



REPORT

Human Health and Ecological Risk Assessment

Lupin Mine, Nunavut

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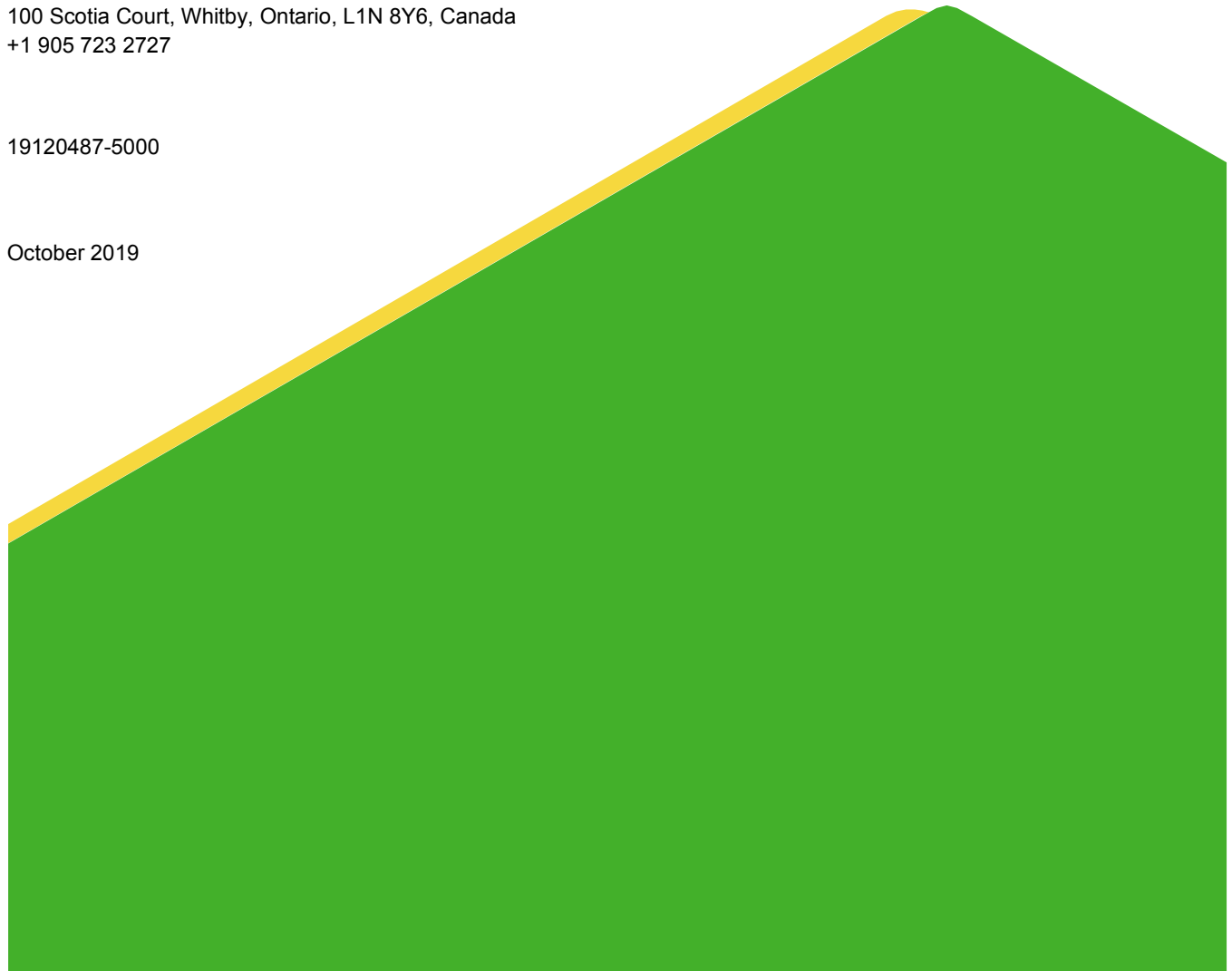
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by Lupin Mines Incorporated (LMI) to provide regulatory support for the Lupin Mine Closure Project (the Project). This report provides the Human Health and Ecological Risk Assessment (HHERA) for the Lupin Mine as required in support of the Final Closure and Reclamation Plan (FCRP; Golder 2018) recently submitted to the Nunavut Water Board (NWB).

1.1 Background

The Lupin Mine is a gold mine located approximately 285 kilometres (km) southeast of Kugluktuk, in the Kitikmeot Region of Nunavut, 400 km north of Yellowknife, Northwest Territories (NWT) (hereafter referred to as the Site; Figure 1). The Site was developed on the western shore of Contwoyto Lake at 65° 46' Latitude and 111° 14' Longitude, approximately 60 km south of the Arctic Circle.

Access to the Site is provided by air from Yellowknife. The Site is also accessible via the Tibbitt to Contwoyto winter road which has been developed to facilitate transportation of bulk supplies and equipment to and from the Site during the winter. The winter road is approximately 570 km from the end of the Ingraham Trail, located near Yellowknife, NWT to the Site (Figure 1).

Figure 2 shows the general arrangement of the Site. Figure 3 shows the current conditions of the mine site, including the mill and camp complex. There are two main areas: the residential complex (camp facilities) consisting of accommodations, kitchen and recreation centre; and the industrial complex comprised of ore processing facilities, as well as maintenance areas, head frame, hoist room, powerhouse, and warehouse and office facilities. The freshwater pump house is situated approximately 1.6 km northwest of the camp, on the shore of Contwoyto Lake. The freshwater pump house is currently not in use as water is currently brought to Site in a water truck from Contwoyto Lake.

In association with the above, there are a number of support areas consisting of: shops and yards (maintenance, surface, backfill, and carpentry), storage/laydown areas (cold storage buildings), the main fuel tank farm, camp sewage facilities, mill tailings line, a 1.9-km airstrip, a recently constructed landfarm and a weather/aircraft control office with exploration shack. Only the main tank farm is currently being used for the storage of bulk fuel.

A tailings containment area (TCA) is situated approximately 3 km south of the mine site. The only physical connections between the TCA and the mine site are two access roads and the 8-inch diameter insulated tailings line, which was used to transport the tailings slurry from the mill to the deposition point in the tailings cells.

Lupin Mine was in operation from 1982 to 2005 with temporary suspensions of activities between January 1998 and April 2000, and again between August 2003 and March 2004. The mine resumed production in March 2004 until February 2005. Since 2005, the mine has remained in "care and maintenance".

General site maintenance and facilities upgrades have been undertaken at Lupin Mine since 2006 and in accordance with the Interim Closure and Restoration Plan (ICRP) and Care and Maintenance Plan (CMP) (March 2013 and updated October 2017). These activities were carried out to assess operational requirements in case the Lupin Mine would resume operations. The activities underway were screened by the Nunavut Impact Review Board (NIRB) under file 99WR053 (16 November 1999) and were approved by the NWB under the current Water Licence (19 August 2015). LMI now intends to complete the full closure and reclamation of the Lupin Mine over the next 2.5 years. LMI prepared and submitted a complete FCRP to the NWB in July 2018 (Golder 2018).

1.2 Previous Environmental Investigations

To inform the closure and reclamation of the Site, a number of environmental investigations have been conducted at the Site since 2004, as follows:

- Golder. 2004. Ecological Risk Assessment for the Lupin Mine Tailings Containment Area. Prepared by Golder Associates Ltd. for Kinross Gold Corporation. December 2004.
- Morrow Environmental Consultants Inc. (Morrow). 2006. Phase 1 and 2 Environmental Site Assessment. Lupin Mine Site, Nunavut Territory. Prepared by Morrow Environmental Consultants Inc. for Lupin Mine Incorporated. January 11, 2006.
- Golder. 2017. Updated Phase I and II Environmental Assessment, Lupin Mine, Nunavut. Prepared by Golder Associates Ltd. for Lupin Mine Incorporated. October 2017.

These environmental investigations are summarized briefly in the following sections.

1.2.1 Golder (2004) Ecological Risk Assessment for Tailings Containment Area

In 2004, Golder (2004) conducted an ecological risk assessment (ERA) for the Lupin Mine TCA. Although the title of the report implies only an ERA was conducted, the objective of the evaluation was to assess potential human health and wildlife risks due to exposure to contaminants of concern (COCs) (metals and cyanide) after the closure of the mine, based on the closure plan for the TCA. At the time of the 2004 ERA, the closure plan for the TCA included two major features:

- Covering exposed tailings with 1 metre (m) of esker sand; and
- Leaving two water clarification ponds (Pond 1 and Pond 2) in place and constructing a spillway between Pond 2 and the receiving environment and keeping water and sediment within Ponds 1 and 2.

Three sources of metals and cyanide were considered in the ERA:

- Settling of tailings in Ponds 1 and 2 and impacts to water and sediment in the ponds;
- Seepage from the esker-covered tailings to the surface of the esker-covered tailings; and
- Wind-blown transport of exposed tailings to the clean esker-covered tailings.

The only human health pathway considered applicable for evaluation was ingestion of caribou meat from caribou that may have been exposed to the tailings. It was concluded that there were no risks to human health via this pathway.

The ERA evaluated 12 terrestrial mammal and bird receptors and the following exposure pathways:

- Incidental ingestion of soil and ingestion of food items that have accumulated COCs from soil;
- Incidental ingestion of sediment and ingestion of food items that have accumulated COCs from sediment that had settled in Pond 1 and Pond 2; and
- Ingestion of water from Pond 1 and Pond 2.

The ERA concluded there were potential risks to individual shorebirds and waterfowl due to arsenic and cyanide exposure via water, sediment and food ingestion but that several assumptions made in the ERA may have led to

an overestimation of risks. Risks to populations of shorebirds and waterfowl were considered unlikely; however, the characterization of risks to populations was uncertain.

The ERA also provided a number of conclusions with respect to the closure plan for the TCA:

- No human health or wildlife risks were expected with placement of 1 m of esker sand over the exposed tailings; and
- Risks to shorebirds and waterfowl were found with leaving Pond 1 and Pond 2 in place and constructing a spillway between Pond 2 and the receiving environment and keeping water and sediment within Ponds 1 and 2. Further work to reduce the uncertainty in the assessment of risk to shorebirds and waterfowl was recommended to better inform the closure plan with respect to Pond 1 and Pond 2.

1.2.2 Morrow (2006) Phase One and Two Environmental Site Assessment

In 2005-2006, Morrow (2006) carried out a Phase 1 and Phase Two Environmental Site Assessment (ESA) to evaluate the environmental quality of the Lupin Gold Mine such that the mine closure plan at the time of the assessment could be finalized. For the purposes of the ESA, the Site was defined as the surface parcel/lease for land occupied by the mine and mill site only, along with the associated roads and water supply facilities at Contwoyto Lake. The ESA indicated that the TCA and associated #1 dump pond were part of a separate reclamation plan and not the subject of the assessment. Similarly, the airstrip would remain in place under a separate lease and was not part of the assessment.

The following summarizes the findings of the Phase One and Two ESA:

- The Phase One ESA identified a total of 61 areas of potential environmental concern (APECs) that had the potential for mine-related impacts (i.e., metals, hydrocarbons, glycols, cyanide, nitrogen and/or salt-based contamination).
- As part of the Phase Two ESA, the 61 APECs were investigated by drilling nine boreholes, excavating 59 test pits, and installing 19 groundwater monitoring wells.
- The results of the soil and groundwater sampling indicated that the primary COCs were arsenic and hydrocarbons (petroleum hydrocarbon [PHC] Fraction [F] 1 and PHC F2). Secondary contaminants (e.g., benzene, toluene ethylbenzene and xylenes (BTEX), polycyclic aromatic hydrocarbons (PAHs) glycols, cyanide, nitrate and nitrite, sulphate and salinity) were localized and for the most part, coincided with primary contaminants.
- Acid rock drainage/metal leaching (ARD/ML) potential at the Site was investigated and it was concluded that localized areas of ARD exist; however, additional monitoring was necessary to evaluate the significance of the drainage.
- Neutral pH leaching of arsenic was widespread with the greatest concentrations existing at or downgradient of areas with hydrocarbon contamination, potentially as a result of changes in soil geochemistry. Although local ARD and widespread neutral pH leaching was found, the metal load was low because the Site is located on a low hill (i.e., groundwater recharge from precipitation only). As a result, it was considered unlikely that a measurable effect would exist in Contwoyto Lake.
- Arsenic concentrations in the development rock pad beneath the Site were elevated above federal criteria and background concentrations.

- Approximately 40,000 cubic metres (m³) of hydrocarbon impacted soil, 8000 m³ of nitrate and/or cyanide containing soil and 2000 m³ of soil with traces of ore fines were estimated to exist on the Site.

The Phase Two ESA concluded the following:

- As per the closure plan, the hydrocarbon-impacted soil could be disposed of in the mine workings.
- Removal of the hydrocarbon-contaminated soil may result in a reduction of dissolved arsenic concentrations due to changes in the soil geochemistry.
- Continued monitoring and sampling of the Site wells and seeps should allow trends in metal concentrations to be established.
- Direct measurement of water quality discharging from the Site would provide the best indication of whether there are significant ARD/ML concerns at the Site.
- A HHERA was required to develop site-specific remediation criteria for metals and to identify an appropriate site closure strategy.

1.2.3 Golder (2017) Phase I and II Environmental Site Assessment Update

In 2017, Golder conducted an updated Phase I and II ESA at the Lupin Gold Mine. The updated ESA was completed in support of the development of an estimation of costs for the closure of the mine and the Water License renewal application. The overall objective of the ESA was to provide an update of the Morrow (2006) ESA and remediation quantities to be used to support the revised cost of closure estimate. For the purposes of the ESA update, the Site was defined as the surface parcel/lease of land occupied by the mine and mill site only, along with the associated roads and water supply facilities at Contwoyto Lake. The TCA was not part of the assessment.

The following summarizes the findings of the Phase I and II ESA Update:

- The release of approximately 10,000 litres (L) of oil contaminated water from the TCA in 2012 represented an APEC. However, as this release was associated with the TCA, which was not included in the assessment, investigation of this APEC was not completed as part of the Phase II ESA update. All other activities conducted at the Site since 2006 were not considered to represent APECs for the Site. Therefore, no additional APECs were identified for the Site as part of the Phase I ESA update.
- The 61 APECs identified in 2006 were further assessed and delineated via the advancement of 45 test pits, the collection of 11 groundwater samples from existing wells and the collection of 10 surface water samples from seeps.
- The Phase II ESA update confirmed that the primary COCs at the Site were arsenic and PHCs. Secondary contaminants were identified (i.e., lead nitrate, cyanide); however, they were localized and coincided with the primary contaminants.
- Approximately 35,200 m³ of PHC impacted soil was identified at 13 historical maintenance, fueling and fuel storage locations across the Site.
- Approximately 400 m³ of lead nitrate and/or cyanide impacted soils was identified at three historical cyanide storage locations.

- Arsenic concentrations in the development/waste rock pad beneath the Site were elevated with respect to the applicable guideline. Approximately 16,300 m³ of arsenic impacted “hot spots” were identified at two locations.
- The depth to groundwater was similar between the 2006 and 2017 groundwater monitoring events (near surface to approximately 2 metres below ground surface [mbgs]) and since 2006, PHC and dissolved metal concentrations in groundwater had generally decreased. No free product was observed in groundwater.
- Since 2006, PHC concentrations in seepage surface water had generally decreased, while the concentrations of total metals had generally increased in seepage surface water.
- The results of the ARD/ML investigation indicated that approximately 67 percent (%) of the combined waste rock dataset (2017 samples, URS (2005) and Morrow (2006)) is classified as potentially acid generating (PAG). The PAG samples were not concentrated in one area but rather distributed throughout the Site.
- Direct measurement of acidic pH values in groundwater and seepage surface water confirmed that acid generation as a result of sulphide mineral oxidation was occurring after many years of waste rock exposure.
- The results of short-term leach testing confirmed that the waste rock used for development at the Site can generate acidity, sulphate and metals by dissolution of soluble oxidation products present in the rock (shake flask extraction testing) and sulphide oxidation (net acid generating leachates). Seepage results collected from Site contact water agreed with those of laboratory leach tests. The primary metal of concern in leachate was arsenic; other parameters exceeding the applicable criteria short-term leachates and Site seepage samples included aluminum, cadmium, cobalt, copper, iron, lead, nickel and zinc. Metals that occurred at elevated concentrations in a few leachate samples included chromium, phosphorous, selenium, uranium and silver.
- The Phase I and II ESA Update indicated that closure alternatives for the Site should take into consideration the acid generation and metal leaching potential of waste rock.
- The Phase I and II ESA Update recommended that a HHERA be considered for the Site to develop site-specific remediation criteria and to inform the development of a closure plan.

1.3 Final Closure and Reclamation Plan

The FCRP (Golder 2018) was submitted by LMI to the NWB in July 2018 to provide the Board in writing confirmation of intent to move to the Final Closure and Reclamation phase for the Site. It was prepared based on the current site conditions and provides the concepts and activities for the full closure and reclamation of the Site. Upon acceptance, the FCRP will supersede the existing ICRP.

The overall objective of the FCRP is to return the Site and affected areas to viable and, where practicable, self-sustaining ecosystems that are compatible with a healthy environment and with human activities. The overall closure goal is supported by the three closure principles of Physical Stability, Chemical Stability and Future Use and Aesthetics for each component of the Project.

The FCRP was prepared on the assumption that all facilities and installations that comprise the Lupin Mine Operations will ultimately be decommissioned, removed or reclaimed under the terms of the land lease and in accordance with the reclamation requirements set out in the Water Licence. Details on the decommissioning and remediation of the following facilities and installations are detailed in the FCRP (Golder 2018):

- Mine Workings (Underground);
- Borrows and Quarries;
- Waste Rock;
- TCA;
- Mill Complex;
- Landfill and Other Waste Disposal; and
- Support Infrastructure (including accommodations, freshwater supply, arsenic treatment facility, explosives magazine, roads and airstrips, sewage and refuse facilities, tailings pipeline, fuel storage, and chemical storage).

