \mathrm{DTED} \times \mathrm{BW}}{SIR \times BF + FIR \times BCF} \quad (5)$$

Where:

SQG_I	=	Soil quality guideline for environmental health based on soil and food ingestion (mg/kg)
DTED	=	Daily threshold effect dose (mg/kg-d) {see Table 4.10}
BW	=	Body weight (kg) {see Table 4.10}
SIR	=	Soil ingestion rate (kg/d) {see Table 4.10}
BF	=	Bioavailability factor (-)
FIR	=	Food ingestion rate (kg/d) {see Table 4.10}
BCF	=	Soil to plant bioconcentration factor (kg dw soil/kg dw plant) {see Table 4.10}

Derivation of the SQG_I is detailed in Appendix C. The 0.75 factor is consistent with the CCME (2006) protocol and is used in recognition that other pathways, such as water and dermal/inhalation, may also contribute to the total exposure so soil and food ingestion should be to no more than 75% of the DTED.

The ecological receptor selected for this calculation was the rabbit, which is consistent with the receptor selected by the CCME as being the species most at risk based on available toxicological data (Environment Canada 1999). The rabbit serves as a surrogate for other wildlife species and represents the most exposed ecological receptor from a soil perspective. The characteristics for the rabbit are provided in Table 4.10 and are also consistent with the CCME guideline.

A bioavailability factor (BF) of 1 was used as there is no information available on the bioavailability of arsenic from ingestion for wildlife. This is consistent with CCME guidance.

Modifications to the CCME guidance were made to reflect current science and site-specific data. The DTED was updated from 4 mg/kg-d[1] used in the CCME guideline to 1.04 mg/kg-d to reflect toxicity values that were used in the GMRP HHERA (CanNorth 2018). Additionally, the soil to plant bioconcentration factor (BCF) was modified from 0.059 kg dw soil/kg dw plant used in the CCME guideline to a site-specific value of 0.019 kg dw soil/kg dw plant that was derived from data used in the GMRP HHERA (CanNorth 2018). Derivation of the BCF is detailed in Appendix C.

[1] LOAEL of 8 mg/kg/d divided by uncertainty factor of 2 because LOAEL was from an acute lethal study.

Based on this approach, an arsenic concentration of 138 mg/kg was derived.

Table 4.10 Parameters used in derivation of soil and food ingestion pathway

Symbol	Characteristic	Units	Value	Detail
DTED	Daily threshold effects dose	mg/kg-d	1.04	U.S. EPA (2005a)
BW	Body weight	kg	3	Rabbit; CCME (Environment Canada 1999)
SIR	Soil ingestion rate	kg/d	0.014	CCME (Environment Canada 1999)
FIR	Food ingestion rate	kg dw/d	0.166	CCME (Environment Canada 1999)
BCF	Bioconcentration factor	kg dw soil /kg dw plant	0.019	Site-specific, see Appendix C. Note that this value is concentration-dependent.

4.2.3 Values Protective of Environmental Health

Table 4.11 summarizes the derived guidelines for different land uses for the direct soil contact pathway for plants and earthworms (SQG_{SC}) and the food ingestion pathway for wildlife (SQG_I). The final SQG_E is based on the lowest concentration between these two pathways; for arsenic, the limiting pathway is the plant and earthworm direct soil contact. It is noted that these data are for sensitive plant species that are not common native species in Yellowknife or Inuvik.

Table 4.11 Summary of environmental health soil quality guidelines for arsenic

Pathway	Land Use			
	Agricultural	Residential / Parkland	Commercial	Industrial
SQG_E (mg/kg)	**16**	**16**	**41**	**41**
SQG_{SC} (soil contact)	16	16	41	41
SQG_I (soil and food ingestion)	138	-	-	-

Note: dash indicates a guideline/check value that is not part of the exposure scenario for this land use and therefore is not calculated.

4.2.4 Sensitivity Analysis

A sensitivity assessment was done to determine if using other BCFs besides the site-specific ones used in the wildlife food ingestion calculations would result in a substantial change to the arsenic concentration. In addition, the sensitivity analysis examined whether changing the toxicity values for arsenic would result in a significantly difference in the soil concentration. A vegetation BCF of 0.059 kg dw soil/kg dw plant from the CCME guidelines (Environment Canada 1999) and 0.03752 kg dw soil/kg dw plant from Eco-SSL (U.S. EPA 2005a) were used in lieu of the site-specific value. For the toxicity, the DTED of 4 mg/kg-d (Environment Canada 1999) was used in lieu of the value selected for the current assessment. The results of the sensitivity assessment (Table 4.12) demonstrated that the BCF and DTED can change the soil and food ingestion value (SQG_I) ranging between 99 mg/kg and 589 mg/kg. The SQG_I of 138 mg/kg presented in Table 4.11 was derived using the plant-to-soil relationship from the GMRP HHERA (CanNorth 2018). This approach was considered to be appropriate; however the sensitivity analysis shows that the range of values would not affect the overall environmental protection value since it is driven by soil contact (SQG_{SC}).

Table 4.12 Sensitivity analysis for wildlife exposure component of soil quality guideline

	SQG_I (Soil quality guideline for environmental health based on soil and food ingestion) (mg/kg)	
BCF/DTED	**Toxicity Value, DTED**	
	1.04	**4**
BCF used by CCME (Environment Canada 1999)	99	380
BCF from Eco-SSL (U.S. EPA 2005a)	116	448
BCF using site-specific information	*138*	589

Note: *Italics* denote values used in the current derivation.

5.0 FINAL ARSENIC SOIL QUALITY GUIDELINES

The CCME (2006) derives a guideline that is protective of human health (SQG_{HH}) as well as a value protective of environmental health (SQG_{E}), and the final SQG becomes the lower of the two values. The final SQG is also checked against non-toxicity considerations and background soil concentrations.

It is noted that the derived NT SQG_{E} values for arsenic are not specific to Yellowknife and are based on literature studies of sensitive plants such as barley, lettuce, and earthworms that are not native to the NT. In addition, observations from plant samples from the Giant Mine site discussed in Section 4.2.2.1 demonstrate that ecological populations are not being adversely affected in the NT. Therefore, the SQG_{E} were not considered in the setting of the final arsenic NT SQGs for remediation.

In selecting the final NT SQGs for Yellowknife and Inuvik, a check was made to determine if derived SQG_{HH} values (Section 4.1.4) were above or below the range of background concentrations for Yellowknife (Stantec 2020a) or Inuvik (Stantec 2020b). The comparisons are shown in Figure 5.1 to Figure 5.3. The background concentration datasets used by Stantec are provided in Appendix D.

Figure 5.1 and Figure 5.2 show the comparisons for both areas in Yellowknife (within the municipal boundary and YGB and outside). As seen from the figures the derived human health SQGs for all land uses are generally above the majority of the background concentrations, and it is reasonable to consider these values when selecting the final SQGs. Thus, the human health SQGs are selected as the final NT SQGs for all land uses for Yellowknife, as summarized in Table 5.1.

For Inuvik (Figure 5.3), the SQG_{HH} for commercial and industrial land uses is at the upper range of background concentrations, while the SQG_{HH} for agricultural and residential/parkland land use is within the range of background concentrations. Therefore further consideration for a more appropriate final SQG is warranted. In deriving the previous SQG for Inuvik, Meridian (2011) selected the 90^{th} percentile of the background dataset as the final SQG for all land uses. The 90^{th} percentile of the revised background dataset developed by Stantec (2020b) is shown in Figure 5.3, which is essentially equal to the SQG_{HH} for commercial and industrial land uses and is above background. Thus, the same approach was applied in the current derivation, setting the final SQG for Inuvik for all land uses equal to the 90^{th} percentile.

Figure 5.1 Comparison of human health soil quality guideline to background concentrations within Yellowknife and the Yellowknife Greenstone Belt

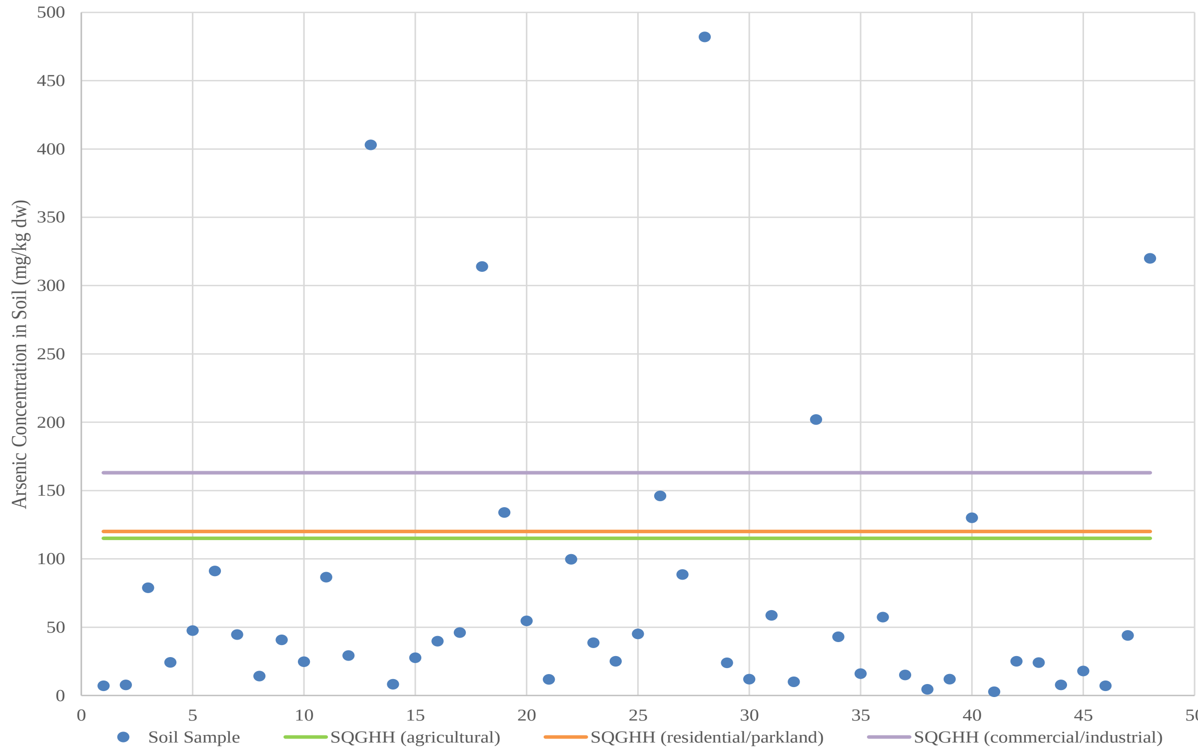


Figure 5.2 Comparison of human health soil quality guideline to background concentrations outside of Yellowknife and the Yellowknife Greenstone Belt

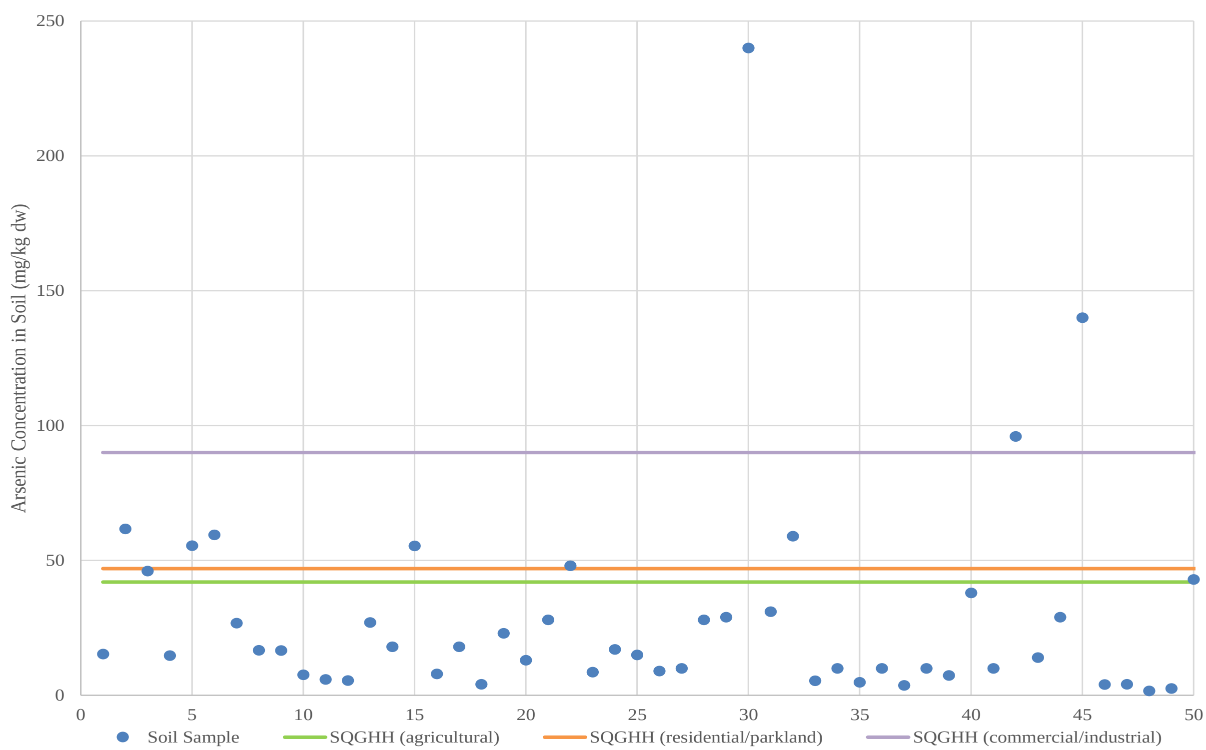
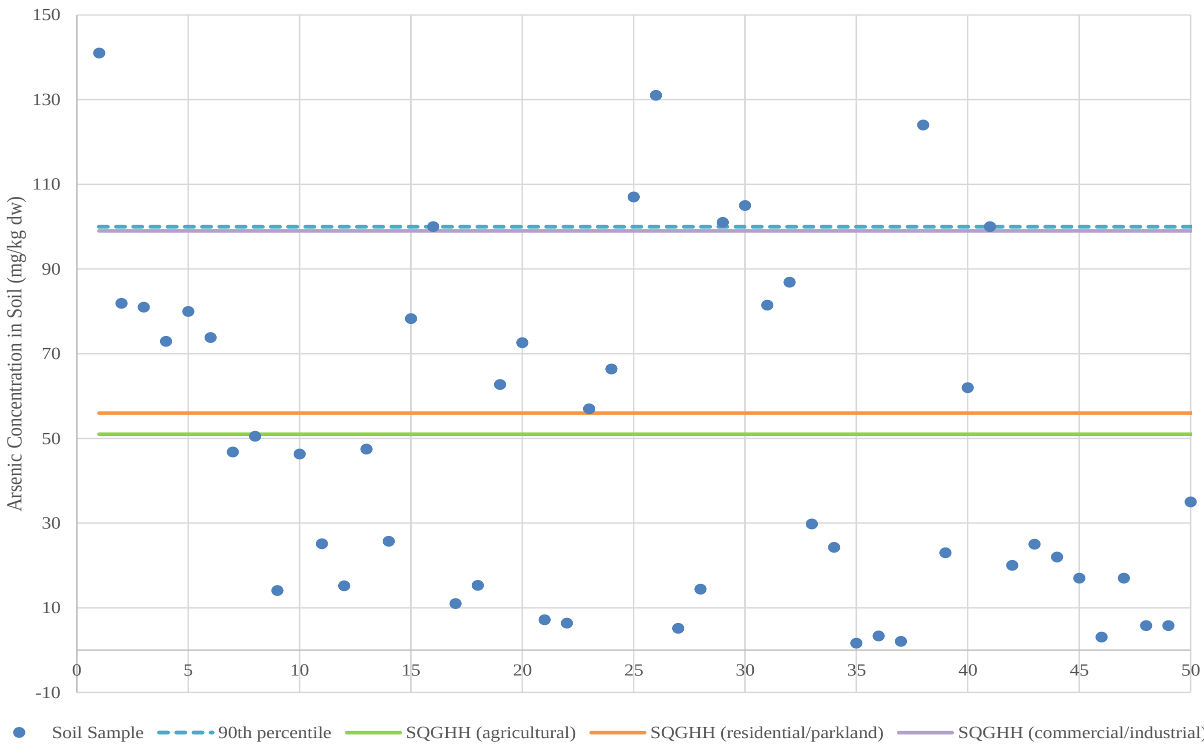


Figure 5.3 Comparison of human health soil quality guideline to background concentrations around Inuvik



The proposed final SQGs for Yellowknife and Inuvik are summarized in Table 5.1. The NT SQG for residential/parkland land use within Yellowknife and the YGB of 120 mg/kg is the same order of magnitude as but lower than the current NT guideline of 160 mg/kg. For commercial and industrial land uses, the NT SQG of 163 mg/kg is much lower than the current NT guideline of 340 mg/kg. The SQG values for within 25 km of the City of Yellowknife but outside of the Yellowknife municipal boundary and the YGB are much lower due to the lower arsenic background concentrations. For Inuvik, the derived NT SQGs for all land uses are lower than the current guideline of 120 mg/kg due to a different background dataset used to derive the 90th percentile value.

Table 5.1 Proposed NT soil quality guidelines for arsenic

Location	Land Use			
	Agricultural	**Residential / Parkland**	**Commercial**	**Industrial**
SQG (mg/kg)[a]				
Within Yellowknife and YGB	**115**	**120**	**163**	**163**
Outside Yellowknife and YGB[b]	**42**	**47**	**90**	**90**
Inuvik	**100[c]**	**100[c]**	**100[c]**	**100[c]**
SQG_{HH} (mg/kg)				
Within Yellowknife and YGB	115	120	163	163
Outside Yellowknife and YGB[b]	42	47	90	90
Inuvik	51	56	99	99
Limiting pathway for SQG_{HH}	Food (produce) ingestion	Food (produce) ingestion	Soil ingestion and skin contact	Soil ingestion and skin contact
SQG_E (mg/kg)	16	16	41	41
Limiting pathway for SQG_E	Soil contact	Soil contact	Soil contact	Soil contact

Note: SQG_E – soil quality guideline for environmental health; SQG_{HH} – soil quality guideline for human health.

[a] Final guideline set equal to SQG_{HH}.

[b] Within 25 km of the City of Yellowknife.

[c] Set equal to 90th percentile background concentration.

6.0 LITERATURE CITED

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APPENDIX A

SOIL TO GARDEN PRODUCE BIOCONCENTRATION FACTOR

APPENDIX A: SOIL TO GARDEN PRODUCE BIOCONCENTRATION FACTOR

In order to calculate a soil quality guideline for food (produce) ingestion (SQG_{FI}), a relationship between the soil concentration and produce concentration must be derived, termed a bioconcentration factor (BCF):

$$BCF\ (kg\ dw/kg\ ww) = \frac{Concentration\ in\ soil\ (mg/kg\ dw)}{Concentration\ in\ produce\ (mg/kg\ ww)}$$

In the CCME (Environment Canada 1999) development of the generic SQG for arsenic, a BCF of 0.059 kg dw soil/kg dw plant was used to evaluate exposure to wildlife from ingestion of plants; ingestion of produce by humans was not evaluated so the CCME did not derive a BCF for garden produce. In developing site-specific human-health soil quality remediation objectives for Yellowknife, Risklogic (2002) used measured soil and garden produce data from a 2001 study in Yellowknife (ESG 2001) to derive a BCF specific to garden produce of 0.001 kg dw soil/kg ww produce. As it was not clear from the Risklogic report how this value was derived, the data from the Yellowknife study were analyzed to confirm the BCF.

In the study, soil and produce samples from a total of 10 gardens in Yellowknife were collected and submitted for analysis. For gardens where multiple soil samples were obtained, an average arsenic concentration for that garden was calculated. The results are shown in Table A.1.

Table A.1 Arsenic soil concentrations in Yellowknife gardens

Garden Number	Arsenic Soil Concentration (mg/kg dw)	
	Single Sample	Garden Average
1	81	202
	351	
	174	
2	17	28
	22	
	44	
3	24	24
4	55	55
5	30	30
6	35	35
7	29	29
8	27	27
9	12	12
10	56	56

Note: Data from ESG (2001).

A BCF was then calculated for each garden produce sample available, using the average soil concentration from the respective garden from which it was obtained. Half of the method detection limit (MDL) was used when the measured concentration was below the MDL. An overall BCF of 0.0023 kg dw soil/kg ww produce was then calculated as the average of the individual BCF values. This value was used in the guideline derivation for food (produce) ingestion. Table A.2 summarizes the individual and overall average BCFs.

Table A.2 Soil to garden produce bioconcentration factors

Garden Number	Species	Arsenic Concentration (mg/kg ww)	Bioconcentration Factor
1	*Raphanus sativus*	0.17	0.0008
1	*Beta vulgaris var. crassa*	0.29	0.0014
1	*Rheum rhababarum*	0.05	0.0002
1	*Amelanchier alnifolia*	0.44	0.0022
2	*Daucus carota*	0.034	0.0012
2	*Solanum tuberosum*	0.034	0.0012
2	*Allium capa*	0.041	0.0015
2	*Beta vulgaris var. crassa*	0.02	0.0007
2	*Beta vulgaris var. crassa*	0.18	0.0065
2	*Allium cepa*	0.15	0.0054
2	*Lactuca sativa*	0.06	0.0022
2	*Lactuca sativa*	0.13	0.0047
2	*Apium graveolens var. dulce*	0.29	0.0105
2	*Apium graveolens var. dulce*	0.05	0.0018
2	*Rheum rhababarum*	0.014	0.0005
2	*Pisum sativum*	0.01[a]	0.0004
2	*Phaseolus vulgaris*	0.016	0.0006
3	*Beta vulgaris var. crassa*	0.19	0.0079
3	*Beta vulgaris var. crassa*	0.13	0.0054
3	*Lactuca sativa*	0.27	0.0113
3	*Lactuca sativa*	0.12	0.0050
3	*Lycopersicon esculentum*	0.009	0.0004
4	*Solanum tuberosum*	0.026	0.0005
4	*Brassica oleracea var. gongylodes*	0.044	0.0008
4	*Brassica oleracea var. capitata*	0.09	0.0016
4	*Brassica oleracea var. acephala*	0.16	0.0029
4	*Pisum sativum*	0.01 [a]	0.0002
4	*Phaseolus vulgaris*	0.018	0.0003
5	*Daucus carota*	0.05	0.0017
5	*Beta vulgaris*	0.09	0.0030
5	*Petroselinum crispum var. neapolitanum*	0.1	0.0033
5	*Origanum sp.*	0.23	0.0077
5	*Rheum rhababarum*	0.005 [a]	0.0002
6	*Daucus carota*	0.06	0.0017
6	*Solanum tuberosum*	0.015 [a]	0.0004
7	*Daucus carota*	0.037	0.0013
7	*Solanum tuberosum*	0.01 [a]	0.0003
8	*Daucus carota*	0.02	0.0007

Garden Number	Species	Arsenic Concentration (mg/kg ww)	Bioconcentration Factor
8	*Solanum tuberosum*	0.01 [a]	0.0004
8	*Allium cepa*	0.017	0.0006
8	*Allium sativum*	0.015 [a]	0.0006
8	*Beta vulgaris var. crassa*	0.034	0.0013
8	*Beta vulgaris var. crassa*	0.1	0.0037
8	*Allium cepa*	0.18	0.0067
8	*Allium sativum*	0.11	0.0041
8	*Brassica oleracea var. capitata*	0.033	0.0012
8	*Anethum graveolens*	0.07	0.0026
8	*Beta vulgaris*	0.06	0.0022
8	*Rheum rhababarum*	0.015	0.0006
8	*Prunus pensylvanica*	0.09	0.0033
8	*Amelanchier alnifolia*	0.15	0.0056
9	*Solanum tuberosum*	0.02	0.0017
9	*Brassica oleracea var. capitata*	0.005 [a]	0.0004
9	*Brassica oleracea cymosa*	0.01 [a]	0.0008
9	*Pisum sativum*	0.036	0.0030
9	*Curcurbita pepo*	0.0025 [a]	0.0002
10	*Daucus carota*	0.07	0.0013
10	*Solanum tuberosum*	0.07	0.0013
10	*Solanum tuberosum*	0.06	0.0011
10	*Lactuca sativa*	0.08	0.0014
10	*Rheum rhababarum*	0.014	0.0003
10	*Phaseolus vulgaris*	0.026	0.0005
	Average	**0.080**	**0.0023**

Note: Data from ESG (2001).
[a] Concentration reported as being less than the method detection limit (MDL); converted to ½ the MDL.

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APPENDIX B

HUMAN HEALTH SOIL QUALITY GUIDELINE DERIVATION

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APPENDIX B: HUMAN HEALTH SOIL QUALITY GUIDELINE DERIVATION

The derived human health arsenic concentrations for different land uses in each of the two different areas in Yellowknife as well as Inuvik for the various exposure pathways (ingestion, dermal contact, particulate inhalation) are summarized in Table B.1 The guidelines were derived based on Health Canada's negligible incremental lifetime cancer risk level is one-in-one hundred thousand people (1 in 100,000), for three different background soil concentrations:

- Within Yellowknife and the Yellowknife Greenstone Belt (YGB): 114 mg/kg
- Outside Yellowknife and the YGB: 41 mg/kg
- Inuvik: 50 mg/kg

Table B.1 Summary of human health soil quality guidelines for arsenic

Pathway	Arsenic Soil Concentration (mg/kg)		
	Agricultural	Residential/ Parkland	Industrial/ Commercial
Ingestion and Dermal Contact (Soil, Dust)			
Within Yellowknife and YGB	130	130	163
Outside Yellowknife and YGB	57	57	90
Inuvik	66	66	99
Particulate Inhalation			
Within Yellowknife and YGB	1114	1114	474
Outside Yellowknife and YGB	1041	1041	401
Inuvik	1050	1050	410
Ingestion (Produce)			
Within Yellowknife and YGB	115	120	-
Outside Yellowknife and YGB	42	47	-
Inuvik	51	56	-

Note: agricultural and residential/parkland values are calculated for a lifetime (composite) receptor, while industrial/commercial values are for an adult; based on background soil concentrations of 114 mg/kg for within Yellowknife and YGB, 41 mg/kg for outside Yellowknife and YGB, and 50 mg/kg for Inuvik.

The equations and calculations for deriving the values in Table B.1 are presented herein. Values of each of the parameters in the equations are provided in Table B.2. For the lifetime (composite) receptor for agricultural and residential/parkland land uses, the receptor characteristics for each individual lifestage (infant, toddler, child, teen, adult, Elder) were averaged over the exposure duration. For example, for body weight:

$$BW_{composite} = \frac{\sum(BW_{lifestage} \times ED_{lifestage})}{\sum ED_{lifestage}}$$

$$= \frac{BW_{infant} \times ED_{infant} + BW_{toddler} \times ED_{toddler} + BW_{child} \times ED_{child} + BW_{teen} \times ED_{teen} + BW_{adult} \times ED_{adult} + BW_{Elder} \times ED_{Elder}}{ED_{infant} + ED_{toddler} + ED_{child} + ED_{teen} + ED_{adult} + ED_{Elder}}$$

$$= \frac{8.2\times0.5+16.5\times4.5+32.9\times7+59.7\times8+70.7\times50+70.7\times10}{0.5+4.5+7+8+50+10}$$

$$= 62.9\ kg$$

For industrial and commercial land uses, the receptor characteristic for an adult were used. In the following sample calculations, BSC is the background soil concentration.