To achieve permanent closure and reclamation of the Site, several measures will need to be implemented, including the remediation and/or risk management of waste rock and contaminated soils at the Site. A HHERA was identified in the FCRP as being required to develop Site-specific target levels (SSTLs) for COCs at the Site.

The primary contaminants of concern at the Site are arsenic (as a component of the solid phase waste rock/ore as arsenopyrite mineralization) and PHCs (related to historical maintenance, fueling and fuel storage at the Site). Secondary contaminants have been identified (i.e., lead nitrate, cyanide); however, they are localized and coincide with the primary contaminants.

The primary goal of the closure and reclamation of contaminated soils is to reduce the release of contaminants from the Site to the surrounding environment. Based on this goal, the following objectives have been identified in the FCRP:

- Manage contaminated soils in-situ or relocate them to final disposal locations in order to reduce unacceptable risk to human and terrestrial ecosystems;
- Impacts to humans, environment and wildlife within risk managed areas are reduced to acceptable levels; and
- Human and wildlife exposure to soil contaminant concentrations above criteria for the designated land use is reduced to acceptable levels.

The main objective of the reclamation of waste rock is to limit the contact between the waste rock and surface runoff.

Several post-closure reclamation options were considered and selection of preferred reclamation activities to address contaminated soils were described as follows:

- Heavily arsenic impacted soil (i.e., arsenic greater than 4000 milligrams per kilogram (mg/kg)) will be ex-situ remediated using conventional techniques (i.e., excavators, haul trucks, and dozers) and will be excavated and disposed of within the shafts or into open crown pillars for isolation. Crown pillars will be backfilled with rock above surface to allow for settlement, then capped with 1.0 m of esker material. Areas of remaining arsenic impacted shallow materials will be regraded to support surface water management (i.e., positive drainage), and then covered with coarse-grained borrow material from the Fingers Lake esker.

- Low impact arsenic impacted material will be left in place. Soil exceeding the SSTLs developed by the HHERA will be risk-managed with the placement of a coarse-grained engineered cover. It is anticipated that the engineered cover will consist of approximately 1.0 m of coarse-grained borrow material from the Fingers Lake esker and will be graded to support positive drainage.
- PHC impacted material will be ex-situ remediated using conventional techniques (i.e., excavators, haul trucks, and dozers) and disposed of in the shafts or open crown pillars. The areas that have been excavated will be regraded to ensure drainage and then covered with 1.0 m of coarse-grained borrow material from the Fingers Lake esker.

The reclamation plan for waste rock present on the surface of the mine and mill area will include a combination of the following two measures:

- As shown on Figure 4, the waste rock will be removed from the perimeter of the mine mill area. The waste rock will be excavated and transported and either disposed of into the shafts, open crown pillars or the landfill, or relocated to the central area to create a “dome”. Waste rock placed in the landfill will be covered by 1.0 m of esker material. The 1.0 m of esker material cover will also be placed on top of any waste rock that is used to infill tops of the open crown pillars, and also on top of any rock that is left in place in the central areas. The objectives of the cover are to: 1) limit the surface exposure of waste rock; and 2) to reduce the amount of infiltration into waste rock in order to control the volume of ARD impacted seepage out of the toe of the dome.
- Waste rock which is not removed will be left in place, generally in the central areas. The surface of the waste rock will be contoured to drain freely and then will be capped with 1.0 m cover of esker material.

The heavily arsenic impacted material generally occurs within the central waste rock area and will likely involve soil and waste rock that are inter-mixed. In such a case, contaminated soil cleanup and waste rock management will be integrated. The waste rock that is not disposed of into the shafts, open crown pillars or the landfill will be relocated into the central area and used to grade the surface of the waste rock that is being left in place. This central pile of waste rock will be covered by at least 1.0 m of esker material.

The FCRP also outlines the post-closure management and monitoring of the Site. Post-closure monitoring will take place to verify the attainment of closure objectives and criteria. Active monitoring is expected to occur for 2.5 years and passive monitoring will take approximately 5 years following the completion of the reclamation work, or until the global objectives for the mine site can be confirmed. The following post-closure monitoring activities will be completed related to contaminated soils:

- Engineered cover monitoring: Regular monitoring and occasional maintenance of the cover is necessary to confirm it does not deteriorate over time. Annual visual inspections will be completed, and maintenance activities will be undertaken as needed.
- Groundwater and Seepage Water Monitoring: After the completion of remedial activities, a new shallow groundwater monitoring well network will be established within the active zone to confirm that remedial activities have been successful. Annual monitoring and sampling of the groundwater monitoring network, along with the current seepage water sample network will be completed and documented to confirm the remedial objectives have been achieved.

Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC) completed a review of the FCRP and provided comments related to the timing of completion of submission of the HHERA. Specifically, they recommended that LMI should incorporate the findings of the HHERA into the final version of the FCRP. CIRNAC also had comments related to the waste rock management and PAG/ML and recommended that LMI include geochemical source modelling and closure water quality modelling to show that the ARD waste rock and long-term impacts to water quality will not be an issue.

1.4 Objectives of the Human Health and Ecological Risk Assessment

The objectives of the HHERA provided herein were as follows:

- To evaluate the potential risks to human health and the environment from the contamination associated with the historical operation of the Site as a gold mine;
- If potential risks are present, to derive SSTLs for remediation and/or risk management that represent acceptable levels of risk to human health and the environment; and
- To define areas requiring remediation and/or risk management to mitigate risks to human health and the environment based upon the derived SSTLs, if applicable, and to confirm whether the measures outlined in the FCRP are sufficiently protective of human health and the environment.

For the purpose of this assessment, the “Site” is defined as the surface parcel/lease of land occupied by the mine and mill site only, along with the associated roads and water supply facilities at Contwoyto Lake. The TCA is not part of this assessment.

The HHERA was completed in the context of returning the Site to a condition that protects the health of Nunavut residents and the environment around the mine and considers the historic use (before mine development) of the area by Inuit and wildlife. Potential risks to human health and the environment were evaluated for use of the Site following closure and reclamation of the Site based on current environmental conditions (e.g., current soil, groundwater and seepage surface water quality data) and without the implementation of the measures proposed in the FCRP (e.g., placement of engineered cover). This was done to focus the SSTL development on those COCs that may pose a potential risk, providing support to and the implementation of those measures outlined in the FCRP.

To address the CIRNAC comment related to the waste rock management and PAG/ML, surface water quality modeling of receiving water bodies was completed to evaluate the performance of the proposed granular esker cover of the waste rock dome with respect to limiting generation of ARD-impacted seepage from the waste rock dome (Golder 2019a; Appendix C). Hydrologic inputs to the water quality model were developed based on the results of thermal-seepage modelling completed by Golder (Golder 2019b; Appendix C). The modelling was used in the HHERA to better understand the importance of the seepage from the waste rock as a potential contaminant transport pathway. The resulting predictions of loading to surface water were evaluated in the HHERA for potential risks to human and ecological receptors.

The remainder of this report is structured as follows:

- Section 2.0, Regulatory Context, provides a brief overview of the risk assessment framework and the applied standards for the Site.

- Section 3.0, Site Characterization, provides a general overview of the Site related to topography, hydrology, hydrogeological (geology and hydrogeology) conditions, vegetation, climate and the environmental quality data (background concentrations, current soil, groundwater and seepage water quality data and predicted surface water quality data) used in support of the HHERA.
- Section 4.0, Human Health Risk Assessment (HHRA), provides the evaluation of the potential risks to human receptors associated with the historical mine site-related impacts and the SSTLs protective of human receptors that may use the Site for those contaminants that pose a potential risk.
- Section 5.0, ERA, provides the evaluation of the potential risks to ecological receptors associated with the historical mine site-related impacts and the SSTLs protective of ecological receptors that may use the Site for those contaminants that pose a potential risk.
- Section 6.0, Overall Conclusions and Recommendations, provides the conclusions of the HHERA and associated recommendations with respect to remediation and/or risk management and the adequacy of the FCRP.

2.0 REGULATORY CONTEXT

2.1 Risk Assessment Framework

Potential risks to human health and the environment associated with the historical mine site-related impacts at the Site were evaluated using the risk assessment framework endorsed by federal and provincial regulatory agencies (Health Canada 2010a, 2012a; CCME 1996, 1997; Environment Canada 2012; MOE 2011a).

For there to be a potential risk, the following three conditions must be met:

- A contaminant must be present at a concentration that could be harmful (i.e., a COC).
- Humans, terrestrial plants, soil invertebrates, wildlife or aquatic life (i.e., a receptor) must be present.
- There must be a way by which the receptor can come into contact with the contaminant (i.e., an exposure pathway).

To determine whether these conditions are present, the risk assessment framework used in Canada typically involves four components, as described below:

- 1) **Problem Formulation** – The problem formulation identifies the COCs, human and ecological receptors and pathways by which exposure may occur on the Site. The information from the problem formulation is summarized in a conceptual site model (CSM) which illustrates the sources of COCs, the pathways of exposure and the receptors that are evaluated in the HHERA.
- 2) **Exposure Assessment** – The exposure assessment quantifies or categorizes the degree to which a receptor is exposed to a COC for each relevant exposure pathway identified in the problem formulation. For human receptors, the exposure assessment involves estimating the daily dose of a COC. The dose is calculated from concentrations of COCs in environmental media (soil, groundwater and surface water), the amount of time the receptor spends in the area and receptor-specific parameters such as body weight, ingestion rate and dietary preferences. For ecological receptors such as wildlife, exposure is estimated in the same way as for human receptors. For terrestrial plants, soil invertebrates and aquatic life, exposure is expressed as the concentrations of the COCs in soil, groundwater or surface water.

- 3) **Effects/Toxicity Assessment** – The effects or toxicity assessment provides the basis for assessing what is an acceptable exposure and what level of exposure may adversely affect receptors. This involves identification of the potentially toxic effects of a COC and determination of the dose (for humans and wildlife) or concentration (terrestrial plants, soil invertebrates and aquatic life) to which a receptor can be exposed without experiencing adverse effects (i.e., dose-response analysis). This value is called the toxicity reference value (TRV). For human receptors, consideration is given to both non-carcinogenic and carcinogenic effects.
- 4) **Risk Characterization** – The final component of the HHERA compares the results of the exposure and toxicity assessments and determines whether there is a potential for COCs at the Site to pose a risk to human and ecological receptors. For human receptors and threshold-acting contaminants, risk estimates are expressed as hazard quotients (HQs) which are calculated as the ratio of the daily doses and their respective tolerable daily intakes (TDIs). For human receptors and non-threshold-acting contaminants (some carcinogens), risk estimates are expressed as incremental lifetime cancer risks (ILCRs) which are calculated by multiplying the daily doses by their respective slope factors (SFs). Risk estimates for ecological receptors are calculated as HQs. The characterization of risks includes consideration of the uncertainty and conservatism in the HHERA.

2.2 Applied Guidelines/Standards

Environmental quality guidelines or standards are not available from the territory of Nunavut to evaluate the environmental quality of soil, groundwater and surface water; as a result, the Site falls under federal jurisdiction for guideline selection. The Canadian Council of Ministers of the Environment (CCME), Federal Contaminated Sites Action Plan (FCSAP) and Canadian Environmental Protection Act (CEPA) guidelines/standards were selected to evaluate the analytical results. These generic, risk-based guidelines/standards are protective of both human health and the environment and are intended to be applied to sites across Canada, including the north.

If federal guidelines/standards were not available, provincial guidelines/standards were applied (Ontario, Alberta, British Columbia). If provincial guidelines/standards were not available, international (e.g., United States Environmental Protection Agency [US EPA]) guidelines/standards were used. The following sections outline the applied guidelines/standards and the rationale for their selection.

2.2.1 Federal Guidelines/Standards

The following federal guidelines/standards were applied in the assessment:

- The CCME Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health (SQG_E and SQG_{HH}) are risk-based numerical guidelines, divided into categories based on land use (CCME 1999a/2019). They are available for specific human and/or ecological exposure pathways (e.g., soil ingestion by humans, soil contact by ecological receptors). The CCME SQGs include guidelines for BTEX, metals and PAHs.
- The CCME Canada-Wide Standard for Petroleum Hydrocarbons in Soil (PHC CWS) are risk-based numerical levels, divided into categories based on land use and soil texture. They are available for specific human and/or ecological exposure pathways (CCME 2008). The CCME PHC CWS includes levels for PHC F1 to F4.
- The Federal Interim Groundwater Quality Guidelines (FIGQGs) are risk-based guidelines developed to protect against the potential for adverse effects to human health and the environment (FCSAP 2016). They

are divided into categories based on land use and soil type for a non-potable water condition. They are available for specific human and/or ecological exposure pathways.

- The guidelines for Canadian Drinking Water Quality (CDWQ Guidelines) were established by the Federal-Provincial-Territorial Committee on Drinking Water and published by Health Canada in June 2019. Each guideline was established from current, published scientific research related to health effects, aesthetic effects and operational considerations.
- The CCME Water Quality Guidelines for the Protection of Aquatic Life (WQG-PAL) are numerical guidelines derived for the protection of aquatic receptors (CCME 1999b/2019). The guidelines are divided into freshwater and marine water categories within which values for short- and long-term exposure are provided. Given the site setting, freshwater guidelines were considered in the HHERA.
- The CCME Water Quality Guidelines (WQGs) for the Protection of Agricultural Water Uses are numerical guidelines derived for the protection of irrigation and livestock water (CCME 1999b/2019). The guidelines are protective of sensitive crop species that may be exposed to toxic substances in irrigation water or the protection of livestock consuming drinking water.
- The Federal Environmental Quality Guidelines (FEQGs) are numerical guidelines for the quality of the ambient environment (Government of Canada 2019a). They are protective of adverse effects on aquatic life exposed by the water or sediment, or where chemicals may bioaccumulate, birds and mammals that consume aquatic life. They are derived using approaches consistent with those used by the CCME in the development of the WQGs-PAL.

2.2.2 Guidelines/Standards from other Jurisdictions

Where federal guidelines/standards were not available, guidelines/standards from the following jurisdictions were applied:

- The Ontario Ministry of the Environment, Conservation and Parks (MECP) defines standards to assess chemical impacts in soil and groundwater. The document entitled *Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act* (MOE 2011b) provides generic risk-based standards for soil, groundwater and surface water developed to protect against the potential for negative effects to human health and the environment for a variety of exposure scenarios associated with typical property use. The document also provides aquatic protection values (APVs) that are designed to provide a scientifically defensible and reasonably conservative level of protection for most aquatic organisms from the migration of contaminated groundwater to surface water resources.
- For properties located in the Province of Alberta, Alberta Environment and Parks (AEP) defines standards to assess chemical impacts in soil, groundwater and surface water. The document entitled *Alberta Tier 1 Soil and Groundwater Remediation Guidelines* (AEP 2019) provides generic risk-based standards for soil and groundwater developed to protect against the potential for negative effects to human health and the environment for a variety of exposure scenarios associated with typical property use. The document entitled *Environmental Quality Guidelines for Alberta Surface Waters* (AEP 2018) provides guidelines for surface water quality to protect aquatic life and agricultural (irrigation and livestock water) uses of water.
- British Columbia Ministry of Environment & Climate Change Strategy (BC MECCS). In British Columbia, environmental matters pertaining to contaminated sites fall under the jurisdiction of the BC MECCS, pursuant to the *Environmental Management Act* (EMA). The Contaminated Sites Regulation (CSR; BC

Regulation (Reg.) 375/96, O.C. 1480/96 and M271/2004, as updated [including amendments up to BC Reg. 11/2019 and 13/2019, 1 October 2019] soil standards (BC MECCS 2019b) are divided into categories based on land use. The land use applicable to the Site is agricultural. The British Columbia WQGs represent safe levels of substances that protect different water uses, including aquatic life, wildlife and agriculture (irrigation and livestock watering). Approved WQGs are summarized in the document entitled *British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture* (BC MECCS 2019a). For aquatic life, both long-term chronic and short-term acute WQGs are provided.

- The US EPA provides Regional Screening Levels (RSLs; 2019a) for use by all US EPA regions to screen for chemicals at Superfund sites. The RSLs are risk-based screening levels protective of human health for residential and commercial/industrial exposures to soil, air and tap water (drinking water) that are developed using the latest toxicity values.

2.2.3 Rationale for Selection of Guidelines/Standards

The following provides a rationale for the selection of the guidelines/standards applied to the Site:

Land Use

The Site is a former gold mine and the intention is for the Site to return as much as possible to its natural state following permanent closure of the mine. A natural areas land use category is not defined in the CCME soil quality guideline derivation protocol (CCME 2006). The CCME indicates that a natural areas land use category could include the presence of campers, hikers, trappers, etc. and consumption of country foods by local people. The protocol indicates that the soil quality guidelines for agricultural land use could be applied to natural areas as a conservative approach. For human receptors, agricultural land use is considered representative for the Site as it is protective of the consumption of plants and wild game pathways. The applied guidelines/standards for human receptors are discussed further in Section 4.1.3.

For ecological receptors, land use for the Site is considered to be agricultural land use given the Site provides habitat for transitory wildlife and birds, consistent with CCME guidance. The applied guidelines/standards for ecological receptors are discussed further in Section 5.1.1.

Soil Texture

Based on the data provided in the 2006 Phase One and Two ESA (Morrow 2006) and observations during the 2017 Phase I and II Update (Golder 2017), the soil at the Site predominantly consists of coarse-grained development/waste rock and overburden fill. Therefore, guidelines/standards for coarse-grained soil were applied.