B.1 Soil and Dust Ingestion and Skin Contact

The arsenic soil value for soil and dust ingestion and skin contact is calculated for three different background soil concentrations (BSCs) as follows:

$$\mathrm{SQG_{DH-IDC}} = \frac{\frac{Risk}{\mathrm{SF_0}}\times\mathrm{BW}}{\mathrm{ET_4}\times\{\mathrm{RAF_{ing}}\times(\mathrm{SIR}\times\mathrm{ET_1}+\mathrm{DIR}\times\mathrm{F_{dust}}\times\mathrm{ET_2})+\mathrm{RAF_d}\times(\mathrm{DCR}_{soil}\times\mathrm{ET_1}+\mathrm{DCR}_{dust}\times\mathrm{F_{dust}}\times\mathrm{ET_2})\}\times\frac{ED}{AT}} + \mathrm{BSC}$$

For a composite receptor for agricultural and residential/parkland land uses:

$$= \frac{\frac{1E-05}{1.8}\times62.9}{1\times\{0.36\times(2.3\mathrm{E}-05\times0.42+7.4\mathrm{E}-06\times0.7\times1)+0.03\times(1.1\mathrm{E}-03\times0.42+1.7\mathrm{E}-04\times0.7\times1)\}\times\frac{80}{80}} + (114, 41, \text{or } 50)$$

$$= 16 + (114, 41, \text{or } 50)$$

$$= 130 \text{ mg/kg (within Yellowknife and YGB)}$$

$$= 57 \text{ mg/kg (outside Yellowknife and YGB)}$$

$$= 66 \text{ mg/kg (Inuvik)}$$

For an adult for industrial and commercial land uses:

$$= \frac{\frac{1E-05}{1.8}\times70.7}{0.71\times\{0.36\times(5.0\mathrm{E}-05\times0.42+2.5\mathrm{E}-06\times0.7\times0)+0.03\times(9.5\mathrm{E}-04\times0.42+1.8\mathrm{E}-04\times0.7\times1)\}\times\frac{35}{60}} + (114, 41, \text{or } 50)$$

$$= 49 + (114, 41, \text{or } 50)$$

$$= 163 \text{ mg/kg (within Yellowknife and YGB)}$$

$$= 90 \text{ mg/kg (outside Yellowknife and YGB)}$$

$$= 99 \text{ mg/kg (Inuvik)}$$

B.2 Particulate Inhalation

The arsenic soil value for particulate inhalation is calculated for three different background soil concentrations (BSCs) as follows:

$$\mathrm{SQG_{DH-PI}} = \frac{\frac{Risk}{UR}}{\mathrm{PM_{10} \times F_{dep} \times RAF_{inh} \times ET_1 \times ET_3 \times ET_4} \times \frac{ED}{AT}} + \mathrm{BSC}$$

For a composite receptor for agricultural and residential/parkland land uses:

$$= \frac{\frac{1E-05}{6.4}}{1\mathrm{E}{-}07 \times 0.6 \times 1 \times 0.42 \times 0.06 \times 1 \times \frac{80}{80}} + (114, 41, \text{or } 50)$$

$$= 1000 + (114, 41, \text{or } 50)$$

$$= 1114 \text{ mg/kg (within Yellowknife and YGB)}$$

$$= 1041 \text{ mg/kg (outside Yellowknife and YGB)}$$

$$= 1050 \text{ mg/kg (Inuvik)}$$

For an adult for industrial and commercial land uses:

$$= \frac{\frac{1E-05}{6.4}}{1\mathrm{E}{-}07 \times 0.6 \times 1 \times 0.42 \times 0.42 \times 0.71 \times \frac{35}{60}} + (114, 41, \text{or } 50)$$

$$= 360 + (114, 41, \text{or } 50)$$

$$= 474 \text{ mg/kg (within Yellowknife and YGB)}$$

$$= 401 \text{ mg/kg (outside Yellowknife and YGB)}$$

$$= 410 \text{ mg/kg (Inuvik)}$$

B.3 Food Ingestion

The arsenic soil value for food (produce) ingestion for agricultural and residential/parkland land uses is calculated for three different background soil concentrations (BSCs) as follows:

$$\mathrm{SQG_{FI}} = \frac{\frac{Risk}{\mathrm{SF_0}} \times \mathrm{BW}}{\mathrm{RAF_{f-ing} \times BCF \times FIR} \times F_{food} \times \frac{ED}{AT}} + \mathrm{BSC}$$

For a composite receptor for agricultural land uses with a higher percent homegrown produce ($F_{food} = 0.5$):

$$= \frac{\frac{1E-05}{1.8} \times 62.9}{1 \times 0.002 \times 0.31 \times 0.5 \times \frac{80}{80}} + (114, 41, \text{or } 50)$$

$$= 1 + (114, 41, \text{or } 50)$$

$$= 115 \text{ mg/kg (within Yellowknife and YGB)}$$

$$= 42 \text{ mg/kg (outside Yellowknife and YGB)}$$

$$= 51 \text{ mg/kg (Inuvik)}$$

For a composite receptor for residential/parkland land uses with a lower percent homegrown produce ($F_{food} = 0.1$):

$$= \frac{\frac{1E-05}{1.8} \times 62.9}{1 \times 0.002 \times 0.31 \times 0.1 \times \frac{80}{80}} + (114, 41, \text{or } 50)$$

$$= 6 + (114, 41, \text{or } 50)$$

$$= 120 \text{ mg/kg (within Yellowknife and YGB)}$$

$$= 47 \text{ mg/kg (outside Yellowknife and YGB)}$$

$$= 56 \text{ mg/kg (Inuvik)}$$

Table B.2 Summary of values used in calculating human health soil quality guidelines

Symbol	**Description**	**Units**	**Value**	**Source**
SF	Oral slope factor	$(mg/kg/d)^{-1}$	1.8	Health Canada
UR	Inhalation unit risk	$(mg/m3)^{-1}$	6.4	Health Canada
RAF_{ing}	Relative absorption factor for soil/dust ingestion	-	0.36	Average of five samples collected from Fred Henne Campground at Long Lake (Golder 2016)
$RAF_{f\text{-}ing}$	Relative absorption factor for food ingestion	-	1	Assumed
RAF_{inh}	Relative absorption factor for lung	-	1	Assumed
RAF_{d}	Relative absorption factor for skin	-	0.03	Health Canada (2010)
F_{dust}	Fraction of soil that is dust (indoors)	-	0.7	U.S. EPA (1998)
F_{dep}	Fraction of inhaled PM_{10} deposited to respiratory system	-	0.6	Ontario Ministry of Environment, Conservation and Parks (MOE 2011)
BCF	Soil to garden produce bioconcentration factor	kg dw soil/ kg ww produce	0.002	Derived from data from garden produce study (ESG 2001); see Appendix A

			Adult Worker	**Composite (Agricultural)**	**Composite (Residential)**	**Infant**	**Toddler**	**Child**	**Teen**	**Adult**	**Elder**	**Individual lifestages shown for calculation of lifetime-averaged characteristics for composite receptors**
BW	Body weight	kg	70.7	62.9	62.9	8.2	16.5	32.9	59.7	70.7	70.7	Health Canada (2012)
SIR	Soil ingestion rate	kg/d	5.0E-05	2.3E-05	2.3E-05	2.0E-05	8.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	Health Canada (2012) for the agricultural and residential land uses; upper percentile for dust and soil exposure for an adult for industrial and commercial land uses (U.S. EPA 2017).
DIR	Dust ingestion rate	kg/d	0	7.4E-06	7.4E-06	3.8E-05	4.1E-05	3.1E-05	2.2E-06	2.5E-06	2.5E-06	Health Canada (2018), Table 4
PM_{10}	Particulate concentration (10 µm in diameter or less)	kg/m^3	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07	Ontario Ministry of Environment, Conservation and Parks (MOE 2011)
DCR_{soil}	Soil dermal contact rate	kg/d	9.5E-04	1.1E-03	1.1E-03	3.8E-04	5.2E-04	7.4E-04	1.0E-03	1.1E-03	1.1E-03	$=[(SA_{hands} \times SL_{hands}) + (SA_{other} \times SL_{other})] \times EV$
SA_{hands}	*Skin Surface Area - hands*	*cm^2*	*890*	*825*	*825*	*320*	*430*	*590*	*800*	*890*	*890*	Health Canada (2012)
SA_{other}	*Skin Surface Area - other*	*cm^2*	*617*	*2281*	*2281*	*550*	*890*	*1480*	*2230*	*2500*	*2500*	Arms for composite; 3.5% of total body (i.e., face) for worker (Liu et al. 2008)
SA_{body}	*Skin Surface Area - whole body*	*cm^2*	*17640*	*16032*	*16032*	*3620*	*6130*	*10140*	*15470*	*17640*	*17640*	Health Canada (2012)
SL_{hands}	*Soil loading - hands*	*$kg/cm^2/event$*	*1.00E-06*	*0.0*	*1.00E-06*	*1.00E-06*	*1.00E-06*	*1.00E-06*	*1.00E-06*	*1.00E-06*	*1.00E-06*	Health Canada (2012)
SL_{other}	*Soil loading - other*	*$kg/cm^2/event$*	*1.00E-07*	*0.0*	*1.00E-07*	*1.00E-07*	*1.00E-07*	*1.00E-07*	*1.00E-07*	*1.00E-07*	*1.00E-07*	Health Canada (2012)
EV	*Soil dermal contact events per day*	*event/d*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	Health Canada (2012)
DCR_{dust}	Dust dermal contact rate	kg/d	1.8E-04	1.7E-04	1.7E-04	6.4E-05	8.6E-05	1.2E-04	1.6E-04	1.8E-04	1.8E-04	$=[(SA_{hands} \times DL_{hands}) + (SA_{other} \times DL_{other})] \times EV_d$
SA_{hands}	*Skin Surface Area - hands*	*cm^2*	*890*	*825.3*	*825.3*	*320*	*430*	*590*	*800*	*890*	*890*	Health Canada PQRA (2012)
SA_{other}	*Skin Surface Area - other*	*cm^2*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	Assume dust contact with hands only
DL_{hands}	*Dust loading - hands*	*$kg/cm^2/event$*	*2.00E-07*	*2.00E-07*	*2.00E-07*	*2.00E-07*	*2.00E-07*	*2.00E-07*	*2.00E-07*	*2.00E-07*	*2.00E-07*	Health Canada (Wilson & Meridian 2011), Table 3.2
DL_{other}	*Dust loading - other*	*$kg/cm^2/event$*	*3.00E-08*	*0.0*	*3.00E-08*	*3.00E-08*	*3.00E-08*	*3.00E-08*	*3.00E-08*	*3.00E-08*	*3.00E-08*	Health Canada (Wilson & Meridian 2011), Table 3.2
EV_d	*Events per day*	*event/d*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	Assumed equal to soil dermal contact events
FIR	Food (produce) ingestion rate	kg ww/d	0	0.31	0.31	0	0.172	0.259	0.347	0.325	0.325	$=FIR_{RV} + FIR_{OV}$
FIR_{RV}	*Root vegetable consumption rate*	*kg ww/d*	*0*	*0.18*	*0.18*	*0.083*	*0.105*	*0.161*	*0.227*	*0.188*	*0.188*	Health Canada (2012)
FIR_{OV}	*Other vegetable consumption rate*	*kg ww/d*	*0*	*0.13*	*0.13*	*0.072*	*0.067*	*0.098*	*0.12*	*0.137*	*0.137*	Health Canada (2012)
F_{food}	Fraction of food (produce) that is homegrown	-	0	0.50	0.10	-	-	-	-	-	-	CCME (2006)
ET1	Months outdoors per year/12 months per year	-	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	Site-specific; five months per year (no snow cover)
ET2	Months indoors per year/12 months per year	-	0	1	1	1	1	1	1	1	1	Year-round
ET3	Hours per day exposed/24 hours per day	-	0.42	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	Outdoors 1.5 hours per day for composite, 10 hours per day for worker (Health Canada 2012)

Symbol	Description	Units	Value	Source								
			Adult Worker	**Composite (Agricultural)**	**Composite (Residential)**	**Infant**	**Toddler**	**Child**	**Teen**	**Adult**	**Elder**	**Individual lifestages shown for calculation of lifetime-averaged characteristics for composite receptors**
ET4	Days per week exposed/7 days per week	-	0.71	1	1	1	1	1	1	1	1	7 days per week for composite, 5 days per week for worker (Health Canada 2012)
ED	years exposed	years	35	80	80	0.5	4.5	7	8	50	10	Health Canada (2012)
AT	Life Expectancy	years	60	80	80	-	-	-	-	-	-	Health Canada (2012); years as an adult/Elder for worker

B.4 Literature Cited

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APPENDIX C

ENVIRONMENTAL HEALTH SOIL QUALITY GUIDELINE DERIVATION

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APPENDIX C: ENVIRONMENTAL HEALTH SOIL QUALITY GUIDELINE DERIVATION

The derived environmental health arsenic soil quality guidelines for different land uses considering the direct soil contact pathway for plants and earthworms and the food ingestion pathway for wildlife are summarized in Table C.1. This appendix provides details on the derivation of these values.

Table C.1 Calculated environmental health soil quality guidelines for arsenic

Pathway	Arsenic Soil Concentration (mg/kg)			
	Agricultural	**Residential / Parkland**	**Commercial**	**Industrial**
SQG_E	**16**	**16**	**41**	**41**
SQG_{SC} (soil contact)	16	16	41	41
SQG_I (soil and food ingestion)	138	-	-	-

Note: dash indicates a guideline/check value that is not part of the exposure scenario for this land use and therefore is not calculated.

C.1 Soil Contact by Plants and Soil Invertebrates

The first step in deriving the soil contact value for Yellowknife and Inuvik was to compile a database of toxicity data for plants and soil invertebrates for exposure to arsenic in soil. This database included the information used by the CCME in the derivation of the 1999 soil quality guideline (Environment Canada 1999) and was augmented by data provided by the Ontario Ministry of the Environment, Conservation and Parks (MECP; formerly Ontario Ministry of the Environment (MOE 2011)), the Ecological Soil Screening Level (Eco-SSL) document for arsenic (U.S. EPA 2005), and a search of the ECOTOX database (a publicly available knowledgebase providing single chemical environmental toxicity data on aquatic life, terrestrial plants, and wildlife hosted by the U.S. EPA).

A literature search was also conducted to determine if there was information available specifically for effects of arsenic on ecological receptors in cold climates; however, no papers were identified that were robust enough to be used in the derivation of the soil contact value.

As per the CCME, the preferred approach is to compile IC_{25} and EC_{25} data (i.e., effect concentration affecting 25% of the test population). For arsenic, only two EC_{25} values were available. Thus, as per the CCME procedure, the two EC_{25} values were augmented with a combined set of “effects” and “no observed effects” endpoints, including EC_{50}, LC_{50}, no observed effects concentration/level and low observed effects concentration/level

(NOEC/NOEL and LOEC/LOEL), and maximum acceptable toxicant concentration (MATC).

The plant database consisted of two EC_{25}, two EC_{50}, 26 NOEC/NOEL, nine LOEL/LOEC, eight MATC, and 24 undefined effect concentration endpoints which were taken to be LOECs for the purposes of the derivation. When paired NOEC and LOEC endpoints were available for a species from a study, then the geometric mean of these values was calculated which corresponds to a MATC. The database is summarized in Table C.2; shaded values represent those values that were used in the final derivation, while non-shaded values indicate the paired NOEC/LOEC values that were used to calculate MATC values.

For plant invertebrates, toxicity data were only available for earthworms (*Eisenia foetida*), with two LC_{50} and three NOEC values. These data are also summarized in Table C.2.

The resulting data were thank ranked, and rank percentiles were determined for each data point as per the following equation:

$$j = \frac{i}{(n+1)} x100$$

Table C.3 provides the ranked data. In total, 50 records from 21 studies were used in the derivation. There were 45 records for plants representing 22 different plant species such as radish, lettuce, beans, tomatoes, cabbage, spinach, corn, oats as well as grasses, clover, barley and rice (none of which are native to the NT). There are five data points for earthworms (*Eisenia foetida*, which may not be present in the NT) based on three literature studies. The rank probability plot of the database is shown in Figure C.1, which shows that there is not a good fit of the data, especially at arsenic concentrations greater than 100 mg/kg. Thus, revised rank percentiles were calculated using data only up to and including concentrations of 100 mg/kg arsenic in soil. The revised rank probability plot is shown in Figure C.2, which shows a much better fit of the data.

As seen from Figure C.2, the $ESSD_{25}$ arsenic soil concentration of the ranked data is 16 mg/kg, which corresponds to the SQG_{SC} for agricultural and residential/parkland land use as per the CCME procedure. The industrial and commercial direct contact value for plants and earthworms, which is the $ESSD_{50}$ of the information provided in Figure C.2, is an arsenic concentration of 41 mg/kg.

Figure C.1 Rank probability plot of complete database of plant and earthworm toxicity data

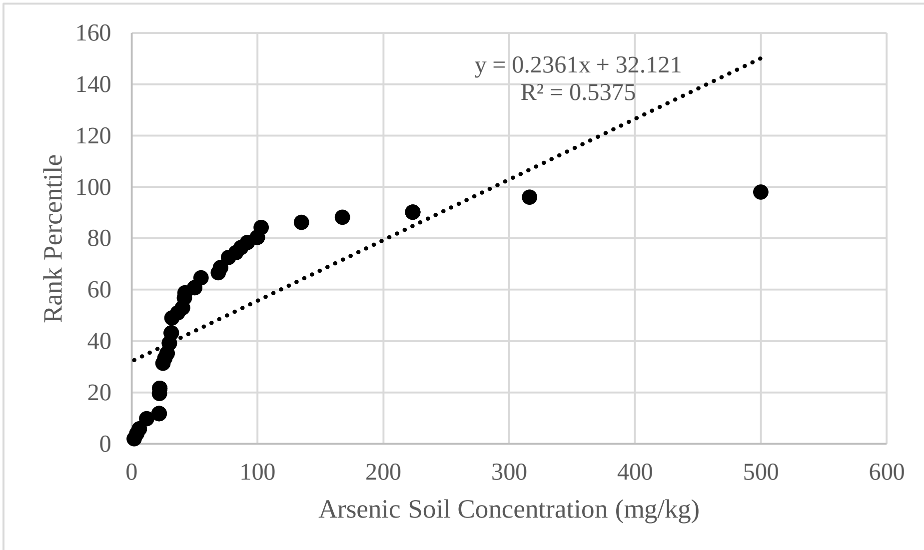

Figure C.2 Rank probability plot of toxicity data for plants and earthworms up to an arsenic concentration of 100 mg/kg

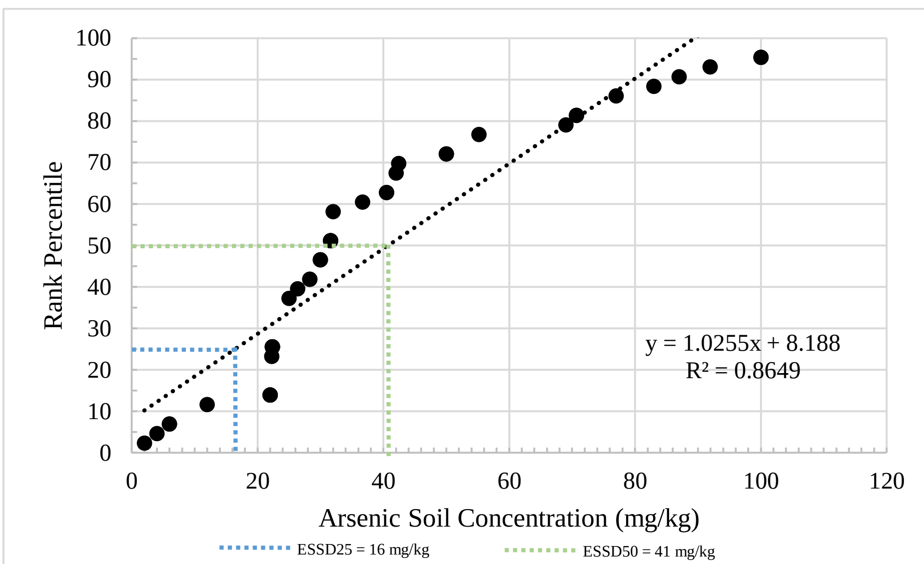

Table C.2 Arsenic toxicity data for soil and plant/invertebrates

Reference	Species Name	Latin Name	Effect	Endpoint	Effective Concentration (mg/kg)	Effective Concentration (mg/kg) - std.dev.	Arsenic Compound	Exposure Period	Soil pH	Test Substrate	Extraction Method	Used for Guideline Calculation?
Environment Canada 1995	Radish	*Raphanus sativus*	Reduced seedling emergence	EC25	12	3	KH_2AsO_4	72 h	4-4.2	Artificial soil; 69-75% sand, 8-9% silt, 16-22% clay, 2.4-3.7% organic content, 2.8-3.3% moisture	HNO_3, HCl, And H_2O_2 digestion analyzed with ICP (#6010A)	Y
Environment Canada 1995	Lettuce	*Lactuca sativa*	Reduced seedling emergence	EC25	32	4	KH_2AsO_4	120 h	4.2-4.3	Artificial soil; 67-75% sand, 8-10% silt, 16-23% clay, 2.7-3.7% organic content, 2.5-3.3% moisture	HNO_3, HCl, And H_2O_2 digestion analyzed with ICP (#6010A)	Y
Woolson 1973	Lima beans	*Phaseolus linensis*	99% total plant yield reduction	NOEC	10	N/A	Na2HAsO4	Grown to maturity	6.2	Loamy sand; 10.5% clay, 0.90% organic matter	Nominal	N; used to calculate geomean
Woolson 1973	Lima beans	*Phaseolus linensis*	99% total plant yield reduction	LOEC*	50	N/A	Na2HAsO4	Grown to maturity	6.2	Loamy sand; 10.5% clay, 0.90% organic matter	Nominal	N; used to calculate geomean
Woolson 1973	Lima beans	*Phaseolus linensis*	99% total plant yield reduction	MATC (calculated)	22.4	N/A	Na2HAsO4	Grown to maturity	6.2	Loamy sand; 10.5% clay, 0.90% organic matter	Nominal	Y; calculated geomean
Woolson 1973	Tomato	*Lycopersicon esculentum*	42% total plant yield reduction	NOEC	10	N/A	Na2HAsO4	Grown to maturity	6.2	Loamy sand; 10.5% clay, 0.90% organic matter	Nominal	N; used to calculate geomean
Woolson 1973	Tomato	*Lycopersicon esculentum*	42% total plant yield reduction	LOEC*	50	N/A	Na2HAsO4	Grown to maturity	6.2	Loamy sand; 10.5% clay, 0.90% organic matter	Nominal	N; used to calculate geomean
Woolson 1973	Tomato	*Lycopersicon esculentum*	42% total plant yield reduction	MATC (calculated)	22.4	N/A	Na2HAsO4	Grown to maturity	6.2	Loamy sand; 10.5% clay, 0.90% organic matter	Nominal	Y; calculated geomean
Woolson 1973	Cabbage	*Brassica oleracea*	68% total plant yield reduction	NOEC	50	N/A	Na2HAsO4	Grown to maturity	6.2	Loamy sand; 10.5% clay, 0.90% organic matter	Nominal	N; used to calculate geomean
Woolson 1973	Cabbage	*Brassica oleracea*	68% total plant yield reduction	LOEC*	100	N/A	Na2HAsO4	Grown to maturity	6.2	Loamy sand; 10.5% clay, 0.90% organic matter	Nominal	N; used to calculate geomean
Woolson 1973	Cabbage	*Brassica oleracea*	68% total plant yield reduction	MATC (calculated)	70.7	N/A	Na2HAsO4	Grown to maturity	6.2	Loamy sand; 10.5% clay, 0.90% organic matter	Nominal	Y; calculated geomean
Woolson 1973	Green beans	*Phaseolus vulgaris*	29% total plant yield reduction	NOEC	10	N/A	Na2HAsO4	Grown to maturity	5.5	Silty clay; 30% clay, 2.5% organic matter	Nominal	N; used to calculate geomean

Reference	Species Name	Latin Name	Effect	Endpoint	Effective Concentration (mg/kg)	Effective Concentration (mg/kg) - std.dev.	Arsenic Compound	Exposure Period	Soil pH	Test Substrate	Extraction Method	Used for Guideline Calculation?
Woolson 1973	Green beans	*Phaseolus vulgaris*	29% total plant yield reduction	LOEC*	50	N/A	Na2HAsO4	Grown to maturity	5.5	Silty clay; 30% clay, 2.5% organic matter	Nominal	N; used to calculate geomean
Woolson 1973	Green beans	*Phaseolus vulgaris*	29% total plant yield reduction	MATC (calculated)	22.4	N/A	Na2HAsO4	Grown to maturity	5.5	Silty clay; 30% clay, 2.5% organic matter	Nominal	Y; calculated geomean
Woolson 1973	Lima beans	*Phaseolus linensis*	16% total plant yield reduction	NOEC	50	N/A	Na2HAsO4	Grown to maturity	5.5	Silty clay; 30% clay, 2.5% organic matter	Nominal	N; used to calculate geomean
Woolson 1973	Lima beans	*Phaseolus linensis*	16% total plant yield reduction	LOEC*	100	N/A	Na2HAsO4	Grown to maturity	5.5	Silty clay; 30% clay, 2.5% organic matter	Nominal	N; used to calculate geomean
Woolson 1973	Lima beans	*Phaseolus linensis*	16% total plant yield reduction	MATC (calculated)	70.7	N/A	Na2HAsO4	Grown to maturity	5.5	Silty clay; 30% clay, 2.5% organic matter	Nominal	Y; calculated geomean
Woolson 1973	Spinach	*Spinacia oleracea*	22% total plant yield reduction	NOEC	10	N/A	Na2HAsO4	Grown to maturity	5.5	Silty clay; 30% clay, 2.5% organic matter	Nominal	N; used to calculate geomean
Woolson 1973	Spinach	*Spinacia oleracea*	22% total plant yield reduction	LOEC*	50	N/A	Na2HAsO4	Grown to maturity	5.5	Silty clay; 30% clay, 2.5% organic matter	Nominal	N; used to calculate geomean
Woolson 1973	Spinach	*Spinacia oleracea*	22% total plant yield reduction	MATC (calculated)	22.4	N/A	Na2HAsO4	Grown to maturity	5.5	Silty clay; 30% clay, 2.5% organic matter	Nominal	Y; calculated geomean
Woolson 1973	Radish	*Raphanus sativus*	25% total plant yield reduction	NOEC	10	N/A	Na2HAsO4	Grown to maturity	5.5	Silty clay; 30% clay, 2.5% organic matter	Nominal	N; used to calculate geomean
Woolson 1973	Radish	*Raphanus sativus*	25% total plant yield reduction	LOEC*	50	N/A	Na2HAsO4	Grown to maturity	5.5	Silty clay; 30% clay, 2.5% organic matter	Nominal	N; used to calculate geomean
Woolson 1973	Radish	*Raphanus sativus*	25% total plant yield reduction	MATC (calculated)	22.4	N/A	Na2HAsO4	Grown to maturity	5.5	Silty clay; 30% clay, 2.5% organic matter	Nominal	Y; calculated geomean
Woolson 1973	Tomato	*Lycopersicon esculentum*	77% total plant yield reduction	NOEC	100	N/A	Na2HAsO4	Grown to maturity	5.5	Silty clay; 30% clay, 2.5% organic matter	Nominal	N; used to calculate geomean
Woolson 1973	Tomato	*Lycopersicon esculentum*	77% total plant yield reduction	LOEC*	500	N/A	Na2HAsO4	Grown to maturity	5.5	Silty clay; 30% clay, 2.5% organic matter	Nominal	N; used to calculate geomean