Soil pH

The CCME and MECP guidelines/standards for soil are generally considered to be applicable to soils with pH ranges between 6 and 8 (CCME 1999a/2019) and 5 and 9 (surface soil; MOE 2011a). This is because soil pH can influence the mobility, bioavailability and toxicity of metals. Soil pH measured at the Site ranged from 2.7 to 12.59 compared to the CCME guideline of 6 to 8 and the MECP standard of 5 to 9 and the background range of 4.13 to 5.67.

In general, the bioavailability and toxicity of cationic metals (e.g., antimony, barium, beryllium, cadmium, cobalt, copper, lead, nickel, and zinc) in soil tend to increase with decreasing pH, whereas the bioavailability and toxicity of anionic metals (e.g., arsenic, chromium, selenium and vanadium) in soil tend to decrease with decreasing pH

(US EPA 1992; Wang et al. 2009). And the reverse is true for increasing pH. Given that the human stomach has a pH of between approximately 1 and 3, the soil pH is not expected to be of importance with respect to the ingestion and absorption of COCs by human receptors and similarly for wildlife. This is because the stomach pH, which is lower than the soil pH, will drive the bioavailability of metals that are ingested by human receptors and wildlife. As such, the soil pH is not relevant for the evaluation of human receptors and wildlife and was only considered for the evaluation of plants and soil invertebrates.

Considering the range of soil pH on the Site is higher and lower than the CCME and MECP guidelines/standards for range, it was considered appropriate to screen metals using the CCME/MECP guidelines/standards as described above because it is expected that the bioavailability and toxicity to plants and soil invertebrates will be less at lower soil pH for anionic metals and less at higher soil pH for cationic metals. Thus, screening against the CCME/MECP guidelines/standards can be considered a conservative approach in these cases.

It is expected that the bioavailability and toxicity of cationic metals may be higher at lower pH and that bioavailability of anionic metals may be higher at higher pH, suggesting that screening of these metals against the CCME/MECP guidelines/standards may not be appropriate in these cases. However, if toxicity data were available at higher or lower soil pH values (i.e., less than 5 or greater than 9), these data were included in the dataset used by the CCME/MECP in their derivations of the guidelines/standards for metals. The CCME/MECP datasets also included studies for which soil pH was not reported. Screening against the CCME/MECP guidelines/standards for metals may underestimate risks to plants and soil invertebrates from some metals under lower and higher pH conditions.

In general, there is a paucity of information on metal mobility, bioavailability and toxicity at low and high soil pH. This may be because extreme pH values in themselves provide challenges to plants and soil invertebrates. For example, earthworms prefer neutral to slightly acid conditions (Environment Canada 2004; Jänsch et al. 2005; Feisthauer et al. 2006). Given the above, metals were screened using the CCME/MECP guidelines/standards; however, this approach may underestimate potential risks to plants and soil invertebrates from some metals under low and high soil pH conditions. Regardless, those areas with pH outside the SSTLs derived for soil for plants and soil invertebrates are considered to pose potential risks to plants and soil invertebrates based on pH alone (refer to discussion provided in Section 5.4.1).

Potable Water

Potable water is currently obtained from Contwoyto Lake. A causeway/breakwater extending out into the lake supports a pump house building and docking facilities. The freshwater supply pumps were decommissioned in 2006; as a care and maintenance requirement. Currently, freshwater is trucked from the breakwater on Contwoyto Lake to a water storage tank at the accommodation buildings. The water supply system will be removed for final closure; however, the breakwater will be left in place for future use. It is expected that following permanent closure, Lake Contwoyto would remain the most likely source of drinking water. Therefore, guidelines/standards for non-potable groundwater use were applied.

Proximity to Surface Water

The Site was developed on the western shore of Contwoyto Lake. Therefore, guidelines/standards protective of surface water quality were applied.

3.0 SITE CHARACTERIZATION

3.1 Topography

The Site is located in the tundra zone of the Canadian Shield, an area of continuous permafrost. It was glaciated multiple times during the Pleistocene age (Golder 2018). The most recent glaciation was the late Wisconsin glacial stage, which reached a maximum extent about 14,000 years before present (BP) and disappeared about 6,000 years BP.

Terrain in the vicinity of the Site is generally low and undulating, ranging between 470 to 505 m in elevation. The Site is located on a hill, with the height augmented by development/waste rock used to form the foundation of the Site buildings (Golder 2017).

Much of the Site exhibits bedrock at surface, and it is typified by “tombstone” topography over some of its area (Golder 2018). These “tombstone” features resemble grave markers and occur as a result of ice-jacking action in heavily jointed rocks where joints tend to be pseudo-vertical and near-horizontal. The frost heave blocks are of various sizes and are scattered in a chaotic fashion. Removal of a block raised by this action would reveal an underlying mass of permanent ice.

3.2 Hydrology

Contwoyto Lake is the major waterbody in the region, with a surface area of approximately 95,900 hectares (ha) and a drainage area of 800,000 ha (Morrow 2006). Contwoyto Lake has two outlets in the Burnside River, which flows from the northwest end of the lake towards Bathurst Inlet, and the Back River at the southeast end of the lake, which flows into Pellatt Lake (Golder 2004). The main body of Contwoyto Lake lies approximately 1.5 km to the east and south of the mine site. To the north of the mine, a portion of Contwoyto Lake extends to the west and south, terminating in a narrow bay (Sun Bay) which lies directly west of the Site (Golder 2004; Morrow 2006).

The aquatic habitat in the receiving environment immediately downstream of the TCA is comprised of three shallow lakes (Dam 2 Lake, Dam 1a Lake and Unnamed Lake), two streams (Seep Creek and Concession Creek), two shallow ponds and two embayment areas of Contwoyto Lake (Inner and Outer Sun Bay) (Figure 2; Golder 2018). All of the small lakes and ponds freeze to the bottom in winter (Morrow 2006). Due to low winter flows, both Seep Creek and Concession Creek freeze to the bottom in winter. As a consequence, overwintering habitat for fish is limited primarily to Outer Sun Bay and the main body of Contwoyto Lake.

Concession Creek drains Concession Lake via Unnamed Lake to Inner Sun Bay. Seep Creek enters the Sun Bay drainage system along the east side of Unnamed Lake. Lower Concession Creek (i.e., that section between Unnamed Lake and Inner Sun Bay) varies in width between 25 and 75 m, depending on seasonal discharges. Side channels are active during spring freshet. Stream depth generally is less than 1 m, except during spring freshet when depths approach 1.5 m. The substrate is primarily large boulders with large and small cobbles occupying the interstices. Seep Creek is approximately 6.5 km in length, flowing from its source in Dam 2 Lake and Dam 1a Lake (via separate branches which join about 2 km downstream) to Unnamed Lake. The stream channel in upper Seep Creek generally is poorly defined, often flowing through marshy areas, or between large boulders or through bedrock fractures. This section of the creek is generally less than 0.5 m in depth and less than 2 m wide. The dominant substrate type is boulders, although localized areas of cobble and gravel are present. Lower Seep Creek (i.e., the 400 m section upstream of Unnamed Lake) is characterized by a well-developed channel varying in width from 1 to 4 m, although during freshet, maximum wetted width was about 20 m. The dominant substrate type is boulders, with localized areas of cobbles and gravel. Inner Sun Bay

(approximate area of 150 ha) is primarily shallow (mean depth of 1.7 m), with a maximum depth of about 6.5 m. Over 91% of the surface area is shallower than 3 m, and much of the bay freezes to the bottom in winter. Outer Sun Bay is deeper (greater than 10 m).

As illustrated in Figure 5, and discussed further in Section 3.9, the waste rock dome proposed in the FCRP is located at an area of watershed divides, with cover runoff and seepage reporting to the following watersheds: Upper Sewage Lake, Lower Sewage Lake, Boot Lake, East Lake, and Contwoyto Lake. All watersheds report to Contwoyto Lake.

3.3 Geology

The Lupin Deposit is situated in an Archean metatubidite sequence of the Contwoyto Formation, part of the Yellowknife Supergroup of supracrustal metasedimentary and metavolcanic rocks of the Slave Geologic Province. The rocks have been subjected to both regional and contact metamorphism and to several phases of deformation and intrusion. The bedrock at the Site consists of a mixture of low grade metamorphosed argillite, siltstone, slate, greywacke, and quartzite, generally phyllite (Golder 2018).

Where bedrock is not present at surface, the ground surface typically consists of glacial till which is occasionally overlain by glacio-fluvial and glacio-lacustrine sand and gravel deposits (in the form of eskers and lake shore deposits) (Golder 2018). The glacial till is characterized as a silty sand with gravel and boulder content and is underlain by weathered and competent low grade clastic metamorphosed bedrock of the Yellowknife Supergroup.

The subsurface conditions recorded during the 2017 Phase II ESA Update (Golder 2017) were generally consistent with those documented in the 2006 Two ESA (Morrow 2006). The subsurface conditions consist of upper development mine rock fill materials, underlain by native silty sand/sand and gravel glacial till and bedrock. The following paragraphs describe these two stratigraphic units.

- **Fill Materials** - The fill materials typically range from 0.5 to 2.0 m in thickness, with an average thickness of 1.0 m across the Site. Upper fill/surface materials typically consist of angular sand, gravel, cobbles and boulders (Unit 1; Morrow 2006). Development/waste rock was placed during Site development and construction. This upper fill material typically ranges in thickness from 0.5 to 1.5 m. Lower fill materials consist of sand and gravel materials, likely sourced from the nearby esker (Unit 2; Morrow 2006). The granular fill material is typically 0.5 m in thickness and frequently directly overlies the native ground conditions. The fill materials are typically dry, within variable quantities of cobbles and boulders. Minimal evidence of debris was observed within the fill materials.
- **Native Soil** - The native soil underlies the fill materials and typically extends from about 0.5 to about 3.0 mbgs. The upper stratum of native soil typically consists of silt/sand glacial till (Unit 3; Morrow 2006). Discontinuous ground ice was noted in the several samples of this unit. The lower stratum of native soil consists of sand and gravel materials, which extend to a depth of approximately 3.0 mbgs (Unit 4; Morrow 2006).

These fill and native soil strata are underlain by bedrock. The typical depth to bedrock ranges from 1.0 to 3.0 mbgs. Permafrost was recorded at an average depth of approximately 1.3 mbgs.

3.4 Hydrogeology

Depth to groundwater at the Site ranged from near surface to 1.75 mbgs (Golder 2017). As indicated previously, the Site is located at the top of a small hill and is augmented by the development/waste rock pad. As a result, the

shallow groundwater is “mounded” in a similar pattern as the topographic contours with radial groundwater flow to the north, east, south, and west. Figure 6 presents the shallow groundwater flow direction map, based on the findings of the Phase II ESA Update (Golder 2017).

Discharge of deep groundwater to Contwoyto Lake may occur because the lake is a very large waterbody and would have a talik (thaw zone) beneath it. Shallow groundwater would not interact with Contwoyto Lake due to the permafrost conditions.

Discharge of groundwater to other surrounding lakes (e.g., Boot Lake, East Lake and Lower Sewage Lake) would not occur due to the permafrost conditions. As these lakes are too small to have taliks beneath them, deep groundwater would also not interact with these lakes.

3.5 Vegetation

The Site is located within an area of sparse vegetation, in the barren land tundra of Nunavut. It is typified as having sparse low-lying vegetation which is extremely tolerant and well adapted to the climatic conditions. Some of the more prevalent types of habitat that can be found throughout the area include upland and lowland tundra, wet meadows and gentle slopes.

Throughout the Site there are diverse types of vegetation consisting of grasses and sedges, and ground cover such as mosses, Labrador tea, cranberry, bilberry, bearberry, and arctic white heather. In wet areas, predominant species include cotton grass, bog rush, and other aquatic grasses. Dwarf birch and willows populate trenches, and examples of colourful flowering plant species include fireweed, Lapland rosebay, azalea and saxifrage (Golder 2018).

3.6 Climate

Climate in this region is classed as semi-arid subarctic, with an average annual precipitation of approximately 300 millimetres (mm). August is the wettest month with average rainfall of 59.8 mm. The annual average temperature is negative (-10.9) degrees Celsius (°C); July is the warmest month with average temperature of 11.7 °C, whereas January is the coldest month with a monthly average of -29.7 °C.

3.7 Background Concentrations

The 2006 Phase One and Two ESA (Morrow 2006) and 2017 Phase I and II ESA Update (Golder 2017) identified elevated natural background concentrations for soil as an APEC. This was based on the interpretation of geology maps for the area of the Lupin Mine. The maps showed the setting of the mine site in the region and showed mineralized (i.e., iron sulphide) veins that extended beyond the area that was mined. Naturally elevated metals concentrations would be expected to be associated with those veins. To investigate this APEC, a surface soil sample (soil sample ID SS76) was collected in July 2005 by Morrow (2006). In addition, 20 transect surface soil samples (soil sample IDs 51171 through 51190) were collected by Kinross (i.e., LMI personnel) in September 2005 to the north, south, east and west of the mill site. Background soil samples were analyzed for total metals, sulphide and pH. No background samples were collected in 2017 by Golder. The background soil analytical results are provided in Table A-1, in Appendix A.

Background concentrations for metals were calculated using all soil data from all depths from the 2006 Morrow and 2005 Kinross investigations. This included calculating the 95% Upper Confidence Limits of the Mean (UCLM) for soil using ProUCL Version 5.1, developed by the US EPA (2016a). The software uses a “goodness of fit” test to determine normality, log normality, or gamma distribution of the data set and provides standard summary

descriptive statistics (e.g., mean, median, etc.). Five parametric UCLMs and ten non-parametric UCLMs are computed and assessed by the program, and a recommendation as to the UCLM best suited to the data is provided by the program.

A description of how the 95% UCLMs were calculated and selected is found in Appendix B. The ProUCL inputs, outputs and summary of background concentrations are also provided in Appendix B. In cases where insufficient numbers of detected values prevented calculation of 95% UCLMs by the ProUCL software, the background concentrations were set as the maximum of measured background soil concentrations.

Background concentrations for groundwater are not available for the Site.

For seepage surface water, one sample from a creek north of the Site (which is considered to be unimpacted by the historical mine operations) was collected as a background sample.

For lake surface water, the background water quality from Fingers Lake as relied upon in the Water Quality Model (Appendix C) was used in the HHERA, as discussed further in Section 3.9.

Background concentrations were used in the HHERA as part of the identification of COCs for further assessment. As described further in Section 4.1.3 and Section 5.1.1, parameters with concentrations in soil and seepage surface water that were lower than background concentrations were not retained for further evaluation in the HHERA. Similarly, for parameters without guidelines/standards, background concentrations were used as a Site-specific point of comparison.

3.8 Soil, Groundwater, and Seepage Surface Water Quality Data

The previous environmental investigations completed at the Site (Section 1.2) have identified exceedances of the federal guidelines/standards applied in support of those investigations (based on industrial land use) for metals and PHCs in soil, groundwater and seepage surface water at the Site. Data are also available for routine physical and chemical parameters (e.g., pH, major ions, etc.) in groundwater and seepage surface water. The data for soil, groundwater and seepage represent current environmental conditions without the implementation of the measures proposed in the FCRP (e.g., placement of engineered cover). The datasets relied upon in the HHERA are provided in Appendix A and briefly described for each environmental medium below:

- Soil quality data from all environmental investigations (from 2006 and 2017) and all depths were used in support of the HHERA (Tables A-2 to A-5, in Appendix A). Soil data are available for PHCs, metals, PAHs and glycols.
- Groundwater quality data are available for 2006 and 2017. Groundwater quality data from 2017 were used in support of the HHERA, as these concentrations were considered to be most representative of current conditions (Tables A-6 to A-9, in Appendix A). Groundwater data from shallow groundwater monitoring wells are available for PHCs, metals, PAHs and glycols. Deep groundwater was not evaluated.
- Seepage surface water data are available for 2017 and 2019 (Tables A-10 to A-12, in Appendix A). Seepage surface water quality data from 2019 were used in support of the HHERA, as these concentrations were considered to be most representative of current conditions. For parameters which were not re-sampled in 2019, the 2017 data were used.

The approximate locations of soil, groundwater and seepage surface water sampling stations are shown in Figures 7, 8 and 9, respectively.

3.9 Water Quality Predictions for Lakes

As noted previously, surface water quality modeling of receiving water bodies was completed to evaluate the performance of the proposed granular esker cover of the waste rock dome with respect to limiting generation of ARD-impacted waters from the waste rock dome (Golder 2019a; Appendix C). After closure, the waste rock dome is expected to be roughly circular and to cover an area of about 30 ha. It will contain about 820,000 m³ of waste rock and it will have a surface slope of about 1.6%. The resulting predictions of loading to surface water were evaluated in the HHRA for potential risks to human and ecological receptors.

The modelling approach, geochemical and hydrologic inputs, key model assumptions and water quality predictions are presented in Appendix C (Golder 2019a) and briefly described here. Hydrologic inputs to the water quality model were developed based on the results of thermal-seepage modelling completed by Golder (Golder 2019b; Appendix C). The proposed waste rock dome is planned to be constructed over historic mine infrastructure including the mill, camp, crown pillar, and tank farm. As illustrated in Figure 5, the dome is located at an area of watershed divides, with cover runoff and seepage reporting to multiple watersheds as follows:

- Upper Sewage Lake;
- Lower Sewage Lake;
- Boot Lake;
- East Lake; and
- Contwoyto Lake.

Water quality predictions were completed for the following prediction nodes in the receiving environment:

- East Lake Outlet;
- Boot Lake Outlet; and
- Lower Sewage Lake Outlet.

All watersheds report to Contwoyto Lake. Given the large size of Contwoyto Lake (greater than 500 km²), it was assumed that mine related effects in the majority of the lake will be negligible and that observable effects (if any) would be limited to the immediate vicinity of stream confluences with Contwoyto Lake for those streams affected by waste rock seepage. It was anticipated that mixing of mine impacted water with Contwoyto Lake at these confluences would result in concentrations at or below background conditions or applicable water quality criteria due to the relatively low flow rates of mine impacted streams. Predictive modelling of water chemistry values for Contwoyto Lake in the vicinity of these confluences has not been completed to date.