Reference	Species Name	Latin Name	Effect	Endpoint	Effective Concentration (mg/kg)	Effective Concentration (mg/kg) - std.dev.	Arsenic Compound	Exposure Period	Soil pH	Test Substrate	Extraction Method	Used for Guideline Calculation?
Woolson 1973	Tomato	*Lycopersicon esculentum*	77% total plant yield reduction	MATC (calculated)	223.6	N/A	Na2HAsO4	Grown to maturity	5.5	Silty clay; 30% clay, 2.5% organic matter	Nominal	Y; calculated geomean
Woolson 1973	Cabbage	*Brassica oleracea*	73% total plant yield reduction	NOEC	100	N/A	Na2HAsO4	Grown to maturity	5.5	Silty clay; 30% clay, 2.5% organic matter	Nominal	N; used to calculate geomean
Woolson 1973	Cabbage	*Brassica oleracea*	73% total plant yield reduction	LOEC*	500	N/A	Na2HAsO4	Grown to maturity	5.5	Silty clay; 30% clay, 2.5% organic matter	Nominal	N; used to calculate geomean
Woolson 1973	Cabbage	*Brassica oleracea*	73% total plant yield reduction	MATC (calculated)	223.6	N/A	Na2HAsO4	Grown to maturity	5.5	Silty clay; 30% clay, 2.5% organic matter	Nominal	Y; calculated geomean
Woolson 1973	Tomato	*Lycopersicon esculentum*	97% total plant yield reduction	NOEC	100	N/A	Na2HAsO4	Grown to maturity	4.4	Clay loam; 24.4% clay, 0.99% organic matter	Nominal	N; used to calculate geomean
Woolson 1973	Tomato	*Lycopersicon esculentum*	97% total plant yield reduction	LOEC*	500	N/A	Na2HAsO4	Grown to maturity	4.4	Clay loam; 24.4% clay, 0.99% organic matter	Nominal	N; used to calculate geomean
Woolson 1973	Tomato	*Lycopersicon esculentum*	97% total plant yield reduction	MATC (calculated)	223.6	N/A	Na2HAsO4	Grown to maturity	4.4	Clay loam; 24.4% clay, 0.99% organic matter	Nominal	Y; calculated geomean
Jacobs et al. 1970	Snap beans	*Phaseolus vulgaris*	54% reduction of fresh weight of marketable portions	NOEC	19	N/A	$NaAsO_2$	1 growing season	5.5	Plainfield sand; 4% silt, 7% clay, 0.7% organic content	$H_2SO_4/HClO_4$ digestion	N; used to calculate geomean
Jacobs et al. 1970	Snap beans	*Phaseolus vulgaris*	54% reduction of fresh weight of marketable portions	LOEC*	26	N/A	$NaAsO_2$	1 growing season	5.5	Plainfield sand; 4% silt, 7% clay, 0.7% organic content	$H_2SO_4/HClO_4$ digestion	N; used to calculate geomean
Jacobs et al. 1970	Snap beans	*Phaseolus vulgaris*	54% reduction of fresh weight of marketable portions	MATC (calculated)	22.2	N/A	$NaAsO_2$	1 growing season	5.5	Plainfield sand; 4% silt, 7% clay, 0.7% organic content	$H_2SO_4/HClO_4$ digestion	Y; calculated geomean
Jacobs et al. 1970	Peas	*Pisium sativum*	54% reduction of fresh weight of marketable portions	NOEC	26	N/A	$NaAsO_2$	1 growing season	5.5	Plainfield sand; 4% silt, 7% clay, 0.7% organic content	$H_2SO_4/HClO_4$ digestion	N; used to calculate geomean

Reference	Species Name	Latin Name	Effect	Endpoint	Effective Concentration (mg/kg)	Effective Concentration (mg/kg) - std.dev.	Arsenic Compound	Exposure Period	Soil pH	Test Substrate	Extraction Method	Used for Guideline Calculation?
Jacobs et al. 1970	Peas	*Pisium sativum*	54% reduction of fresh weight of marketable portions	LOEC*	63	N/A	$NaAsO_2$	1 growing season	5.5	Plainfield sand; 4% silt, 7% clay, 0.7% organic content	$H_2SO_4/HClO_4$ digestion	N; used to calculate geomean
Jacobs et al. 1970	Peas	*Pisium sativum*	54% reduction of fresh weight of marketable portions	MATC (calculated)	40.5	N/A	$NaAsO_2$	1 growing season	5.5	Plainfield sand; 4% silt, 7% clay, 0.7% organic content	$H_2SO_4/HClO_4$ digestion	Y; calculated geomean
Jacobs et al. 1970	Corn	*Zea mays*	54% reduction of fresh weight of marketable portions	NOEC	26	N/A	$NaAsO_2$	1 growing season	5.5	Plainfield sand; 4% silt, 7% clay, 0.7% organic content	$H_2SO_4/HClO_4$ digestion	N; used to calculate geomean
Jacobs et al. 1970	Corn	*Zea mays*	54% reduction of fresh weight of marketable portions	LOEC*	63	N/A	$NaAsO_2$	1 growing season	5.5	Plainfield sand; 4% silt, 7% clay, 0.7% organic content	$H_2SO_4/HClO_4$ digestion	N; used to calculate geomean
Jacobs et al. 1970	Corn	*Zea mays*	54% reduction of fresh weight of marketable portions	MATC (calculated)	40.5	N/A	$NaAsO_2$	1 growing season	5.5	Plainfield sand; 4% silt, 7% clay, 0.7% organic content	$H_2SO_4/HClO_4$ digestion	Y; calculated geomean
Jacobs et al. 1970	Potato	*Solanum dulce*	76% reduction of fresh weight of marketable portions	NOEC	73	N/A	$NaAsO_2$	1 growing season	5.5	Plainfield sand; 4% silt, 7% clay, 0.7% organic content	$H_2SO_4/HClO_4$ digestion	N; used to calculate geomean
Jacobs et al. 1970	Potato	*Solanum dulce*	76% reduction of fresh weight of marketable portions	LOEC*	250	N/A	$NaAsO_2$	1 growing season	5.5	Plainfield sand; 4% silt, 7% clay, 0.7% organic content	$H_2SO_4/HClO_4$ digestion	N; used to calculate geomean
Jacobs et al. 1970	Potato	*Solanum dulce*	76% reduction of fresh weight of marketable portions	MATC (calculated)	135.1	N/A	$NaAsO_2$	1 growing season	5.5	Plainfield sand; 4% silt, 7% clay, 0.7% organic content	$H_2SO_4/HClO_4$ digestion	Y; calculated geomean
Woolson et al. 1971	Corn	*Zea mays*	Growth reduction measured in fresh weight	EC50	42	N/A	NaH_2AsO_4	4 weeks	6.2	Lakeland loamy sand; 10.5% clay, 0.90% organic matter	$H_2SO_4/HClO_4/HNO_3$ digestion	Y

Reference	Species Name	Latin Name	Effect	Endpoint	Effective Concentration (mg/kg)	Effective Concentration (mg/kg) - std.dev.	Arsenic Compound	Exposure Period	Soil pH	Test Substrate	Extraction Method	Used for Guideline Calculation?
Woolson et al. 1971	Corn	*Zea mays*	Growth reduction measured in fresh weight	EC50	77	N/A	$Ca(H_2AsO_4)_2$	4 weeks	6.2	Lakeland loamy sand; 10.5% clay, 0.90% organic matter	$H_2SO_4/HClO_4/HNO_3$ digestion	Y
Anastasia and Kender 1973	Lowbush blueberry	*Vaccinium angustifolium*	22% reduction in total linear growth	NOEC	43.8	N/A	As_2O_3	17 weeks	4.6	Loamy sand	NR	N; used to calculate geomean
Anastasia and Kender 1973	Lowbush blueberry	*Vaccinium angustifolium*	22% reduction in total linear growth	LOEC*	69.5	N/A	As_2O_3	17 weeks	4.6	Loamy sand	NR	N; used to calculate geomean
Anastasia and Kender 1973	Lowbush blueberry	*Vaccinium angustifolium*	22% reduction in total linear growth	MATC (calculated)	55.2	N/A	As_2O_3	17 weeks	4.6	Loamy sand	NR	Y; calculated geomean
Woolson et al. 1973	Corn	*Zea mays*	97% reduction in dry weight yield	NOEC	100	N/A	Na_2HAsO_4	4 weeks	5.5	Silty clay loam; 30.0% clay, 2.5% organic matter	Nominal	N; used to calculate geomean
Woolson et al. 1973	Corn	*Zea mays*	97% reduction in dry weight yield	LOEC*	1000	N/A	Na_2HAsO_4	4 weeks	5.5	Silty clay loam; 30.0% clay, 2.5% organic matter	Nominal	N; used to calculate geomean
Woolson et al. 1973	Corn	*Zea mays*	97% reduction in dry weight yield	MATC (calculated)	316.2	N/A	Na_2HAsO_4	4 weeks	5.5	Silty clay loam; 30.0% clay, 2.5% organic matter	Nominal	Y; calculated geomean
Woolson et al. 1973	Oats	*Avena sativa*	94% reduction in dry weight yield	NOEC	10	N/A	Na_2HAsO_4	4 weeks	5.5	Silty clay loam; 30.0% clay, 2.5% organic matter	Nominal	N; used to calculate geomean
Woolson et al. 1973	Oats	*Avena sativa*	94% reduction in dry weight yield	LOEC*	100	N/A	Na_2HAsO_4	4 weeks	5.5	Silty clay loam; 30.0% clay, 2.5% organic matter	Nominal	N; used to calculate geomean
Woolson et al. 1973	Oats	*Avena sativa*	94% reduction in dry weight yield	MATC (calculated)	31.6	N/A	Na_2HAsO_4	4 weeks	5.5	Silty clay loam; 30.0% clay, 2.5% organic matter	Nominal	Y; calculated geomean
Woolson et al. 1973	Corn	*Zea mays*	86% reduction in dry weight yield	NOEC	10	N/A	Na_2HAsO_4	4 weeks	6.2	Loamy sand; 10.5% clay, 0.90% organic matter	Nominal	N; used to calculate geomean
Woolson et al. 1973	Corn	*Zea mays*	86% reduction in dry weight yield	LOEC*	100	N/A	Na_2HAsO_4	4 weeks	6.2	Loamy sand; 10.5% clay, 0.90% organic matter	Nominal	N; used to calculate geomean
Woolson et al. 1973	Corn	*Zea mays*	86% reduction in dry weight yield	MATC (calculated)	31.6	N/A	Na_2HAsO_4	4 weeks	6.2	Loamy sand; 10.5% clay, 0.90% organic matter	Nominal	Y; calculated geomean

Reference	Species Name	Latin Name	Effect	Endpoint	Effective Concentration (mg/kg)	Effective Concentration (mg/kg) - std.dev.	Arsenic Compound	Exposure Period	Soil pH	Test Substrate	Extraction Method	Used for Guideline Calculation?
Woolson et al. 1973	Oats	*Avena sativa*	94% reduction in dry weight yield	NOEC	10	N/A	Na_2HAsO_4	4 weeks	6.2	Loamy sand; 10.5% clay, 0.90% organic matter	Nominal	N; used to calculate geomean
Woolson et al. 1973	Oats	*Avena sativa*	94% reduction in dry weight yield	LOEC*	100	N/A	Na_2HAsO_4	4 weeks	6.2	Loamy sand; 10.5% clay, 0.90% organic matter	Nominal	N; used to calculate geomean
Woolson et al. 1973	Oats	*Avena sativa*	94% reduction in dry weight yield	MATC (calculated)	31.6	N/A	Na_2HAsO_4	4 weeks	6.2	Loamy sand; 10.5% clay, 0.90% organic matter	Nominal	Y; calculated geomean
Kulich 1984	Oats	*Avena sativa*	Straw yield 39% reduction	NOEC	20	N/A	Na_2HAsO_4	21 d	6.7	Sandy loam; 1.2% organic matter	Nominal	N; used to calculate geomean
Kulich 1984	Oats	*Avena sativa*	Straw yield 39% reduction	LOEC*	40	N/A	Na_2HAsO_4	21 d	6.7	Sandy loam; 1.2% organic matter	Nominal	N; used to calculate geomean
Kulich 1984	Oats	*Avena sativa*	Straw yield 39% reduction	MATC (calculated)	28.3	N/A	Na_2HAsO_4	21 d	6.7	Sandy loam; 1.2% organic matter	Nominal	Y; calculated geomean
Deuel and Swoboda 1972	Cotton	*Gossypium hirsutum*	52% growth reduction	NOEC	18.8	N/A	As_2O_3	6 weeks	NR	Sandy loam	Nominal	N; used to calculate geomean
Deuel and Swoboda 1972	Cotton	*Gossypium hirsutum*	52% growth reduction	LOEC*	37	N/A	As_2O_3	6 weeks	NR	Sandy loam	Nominal	N; used to calculate geomean
Deuel and Swoboda 1972	Cotton	*Gossypium hirsutum*	52% growth reduction	MATC (calculated)	26.4	N/A	As_2O_3	6 weeks	NR	Sandy loam	Nominal	Y; calculated geomean
Deuel and Swoboda 1972	Cotton	*Gossypium hirsutum*	40% growth reduction	NOEC	150	N/A	As_2O_3	6 weeks	NR	Clay	Nominal	N; used to calculate geomean
Deuel and Swoboda 1972	Cotton	*Gossypium hirsutum*	40% growth reduction	LOEC*	187	N/A	As_2O_3	6 weeks	NR	Clay	Nominal	N; used to calculate geomean
Deuel and Swoboda 1972	Cotton	*Gossypium hirsutum*	40% growth reduction	MATC (calculated)	167.5	N/A	As_2O_3	6 weeks	NR	Clay	Nominal	Y; calculated geomean
Deuel and Swoboda 1972	Soybean	*Glycine max*	40% growth reduction	NOEC	75.5	N/A	As_2O_3	6 weeks	NR	Clay	Nominal	N; used to calculate geomean

Reference	Species Name	Latin Name	Effect	Endpoint	Effective Concentration (mg/kg)	Effective Concentration (mg/kg) - std.dev.	Arsenic Compound	Exposure Period	Soil pH	Test Substrate	Extraction Method	Used for Guideline Calculation?
Deuel and Swoboda 1972	Soybean	*Glycine max*	40% growth reduction	LOEC*	112	N/A	As_2O_3	6 weeks	NR	Clay	Nominal	N; used to calculate geomean
Deuel and Swoboda 1972	Soybean	*Glycine max*	40% growth reduction	MATC (calculated)	92.0	N/A	As_2O_3	6 weeks	NR	Clay	Nominal	Y; calculated geomean
Kulich 1987	Oats	*Aveena sativa*	Straw yield	NOEC	20	N/A	Na_2HAsO_4	21 d	6.7	Sandy loam; 12% organic matter	Nominal	N; used to calculate geomean
Kulich 1987	Oats	*Aveena sativa*	41% reduction in straw yield	LOEC*	40	N/A	Na_2HAsO_4	21 d	6.7	Sandy loam; 12% organic matter	Nominal	N; used to calculate geomean
Kulich 1987	Oats	*Aveena sativa*	41% reduction in straw yield	MATC (calculated)	28.3	N/A	Na_2HAsO_4	21 d	6.7	Sandy loam; 12% organic matter	Nominal	Y; calculated geomean
Biro et al. 1998	Alfafa	*Medicago sative*	30% reduction of biomass (root)	LOEC	30	N/A	Arsenic	2 months	7	Natural soil	N/A	Y
Weaver et al. 1984	Bermuda grass	*Cynodon dactylon*	Biomass (shoot)	NOEC	21	N/A	As_2O_3	6 weeks	7.6	Natural soil	N/A	N; used to calculate geomean
Weaver et al. 1984	Bermuda grass	*Cynodon dactylon*	Biomass (shoot)	LOEC	64	N/A	As_2O_3	6 weeks	7.6	Natural soil	N/A	N; used to calculate geomean
Weaver et al. 1984	Bermuda grass	*Cynodon dactylon*	Biomass (shoot)	MATC (calculated)	36.7	N/A	As_2O_3	6 weeks	7.6	Natural soil	N/A	Y; calculated geomean
Woolson 1972	Corn	*Zea mays*	67% reduction of biomass (unspecified)	LOEC	500	N/A	Na_2HAsO_4	4 weeks	NR	Natural soil	N/A	Y
Biro et al. 1998	Red clover	*Trifolium pratense*	57% reduction of biomass (root)	LOEC	30	N/A	Arsenic	2 months	7	Natural soil	N/A	Y
Onken and Hossner 1995	Rice	*Oryza sativa L.*	42% As5+ or 52% As3+ 33% reduction of biomass (aboveground portion)	LOEC	25	N/A	NaH_2AsO_4	60 d	7.25	Natural soil	N/A	Y
Jiang and Singh 1994	Ryegrass	*Lolium perenne*	Growth	MATC	22	N/A	N/A	N/A	5.6	0.7% organic matter	N/A	Y

Reference	Species Name	Latin Name	Effect	Endpoint	Effective Concentration (mg/kg)	Effective Concentration (mg/kg) - std.dev.	Arsenic Compound	Exposure Period	Soil pH	Test Substrate	Extraction Method	Used for Guideline Calculation?
Schweizer 1967	Cotton	*Gossypium hirsutum stoneville 7A*	Growth	MATC	69	N/A	N/A	N/A	7.9	1.1% organic matter	N/A	Y
Schweizer 1967	Rice	*Oryza sativa L.var. Nato*	Growth	MATC	4	N/A	N/A	N/A	7.9	1.1% organic matter	N/A	Y
Jiang and Singh 1994	Bayley	*Hordeum vulgare*	Growth	LOAEC	2	N/A	N/A	N/A	5.6	0.7% organic matter	N/A	Y
Jiang and Singh 1994	Ryegrass	*Lolium perenne*	Growth	MATC	22	N/A	N/A	N/A	5.6	0.7% organic matter	N/A	Y
Woolson and Isensee 1981	Radish	*Raphanus sativus*	Population	MATC	6	N/A	N/A	N/A	5.1	1.5% organic matter	N/A	Y
Woolson and Isensee 1981	Soybean	*Glycine max*	Population	MATC	6	N/A	N/A	N/A	5.1	1.5% organic matter	N/A	Y
Jiang and Singh 1994	Ryegrass	*Lolium perenne*	Growth	MATC	22	N/A	N/A	N/A	4.9	5.3% organic matter	N/A	Y
Jiang and Singh 1994	Bayley	*Hordeum vulgare*	Growth	MATC	22	N/A	N/A	N/A	4.9	5.3% organic matter	N/A	Y
Juzl and Stefl 2002	Potato	*Solanum tuberosum*	Growth	LOEL	60	N/A	Arsenic	3 d	NR	Natural soil	N/A	N; used to calculate geomean
Juzl and Stefl 2002	Potato	*Solanum tuberosum*	Growth	NOEL	30	N/A	Arsenic	3 d	NR	Natural soil	N/A	N; used to calculate geomean
Juzl and Stefl 2002	Potato	*Solanum tuberosum*	Growth	MATC (calculated)	42.4	N/A	Arsenic	3 d	NR	Natural soil	N/A	Y; calculated geomean
Chiu et al. 2005	Vetiver grass	*Chrysopogon zizanioides*	Growth (whole organism)	LOEL	100	N/A	Arsenenous acid, Sodium salt (1:1)	121.76 d	NR	Natural soil	N/A	Y
Chiu et al. 2005	Corn	*Zea mays*	Growth (whole organism)	LOEL	100	N/A	Arsenenous acid, Sodium salt (1:1)	121.76 d	NR	Natural soil	N/A	Y
Fisher and Koszorus 1992	Earthworm	*Eisenia foetida*	Mortality	NOEC	50	N/A	KH2AsO4	8 weeks	7.6	1:1 mixture of peaty marshland soil and horse manure	Nominal	Y
Environment Canada 1995	Earthworm	*Eisenia foetida*	Mortality	NOEC	83	36	KH2AsO4	14 d	4-4.3	Artificial soil; 67-75% sand, 8-12% silt, 16-21% clay, 2.5-3.3% moisture, 2.7-4.1% organic content	Nominal	Y

Reference	Species Name	Latin Name	Effect	Endpoint	Effective Concentration (mg/kg)	Effective Concentration (mg/kg) - std.dev.	Arsenic Compound	Exposure Period	Soil pH	Test Substrate	Extraction Method	Used for Guideline Calculation?
Gal et al. 1988	Earthworm	*Eisenia foetida andrei*	5% mortality	LC50	87	N/A	NaAsO2	4 weeks	NR	Artisol (a mixture of glass balls and silica)	Nominal	Y
Gal et al. 1988	Earthworm	*Eisenia foetida andrei*	50% mortality	LC50	103	N/A	NaAsO2	4 weeks	NR	Artisol (a mixture of glass balls and silica)	Nominal	Y
Fischer and Koszorus 1992	Earthworm	*Eisenia foetida*	Mortality	NOEC	50	N/A	KH2AsO4	8 weeks	7.6	Natural soil	NR	Y

Note: shading indicates studies that were used in deriving the soil quality guideline for soil contact.

*Endpoint not reported; taken to be the lowest observed effect concentration.

Table C.3 Ranked arsenic toxicity data for soil and plant/invertebrates

Species	Endpoint	Soil Concentration (mg/kg)	All Data		Data up to 100 mg/kg	
			Rank	Rank percentile	Rank	Rank percentile
Hordeum vulgare	LOAEC	2	1	2.0	1	2.3
Oryza sativa L.var. Nato	MATC	4	2	3.9	2	4.7
Raphanus sativus	MATC	6	3	5.9	3	7.0
Glycine max	MATC	6	3	5.9	3	7.0
Raphanus sativus	EC25	12	5	9.8	5	11.6
Lolium perenne	MATC	22	6	11.8	6	14.0
Lolium perenne	MATC	22	6	11.8	6	14.0
Lolium perenne	MATC	22	6	11.8	6	14.0
Hordeum vulgare	MATC	22	6	11.8	6	14.0
Phaseolus vulgaris	Geomean	22.2	10	19.6	10	23.3
Phaseolus linensis	Geomean	22.4	11	21.6	11	25.6
Lycopersicon esculentum	Geomean	22.4	11	21.6	11	25.6
Phaseolus vulgaris	Geomean	22.4	11	21.6	11	25.6
Spinacia oleracea	Geomean	22.4	11	21.6	11	25.6
Raphanus sativus	Geomean	22.4	11	21.6	11	25.6
Oryza sativa L.	LOEC	25	16	31.4	16	37.2
Gossypium hirsutum	Geomean	26.4	17	33.3	17	39.5
Avena sativa	Geomean	28.3	18	35.3	18	41.9
Aveena sativa	Geomean	28.3	18	35.3	18	41.9
Medicago sative	LOEC	30	20	39.2	20	46.5
Trifolium pratense	LOEC	30	20	39.2	20	46.5
Avena sativa	Geomean	31.6	22	43.1	22	51.2
Zea mays	Geomean	31.6	22	43.1	22	51.2
Avena sativa	Geomean	31.6	22	43.1	22	51.2
Lactuca sativa	EC25	32	25	49.0	25	58.1
Cynodon dactylon	Geomean	36.7	26	51.0	26	60.5
Pisium sativum	Geomean	40.5	27	52.9	27	62.8
Zea mays	Geomean	40.5	27	52.9	27	62.8
Zea mays	EC50	42	29	56.9	29	67.4
Solanum tuberosum	Geomean	42.4	30	58.8	30	69.8
Eisenia foetida	NOEC	50	31	60.8	31	72.1
Eisenia foetida	NOEC	50	31	60.8	31	72.1
Vaccinium angustifolium	Geomean	55.2	33	64.7	33	76.7
Gossypium hirsutum stoneville 7A	MATC	69	34	66.7	34	79.1
Brassica oleracea	Geomean	70.7	35	68.6	35	81.4

Phaseolus linensis	Geomean	70.7	35	68.6	35	81.4
Zea mays	EC50	77	37	72.5	37	86.0
Eisenia foetida	NOEC	83	38	74.5	38	88.4
Eisenia foetida andrei	LC50	87	39	76.5	39	90.7
Glycine max	Geomean	92	40	78.4	40	93.0
Chrysopogon zizanioides	LOEL	100	41	80.4	41	95.3
Zea mays	LOEL	100	41	80.4	41	95.3
Eisenia foetida andrei	LC50	103	43	84.3	-	-
Solanum dulce	Geomean	135	44	86.3	-	-
Gossypium hirsutum	Geomean	168	45	88.2	-	-
Lycopersicon esculentum	Geomean	224	46	90.2	-	-
Brassica oleracea	Geomean	224	46	90.2	-	-
Lycopersicon esculentum	Geomean	224	46	90.2	-	-
Zea mays	Geomean	316	49	96.1	-	-
Zea mays	LOEC	500	50	98.0	-	-

Note: Shadowed data were not used in the calculation of the final value for soil contact.

C.2 Soil Ingestion by Wildlife

The soil and food ingestion guideline involves the estimation of the daily threshold effect dose (DTED) for the species most at risk at each level of the food web (i.e. primary, secondary, and tertiary consumers); since arsenic does not biomagnify, only the primary consumer is considered based on the CCME guidance. The SQG_I is then calculated based on the DTED, soil and food ingestion rates, body weight, bioavailability factor, and the bioaccumulation factor. By combining and rearranging the equations for soil and food ingestion, a SQG_I can be derived that will prevent primary consumers from being exposed to no more than 75% of the DTED from the ingestion of soil and plants:

$$\mathrm{SQG_I} = \frac{0.75 \times \mathrm{DTED} \times \mathrm{BW}}{SIR \times BF + FIR \times BCF} \qquad \text{(C-1)}$$

Characteristics of a rabbit from the CCME (Environment Canada 1999) were used in the above equation, as summarized in Table C.4. Consistent with CCME guidance, a bioaccessibility factor (BF) of 1 was used.

Table C.4 Parameters used in derivation of soil and food ingestion pathway

Symbol	Characteristic	Units	Value	Detail
DTED	Daily threshold effects dose	mg/kg-d	1.04	U.S. EPA (2005)
BW	Body weight	kg	3	CCME (Environment Canada 1999)
SIR	Soil ingestion rate	kg/d	0.014	CCME (Environment Canada 1999)
FIR	Food ingestion rate	kg dw/d	0.166	CCME (Environment Canada 1999)
BCF	Bioconcentration factor	kg dw soil /kg dw plant	0.019	Site-specific, see equations below

Note: receptor characteristics are for a rabbit.