The predicted composition of water at each receiving node were expected to vary on a monthly basis during the open-water season depending on the proportion of precipitation and snowmelt that report as cover runoff versus infiltration. The relatively smaller watersheds of Lower Sewage Lake and East Lake were anticipated to see generally higher metal concentrations as compared to Boot Lake, where the larger watershed results in a greater proportion of natural runoff relative to contact water.

No channels have been observed to transport flow from existing waste rock piles to receiving water bodies. It was considered probable that a portion of waste rock seepage flows travelling overland from the toe of the proposed waste rock dome to the receiving water body would either evaporate or infiltrate prior to reaching a receiving

water body. The model was constructed based on the conceptualization of sources and release mechanisms, combined with data interpretation, to describe water quality conditions at the Site. Where uncertainty existed in model input values, conservative inputs and assumptions were applied. Climatic controls, which may influence infiltration, evaporation, geochemical processes, and flow within the catchments, were not modelled, except for those which were captured in thermal-seepage modelling of the waste rock dome (Golder 2019b; Appendix C). Therefore, the model may overestimate the predicted concentrations in the modelled catchments.

Water quality modelling was completed based on results from the thermal and seepage modelling under current (2019) climatic conditions (Appendix C; Golder 2019b). Results based on predicted future climatic conditions to the year 2100 were also produced from the thermal and seepage model and were evaluated for applicability to the water quality model. The range of concentrations produced using current climate data is equal to the range of concentrations under future climate conditions, and predictions are only affected by the month to which they apply, the values are unchanged. Under future climate conditions, all monthly results are advanced one month earlier (i.e., June values become applicable to May, September values become applicable to August) and current September values are applicable to both September and October. Therefore, the duration of peak concentrations (controlled by months in which water loss from the waste rock dome is 100% seepage) would increase from two months (August and September) to four months (July through October).

The water quality model provided predictions for the four months of the open-water season (June, July, August and September). The model included two scenarios to represent uncertainty in geochemical source terms: 50th percentile of source data concentrations, to represent expected conditions; and 75th percentile of source data concentrations, to represent upset conditions (i.e., worst-case). Given that the model is considered to be conservative, the water quality model results for the 50th percentile source terms scenario were used in support of the HHERA.

Background concentrations used in the model were data from 2006 through 2016 for Fingers Lake (approximately 6 km southeast of the mill site). Fingers Lake is also used as a background water quality monitoring location in Environmental Effects Monitoring studies for Lupin Mine. The 50th percentile background concentration was used in the HHERA to be consistent with the predicted surface water concentrations used in the HHERA.

4.0 HUMAN HEALTH RISK ASSESSMENT

The objectives of the HHRA provided herein were as follows:

- To evaluate the potential risks to human health from the contamination associated with the historical operation of the Site as a gold mine; and
- If potential risks are present, to derive SSTLs for remediation and/or risk management that represent acceptable levels of risk to human health.

Potential risks to human health were evaluated for use of the Site following closure and reclamation of the Site based on current environmental conditions (e.g., current soil, groundwater and seepage surface water quality data) and without the implementation of the measures proposed in the FCRP (e.g., placement of engineered cover). This was done to focus the SSTL development on those COCs that may pose a potential risk, providing support to and the implementation of those measures outlined in the FCRP.

To address the CIRNAC comment related to the waste rock management and PAG/ML, surface water quality modeling of receiving water bodies was completed to evaluate the performance of the proposed granular esker

cover of the waste rock dome with respect to limiting generation of ARD-impacted seepage from the waste rock dome (Golder 2019a; Appendix C). Hydrologic inputs to the water quality model were developed based on the results of thermal-seepage modelling completed by Golder (Golder 2019b; Appendix C). The modelling was used in the HHRA to better understand the importance of the seepage from the waste rock as a potential contaminant transport pathway. The resulting predictions of loading to surface water were evaluated in the HHRA for potential risks to human receptors.

4.1 Problem Formulation

The problem formulation involves developing a focused understanding of how environmental quality might affect the health of receptors (i.e., humans) near the Site. The problem formulation identifies the following:

- A representative set of receptors (i.e., humans) that may be present in the vicinity of the Site;
- Pathways by which receptors may be exposed to contaminants; and
- Contaminants that may be present at levels that may be harmful to receptors (COCs).

The information from the problem formulation is summarized in a CSM, which illustrates the potential links between sources of COCs, exposure pathways and receptors.

The details of the problem formulation for the Site are provided below.

4.1.1 Receptors of Concern

The HHRA assesses potential human exposures at the Site following final closure and reclamation when all decommissioning, remediation and monitoring activities have ceased. The following human receptors were considered in the HHRA:

- Community Member; and
- Site Visitor.

The exposure factors and receptor characteristics for the Community Member and Site Visitor are shown in Tables 4.1 and 4.2. Each of the receptors are described in more detail below:

Community Member

The Community Member is considered to be a resident of the closest community of Kugluktuk, located approximately 285 km from the Site. This receptor would also be representative of residents of Bathurst Inlet, Cambridge Bay and Umingmaktok located farther from the Site. The Community Member was considered to consume country foods (i.e., wild game, fish and edible plants) that have been harvested from the Site. Given the distance between the closest community and the Site, it is expected that the community member would not be present on the Site but would remain in-community and be supplied with country foods by a local harvester.

Site Visitor

The Site Visitor is considered to be a resident of the closest communities (Kugluktuk, Bathurst Inlet, Cambridge Bay and Umingmaktok) that may visit the Site and harvest country foods (i.e., wild game, fish and edible plants) for approximately two weeks per year. Based on the 2004 ERA (Golder 2004), caribou is an important food source. It is expected that a Site Visitor would follow the caribou migration through the area and would not be present on the Site for extended periods of time. While it is unknown whether there are established trapper cabins

or known areas of hunting or fishing close to the Site, the 2004 ERA reported residences near the Site, that will likely be unoccupied following final closure of the mine but may serve as hunting cabins in the future.

As the HHRA assesses the period following closure and reclamation, workers were not identified as receptors and instead the HHRA focusses on members of the public. As noted above, the 2004 ERA (Golder 2004) identified residences near the Site, but indicated that these residences are unlikely to be used following closure and reclamation as occupants have relied on the mine for provisions (e.g., food, water, power/fuel). Therefore, residents were not identified as receptors.

4.1.2 Exposure Pathways

Exposure pathways are the means by which a receptor comes into contact with a COC. Numerous pathways were considered when identifying COCs for the HHRA. Pathways considered to be complete are identified in the sections below. Pathways that were deemed to be incomplete or negligible were not evaluated and justification for their exclusion is provided below.

The following pathways were considered complete and were evaluated quantitatively:

- Direct contact with soil (ingestion and dermal contact) and exposure by a Site Visitor;
- Inhalation of soil particulates and exposure by a Site Visitor;
- Direct contact with seepage surface water (incidental ingestion and dermal contact) and exposure by a Site Visitor;
- Ingestion of edible terrestrial plants by a Community Member and Site Visitor; and
- Ingestion of wild game (e.g., caribou) that have been exposed to contaminated soil and seepage surface water from the Site and exposure by a Community Member and Site Visitor.

The following pathways were considered incomplete or negligible and therefore were not evaluated:

- Inhalation of vapours in outdoor air and exposure by a Site Visitor;
- Direct contact with surface water (ingestion and dermal contact) from Lake Contwoyto, Boot Lake, East Lake and Lower Sewage Lake and exposure by a Site Visitor;
- Ingestion of fish by a Community Member and Site Visitor;
- Use of groundwater and seepage surface water as a drinking water source because Lake Contwoyto is a more likely source of drinking water;
- Direct contact with groundwater (ingestion and dermal contact) because people are not expected to come in contact with the subsurface;
- Direct contact with sediment (ingestion and dermal contact); and
- Inhalation of vapours in indoor air by human receptors because all buildings will be removed during final closure and reclamation.

Direct Contact with Soil

Direct contact with soil was considered to be relevant for receptors present on the Site spending time outdoors, including the Site Visitor. Direct contact with soil includes both incidental ingestion of soil (e.g., through hand-to-mouth behaviour) and dermal contact with soil. Soil of all depths (0 to 2.0 mbgs) were considered.

Inhalation of Soil Particulates

Inhalation of soil particulates (or soil dust) was considered to be complete for receptors that would spend time on the Site outdoors, including the Site Visitor.

Direct Contact with Seepage Surface Water

The Site Visitor was considered to potentially come into direct contact (incidental ingestion and dermal contact) with COCs in surface water from seepage on-Site. Seeps are present in thirteen locations around the perimeter of the Site and the Site Visitor may come into contact with seepage surface water while present on the Site.

Consumption of Edible Plants and Wild Game

Consumption of edible plants is a potential pathway for the Community Member and Site Visitor. Previous reports indicate edible plants such as cranberry, bilberry, bearberry and Labrador tea may grow on the Site (Morrow 2006; Golder 2017).

Consumption of wild game (e.g. caribou) was considered as a potential pathway for the Community Member and Site Visitor as caribou are known to pass through the Site during their migration (Golder 2004).

Inhalation of Vapours in Outdoor Air

The inhalation of vapours in outdoor air is a potentially complete exposure pathway for the Site Visitor. However, this pathway was not evaluated further in the HHRA because exposure via this pathway is typically negligible considering the rapid dilution of vapour in outdoor air.

Direct Contact with Lake Surface Water

The Site Visitor may come in contact with surface water from Lake Contwoyto while fishing or consume it as a drinking water source. However, as discussed in Section 3.9, impacts to the surface water in Lake Contwoyto from the Site are considered to be negligible. Boot Lake, East Lake and Lower Sewage Lake are considered to be impacted by seepage from the Site; however it is unlikely that people would be present at these lakes given that: 1) they present unsuitable habitat for fish, and 2) Lake Contwoyto would be a more likely source of drinking water while fishing.

Consumption of Fish

Consumption of fish as a potential pathway for the Site Visitor was initially considered. However, as discussed in Section 3.9, impacts to the surface water in Lake Contwoyto from the Site are considered to be negligible. All of the small lakes and ponds freeze to the bottom in winter (Morrow 2006). Over wintering habitat for fish is limited primarily to Outer Sun Bay and the main body of Contwoyto Lake (Golder 2018). It was assumed that there were no fish present in Boot Lake, East Lake and Lower Sewage Lake because these lakes are too shallow to provide overwintering habitat for fish. Therefore, consumption of fish was considered to be an incomplete pathway of exposure.

4.1.3 Contaminants of Concern

A comprehensive screening process was used to identify COCs in soil and seepage surface water (current conditions) for the HHRA. Concentrations of parameters in these media were screened against the applied federal guidelines/standards (as described in Section 2.2) or their component values that are considered protective of human receptors (termed “screening values”). In the absence of federal guidelines/standards, provincial (Ontario, Alberta, British Columbia) followed by international (e.g., US EPA) guidelines/standards were used. Concentrations of parameters in soil and seepage surface water were also screened against background concentrations (Section 3.7).

The following approach was used to identify COCs for the HHRA:

- Maximum concentrations of parameters in soil, and seepage surface water were compared to their respective human health screening values. If the maximum concentration exceeded its screening value and background concentration (if available), the parameter was retained as a COC for further evaluation in the HHRA. If the maximum concentration was below the screening value but exceeded background, the parameter was not retained as a COC for further evaluation in the HHRA. This is because the screening value represents a concentration to which a receptor can be exposed without experiencing adverse effects.
- If no human health screening values were available, and the parameter was detected and greater than background (if available), it was evaluated on a case-by-case basis.
- If no human health screening values were available, and the parameter was not detected, it was not retained as a COC for further evaluation in the HHRA.

Comparison to human health screening values and background was considered a conservative evaluation of the potential risks to human receptors. That is, parameters with concentrations below the human health screening values and background (if available) were considered to pose negligible risks to human receptors. Parameters with concentrations above the human health screening values and background (if available) were identified as COCs and further evaluated to determine potential risks to human receptors. The details of the screening for soil and surface water are provided in the following sections.

4.1.3.1 Soil (Current Conditions)

Human Health Screening Values

Human receptors may be exposed to parameters in soil via direct contact with soil through ingestion or dermal contact, or indirectly through inhalation of soil dust or consumption of wild game or plants. To address these pathways, maximum concentrations of parameters in soil were compared to the following human health screening values protective of soil ingestion, dermal contact and ingestion of country foods. The following screening values were selected for the assessment:

- CCME SQG_{HHS} (for BTEX and metals) (CCME 1999a/2019) and CCME CWS (for PHCs) (CCME 2008) for agricultural land use:
 - Soil ingestion – soil concentration protective of human receptors of all ages incidentally ingesting soil;
 - Soil dermal contact – soil concentration protective of human receptors of all ages in direct skin contact with soil; and

- Produce, Meat and Milk – soil concentration protective of toddlers and adults ingesting produce, meat and milk grown/raised in impacted soil. Note that no soil components have been derived for any of the parameters measured in soil. Therefore, CCME guidance was followed which suggests that agricultural SQG_{HHS} should be used in the absence of guidelines protective of this pathway (CCME 2006).
- MECP Soil Components for Table 3 – Full Depth, Non-Potable Water Scenario, residential/parkland/institutional land use (MOECC 2016):
 - S1 – soil concentration protective of human receptors of all ages incidentally ingesting soil and in direct skin contact with soil.
- AEP Surface Soil Remediation Guideline Values for agricultural land use (AEP 2019), including:
 - Direct soil contact – soil concentration protective of direct human contact with soil, including soil ingestion, dermal contact and inhalation of soil particulates.
- BC MECCS Contaminated Sites Regulation, Numerical Soil Standards, agricultural (BC MECCS 2019b):
 - Intake of Contaminated Soil – soil concentration protective of direct human contact with soil.
- US EPA RSLs for residential land use (US EPA 2019a):
 - Residential soil – soil concentration protective of human receptors of all ages incidentally ingesting soil and in direct skin contact with soil.

Preference was given to the CCME SQG_{HHS} (for BTEX and metals) and CCME PHC CWS (for PHCs) followed by the provincial screening values. The lowest available provincial screening value was used unless otherwise noted. In the absences of these, the lowest of the other available international screening values were used.

There are no screening values for sulphide and sulphate for direct contact with soil. For reasons described below, these parameters were not retained as COCs for direct contact by human receptors in the HHRA:

- The estimated average daily dietary intake of sulphate from food, water and air is 500 mg (Health Canada 1994a). Given the soil ingestion rates of 0.00002 kilogram per day (kg/d) for an adult and 0.00008 kg/d for a toddler and the maximum concentration of sulphate (821 mg/kg), the maximum daily intakes would be 0.02 milligrams per day (mg/d) and 0.07 mg/d, which are well below the average daily dietary intake.
- The daily intake of sulphides by Canadians has not been estimated (Health Canada 1994a). In England, the maximum likely daily intake of dimethyl sulphide from artificially flavoured candies, soft drinks, creams and jellies was estimated to be 1.7 milligrams (mg). Sulphides are present in a wide range of foods, including milk, beer, ale, meat and vegetables so the daily intake of sulphides is likely higher than that estimated based on only candies, soft drinks, creams and jellies. Based on a soil ingestion rate of 0.00002 kg/d for an adult and 0.00008 kg/d for a toddler and the maximum concentration for sulphide (21.9 mg/kg), the maximum daily intakes would be about 0.0004 mg/d and 0.002 mg/d. It has been estimated that an oral dose of 10,000 to 15,000 mg sodium sulphide would be fatal to humans (Health Canada 1994a). The maximum daily intake of an adult and toddler is well below the intake considered to be toxic.

As there are no pathway-specific guidelines/component values for metals for consumption of plants, the agricultural CCME SQG_{HHS} were used to screen this pathway, as noted previously. As PHCs and BTEX parameters do not tend to bioaccumulate in plants (Lansdell and McConnell 2003; CCME 2008), they were not

retained for further evaluation for consumption of plants. In addition, as plants exhibit very limited ability to accumulate PAHs from soils, and to translocate PAHs from root tissue into aboveground biomass (Simonich and Hites 1995; as cited by CCME 2010), PAHs were not considered for the consumption of plants pathway.

For the consumption of wild game pathway, metals and glycols were initially screened against background, if available. Metals that exceeded the background concentration were retained as COCs for ingestion of wild game if they were also considered to bioaccumulate. Based on the protocol by CEPA (1999), a parameter was considered to bioaccumulate if the bioaccumulation factor (BAF) (or bioconcentration factor [BCF], in the absence of a BAF) was greater than or equal to ($\geq$) 5000. If neither a BAF nor BCF was available, a parameter was considered to bioaccumulate if the log octanol-water partition coefficient (K_{ow}) was ≥ 5 . Where available, BAFs were obtained from Sample et al. (1998). BCFs and log K_{ow} values were obtained from the Hazardous Substances Databank (HSDB; 2019), Risk Assessment Information System (RAIS; 2019) or MECP (MOECC 2016). In the absence of a BAF, BCF or log K_{ow} , a BAF of one was assumed as per the protocol developed by the Environmental Restoration Division (ERD) of the Savannah River Site (SRS) (US DOE, 1999). Table 4.3 presents the BAFs, BCFs and log K_{ow} values used in the bioaccumulation screening.

As per US EPA (2007a), the bioaccumulation of PAHs in wild game is expected to be negligible because of the rapid metabolism of these compounds following ingestion. Similarly, the CCME (2008) indicates that PHCs are readily metabolized and excreted by vertebrates and bioaccumulation would be similarly negligible. Therefore, the concentrations of PAHs and PHCs in wild game (e.g. caribou) were assumed to be zero and the consumption of wild game pathway was not assessed for these parameter groups.

Results

The detailed results of the screening for soil are presented in Table 4.4. The following parameters were retained as COCs for direct contact with soil for the Site Visitor:

- | | |
|-------------|---------------|
| ■ PHC F2; | ■ Lead; |
| ■ Antimony; | ■ Molybdenum; |
| ■ Arsenic; | ■ Tin; and |
| ■ Cadmium; | ■ Vanadium. |

The following parameters were retained as COCs for consumption of plants by the Community Member and Site Visitor:

- | | |
|-------------|---------------|
| ■ Cyanide; | ■ Lead; |
| ■ Antimony; | ■ Molybdenum; |
| ■ Arsenic; | ■ Nickel; |
| ■ Cadmium; | ■ Tin; and |
| ■ Chromium; | ■ Zinc. |
| ■ Copper; | |

Parameters were screened for the consumption of wild game pathway for the Community Member and Site Visitor according to the method described above. All metals were above their respective background concentrations,

where available. No metals were considered to sufficiently bioaccumulate in wild game (Table 4.3). In addition, given the large home range of caribou (autumn range of 36,000 km²), the time spent on the Site in contact with contaminated soil would be minimal. Therefore, this pathway was not evaluated further in the HHRA.

4.1.3.2 Seepage Surface Water (Current Conditions)

Human Health Screening Values

There are no federal or provincial guidelines/standards for the protection of human health specific to surface water when used for recreational purposes or during incidental contact (i.e., splashing and hand-to-mouth contact) while on a site. In the absence of surface water guidelines, the screening values included Health Canada CDWQ Guidelines (Health Canada 2019a) adjusted by a factor of 60, which is based on average water ingestion rates during recreational activities (i.e., swimming) from Health Canada (2012b). Health Canada assumes adults could be ingesting an average value of 0.024 litres per day (L/d) while swimming, which is approximately 60 times lower than the daily drinking water rate of an adult (1.5 L/d). Given that exposure by splashing and hand-to-mouth contact is far lower than would occur swimming, an adjustment factor of 60 was considered reasonable. In the absence of Health Canada CDWQ Guideline, the lowest provincial component value (Ontario Ministry of the Environment and Climate Change (MOECC) GW1 (2016), AEP Potable water (2019) or BC MECCS (2019b)) adjusted by a factor of 60 was used, which are groundwater concentrations based on the protection of groundwater as a drinking water supply.

For parameters with no Health Canada CDWQ Guideline or provincial component value available, the US EPA RSLs (US EPA 2019a) for resident tapwater were used. The RSLs are based on a target HQ of 0.1 for non-carcinogens, so the RSLs were adjusted to a target HQ of 0.2 to be consistent with CCME guidance. The RSLs were derived based on an ingestion rate of 2.5 L/d for an adult, which is approximately 100 times higher than the ingestion rate while swimming. Therefore, the RSLs were adjusted by a factor of 100 for incidental contact, as described above.

Results

The detailed results of the screening for surface water are presented in Table 4.5. The maximum concentration of cobalt was above the screening level for surface water, therefore cobalt was retained as a COC for the Site Visitor for direct contact with seepage surface water.

There are no screening values for bismuth, calcium, cesium, magnesium, phosphorus, potassium, rubidium, silicon, sulphur, tellurium, thorium and titanium. These parameters are ubiquitous in the environment and non-toxic (except when ingested in extreme quantities). Calcium, magnesium, phosphorus, and potassium are essential elements of living organisms (MERAG 2007; CCME 2004). For reasons described below, these parameters were not retained as COCs for further evaluation in the HHRA.

- Bismuth is most commonly used as an ingredient in over-the-counter remedies for gastrointestinal distress (e.g. Pepto-Bismol®). Pepto-Bismol contains 262 mg of bismuth subsalicylate in a single adult dose (DrugBank 2019). Bismuth was identified in seepage surface water at a concentration of 0.000067 milligram per litre (mg/L), which exceeded the background concentration of <0.00005 mg/L. Assuming a seepage water ingestion rate of 0.01 L/d for an adult, and the maximum concentration of 0.000067 mg/L, the maximum daily intake from seepage surface water would be 6.7×10^{-7} mg/d. This is well below the dose for medicinal use, therefore no adverse effects are expected.

- Calcium is ubiquitous in the environment. It is the fifth most abundant element, constituting 3.63% of the earth's crust, and is found in numerous mineral compounds (HSDB 2000). Calcium is an essential element in living organisms as a constituent of bones, teeth, shell and coral (HSDB 2000). There is no Health Canada CDWQ Guideline for calcium as there is no evidence of adverse effects from calcium in drinking water; rather, it contributes to water hardness (Health Canada 2019a). For calcium, the recommended daily allowance for children and adults is 1000 to 1300 mg/d and the tolerable upper intake level (highest level at which no adverse effects are likely to occur) is 2000 to 3000 mg/d (Health Canada 2006). Given a seepage water ingestion rate of 0.01 L/d for an adult, and the maximum concentration of 270 mg/L in seepage surface water, the maximum daily intake from seepage water would be 2.7 mg/d, which is well below the recommended daily allowance for calcium.
- Cesium is the rarest of the naturally occurring alkali metals. It is widely distributed in the earth's crust at low concentrations (HSDB 2006a). No short-term or long-term toxicity data in humans were found on the potential oral toxicity of cesium, but a lethal dose of 1700 mg/kg was available for mice (Lewis, R.J. 1996; as summarized in HSDB 2006a). Cesium was identified in seepage surface water at a concentration of 0.0038 mg/L, which exceeded the background concentration of 0.000024 mg/L. Given a seepage water ingestion rate of 0.01 L/d and a body weight of 70 kilograms (kg) for an adult, the seepage surface water concentration would have to be approximately 1.2E+07 mg/L to approach the lethal dose of 1700 mg/kg.
- Magnesium is ubiquitous in the environment. It is the eighth most abundant metal and makes up approximately 2% of the earth's crust (HSDB 2003). Magnesium is an essential nutrient for humans, animals and plants. For magnesium, the recommended daily allowance of magnesium is 300 to 400 mg/d for adults (Health Canada 2006). Given a seepage water ingestion rate of 0.01 L/d for an adult, and the maximum concentration of 44.5 mg/L in the seepage surface water, the maximum daily intake from seepage water would be 0.45 mg/d, which is well below the recommended daily allowance for magnesium.
- Phosphorus is an essential nutrient for all living things (CCME 2004). The recommended daily allowance of phosphorus for an adult is 700 mg/d (National Academies of Science 1997). Given a seepage water ingestion rate for an adult of 0.01 L/d and the maximum concentration of 0.13 mg/L in seepage surface water, the maximum daily intake from seepage water would be 0.0013 mg/d, which is well below the recommended daily allowance.
- Potassium is ubiquitous in the environment and constitutes 3.59% of the earth's crust (HSDB 2006b). Potassium is an essential nutrient for humans, animals and plants. For potassium, the adequate intake of potassium is 4700 mg/d for adults (Health Canada 2006). Given a seepage water ingestion rate of 0.01 L/d for an adult, and the maximum concentration of 20 mg/L in the seepage surface water, the maximum daily intake from seepage water would be 0.2 mg/d, which is well below the adequate intake for potassium.
- Rubidium is a rare, metallic element. There are no naturally-occurring minerals in which rubidium is the primary element. It is naturally found in the earth's crust in trace amounts in rock-forming silicate minerals, such as potassium feldspars and micas (US EPA 2016b). No short-term or long-term toxicity data in either humans or laboratory animals were found on the potential oral toxicity of elemental rubidium. However, a lowest observed adverse effect level (LOAEL) of 5.1 milligram per kilogram per day (mg/kg/d) based on the short-term oral exposure to rubidium chloride were available for humans (Placidi et al. 1998; as summarized by US EPA 2016b). Rubidium was identified in seepage surface water a concentration of 0.0325 mg/L, which exceeded the background concentration of 0.00149 mg/L. Given a seepage water ingestion rate of

0.01 L/d for an adult and a body weight of 70 kg for an adult, the seepage water concentration would have to be approximately 35,700 mg/L to approach the LOAEL of 5.1 mg/kg/d.

- Silicon makes up 25.7% of the earth's crust and is the second most abundant element in the earth's crust (HSDB 2011). Silicon is fundamentally non-toxic. No short-term or long-term toxicity data in either humans or laboratory animals were found on the potential oral toxicity of elemental silicon (HSDB 2011). The maximum concentration in the seepage surface water was 17.6 mg/L and all 14 locations had concentrations that exceeded the background concentration (0.88 mg/L). Silicon and silica are found in Canadian surface water at typical concentrations of 3-4 mg/L and range up to 30 mg/L (CCME 2006). Given that silicon is often present in natural waters in particulate form, if the seepage contains suspended solids, it is expected that silicon could be detected.
- Sulphur is naturally-occurring and makes up 15% of the inner core of the earth and 0.052% of the earth's crust (HSDB 2012a). The estimated average daily dietary intake of sulphur of a Canadian adult is 930-1100 mg (Health Canada 1994a). Given a seepage water ingestion rate for an adult of 0.01 L/d and the maximum detected sulphur concentration in seepage surface water of 309 mg/L, the maximum daily intake would be 3.1 mg/d, which is well below the average daily intake.
- Tellurium is widely distributed in the earth's crust in deposits of many different types, particularly in deposits associated with silver and gold (HSDS 2002a). No short-term or long-term toxicity data in humans were found on the potential oral toxicity of elemental tellurium, but a lethal dose of 45 mg/kg was available for guinea pigs (Lewis, R.J. 1996; as summarized in HSDB 2002a). Tellurium was identified in seepage surface water a concentration of 0.00022 mg/L, which only slightly exceeded the background concentration of <0.0002 mg/L. Given a seepage water ingestion rate of 0.01 L/d and a body weight of 70 kg for an adult, the seepage surface water concentration would have to be approximately 315,000 mg/L to approach the lethal dose of 45 mg/kg.
- Thorium is found in rare earth-thorium-phosphate minerals, monazite, thorite, huttonite, and the hydrated thorium silicate mineral. Overall, thorium is present at approximately 8 to 15 mg/kg in the earth's crust (HSDB 2008a). No short-term or long-term toxicity data in either humans or laboratory animals were found on the potential oral toxicity of elemental thorium, as its toxicity is generally associated with its radioactive forms (HSDB 2008b). The maximum concentration in the seepage surface water was 0.00092 mg/L and all 14 locations had concentrations that exceeded the background concentration (<0.0001 mg/L). Given that the maximum concentration is only slightly above the background concentration, it is not expected that thorium would be a human health concern.
- Titanium is relatively inert and found in consumer products such as sun block and medical products such as surgical implants. The World Health Organization (WHO) reports that based on available data, "there is no reason to believe that exposure to titanium would constitute any health risks for the general population" (WHO 1982). In addition, the maximum concentration of titanium in seepage surface water (0.254 mg/L) was below the Texas Risk Reduction Program (TRRP) Tier 1 Protective Concentration Level (PCL) for groundwater for commercial/industrial land use (370 mg/L; TCEQ 2018).

4.1.4 Human Health Conceptual Site Model

A CSM was developed for human receptors to summarize the results of the problem formulation. The CSM illustrates the potential links between sources of COCs, exposure pathways and human receptors (Figure 10). The complete pathways assessed in the HHRA include the following:

- Ingestion and dermal contact with soil;
- Inhalation of soil particulates;
- Consumption of plants; and
- Direct contact (incidental ingestion and dermal contact) with seepage surface water.

As a result of the COC screening, the pathway for ingestion of wild game (e.g., caribou) that have been exposed to contaminated soil from the Site was determined to be negligible and was not considered further in the HHRA.

4.2 Exposure Assessment

The exposure assessment estimates the doses that receptors may receive from exposure to COCs on the Site. In subsequent phases of the HHRA, estimated doses are combined with TRVs to determine risk estimates. As discussed in Section 4.1.2, a quantitative exposure assessment was completed for direct contact with soil and seepage surface water by the Site Visitor, and consumption of plants by the Community Member and Site Visitor.

The assumptions used in the exposure assessment, including chemical concentrations, receptor characteristics exposure durations and frequencies, exposure amortization, bioavailability of COCs and exposure dose equations, are presented in the following sections.

4.2.1 Receptor Characterization

Tables 4.1 and 4.2 provide summaries of exposure factors and receptor characteristics assumed for the exposure assessment. Health Canada (2012a) is the primary source of these assumptions. Those taken from other sources or assumed based on Site-specific knowledge are discussed below and/or indicated in Tables 4.1 and 4.2.

Community Member

Age groups for the Community Member considered in the assessment include an adult and toddler as well as a composite receptor representing exposure throughout all life stages. The receptor characteristics (e.g., body weight, skin surface area, soil ingestion rate) of the Community Member were modeled after the “resident” receptor defined by Health Canada (2012a), which is a person of any age group as defined by Health Canada guidance (2010a) (i.e., infant, toddler, child, teen, and adult). However, toddlers are generally considered the most exposed at contaminated sites since their soil ingestion rate to body weight ratio is the highest amongst all of the age groups. Therefore, the toddler is considered the most sensitive age category and assessing health risks considering this receptor is conservative. The adult was included for comparative purposes.

For the assessment of carcinogenic COCs, a composite receptor was assessed, which includes all life stages as exposures to carcinogenic COCs are evaluated over a lifetime. Considering that the nearest community is located 285 km away, it is expected that the Community Member would not be present on the Site and that their only exposure would occur through consumption of country foods brought home (i.e., edible plants).

The plant ingestion rate was assumed to be 0.00434 kg/d. This was calculated based on traditional diet data from the First Nations Food, Nutrition and Environment Study (FNFNES) for Saskatchewan (Chan et al. 2018). In the absence of data specific to Nunavut, data from Saskatchewan was used as the plant species presented were similar to those found on the Site. The total plant ingestion was calculated by summing the ingestion rates for bearberry (0.02 grams per person per day [g/person/d]), bilberry (combined with blueberry; 3.95 g/person/d), cranberry (0.1 g/person/d) and Labrador tea (0.27 g/person/d). The CCME (2006) considers that 10% and 50% of

produce ingested is grown on-Site for residential land use and agricultural land use scenarios, respectively. Given the distance between the Site and the closest community, it was assumed that 10% of the plants ingested come from the Site. Although the resident receptor characteristics were considered for the Community Member, the exposure factors (e.g., exposure frequency in terms of days consuming food from the Site) were modified from those of the resident to be more consistent with Site-specific assumptions.

Site Visitor

The Site Visitor is considered to be a resident of the closest communities (Kugluktuk, Bathurst Inlet, Cambridge Bay, Umingmaktok) that may visit the Site and harvest country foods (i.e., edible plants) for approximately two weeks per year (it is assumed that this receptor would return to the Site each year during the time of year that the caribou migration occurs). Due to the distance from the nearest community, it was assumed that families would not be gathering plants on the Site, therefore, age groups considered in the assessment included an adult. It was assumed that the Site Visitor may spend up to two weeks on the Site (i.e. 7 days/week for 2 weeks per year). This is considered reasonable given the remote nature of the Site, lack of facilities (i.e. hunting cabins) or other features that would attract people to the Site. It was assumed that 100% of the plants they ingest during that time would be from the Site. A plant ingestion rate of 0.00434 kg/d (Chan et al. 2018) was used, as described above.

Site Visitors may also come in direct contact with soil and seepage surface water on the Site. The 2011 Exposure Factors Handbook from the US EPA (US EPA 2011) was used to identify the number of hours the Site Visitor would be expected to be inhaling soil dusts on-Site (i.e., 121 minutes per day, rounded to 2 hours per day). Health Canada (2012b) reports an average water ingestion rate of 0.024 L/d for adults during swimming. As exposure via incidental ingestion of seepage surface water is expected to be significantly less than during swimming, an ingestion rate of 0.01 L/d was assumed.

4.2.2 Exposure Amortization

Exposure amortization (or dose averaging) takes into account the frequency and duration of exposure at the Site. Adjustments to the pro-rating of the exposure term can be considered for acute and subchronic exposure durations and developmental toxicants. These considerations are described in more detail below.

Exposure Duration

Consideration must be given to exposure durations in order to ensure that the exposure is properly amortized, and the toxicity information is consistent with the exposure duration. Health Canada (2010a) has divided exposure duration into three categories: acute (high intensity exposure, less than 14 days), subchronic (exposure greater than 14 days and less than 90 days) and chronic (exposure greater than 90 days).

According to Health Canada (2010a), acute or subchronic exposure is generally based on one exposure per lifetime; however, repeated acute or subchronic exposures are not true chronic exposures. To evaluate such less-than-chronic exposures Health Canada (2016) recommends the following tiered approach:

- An initial screening step for chemicals with non-carcinogenic effects where the unamortized exposure (i.e., an exposure term of one) is compared to a chronic TRV. Health effects are not anticipated if target risk levels are not exceeded. This is considered a conservative approach to eliminate chemicals that do not need to be considered further.
- If target risk levels are exceeded when the unamortized exposure is compared to a chronic TRV, a more detailed evaluation is required that may include the following approaches:

- Comparison of exposure to short-duration TRVs developed for a similar (or longer) duration as the exposure scenario of interest.
- Derivation of de novo TRVs of appropriate duration as per Health Canada's Detailed Qualitative Risk Assessment (DQRA) guidance (2010a).
- Amortization may be used provided that appropriate, scientifically based rationale is provided in the assessment report.

Although the Site Visitor was assumed to be on-Site for 14 days per year, it is assumed that this receptor would return to the Site each year during the time of year that the caribou migration occurs. Therefore, exposure of this receptor was considered to be subchronic.

As discussed in Section 4.3, TRVs for subchronic exposure for the COCs evaluated by the HHRA are not available. As an initial screening step recommended by Health Canada (2016), unamortized exposures for all COCs were compared to TRVs for chronic exposure, which is considered to be an overly conservative approach. Risks met the target HQs for all COCs, with the exception of arsenic and lead (Table D.1 and Table D.2 in Appendix D).