The bioconcentration factor is the relationship between the plant and soil concentrations; in equation C-1, the units are on a dry weight plant basis to be consistent with the food ingestion rate (FIR).

$$BCF = \frac{C_{plant}\ (mg/kg\ dw\ plant)}{C_{soil}\ (mg/kg\ dw\ soil)} \qquad \text{(C-2)}$$

A site-specific plant to soil relationship was derived in support of the Giant Mine Remediation Plan Human Health and Ecological Risk Assessment (GMRP HHERA; CanNorth 2018). Paired soil and vegetation samples were collected from the same area; vegetation samples included leaves of cranberry (*Vaccinium vitis-idaea*) and alder (*Alnus* sp.) to represent terrestrial forbs and shrubs. Surficial soil samples (i.e., top 15 cm) were obtained. The data were analyzed to determine if the relationship between the two was linear or log-linear. For arsenic, a log-linear relationship was determined between the dry weight soil and wet weight plant concentrations:

$$C_{plant}(mg/kg\ ww) = e^{0.47\times\ln(C_{soil})-2.2} \qquad \text{(C-3)}$$

To convert the relationship to a dry weight plant concentration, the wet weight concentration is divided by (1-moisture), where a moisture content of 57% was used based on the measured data. Combining equations C-2 and C-3 results in the following BCF:

$$BCF\ (kg\ dw\ soil/kg\ dw\ plant) = \frac{\frac{e^{0.47\times\ln(C_{soil})-2.2}}{1-moisture}}{C_{soil}} \qquad \text{(C-4)}$$

Since the BCF is dependent on the SQG_I, a trial and error approach was adopted whereby the soil concentration was adjusted until the intake was equal to 75% of the DTED.

At a soil concentration of 138 mg/kg the BCF is equal to 0.019 kg dw soil/kg dw plant.

$$SQG_I = \frac{0.75 \times 1.04 \times 3}{0.014 \times 1 + 0.166 \times 0.019} \qquad \text{(C-5)}$$

$$= 138 \text{ mg/kg}$$

An SQG_I of 138 mg/kg results in an intake that is 75% of the DTED (i.e., 0.78 mg/kg-d).

C.3 Literature Cited

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APPENDIX D

BACKGROUND SOIL CONCENTRATION DATASETS

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APPENDIX D: BACKGROUND SOIL CONCENTRATION DATASETS

In deriving updated background soil concentrations for Yellowknife (within the municipal boundary and Yellowknife Greenstone Belt [YGB] and outside) and Inuvik, Stantec (2020a, 2020b) developed datasets summarizing available concentrations of arsenic in soil in the area. Table D.1 provides the dataset for within 25 km of the City of Yellowknife and identifies data that were not considered when developing the background concentrations (i.e., samples collected directly from the Giant or Con Mine properties or outliers). Data collected from within 5 km of the mine sites are included. The underlying geology and associated group (YGB or non-YGB) are also identified. The dataset for Inuvik is provided in Table D.2. Further details on the derivation of these datasets and outlier analyses are provided in the original documents (Stantec 2020a, 2020b) and are provided here for reference purposes only.

Table D.1 Arsenic background soil concentrations for Yellowknife

Sample ID	Sample Year	Source	Bedrock Geology Reported by Source	Underlying Geology Group	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Distance to Con Mine (km)	Distance to Giant Mine (km)	Arsenic Concentration (mg/kg)	Outlier?	Located on Mine Property?	Include in Summary Statistic Calculations?
01KKA7000	2001	GSC	Not reported	Non-YGB	62.5194	-114.2006	12.4	8.3	15.3	N	N	Y
01KKA7001	2001	GSC	Not reported	Non-YGB	62.5495	-114.1825	15.5	10.5	61.7	N	N	Y
01KKA7002	2001	GSC	Not reported	Non-YGB	62.5144	-114.2134	11.6	7.5	46.1	N	N	Y
01KKA7003	2001	GSC	Not reported	Non-YGB	62.5039	-114.2421	9.7	5.9	14.7	N	N	Y
01KKA7004	2001	GSC	Not reported	Non-YGB	62.4790	-114.2976	5.8	3.8	55.5	N	N	Y
01KKA7005	2001	GSC	Not reported	Non-YGB	62.4374	-114.3108	3.1	7.3	59.5	N	N	Y
01KKA7006	2001	GSC	Not reported	Non-YGB	62.5075	-114.2975	8.4	3.2	26.8	N	N	Y
01KKA7010	2001	GSC	Not reported	Non-YGB	62.6510	-114.2852	23.7	17.0	16.7	N	N	Y
01KKA7012	2001	GSC	Not reported	Non-YGB	62.6278	-114.2511	21.6	15.1	16.6	N	N	Y
99KKA6003T	1999	GSC	granite	Non-YGB	62.4985	-114.7851	22.0	21.7	7.6	N	N	Y
99KKA6004T	1999	GSC	granite	Non-YGB	62.4807	-114.7081	17.7	17.9	5.9	N	N	Y
99KKA6005T	1999	GSC	granite	Non-YGB	62.4609	-114.6061	12.2	13.3	5.5	N	N	Y
99KKA6006T	1999	GSC	granite	Non-YGB	62.4660	-114.4999	7.2	8.1	27	N	N	Y
99KKA6007T	1999	GSC	granite	Non-YGB	62.4756	-114.4491	5.6	5.3	18	N	N	Y
99KKA6013T	1999	GSC	schist	Non-YGB	62.5494	-114.0363	20.9	17.2	55.4	N	N	Y
99KKA6014T	1999	GSC	schist	Non-YGB	62.5384	-114.1212	16.8	12.8	7.9	N	N	Y
99KKA6015T	1999	GSC	metasedimentary	Non-YGB	62.5211	-114.1978	12.6	8.5	18	N	N	Y
99KKA6016T	1999	GSC	metasedimentary	Non-YGB	62.5020	-114.2324	9.9	6.4	4.1	N	N	Y
99KKA6017T	1999	GSC	basalt	Non-YGB	62.5047	-114.2766	8.7	4.2	23	N	N	Y
99KKA6018T	1999	GSC	metasedimentary	Non-YGB	62.4525	-114.3116	3.4	5.7	13	N	N	Y
99KKA6019T	1999	GSC	metasedimentary	Non-YGB	62.4737	-114.3001	5.3	4.1	28	N	N	Y
99KKA6021T	1999	GSC	granite	Non-YGB	62.4311	-114.4197	2.6	8.2	48	N	N	Y
99KKA6022T	1999	GSC	granite	Non-YGB	62.4446	-114.4848	5.8	8.8	8.6	N	N	Y
99KKA6023T	1999	GSC	granite	Non-YGB	62.4380	-114.4439	3.7	8.0	17	N	N	Y
99KKA6064T	1999	GSC	granite	Non-YGB	62.4486	-113.9165	23.2	23.2	15	N	N	Y
99KKA6065T	1999	GSC	metasedimentary	Non-YGB	62.4479	-114.0764	15.1	15.4	9	N	N	Y
99KKA6066T	1999	GSC	metasedimentary	Non-YGB	62.3175	-114.1306	18.1	23.1	10	N	N	Y
99KKA6056T	1999	GSC	metasedimentary	Non-YGB	62.6099	-114.2441	19.9	13.4	28	N	N	Y
00KKA6516	2000	GSC	volcanic	YGB	62.4635	-114.0617	16.0	15.7	7.1	N	N	Y
00KKA6517	2000	GSC	volcanic	YGB	62.4498	-114.0887	14.5	14.9	7.7	N	N	Y

Sample ID	Sample Year	Source	Bedrock Geology Reported by Source	Underlying Geology Group	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Distance to Con Mine (km)	Distance to Giant Mine (km)	Arsenic Concentration (mg/kg)	Outlier?	Located on Mine Property?	Include in Summary Statistic Calculations?
00KKA6500	2000	GSC	volcanic	YGB	62.4429	-114.3663	0.4	6.5	78.9	N	N	Y
00KKA6503	2000	GSC	volcanic	YGB	62.5749	-114.3620	14.7	8.0	24.3	N	N	Y
00KKA6504	2000	GSC	volcanic	YGB	62.5594	-114.3610	13.0	6.3	47.5	N	N	Y
00KKA6505	2000	GSC	volcanic	YGB	62.5480	-114.3683	11.8	5.1	91.2	N	N	Y
00KKA6506	2000	GSC	volcanic	YGB	62.5241	-114.3542	9.2	2.5	55.5	N	**Y (Giant Mine)**	N (On Mine Property)
00KKA6507	2000	GSC	volcanic	YGB	62.4739	-114.3833	3.7	3.3	44.6	N	N	Y
00KKA6508	2000	GSC	volcanic	YGB	62.4690	-114.4123	3.7	4.5	14.2	N	N	Y
00KKA6509	2000	GSC	volcanic	YGB	62.4840	-114.3686	4.7	2.0	118	N	**Y (Giant Mine)**	N (On Mine Property)
00KKA6510	2000	GSC	volcanic	YGB	62.4355	-114.3893	1.0	7.4	42.7	N	**Y (Con Mine)**	N (On Mine Property)
00KKA6511	2000	GSC	volcanic	YGB	62.4661	-114.3649	2.8	3.9	40.7	N	N	Y
00KKA6512	2000	GSC	volcanic	YGB	62.5028	-114.3707	6.8	0.6	320	N	**Y (Giant Mine)**	N (On Mine Property)
00KKA6513	2000	GSC	volcanic	YGB	62.5368	-114.3616	10.5	3.9	30.8	N	**Y (Giant Mine)**	N (On Mine Property)
00KKA6514	2000	GSC	volcanic	YGB	62.5229	-114.3358	9.2	2.6	24.7	N	N	Y
00KKA6515	2000	GSC	volcanic	YGB	62.4390	-114.3582	0.8	6.9	813	**Y**	N	N (Outlier)
00KKA6518	2000	GSC	volcanic	YGB	62.3851	-114.2530	8.7	13.9	86.6	N	N	Y
00KKA6519	2000	GSC	volcanic	YGB	62.3889	-114.2725	7.7	13.2	29.3	N	N	Y
00KKA6520	2000	GSC	volcanic	YGB	62.4262	-114.2547	6.2	9.9	403	N	N	Y
00KKA6521	2000	GSC	volcanic	YGB	62.4417	-114.2778	4.8	7.8	8.3	N	N	Y
00KKA6522	2000	GSC	volcanic	YGB	62.4836	-114.3963	4.8	2.7	27.6	N	N	Y
00KKA6523	2000	GSC	volcanic	YGB	62.3739	-114.4846	9.3	15.4	39.8	N	N	Y
00KKA6524	2000	GSC	volcanic	YGB	62.3850	-114.4319	6.8	13.3	46.1	N	N	Y
00KKA6525	2000	GSC	volcanic	YGB	62.3962	-114.3752	4.9	11.6	314	N	N	Y
00KKA6526	2000	GSC	volcanic	YGB	62.4161	-114.3693	2.7	9.4	1560	**Y**	N	N (Outlier)
00KKA6527	2000	GSC	volcanic	YGB	62.4277	-114.3595	1.6	8.1	134	N	N	Y
00KKA6529	2000	GSC	volcanic	YGB	62.6743	-114.3197	25.8	19.1	54.7	N	N	Y
00KKA6530	2000	GSC	volcanic	YGB	62.6579	-114.3010	24.1	17.4	1190	**Y**	N	N (Outlier)
00KKA6531	2000	GSC	volcanic	YGB	62.6404	-114.2775	22.4	15.8	11.8	N	N	Y
00KKA6532	2000	GSC	volcanic	YGB	62.6375	-114.3120	21.8	15.1	99.7	N	N	Y
00KKA6533	2000	GSC	volcanic	YGB	62.6403	-114.3552	21.9	15.2	38.6	N	N	Y
00KKA6534	2000	GSC	volcanic	YGB	62.6260	-114.4234	20.5	14.0	25.1	N	N	Y
00KKA6535	2000	GSC	volcanic	YGB	62.6214	-114.3656	19.8	13.1	45.1	N	N	Y

Sample ID	Sample Year	Source	Bedrock Geology Reported by Source	Underlying Geology Group	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Distance to Con Mine (km)	Distance to Giant Mine (km)	Arsenic Concentration (mg/kg)	Outlier?	Located on Mine Property?	Include in Summary Statistic Calculations?
00KKA6536	2000	GSC	volcanic	YGB	62.6069	-114.3580	18.2	11.5	146	N	N	Y
00KKA6537	2000	GSC	volcanic	YGB	62.6096	-114.2868	19.0	12.4	88.5	N	N	Y
00KKA6538	2000	GSC	volcanic	YGB	62.5945	-114.3315	17.0	10.3	482	N	N	Y
00KKA6539	2000	GSC	volcanic	YGB	62.5780	-114.3175	15.3	8.7	1500	**Y**	N	N (Outlier)
00KKA6540	2000	GSC	volcanic	YGB	62.5670	-114.2801	14.6	8.2	23.9	N	N	Y
00KKA6541	2000	GSC	volcanic	YGB	62.5486	-114.3225	12.1	5.5	11.9	N	N	Y
00KKA6562	2000	GSC	volcanic	YGB	62.5612	-114.3872	13.2	6.7	58.6	N	N	Y
01KKA7007	2001	GSC	Not reported	YGB	62.5172	-114.3675	8.6	2.0	71.8	N	**Y (Giant Mine)**	N (On Mine Property)
01KKA7009	2001	GSC	Not reported	YGB	62.6200	-114.3419	19.9	13.2	10.1	N	N	Y
01KKA7014	2001	GSC	Not reported	YGB	62.5910	-114.2807	17.3	10.8	202	N	N	Y
99KKA6020T	1999	GSC	volcanic	YGB	62.5062	-114.3559	7.4	0.7	55.9	N	**Y (Giant Mine)**	N (On Mine Property)
99KKA6024T	1999	GSC	volcanic	YGB	62.4402	-114.3645	0.4	6.5	43	N	N	Y
99KKA6025T	1999	GSC	volcanic	YGB	62.5774	-114.3668	15.2	8.5	16	N	N	Y
99KKA6067T	1999	GSC	volcanic	YGB	62.3860	-114.2647	8.0	13.4	57.3	N	N	Y
99KKA6068T	1999	GSC	volcanic	YGB	62.3836	-114.4360	6.9	13.3	15	N	N	Y
BPR-FCSC-02	2015	Jamieson	Granitoid	Non-YGB	62.4990	-114.3858	7.5	1.5	29	N	N	Y
BPR-FCSC-21	2015	Jamieson	Granitoid	Non-YGB	62.5071	-114.3754	8.4	1.1	42	N	**Y (Giant Mine)**	N (On Mine Property)
BPR-PSC-161B	2015	Jamieson	Granitoid	Non-YGB	62.4965	-114.3840	7.2	1.5	240	N	N	Y
BPR-PSC-161C	2015	Jamieson	Granitoid	Non-YGB	62.4965	-114.3840	7.2	1.5	1200	**Y**	N	N (Outlier)
BPR-PSG-08	2015	Jamieson	Granitoid	Non-YGB	62.4976	-114.3868	7.4	1.6	31	N	N	Y
DETR-FCOSC-35	2015	Jamieson	Sedimentary	Non-YGB	62.4398	-114.3072	3.2	7.4	59	N	N	Y
DETR-FCSC-38	2015	Jamieson	Sedimentary	Non-YGB	62.4402	-114.3097	3.1	7.3	5.4	N	N	Y
HW3-FCSC-132	2015	Jamieson	Granitoid	Non-YGB	62.4602	-114.5911	11.9	12.9	10	N	N	Y
HW3-FCSC-134	2015	Jamieson	Granitoid	Non-YGB	62.4616	-114.5887	11.9	12.7	4.8	N	N	Y
HW3-FCSC-135	2015	Jamieson	Granitoid	Non-YGB	62.4659	-114.5032	8.0	8.5	10	N	N	Y
HW3-OSC-136	2015	Jamieson	Granitoid	Non-YGB	62.4657	-114.5033	7.9	8.5	3.7	N	N	Y
INGT-FCOSC-141	2015	Jamieson	Sedimentary	Non-YGB	62.5371	-114.1451	16.3	11.6	10	N	N	Y
INGT-FCOSC-42	2015	Jamieson	Sedimentary	Non-YGB	62.5409	-114.0908	18.7	14.3	7.4	N	N	Y
INGT-FCSC-28	2015	Jamieson	Sedimentary	Non-YGB	62.5081	-114.2901	9.4	3.5	38	N	N	Y
BC20-FCSC-163	2015	Jamieson	Granitoid	Non-YGB	62.5006	-114.3909	7.7	1.7	10	N	N	Y