Amortization was considered appropriate to use for the assessment of arsenic given that it does not persist in the body and is rapidly eliminated. According to the Agency for Toxic Substances and Disease Registry (ATSDR; 2007), ingested arsenic is rapidly absorbed; whole-body clearance typically occurs by urinary excretion within 1-3 days in humans with no expected retention in the body (ATSDR 2007).

Amortization was not considered appropriate for lead considering that elimination from the body varies depending on the tissue. An elimination half-life in blood ranges from 1 week to 2 years and elimination of lead from bone occurs with a half-life of 1-2 decades (ATSDR 2019).

Developmental Toxicants

In cases where the TRV is selected based on developmental effects and the effect can occur based on a single exposure, or a short duration exposure during a specific developmental period ("window of susceptibility"), instead of repeated or extended exposure, the exposure term is considered to be one to take into account that the exposure could occur at the critical developmental phase of the fetus or childhood stage. While developmental effects are associated with certain COCs retained in the HHRA, TRVs were either not selected based on the developmental effect or the effect was not considered to occur based on a single exposure, with the exceptions of lead and vanadium.

Lead is considered a developmental toxicant as there is a "window of susceptibility" for exposure to the effects of lead during fetal and early lifestages during which the central nervous system is developing. An oral TRV for lead is available from WHO (2011), therefore lead was evaluated quantitatively.

Vanadium has developmental and reproductive effects including decreased body weights and reduced length in offspring of rats. An oral TRV for vanadium is available from the MOECC (2016); therefore, vanadium was evaluated quantitatively.

A female receptor assuming no exposure amortization was considered for the evaluation of lead and vanadium.

4.2.3 Bioavailability Assessment

The term bioavailability, or absolute bioavailability, describes the extent or rate at which a chemical enters the body and becomes available to target tissues and organs. In terms of exposure, bioavailability is the fraction of a dose that is actually absorbed by the body. Relative bioavailability is the absolute bioavailability of a chemical from the sample divided by the absolute bioavailability of the chemical under the conditions used to derive the TRV; this is termed a relative absorption factor (RAF). RAFs assumed for the current study are presented in Table 4.6.

Relative absorption factors from Health Canada (2010b) were used when available (with the exception of the RAF from the gastrointestinal tract for arsenic, discussed further below). In the absence of a Health Canada value, RAFs from the MECP (MOECC 2016) were used.

The RAFs from the gastrointestinal tract were one (1) for COCs other than arsenic. A RAF of 0.5 (MOECC 2016) was used for arsenic for soil oral exposures and a value of one (1) was used for food exposures. The National Environmental Policy Institute (NEPI) (2000 (as referenced in MOE 2011a)) reports that based on numerous studies on lab animals, arsenic in soil is typically one tenth to one half as bioavailable as soluble forms of arsenic. Although some studies report higher bioavailabilities, the assumption of a RAF of 0.5, which is the upper range of that reported on by the NEPI is considered to be sufficiently conservative.

4.2.4 Direct Contact with Soil and Inhalation of Soil Particulates

4.2.4.1 Concentrations in Soil (Current Conditions)

Measured concentrations of COCs in soil were used to estimate exposure for direct contact pathways. Where data are sufficiently numerous, Health Canada (2010a) recommends use of the 95% UCLM to represent the exposure point concentrations (EPCs) for repeated exposure.

For evaluating the Site Visitor, it was assumed that the receptors would spend approximately equal proportions of time across all areas of the Site; therefore, the use of a 95% UCLM as the EPC was considered appropriate. The approach for calculating and selecting the 95% UCLMs is described in Appendix B, along with the ProUCL inputs and outputs for the HHRA.

The EPCs assumed for COCs in soil (and soil dust, which was considered to have equal COC concentrations to soil) (95% UCLMs) used in the exposure assessment are presented in Table 4.7. Where PHCs were retained, the PHC fractionation of aliphatic and aromatic constituents (Table 4.8, Health Canada 2011) was applied given that TRVs for PHCs are provided in terms of aliphatic and aromatic sub-fractions.

As was determined in the supporting environmental investigations, concentrations of arsenic are naturally present in local background soil, ranging from 8.6 to 189 mg/kg (95% UCLM = 79 mg/kg). This is generally similar to or higher than typical Canadian background concentrations of arsenic. For example, mean arsenic concentrations in several Canadian uncontaminated sites range from 4.8 to 13.6 mg/kg dry weight (Kabata-Pendias and Pendias 1992, as cited by CCME 2001); concentrations of arsenic in glacial till samples from a number of Canadian sites range from 1 to 6590 mg/kg (CCME 2001); and average urban and agricultural concentrations are at or below 10 mg/kg dry weight (Environment Canada 1996, as cited by CCME 2001). Given that arsenic is known to be a primary COC on the Site, consideration of background was taken into account in the exposure and risk calculations. Exposure (and risks) were calculated considering both total concentrations (i.e., total concentrations measured on-site), but also the incremental difference between total concentrations and background.

4.2.4.2 Exposure Equations and Estimates

Estimated doses of COCs from direct contact with soil (ingestion, dermal contact and inhalation of soil particulates) were calculated according to the equations provided by Health Canada (2012a) as presented in Appendix E (E.1 to E.6).

Sample calculations for doses via ingestion, dermal contact and inhalation are also presented in Appendix E (E.1 to E.6). Exposure estimates for the adult Site Visitor are presented in Table 4.10.

4.2.5 Consumption of Plants

4.2.5.1 Concentrations in Plants (Current Conditions)

Measured plant tissue concentrations were not available for the Site. As per guidance by Health Canada (2010a), in the absence of site-specific tissue data, tissue concentrations can be modelled through the use of literature uptake equations or uptake factors. Use of a 95% UCLM to estimate uptake into plants assumes equal potential for the Site Visitor to collect plants from anywhere on the Site. EPCs for ingestion of COCs in plants were calculated based on 95% UCLM soil concentrations using uptake equations provided by the US EPA (2007b) or uptake factors provided by Baes et al. (1984) and are presented in Table 4.9. For parameters for which the Baes et al. (1984) uptake factors were used (e.g., molybdenum and tin), the soil-to-plant concentration factor for vegetative parts was used as it was more conservative than that for reproductive parts. While the uptake of some metals into plants is influenced by soil pH, the uptake equations were still deemed appropriate to estimate COC concentrations in plants. This is because for those metals evaluated with respect to pH, the source of the uptake equations provided by the US EPA (Bechtel Jacobs Company 1998) recommends use of the single-variable regression or multiple regression with pH (with no preference given except for mercury). Given that areas of low and high pH have been identified on the Site, it was considered reasonable to apply the single-variable regression to provide an estimate of plant tissue concentrations reflective of the range in soil pH across the Site. As discussed in Section 4.4.3, this is considered to be a source of uncertainty in the HHRA.

4.2.5.2 Exposure Equations and Estimates

Estimated doses of COCs from consumption of plants were calculated according to the equations provided by Health Canada (2012a) as presented in Appendix E (E.7 and E.8).

Sample calculations for doses via consumption of plants are also presented in Appendix E (E.7 and E.8). Exposure estimates for the adult Site Visitor are presented in Table 4.10.

4.2.6 Direct Contact with Seepage Surface Water

4.2.6.1 Concentrations in Seepage Surface Water (Current Conditions)

Concentrations of COCs in seepage surface water were measured directly and used to determine exposure for direct contact pathways. For evaluating the Site Visitor, the EPCs for seepage surface water (95% UCLM) were determined using the same approach as described in Appendix B. Data included samples collected from the most recent round of sampling (2019) as they are considered to be most representative of current conditions. Given the reclamation plan for waste rock designed to limit the contact between waste rock and surface runoff, and thus reducing the impacts to seepage surface water (Section 1.3), current conditions are likely a conservative representation of seepage surface water following closure and reclamation. The seepage surface water EPCs (95% UCLMs) used in the exposure assessment are presented in Table 4.11.

4.2.6.2 Exposure Equations and Estimates

Estimated doses of COCs from direct contact with seepage surface water (incidental ingestion and dermal contact) were calculated according to the equations provided by Health Canada (2012a) for ingestion and the US EPA (2004) for dermal contact as presented in Appendix E (E.9 to E.10). Exposure estimates for the Site Visitor are presented in Table 4.12.

4.3 Toxicity Assessment

4.3.1 Nature of Toxicity (Hazard Assessment)

Toxicity assessment involves the classification of the potential toxic effects of chemicals and the estimation of the concentrations of chemicals to which human receptors could be exposed without experiencing adverse effects on their health. Toxicity assessment is conducted for all COCs and considers the possible modes of toxicity associated with different routes and durations of exposure, and sensitive receptors. The toxicity assessment provides an estimate of the maximum acceptable doses that may occur over a lifetime (or significant portion of) without unacceptable health effects and provides a basis to interpret potential effects of predicted exposure rates.

4.3.1.1 Contaminant Classification

Regulatory agencies classify contaminants based on their mode of action (i.e., threshold versus non-threshold substances). For substances exhibiting a threshold for toxicity, an acceptable level of exposure at or below which no adverse effects are anticipated is established. For non-threshold substances (including carcinogens), any level of exposure is assumed to theoretically pose a potential risk, and a SF is used to predict risks from estimated exposures. The carcinogenicity classifications systems from Health Canada (1994b), US EPA Integrated Risk Information System (IRIS; US EPA 2019b) and the International Agency for Research on Cancer (IARC; 2019) are presented in Table 4.13a and the carcinogenicity of COCs is presented in Table 4.13b.

Non-Carcinogens

For substances exhibiting a toxicity threshold (i.e., non-carcinogens), an acceptable level of exposure at or below which no adverse effects are anticipated is established. The TRV that represents this acceptable level of exposure is typically referred to as a reference dose (RfD) or TDI (in units of mg/kg/d). For the inhalation pathway, the TRV is referred to as a reference concentration (RfC) or tolerable concentration (TC) (in units of milligrams per cubic metre [mg/m³]).

In developing TRVs for humans, safety or uncertainty factors are applied in extrapolating TRVs from animal studies or occupational data. Exposures above the TDI or TC may pose a health risk, but the true threshold for a toxic response in humans may in fact be higher than the TDI or TC.

PHC F2, antimony, cobalt, lead, molybdenum, tin and vanadium were evaluated as non-carcinogens in the HHRA. Non-threshold acting substances may also cause threshold effects. As such, arsenic and cadmium, which are considered to be carcinogens (see below), were also assessed for non-carcinogenic effects.

Carcinogens

For non-threshold acting substances (e.g., carcinogens), any level of exposure is assumed to theoretically pose a potential risk. TRVs represent carcinogen potency and are typically expressed as SFs, the rate of cancer incidence per unit dose (in units of (mg/kg-day)⁻¹). For the inhalation pathway TRVs are typically expressed as inhalation unit risks (IURs), the rate of cancer incidence per unit concentration (in units of (mg/m³)⁻¹). However,

TRVs for this pathway may also be expressed as the tumorigenic concentration in air (TC₀₅) associated with a 5% increase in the incidence of cancer (in units of mg/m³).

The TRVs are typically derived by characterizing responses observed in animals (in laboratory studies) or occupationally-exposed humans (in epidemiological studies) at high doses and extrapolating to the low doses expected to be received by human receptors in the environment. The calculated ILCRs are generally thought to provide conservative estimates of true risk.

Arsenic (all exposure routes) and cadmium (inhalation only) are considered to be carcinogenic via their specified pathways and were assessed for carcinogenic effects.

4.3.2 Dose-Response Assessment

Chemical compounds may exhibit different toxicological mechanisms of action depending on the route of exposure (i.e., ingestion, inhalation, dermal). Chronic TRVs were considered from the following sources, which is considered a conservative approach when applied to a subchronic exposure scenario:

- Health Canada (2010b);
- MECP (MOECC 2016, 2017);
- US EPA IRIS (US EPA 2019b) or those relied upon in the development of the RSLs (US EPA 2019a); and
- WHO (2011).

Preference was given to Health Canada TRVs, and in the absence of these, TRVs available from the other agencies were used. The agencies consulted included the same agencies recommended by the CCME (2006) in the development of the generic standards and were considered appropriate for use in the HHRA. In the absence of Health Canada TRVs, the TRVs from MECP (MOECC 2016, 2017) were used for PHC F2, antimony, arsenic, cobalt and vanadium. The TRV for lead provided by WHO (2011) was used. The TRV used for tin is that which forms the basis of the US EPA RSL for this metal (2019a).

TRVs used in the assessment and critical toxicity endpoints are provided in Table 4.14. TRVs are typically not available for the dermal route of exposure. As such, the TDI and oral SF used to assess effects from oral exposure were adopted for the dermal route of exposure. As TRVs for subchronic exposure are not available for the COCs, TRVs for chronic exposure were used for risk characterization of repeated subchronic exposures by the Site Visitor. As discussed in Section 4.4.3, this is considered to be a source of uncertainty but a conservative approach in the HHRA.

4.3.3 Evaluation of Potential Toxic Interactions

Combined toxic effects may occur due to exposure to interacting COCs. Combined effects may be additive, synergistic, or antagonistic. These combined effects could arise because two or more COCs target the same organs or tissues in the body, affect each other's bioavailability, or disturb biological processes in a similar manner. In order to assess these combined effects quantitatively, however, detailed studies of the interactions between COCs are required, and little scientific literature is available in this regard. Therefore, potential toxic interactions were not incorporated into the HHRA.

4.4 Risk Characterization

Risk characterization involves integrating the results of the exposure assessment and the toxicity assessment to determine if exposure scenarios are considered negligible or significant in terms of potential risks to human health.

As discussed in Section 4.1.2, the exposure pathways retained for further quantitative assessment in the HHRA included direct contact with soil (including inhalation of soil particulates), consumption of plants, and direct contact with seepage surface water for a Site Visitor and consumption of plants by a Community Member. As noted previously, for soil and seepage water, the HHRA was completed assuming that no remediation and/or risk management has been implemented through the FCRP.

Risks to human health were evaluated quantitatively through the calculation of risk estimates for predicted exposure scenarios.

For COCs that exhibit a toxicity threshold (i.e., non-carcinogens), the risk to human health associated with exposure is expressed as an HQ. For non-threshold acting COCs (i.e., carcinogens) the risk estimate is expressed as an ILCR.

Hazard Quotients

An HQ is the ratio of the estimated dose to the TRV (RfD or TDI). The HQ is expressed by the equation below:

$$\text{HQ} = \frac{\text{Estimated Dose (mg/kg/d)}}{\text{TRV (mg/kg/d)}}$$

The default target HQ indicated by Health Canada is 0.2 (Health Canada 2010a; 2012a), representing 20% of the TRV; this conservatively allows for doses from other sources to account for 80% of total doses received by receptors. For PHCs, the target HQ is 0.5, consistent with CCME guidance (CCME 2008). Note that the exposure estimates and HQs were calculated for each aliphatic and aromatic subfraction and the HQs for each aliphatic and aromatic subfraction were summed to calculate a total HQ for the total PHC fraction (e.g. PHC F2).

A calculated HQ that is greater than the target HQ indicates a potential health risk is possible. Conversely, an HQ equal to or less than 0.2 (or 0.5 for PHCs) indicates that health risks are negligible. When evaluating the magnitude of HQs, especially ones that are marginally different from 0.2 (or 0.5 for PHCs) it is important to consider the sources of uncertainty and conservative assumptions that may have influenced the calculations.

Incremental Lifetime Cancer Risks

An ILCR is the product of the estimated dose and the TRV (SF). The ILCR is expressed by the equation below:

$$\text{ILCR} = \text{Lifetime Average Daily Dose (mg/kg/d)} \times \text{TRV (mg/kg/d)}^{-1}$$

According to Health Canada (2010a; 2012a), the target ILCR is 1E-05 and an estimated ILCR that is greater than this value indicates a potential health risk is possible. Conversely, an ILCR less than 1E-05 indicates that health risks are negligible. When evaluating the magnitude of ILCRs, especially ones which are marginally different from 1E-05, it is important to consider the sources of uncertainty and conservative assumptions that have influenced the calculations.

As was determined in the supporting environmental investigations, arsenic is naturally present in the soil around the mine site. Given that the evaluation of risk (and the calculation of SSTLs) must focus on the contribution of the historical mining operations to exposure, background arsenic was not included in the risk calculations.

Therefore, the calculated ILCR is representative of the risk level attributable to the incremental difference in arsenic concentrations between background and the mine.

4.4.1 Direct Contact with Soil and Inhalation of Soil Particulates and Consumption of Plants (Current Conditions)

Exposure pathways quantitatively evaluated for direct contact with soil included incidental ingestion of soil, dermal contact with soil and inhalation of soil particulates by the Site Visitor. Consumption of plants was also evaluated for the Site Visitor and toddler and adult Community Member. Sample calculations are presented in Appendix E and HQs and ILCRs for all receptors are presented in Table 4.15 and 4.16, respectively.

For the direct contact with soil pathway (i.e., the sum of ingestion, dermal contact and inhalation of soil particulates pathways), HQs met their respective HQs for all COCs for the Site Visitor, with the exception of lead (HQ = 0.39). HQs were above the target HQ for the Site Visitor for the consumption of plants pathway for arsenic (HQ = 0.48) and lead (HQ = 0.24).

For the Community Member, HQs met their target HQs for all COCs for the consumption of plants pathway, with the exception of arsenic (HQ = 5.3 for the toddler and 1.2 for the adult).

The ILCR for cadmium for inhalation of soil particulates by the Site Visitor met the target ILCR.

The ILCRs for arsenic apply to the incremental difference in arsenic concentration attributable to the historical mining operations. For the direct contact with soil pathway (i.e., sum of ingestion, dermal contact and inhalation of soil particulates pathways), the ILCR for arsenic was above the target ILCR for the Site Visitor (ILCR = $1.7\text{E}-05$). The ILCR for arsenic was above the target ILCR for the Site Visitor (ILCR = $1.8\text{E}-04$) and the Community Member (ILCR = $8.3\text{E}-04$) for the consumption of plants pathway.