Sample ID	Sample Year	Source	Bedrock Geology Reported by Source	Underlying Geology Group	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Distance to Con Mine (km)	Distance to Giant Mine (km)	Arsenic Concentration (mg/kg)	Outlier?	Located on Mine Property?	Include in Summary Statistic Calculations?
HL-OSC-165	2015	Jamieson	Granitoid	Non-YGB	62.4947	-114.3938	7.1	2.0	96	N	N	Y
ML-FCSC-102	2015	Jamieson	Granitoid	Non-YGB	62.5335	-114.4284	11.7	5.1	14	N	N	Y
ML-OSC-98	2015	Jamieson	Granitoid	Non-YGB	62.5383	-114.4107	12.0	4.9	29	N	N	Y
ML-OSG-104.2	2015	Jamieson	Granitoid	Non-YGB	62.5292	-114.4339	11.4	5.0	140	N	N	Y
NWFAR1-FCSC-75	2015	Jamieson	Granitoid	Non-YGB	62.5707	-114.7815	26.3	23.1	4	N	N	Y
SW3-PSG-89.1	2015	Jamieson	Granitoid	Non-YGB	62.4028	-114.6271	13.8	17.7	4.1	N	N	Y
LL-OSC-119	2015	Jamieson	Granitoid	Non-YGB	62.5583	-114.3990	14.2	6.6	1.6	N	N	Y
LL-OSC-120	2015	Jamieson	Granitoid	Non-YGB	62.5577	-114.3986	14.1	6.6	2.5	N	N	Y
LL-PSG-117.1	2015	Jamieson	Granitoid	Non-YGB	62.5686	-114.4106	15.4	7.9	43	N	N	Y
LL-PSG-117.2	2015	Jamieson	Granitoid	Non-YGB	62.5686	-114.4106	15.4	7.9	19	N	N	Y
VL-FCSC-111	2015	Jamieson	Granitoid	Non-YGB	62.5875	-114.4272	17.6	10.2	3.8	N	N	Y
BPR-FCSC-14	2015	Jamieson	Granitoid	Non-YGB	62.4873	-114.3912	6.3	2.4	63	N	N	Y
EAST2-FCSC-66	2015	Jamieson	Volcanic	YGB	62.4492	-114.0879	14.5	15.0	4.6	N	N	Y
BPR-MFENC-22	2015	Jamieson	Volcanic	YGB	62.5095	-114.3673	8.6	1.0	29	N	**Y (Giant Mine)**	N (On Mine Property)
BPR-OSC-16	2015	Jamieson	Volcanic	YGB	62.4727	-114.4130	5.1	4.3	12	N	N	Y
BPR-PSG-19.2	2015	Jamieson	Volcanic	YGB	62.4734	-114.4106	5.1	4.2	130	N	N	Y
INGT-FCSC-45	2015	Jamieson	Volcanic	YGB	62.5225	-114.3334	10.2	2.6	2.7	N	N	Y
INGT-FCSC-50	2015	Jamieson	Volcanic	YGB	62.5219	-114.3254	10.2	2.8	25	N	N	Y
HOML-FCSC-56	2015	Jamieson	Volcanic	YGB	62.6571	-114.3046	25.2	17.5	24	N	N	Y
HOML-PSC-58	2015	Jamieson	Volcanic	YGB	62.6560	-114.3031	25.1	17.3	7.8	N	N	Y
TX-FCOSC-150	2015	Jamieson	Volcanic	YGB	62.5733	-114.3600	15.7	7.9	18	N	N	Y
TX-FCOSC-155	2015	Jamieson	Volcanic	YGB	62.5817	-114.3551	16.7	8.9	7.1	N	N	Y
TX-FCSC-144	2015	Jamieson	Volcanic	YGB	62.5571	-114.3601	13.9	6.1	44	N	N	Y
TX-OSC-145	2015	Jamieson	Volcanic	YGB	62.5574	-114.3596	14.0	6.2	320	N	N	Y

Note: As reported in Stantec (2020a).

Table D.2 Arsenic background soil concentrations for Inuvik

Sample Year	Sample ID	Source	Type	Sample Description	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Sample Depth (cm)	Arsenic Concentration (mg/kg)
2010	1-A	Meridian (2011)	Town	Brown native fill	68.3549	-133.7000	15	141
2010	1-B	Meridian (2011)	Town	Brown native fill	68.3549	-133.7000	15	81.9
2010	2-A	Meridian (2011)	Town	Brown fill	68.3540	-133.7086	15	81
2010	2-B	Meridian (2011)	Town	Brown fill	68.3540	-133.7086	15	72.9
2010	3-A	Meridian (2011)	Town	Brown fill	68.3555	-133.7127	15	80
2010	3-B	Meridian (2011)	Town	Brown fill	68.3555	-133.7127	15	73.8
2010	4-A	Meridian (2011)	Town	Brown fill	68.3553	-133.7194	15	46.8
2010	4-B	Meridian (2011)	Town	Brown fill	68.3553	-133.7194	15	50.5
2010	5-A	Meridian (2011)	Town	Brown fill	68.3550	-133.7221	15	14.1
2010	5-B	Meridian (2011)	Town	Brown fill	68.3550	-133.7221	15	46.3
2010	6-A	Meridian (2011)	Town	Brown fill	68.3581	-133.7117	15	25.1
2010	6-B	Meridian (2011)	Town	Brown fill	68.3581	-133.7117	15	15.2
2010	7-A	Meridian (2011)	Town	Native soil	68.3590	-133.7152	15	47.5
2010	7-B	Meridian (2011)	Town	Native soil	68.3590	-133.7152	15	25.7
2010	8-A	Meridian (2011)	Town	Brown fill	68.3610	-133.7175	15	78.3
2010	8-B	Meridian (2011)	Town	Brown fill	68.3610	-133.7175	15	100
2010	9-A	Meridian (2011)	Town	Brown fill	68.3623	-133.7195	15	11
2010	9-B	Meridian (2011)	Town	Brown fill	68.3623	-133.7195	15	15.3
2010	10-A	Meridian (2011)	Town	Brown fill	68.3638	-133.7241	15	62.7
2010	10-B	Meridian (2011)	Town	Brown fill	68.3638	-133.7241	15	72.6
2010	11-A	Meridian (2011)	Town	Brown fill	68.3641	-133.7206	15	7.18
2010	11-B	Meridian (2011)	Town	Brown fill	68.3641	-133.7206	15	6.39
2010	12-A	Meridian (2011)	Town	Brown fill	68.3633	-133.7253	15	57
2010	12-B	Meridian (2011)	Town	Brown fill	68.3633	-133.7253	15	66.4
2010	13-A	Meridian (2011)	Town	Brown fill	68.3616	-133.7281	15	107
2010	13-B	Meridian (2011)	Town	Brown fill	68.3616	-133.7281	15	131
2010	14-A	Meridian (2011)	Town	Brown fill	68.3616	-133.7304	15	5.13
2010	14-B	Meridian (2011)	Town	Brown fill	68.3616	-133.7304	15	14.4
2010	15-A	Meridian (2011)	Town	Brown fill	68.3579	-133.7219	15	101
2010	15-B	Meridian (2011)	Town	Brown fill	68.3579	-133.7219	15	105

Sample Year	Sample ID	Source	Type	Sample Description	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Sample Depth (cm)	Arsenic Concentration (mg/kg)
2010	16-A	Meridian (2011)	Town	Brown fill	68.3576	-133.7221	15	81.5
2010	16-B	Meridian (2011)	Town	Brown fill	68.3576	-133.7221	15	86.9
2010	17-A	Meridian (2011)	Town	Brown fill	68.3574	-133.7251	15	29.8
2010	17-B	Meridian (2011)	Town	Brown fill	68.3574	-133.7251	15	24.3
2010	18-A	Meridian (2011)	Town	Grey crush	68.3574	-133.7255	15	1.67
2010	18-B	Meridian (2011)	Town	Grey crush	68.3574	-133.7255	15	3.34
2009	119157-H1-1	Meridian (2011)	Town	NA	68.3563	-133.7223	15	2.1
2009	119157-H4-S1-6	Meridian (2011)	Town	NA	68.3549	-133.7201	15	124
2017	TI-SS-01	Stantec (2017)	Town	NA	68.3568	-133.7032	15	23
2017	TI-SS-02	Stantec (2017)	Town	NA	68.3569	-133.7146	15	62
2017	TI-SS-03	Stantec (2017)	Town	NA	68.3576	-133.7190	15	100
2017	TI-SS-04	Stantec (2017)	Town	NA	68.3562	-133.7326	15	20
2017	TI-SS-05	Stantec (2017)	Town	NA	68.3637	-133.7177	15	25
2017	TI-SS-06	Stantec (2017)	Town	NA	68.3660	-133.7227	15	22
2017	TI-SS-07	Stantec (2017)	Town	NA	68.3640	-133.7296	15	17
2017	TI-SS-08	Stantec (2017)	Town	NA	68.3624	-133.7343	15	3.1
2017	TI-SS-09	Stantec (2017)	Town	NA	68.3622	-133.7403	15	17
2017	TI-SS-10	Stantec (2017)	Town	NA	68.3673	-133.7324	15	5.8
2017	TI-SS-11	Stantec (2017)	Town	NA	68.3667	-133.7382	15	5.8
2017	TI-SS-12	Stantec (2017)	Town	NA	68.3631	-133.7434	15	35
2017	TI-SS-13	Stantec (2017)	Town	NA	68.3683	-133.7431	15	11
2017	TI-SS-14	Stantec (2017)	Town	NA	68.3731	-133.7484	15	39
2017	TI-SS-15	Stantec (2017)	Town	NA	68.3783	-133.7531	15	59
2017	RB-SS-01	Stantec (2017)	Regional Background	NA	68.4105	-133.7688	15	12
2017	RB-SS-02	Stantec (2017)	Regional Background	NA	68.4010	-133.7628	15	16
2017	RB-SS-03	Stantec (2017)	Regional Background	NA	68.3707	-133.7211	15	5.4
2017	RB-SS-04	Stantec (2017)	Regional Background	NA	68.3633	-133.7066	15	24
2017	RB-SS-05	Stantec (2017)	Regional Background	NA	68.3471	-133.6987	15	2.1
2017	RB-SS-06	Stantec (2017)	Regional Background	NA	68.3401	-133.6797	15	37
2017	RB-SS-07	Stantec (2017)	Regional Background	NA	68.3303	-133.6478	15	14
2017	RB-SS-08	Stantec (2017)	Regional Background	NA	68.3239	-133.6088	15	4.2

Sample Year	Sample ID	Source	Type	Sample Description	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Sample Depth (cm)	Arsenic Concentration (mg/kg)
2017	RB-SS-09	Stantec (2017)	Regional Background	NA	68.3328	-133.5691	15	3.4
2017	RB-SS-10	Stantec (2017)	Regional Background	NA	68.3358	-133.5471	15	9.1
2017	RB-SS-11	Stantec (2017)	Regional Background	NA	68.3293	-133.5427	15	9.9
2017	RB-SS-12	Stantec (2017)	Regional Background	NA	68.3136	-133.5085	15	11
2017	RB-SS-13	Stantec (2017)	Regional Background	NA	68.3174	-133.4429	15	<2
2017	RB-SS-14	Stantec (2017)	Regional Background	NA	68.3130	-133.3884	15	11

Note: As reported in Stantec (2020b).

D.1 Literature Cited

Stantec. 2020a. Yellowknife background soil arsenic review. Final report. Prepared for Government of Northwest Territories, December.

Stantec. 2020b. Inuvik background soil arsenic review. Final report. Prepared for Government of Northwest Territories, December.