4.4.2 Direct Contact with Seepage Surface Water (Current Conditions)

Exposure pathways quantitatively evaluated for direct contact with seepage surface water included incidental ingestion and dermal contact by a Site Visitor. Sample calculations are presented in Appendix E. HQs are presented in Table 4.17.

For the Site Visitor, the HQ was below the target of 0.2 for cobalt (the only COC retained for this exposure pathway). Therefore, risks to this receptor via direct contact with seepage surface water were considered to be negligible.

4.4.3 Uncertainty Assessment

Numerous assumptions were made in the HHRA. The most significant assumptions and their implications on the risk conclusions are presented in Table 4.18. In general, the assumptions are conservative and overestimate risk.

4.5 Site-Specific Target Levels

Human health-based SSTLs were derived for direct contact with soil and consumption of plants for the COCs and receptors for which potential risks to human receptors were identified as summarized below and in Section 4.4.1:

- Arsenic for direct contact with soil by the Site Visitor and consumption of plants by the Site Visitor and Community Member; and
- Lead for direct contact with soil and consumption of plants by the Community Member.

The SSTLs were calculated iteratively by inputting the calculated soil concentrations into the equations used to calculate doses and HQs for these receptors and exposure pathways to obtain HQs of 0.2 and ILCRs of 1E-05, consistent with Health Canada (2010a; 2012a) guidance.

The lowest SSTL derived for soil for a COC for all receptors, exposure pathways and endpoints (i.e., threshold versus non-threshold effects) considered, was selected as the SSTL. For arsenic, the lowest calculated SSTL was for non-threshold effects for consumption of plants by a composite Community Member (98 mg/kg) and this value was selected as the SSTL.

For lead, the lowest calculated SSTL was for direct contact with soil by a Site Visitor (95 mg/kg) and this value was selected as the SSTL. The human health-based SSTLs for soil are presented in Table 4.19.

4.6 Summary and Conclusions

An HHRA was completed to evaluate the potential risks to human receptors from contamination associated with the historical operation of the Site as a gold mine assuming that no remediation and/or risk management has been implemented through the FCRP, with respect to soil and groundwater. The HHRA also evaluated potential risks to human receptors from ARD-impacted seepage and impacts to surface water quality in the receiving water bodies from the esker-covered waste rock dome proposed in the FCRP. If risks were identified, SSTLs were derived which represent acceptable levels of risk to human health. The final SSTLs for the Site, which incorporate protection of both human health and the environment, were considered in Section 6.0 below to confirm whether the measures outlined in the FCRP for the Site are sufficiently protective of human health and the environment. The following summarizes the results of the HHRA:

- A number of metals and PHC F2 were identified as COCs for the assessment.
- A Site Visitor and Community Member were identified as receptors for the assessment.
- The Site Visitor was evaluated considering direct contact with soil, inhalation of soil particulates and consumption of plants while visiting the Site. The Community Member was evaluated considering the consumption of plants obtained from the Site throughout the year.
- The HHRA identified potential risks for a Site Visitor from arsenic and lead via direct contact with soil, inhalation of soil particulates, and from arsenic via consumption of plants. Potential risks were identified for a Community Member from arsenic via consumption of plants. Therefore, consideration of whether the final closure and reclamation plans for the Site are adequate to protect receptors from these COCs and exposure pathways is required.
- Based on the results of the HHRA, risks were negligible for a Site Visitor in direct contact with seepage surface water. Therefore, remediation and/or risk management is not required for seepage for the protection of human health.
- Given that unacceptable risks were calculated, human health-based SSTLs were calculated for arsenic (98 mg/kg) and lead (95 mg/kg), which represent acceptable levels of risk to human health for the use of the Site following closure and reclamation.
- A number of conservative assumptions were used in the HHRA such that potential risks have likely been overestimated and consequently the SSTLs are sufficiently protective of human health.

Section 6.0 below defines areas requiring remediation and/or risk management to mitigate risks to human health and the environment based upon the derived SSTLs and confirms whether the measures outlined in the FCRP are sufficiently protective of human health and the environment.

5.0 ECOLOGICAL RISK ASSESSMENT

The objectives of the ERA provided herein were as follows:

- To evaluate the potential risks to ecological receptors from the contamination associated with the historical operation of the Site as a gold mine; and
- If potential risks are present, to derive SSTLs for remediation and/or risk management that represent acceptable levels of risk to ecological receptors.

Potential risks to ecological receptors were evaluated for use of the Site following closure and reclamation of the Site based on current environmental conditions (e.g., current soil, groundwater and seepage surface water quality data) and without the implementation of the measures proposed in the FCRP (e.g., placement of engineered cover). This was done to focus the SSTL development on those COCs that may pose a potential risk, providing support to and the implementation of those measures outlined in the FCRP.

To address the CIRNAC comment related to the waste rock management and PAG/ML, surface water quality modeling of receiving water bodies was completed to evaluate the performance of the proposed granular esker cover of the waste rock dome with respect to limiting generation of ARD-impacted seepage from the waste rock dome (Golder 2019a; Appendix C). Hydrologic inputs to the water quality model were developed based on the results of thermal-seepage modelling completed by Golder (Golder 2019b; Appendix C). The modelling was used in the ERA to better understand the importance of the seepage from the waste rock as a potential contaminant transport pathway. The resulting predictions of loading to surface water were evaluated in the ERA for potential risks to ecological receptors.

The ERA follows the principles of risk assessment frameworks endorsed by federal and provincial regulatory agencies. It was completed based on guidance provided by the CCME (CCME 1996; 1997), FCSAP (Environment Canada 2012) and US EPA (US EPA 1993; 1998) and other applicable risk assessment guidance documents (e.g., Sample et al. 1996).

5.1 Problem Formulation

In ERA, the problem formulation frames the issues at the site by identifying the substances on a site that may be harmful to terrestrial and aquatic ecosystems (i.e., COCs), the terrestrial and aquatic receptors expected to occur on or use the site (i.e., receptors of concern [ROCs]) and the plausible exposure pathways between the ROCs and COCs. The potential for risk is predicated on the coexistence of the following three elements. Substances must be present at harmful levels, receptors must be present and there must be a way for receptors to come into contact with the substances. The information from the problem formulation is summarized in a CSM, which illustrates the potential links between sources of COCs, exposure pathways and ROCs.

The problem formulation also outlines the approach that will be used to assess risks, including the tools that will be used and how the results will be evaluated. The details of the problem formulation for the Site are provided below.

5.1.1 Contaminants of Concern

A comprehensive screening process was used to identify COCs in soil, groundwater, seepage surface water (current conditions), and lake surface water (predicted future conditions based on implementation of the esker-covered waste rock dome) for the ERA. Concentrations of parameters in these media were screened against the applied guidelines/standards (as described in Section 2.2), or their components that are considered protective of ecological receptors (termed “screening values”). In the absence of federal screening values, provincial (Ontario, Alberta, British Columbia) followed by international (e.g., US EPA) screening values were used. Concentrations of parameters in soil and surface water (seepages and lakes) were also screened against background concentrations (Section 3.7).

The following approach was used to identify COCs for the ERA:

- Maximum concentrations of parameters in soil, groundwater and seepage surface water, and highest seasonal predicted concentrations (50th percentile scenario) of parameters in lake surface water were compared to the screening values. If the maximum (or highest predicted of 50th percentile scenario) concentration of a parameter exceeded the screening value and background concentration (if available), it was retained as a COC for further evaluation in the ERA. If the maximum (or highest predicted of 50th percentile scenario) concentration of a parameter was below the screening value but exceeded background, it was not retained as a COC for further evaluation in the ERA. This is because the screening value represents a concentration to which a receptor can be exposed without experiencing adverse effects.
- If no screening values were available, and the parameter was detected and greater than background (if available), it was evaluated on a case-by-case basis.
- If no screening values were available, and the parameter was not detected, it was not retained as a COC for further evaluation in the ERA.

Comparison to screening values and background (if available) was considered a conservative evaluation of the potential risks to ecological receptors. Therefore, parameters with concentrations below the screening values and/or background (if available) were considered to pose negligible risks to ecological receptors. Parameters with concentrations above screening values and background (if available) were identified as COCs and further evaluated to determine potential risks to ecological receptors. The details of the screening for soil, groundwater, seepage surface water and lake surface water are provided in the following sections.

5.1.1.1 Soil (Current Conditions)

Ecological Screening Values

Terrestrial plants and soil invertebrates may be exposed to parameters in soil via direct contact with soil. Wildlife (mammals and birds) may be exposed to parameters in soil via incidental ingestion of soil and via consumption of food items (plants and/or prey) that have accumulated parameters from soil. To address these receptors and pathways, parameter concentrations in soil were compared to component values protective of soil direct contact and soil and food ingestion. The following component values were selected for the assessment:

- CCME SQG_{ES} (for BTEX, metals and PAHs) and CCME PHC CWS (for PHCs) for agricultural land use (CCME 1999a/2019; CCME 2008), including:
 - Soil contact - soil concentration protective of terrestrial plants and soil invertebrates from direct contact with soil; and

- Soil and food ingestion – soil concentration protective of wildlife from incidental ingestion of soil and consumption of food items that have accumulated contaminants from soil.
- MECP Soil Components for Table 2 – Full Depth, Potable Water Scenario, agricultural land use (MOECC 2016), including:
 - Plants & Soil Organisms – soil concentration protective of terrestrial plants and soil invertebrates from direct contact with soil; and
 - Mammals & Birds – soil concentration protective of mammals and birds from incidental ingestion of soil and from consumption of food items that have accumulated contaminants from soil.
- AEP Surface Soil Remediation Guideline Values for Agricultural Land Use (AEP 2019), including:
 - Direct soil contact – soil concentration protective of terrestrial plants and soil invertebrates from direct contact with soil; and
 - Wildlife soil and food ingestion – soil concentration protective of mammals and birds from incidental ingestion of soil and from consumption of food items that have accumulated contaminants from soil.
- BC MECCS CSR Schedule 3.1 Numerical Soil Standards, Agricultural (BC MECCS 2019b), including:
 - Toxicity to soil invertebrates and plants – soil concentration protective of terrestrial plants and soil invertebrates from direct contact with soil.

Preference was given to the CCME SQG_{ES} (for BTEX, metals and PAHs) and CCME PHC CWS (for PHCs), followed by the provincial screening values. The lowest available provincial screening value was used unless otherwise noted. In the absence of these, the lowest of the other available international screening values were used. These screening values were considered appropriate for use because supporting documentation that details the development of the values is available and/or they have been developed using approaches similar to those used in the development of the CCME SQG_{ES} and CCME PHC CWS.

There were no screening values available for fluorene for terrestrial plants and soil invertebrates; therefore, the screening value for naphthalene was used as a surrogate for low molecular weight PAHs when PAH-specific values were not available.

Terrestrial plants, soil invertebrates, mammals, and birds are generally considered to come in contact with surface soil (0 to 1.5 mbgs). As analytical data for soil was only collected from the top 2.0 m at the Site, as a conservative approach data from all sampling depths were used in the comparison to screening values and background.

Results

The detailed results of the screening for soil are presented in Table 5.1a for terrestrial plants and soil invertebrates and Table 5.1b for wildlife. The parameters in soil that were retained as COCs and the receptors and pathways for which they were assessed in the ERA are summarized below:

- PHC F1 to F3, pH, sulphate, cyanide, antimony, arsenic, chromium, copper, lead, molybdenum, nickel, tin, zinc, fluorene and naphthalene – direct contact with soil by terrestrial plants and soil invertebrates; and

- PHC F2, sulphide, sulphate, cyanide, antimony, arsenic, barium, cadmium, copper, lead, molybdenum, tin, vanadium, zinc, naphthalene and ethylene glycol – Incidental ingestion of soil and consumption of food items that have accumulated contaminants from soil by wildlife.

There are no screening values available for sulphide for soil direct contact with plants and soil invertebrates. Sulphur is an essential nutrient for plants and soil invertebrates. It is only available for absorption by plants and soil invertebrates when it is in its biologically available form, sulphate (Holobrá 1981). Therefore, sulphide was not retained as a COC for plants and soil invertebrates.

Soil pH is less important for soils/food that are incidentally ingested by wildlife given that gut physiology (including gastric and intestinal pH) is an important parameter influencing metal bioavailability. Therefore, soil pH was not retained as a COC for mammals and birds.

5.1.1.2 Groundwater (Current Conditions)

Ecological Screening Values

For ecological receptors, concerns with parameters in groundwater stem from direct contact with shallow groundwater by terrestrial plants.

As discussed in Section 3.4, shallow and deep groundwater discharge to Boot Lake, East Lake and Lower Sewage Lake is not expected. Shallow groundwater discharge to Contwoyto Lake is also not expected; however, deep groundwater discharge may occur. Deep groundwater (i.e., >500 mbgs) has not been investigated as part of the Morrow (2006) and Golder (2017) investigations. Surface runoff and shallow groundwater flow around the Site is also isolated from deep groundwater by the permafrost. The observation in June 2019 that the water level in the flooded mine workings is more than 50 m below the water level in Contwoyto Lake is evidence that there is not a strong hydraulic connection between the flooded mine workings and the deep groundwater flow system. Therefore, all exposure pathways associated with this contaminant transport pathway were not considered further in the screening for groundwater.

Based on the 2017 monitoring results, the groundwater table in the monitoring wells ranged from near surface to 1.75 mbgs (Golder 2017), within the rooting depth of terrestrial plants. To address direct contact with groundwater by terrestrial plants, parameter concentrations in groundwater were compared to screening values protective of terrestrial plants. The following screening values were selected for the assessment:

- FIGQGs, agricultural land use (FCSAP 2016), including:
 - Soil organisms direct contact (SODC) – groundwater concentration protective of terrestrial plants and soil organisms from direct contact with groundwater;
- AEP Tier 1 Groundwater Remediation Guidelines for agricultural land, coarse grained soil (AEP 2019), including:
 - Eco Soil Contact – groundwater concentration protective of terrestrial plants and soil organisms from direct contact with groundwater;
- Efroymsen et al. 1997 – Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants, soil solution values; and
- MECP Groundwater Components for Shallow Soil Scenario (Table 7), non-potable scenario (MOECC 2016), including:

- GW3 – This is a groundwater concentration protective of aquatic life from migration of groundwater to a downgradient surface water body. The GW3 is considered to provide a sufficient degree of protection to terrestrial plants from exposure to shallow groundwater (MOE 2011a).

Preference was given to the FIGQGs, and in the absence of these, provincial screening values (i.e. AEP). Although the MECP provides a screening value for groundwater for plants, it is based on the protection of aquatic life rather than terrestrial plants. As such, the toxicological benchmarks from Efroymson et al. (1997) which are based on exposure by terrestrial plants to soil solution were applied in preference over those from the MECP.

In the absence of screening values specifically for groundwater, the CCME WQGs-PAL (freshwater, long term) were used as they are considered protective of aquatic plants.

These screening values were considered appropriate for use because supporting documentation that details the development of the values is available and/or they have been developed using approaches similar to those used in the development of the FIGQGs.

Results

The detailed results of the screening for groundwater are presented in Table 5.2. PHC F2, aluminum, arsenic, cobalt, iron, zinc and sulphate were identified as COCs in groundwater for direct contact by terrestrial plants.

There are no screening values available for strontium in groundwater. As noted previously, in the absence of screening values specifically for groundwater, surface water screening values protective of aquatic life (including aquatic plants) were considered applicable. There is no WQG-PAL for strontium. The groundwater concentration of strontium was below the chronic effects benchmark for aquatic life derived by McPherson et al. (2014). Therefore, strontium was not retained as a COC in groundwater for the ERA.

There are no screening values available for sulphur and sulphate. Sulphur is an essential nutrient for plants and is only available for absorption when it is in the form of sulphate (Holobrá 1981). Given this, sulphur has not been retained as a COC for further evaluation for uptake from groundwater by plants, but sulphate has been retained.

There are no screening values available for calcium, magnesium, phosphorus, potassium and silicon but these parameters were detected in groundwater. These parameters are ubiquitous in the environment and non-toxic (except at extreme concentrations). Calcium, magnesium, and potassium are essential elements of living organisms (MERAG 2007; CCME 2004). Phosphorus is an essential element for plants. Concerns with this parameter are related to aesthetics (i.e., algal blooms) and effects to aquatic life rather than adverse effects to terrestrial plants. For these reasons, these parameters were not retained as COCs for further evaluation for terrestrial plants.

A number of routine physical and chemical parameters were measured in groundwater that lacked screening values that were not identified as COCs for further evaluation for terrestrial plants. These parameters were not identified as COCs in groundwater because they were physical water quality parameters and not directly toxic.

5.1.1.3 Surface Water (Current Seepage and Predicted Future Lake Conditions)

5.1.1.3.1 Consumption of Surface Water by Wildlife

Ecological Screening Values

Wildlife (mammals and birds) may be exposed to parameters in surface water (i.e. seepage and lake surface water) via water consumption. Wildlife may also be exposed to parameters in surface water (i.e., lake surface

water) via ingestion of food items that have accumulated parameters from surface water. However, this potential exposure pathway was not considered further in the ERA. For those parameters for which exposure via the diet is the dominant pathway of exposure (e.g., selenium), concentrations were only marginally above background and/or below water quality guidelines protective of wildlife for this pathway. For example, maximum predicted concentrations of selenium in Boot Lake (0.000052 mg/L), East Lake (0.000055 mg/L) and Lower Sewage Lake (0.000063 mg/L) were below the BC MECCS guideline for the protection of wildlife (0.002 mg/L) (BC MECCS 2019a).

The CCME and MECP do not provide screening values that are protective of wildlife consumption of surface water. To address these receptors and pathways, parameter concentrations in surface water were compared to the following screening values protective of mammals and birds:

- AEP Tier 1 Soil and Remediation Guidelines (AEP 2019), including:
 - Surface Water Quality Guidelines (SWQG) for Wildlife Water - surface water concentrations protective of water consumption by wildlife;
- BC MECCS Approved WQGs, Wildlife (BC MECCS 2019a);
- Sample et al. Toxicological Benchmarks for Wildlife for water ingestion (1996), as described below; and
- CCME WQGs for the Protection of Agricultural Water Uses (CCME 1999b/2019), including:
 - Livestock Water – surface water concentrations protective of water consumption by livestock.

Preference was given to the provincial screening values (AEP and BC MECCS) rather than the CCME screening value because these were derived based on wildlife water ingestion rather than livestock watering. The lowest available provincial screening value was selected with the exception of arsenic. Given that the BC MECCS wildlife value for arsenic was derived based on livestock, it was not selected as the screening value.

In the absence of provincial screening values, the Sample et al. (1996) Toxicological Benchmarks for Wildlife were used as these were derived based on wildlife water ingestion. In the absence of these, the CCME WQGs for Livestock Water were used.

Sample et al. (1996) derived benchmarks for water ingestion for several wildlife species and contaminants. The toxicological benchmarks for each species were derived using TRVs (no observed adverse effect levels [NOAELs] and LOAELs) from the toxicity tests that were subsequently scaled to the body weight of each wildlife species to derive species-specific TRVs. However, scaling TRVs to body weight to derive species-specific TRVs (i.e., allometric dose scaling) is no longer considered to be appropriate (MOE 2011a). As such, the toxicological benchmarks derived by Sample et al. (1996) were re-calculated by multiplying the LOAELs (NOAELs were used where LOAELs were not available) from the toxicity tests (as provided in Sample et al. [1996]) by the body weight of each receptor and dividing by the water ingestion rate for the wildlife species, as per the equation below:

$$\text{Toxicological Benchmark} = \frac{LOAEL_{\text{Test Species}} \times \text{Body Weight}_{\text{Wildlife Species}}}{\text{Water Intake}_{\text{Wildlife Species}}}$$

The TRVs, body weights and water intakes provided by Sample et al. (1996) were used to re-calculate the benchmarks and are summarized in Table 5.3. Where TRVs were not available from Sample et al. (1996), TRVs were taken from Los Alamos National Library (LANL; 2017), MECP (MOE 2011a) or Sano et al. (2005; bismuth).

The resulting toxicological benchmarks are also provided in Table 5.3. The most stringent of the benchmarks calculated for each wildlife species was used in the screening for each COC. Use of the re-calculated Sample et al. (1996) benchmarks was considered appropriate because Sample et al. (1996) is cited by Environment and Climate Change Canada (ECCC) as a source in the derivation of wildlife TRVs for use at FCSAP sites (FCSAP 2017).

No screening value was available for ammonia. In the absence of a surface water guideline for wildlife water, the CCME WQG-PAL for total ammonia was used. This was considered protective of wildlife consuming the surface water as they would be less exposed than aquatic life fully immersed in the water.

No screening value was available for fluoride. In the absence of a wildlife guideline for fluoride, the CCME livestock value was used. The CCME livestock value for fluoride is 2 mg/L where the feed of livestock does not contain fluoride, and 1 mg/L where feed does contain fluoride. As the livestock values are being applied to wildlife which does not ingest supplied feed, the non-fluoride added value of 2 mg/L was selected.

Results

The detailed results of the screening for seepage surface water (current conditions) for wildlife consumption are presented in Table 5.4. The detailed results of the screening for lake surface water (predicted future conditions) for wildlife consumption are presented in Table 5.5. All seepage surface water concentrations and predicted lake surface water concentrations met the applicable screening values; therefore, no COCs were retained for the consumption of water pathway for mammals and birds.

A number of routine physical and chemical parameters were measured in seepage surface water or predicted in lake surface water above screening values or that lacked screening values that were not identified as COCs for wildlife consumption in the ERA. These are discussed further below:

- Anion/cation sum, hardness, ion balance, conductivity, acidity, alkalinity, bicarbonate, carbonate and hydroxide are routine physical and chemical parameters and are not directly toxic.
- pH is not a concern to wildlife as the pH of the gut is lower than that of the seepage surface water ingested by the wildlife.
- Cesium is the rarest of the naturally occurring alkali metals. It is widely distributed in the earth's crust at low concentrations (HSDB 2006a). A lethal dose of 1700 mg/kg is available for mice (Lewis, R.J. 1996; as summarized in HSDB 2006a). Cesium was identified in seepage surface water at a maximum concentration of 0.0038 mg/L and, which exceeded the background concentration of 0.000024 mg/L. Assuming a water ingestion rate of 0.08 L/d and a body weight of 0.75 kg for the arctic ground squirrel (ecological receptor with the highest water ingestion rate to body weight ratio), the surface water concentration would have to be approximately 15,000 mg/L (versus the maximum seepage surface water concentration of 0.0038 mg/L) to approach the lethal dose of 1700 mg/kg.
- Iron is an essential nutrient for mammals and birds and relevant TRVs have not been published for these receptors. The US EPA (2006) published a TRV based on the geometric mean of the LOAELs for decreased body weight in rats; however, the effect was attributed to the decreased palatability of water as opposed to the toxicity of iron itself.
- Magnesium is ubiquitous in the environment. It is the eighth most abundant metal and makes up approximately 2% of the earth's crust (HSDB 2003). Magnesium is an essential nutrient for living organisms

(MERAG 2007). Magnesium as magnesium chloride has an oral 50% lethal dose (LD₅₀) of 3800 mg/kg and magnesium oxide has an oral LD₅₀ of 3900 mg/kg in rats (HSDB 2003; 2012b). Assuming a water ingestion rate of 0.08 L/d and a body weight of 0.75 kg for the arctic ground squirrel (ecological receptor with the highest water ingestion rate to body weight ratio), the surface water concentration would have to be over 35,000 mg/L (versus the maximum seepage and predicted lake surface water concentrations of 44.5 mg/L and 2.1 mg/L, respectively) to approach the lowest oral LD₅₀ of 3800 mg/kg.

- Phosphorus concerns are related to aesthetics (i.e., algal blooms) and effects to aquatic life rather than adverse effects to wildlife.
- Potassium is ubiquitous in the environment and constitutes 3.59% of the earth's crust (HSDB 2006b). Potassium is an essential nutrient for living organisms (MERAG 2007). Potassium as potassium chloride has an oral LD₅₀ of 380 to 2600 mg/kg in mice and rats (HSDB 2015). Assuming a water ingestion rate of 0.08 L/d and a body weight of 0.75 kg for the arctic ground squirrel (ecological receptor with the highest water ingestion rate to body weight ratio), the surface water concentration would have to be over 3,500 mg/L (versus the maximum seepage and predicted lake surface water concentrations of 20.1 mg/L and 1.2 mg/L, respectively) to approach the lowest oral LD₅₀ of 380 mg/kg.
- Rubidium is a rare, metallic element. There are no naturally-occurring minerals in which rubidium is the primary element. It is naturally found in the earth's crust in trace amounts in rock-forming silicate minerals, such as potassium feldspars and micas (US EPA 2016). No short-term or long-term toxicity data in laboratory animals were found on the potential oral toxicity of elemental rubidium. However, LOAEL values ranging from 167 mg/kg/d to 896 mg/kg/d based on the short-term oral exposure via drinking water to rubidium chloride were available for mammalian test animals (US EPA 2016). Rubidium was measured in seepage surface water a concentration of 0.0325 mg/L, which exceeded the background concentration of 0.00149 mg/L. Assuming a water ingestion rate of 0.08 L/d and a body weight of 0.75 kg for the arctic ground squirrel (ecological receptor with the highest water ingestion rate to body weight ratio), the surface water concentration would have to be approximately 1,500 mg/L (versus the maximum seepage surface water concentration of 0.0325 mg/L) to approach the lowest LOAEL of 167 mg/kg/d.
- Silicon makes up 25.7% of the earth's crust and is the second most abundant element in the earth's crust (HSDB 2011). Silicon is fundamentally non-toxic. No short-term or long-term toxicity data in laboratory animals were found on the potential oral toxicity of elemental silicon (HSDB 2011). The maximum concentration in the seepage surface water was 17.6 mg/L and the predicted concentration in lake surface water was 0.22 mg/L, both of which exceeded their respective background concentrations of 0.88 mg/L and 0.0025 mg/L. Silicon and silica are found in Canadian surface water at typical concentrations of 3-4 mg/L and range up to 30 mg/L (CCME 2006). Given that silicon is often present in natural waters in particulate form, if the seepage or lake surface water contains suspended solids, it is expected that silicon could be detected.
- Sodium is ubiquitous in the environment and makes up 2.83% of the earth's crust (HSDB 2007). It is an essential element of living organisms (MERAG 2007). The oral LD₅₀ value for sodium chloride in laboratory animals has been reported as 3000 mg/kg and 4000 mg/kg of body weight in rats and mice, respectively (HSDB 2014). Assuming a water ingestion rate of 0.08 L/d and a body weight of 0.75 kg for the arctic ground squirrel (ecological receptor with the highest water ingestion rate to body weight ratio), the surface water concentration would have to be over 28,000 mg/L (versus the maximum seepage and predicted lake surface

water concentrations of 32 mg/L and 3.9 mg/L, respectively) to approach the lowest oral LD₅₀ of 3000 mg/kg for rats.

- Tellurium is widely distributed in the earth's crust in deposits of many different types, particularly in deposits associated with silver and gold (HDSB 2002a). A lethal dose of 45 mg/kg was available for guinea pigs (Lewis, R.J. 1996; as summarized in HDSB 2002a). Tellurium was identified in seepage surface water a concentration of 0.00022 mg/L, which only slightly exceeded the background concentration of <0.0002 mg/L. Given a seepage water ingestion rate of 0.08 L/d and a body weight of 0.75 kg for the arctic ground squirrel (ecological receptor with the highest water ingestion rate to body weight ratio), the surface water concentration would have to be 420 mg/L (versus the maximum seepage surface water concentration of 0.00022 mg/L) to approach the lethal dose of 45 mg/kg.
- Thorium is found in rare earth-thorium-phosphate minerals, monazite, thorite, huttonite, and the hydrated thorium silicate mineral. Overall, thorium is present at approximately 8 to 15 mg/kg in the earth's crust (HSDb 2008a). No short-term or long-term toxicity data in laboratory animals were found on the potential oral toxicity of elemental thorium, as its toxicity is generally associated with its radioactive forms (HSDb 2008b). The maximum concentration in the seepage surface water was 0.00092 mg/L and all 14 locations had concentrations that exceeded the background concentration (<0.0001 mg/L). Given that the maximum concentration is only slightly above the background concentration, it is not expected that thorium would be a wildlife water consumption concern.
- Elemental tin is considered to be generally non-toxic by the oral route (WHO 2005). Inorganic tin compounds have low solubility, poor absorption, low accumulations in tissues, and rapid excretion. Consequently, toxicological risks from these compounds are considered to be low (WHO 2005). Some organotin compounds, however, can result in harmful effects in animals. However, LOAEL values ranging from 0.05 mg/kg/d to 500 mg/kg/d based on the short- and intermediate-term oral exposure to organotin compounds were available for mammalian test animals (ATSDR 2005). Tin was measured in seepage surface water a concentration of 0.00023 mg/L, which exceeded the background concentration of <0.0001 mg/L. Assuming a water ingestion rate of 0.08 L/d and a body weight of 0.75 kg for the arctic ground squirrel (ecological receptor with the highest water ingestion rate to body weight ratio), the surface water concentration would have to be approximately 0.47 mg/L (versus the maximum seepage surface water concentration of 0.00023 mg/L) to approach the lowest LOAEL of 0.05 mg/kg/d. It is also noted that the use of the lowest LOAEL for comparison is highly conservative as it assumes tin in seepage surface water will form a highly toxic organotin compound (i.e., trimethyltin) at the maximum measured concentration of tin.
- Tungsten is naturally occurring in rocks in minerals (HSDb 2002b). It exists in the environment in combination with other chemicals and does not occur as a pure metal. It is present in air, water and food at very low levels (HSDb 2002b). No short-term or long-term toxicity data in laboratory animals were found on the potential oral toxicity of elemental tungsten. However, LOAEL values ranging from 78 mg/kg/d to 250 mg/kg/d based on the short-term oral exposure via drinking water to soluble tungsten compounds (i.e., sodium tungsten dihydrate) were available for mammalian test animals (US EPA 2015). Tungsten was measured in seepage surface water a concentration of 0.00086 mg/L, which exceeded the background concentration of <0.0001 mg/L. Assuming a water ingestion rate of 0.08 L/d and a body weight of 0.75 kg for the arctic ground squirrel (ecological receptor with the highest water ingestion rate to body weight ratio), the surface water concentration would have to be approximately 730 mg/L (versus the maximum seepage surface water concentration of 0.00086 mg/L) to approach the lowest LOAEL of 78 mg/kg/d.

- Zirconium is ubiquitous in the environment, present in at least 37 types of minerals and found in Earth's crust at concentrations ranging from 150 to 300 mg/kg (TOXNET 2009). It is present in all animal tissues. No short-term or long-term toxicity data in laboratory animals were found on the potential oral toxicity of elemental zirconium. However, LOAEL values ranging from 0.79 mg/kg/d to 1.75 mg/kg/d based on the chronic oral exposure via drinking water to soluble zirconium compounds (i.e., zirconium sulfate) were available for mammalian test animals (US EPA 2012). Zirconium was measured in seepage surface water a concentration of 0.00063 mg/L, which exceeded the background concentration of <0.0002 mg/L. Assuming a water ingestion rate of 0.08 L/d and a body weight of 0.75 kg for the arctic ground squirrel (ecological receptor with the highest water ingestion rate to body weight ratio), the surface water concentration would have to be approximately 7 mg/L (versus the maximum seepage surface water concentration of 0.00063 mg/L) to approach the lowest LOAEL of 0.79 mg/kg/d.

5.1.1.3.2 Direct Contact with Surface Water by Aquatic Life Ecological Screening Values

Aquatic life may be exposed to parameters in lake surface water via direct contact with surface water and consumption of food items that have accumulated parameters from surface water. To address direct contact with surface water by aquatic life, parameter concentrations in surface water were compared to long-term or chronic water screening values protective of freshwater aquatic life. As noted previously, the surface water concentrations in the lakes were predicted using a model that incorporated the proposed risk management measures outlined in the FCRP (i.e., waste rock consolidation and placement of engineered cover). The following screening values were selected for the assessment:

- CCME WQGs-PAL, freshwater (CCME 1999b/2019);
- FEQGs and screening assessments conducted on high priority substances as part of the Chemicals Management Plan pursuant to the CEPA, 1999 (for vanadium, ECCC 2016; for cobalt, Environment Canada 2017a);
- MECP APVs (MOECC 2016);
- BC MECCS Approved WQGs, Aquatic Life (BC MECCS 2019b); and
- AEP Tier 1 Soil and Groundwater Remediation Guidelines. SWQGs - Aquatic Life (AEP 2019).

Preference was given to the CCME WQG-PALs, and in the absence of these, the FEQGs. In the absence of federal screening values, the lowest of the provincial screening values were used. These screening values were considered appropriate for use because supporting documentation that details the development of the screening values is available and/or they have been developed using approaches similar to those used in the development of the WQG-PALs and FEQGs.

It is noted that the screening values summarized above do not address uptake from the diet (i.e., food consumption) by aquatic life. However, uptake from the water is expected to be the dominant uptake route for most of the parameters predicted in surface water. For those parameters for which uptake from the diet may be important (e.g., selenium), predicted concentrations in the lakes were not much above reference conditions and/or below water quality guidelines protective of this pathway and thus are not expected to drive uptake by aquatic life. For example, maximum predicted concentrations of selenium in Boot Lake (0.000052 mg/L), East Lake (0.000055 mg/L) and Lower Sewage Lake (0.000063 mg/L) were below the BC MECCS guideline for the protection of

aquatic life for this pathway (0.002 mg/L) (BC MECCS 2019a) and the US EPA Ambient Water Quality Criterion for the protection of aquatic life for this pathway (0.0015 mg/L; lotic system) (US EPA 2019d). This is a source of uncertainty as noted in Section 5.5.

Federal or provincial screening values for the protection of freshwater aquatic life are currently not available for strontium. The screening value for strontium of 10.7 mg/L was selected from the McPherson et al. (2014) assessment of chronic toxicity of strontium to freshwater aquatic life, which was deemed to represent the current state of the science regarding chronic toxicity for Canadian waters.

Results

The detailed results of the screening for lake surface water (predicted future conditions) are presented in Table 5.6, Table 5.7 and Table 5.8 for Boot Lake, East Lake and Lower Sewage Lake, respectively. All predicted lake surface water concentrations met the applicable screening values, with the following exceptions:

- pH – Boot Lake and East Lake;
- Cadmium – East Lake;
- Cobalt – Boot Lake, East Lake, Lower Sewage Lake; and
- Copper – East Lake.

These parameters were retained as COCs for aquatic life for further evaluation in the ERA.

A number of routine physical and chemical parameters were predicted in lake surface water but lacked screening values that were not identified as COCs for aquatic life in the ERA. These are discussed further below:

- Alkalinity is a routine physical and chemical parameter and is not directly toxic.
- Calcium, magnesium and potassium are not expected to result in adverse health effects to aquatic life. Major ions such as these can effectively reduce metal toxicity in aquatic biota through competitive interactions at uptake sites (US EPA 2007c). As such, an increase in the concentration of these parameters above reference concentrations would not necessarily constitute a potential adverse effect but would serve to ameliorate metal toxicity to aquatic biota.
- As discussed above, silicon is ubiquitous in the environment and fundamentally non-toxic.
- In the absence of federal or provincial screening values, the ecological benchmarks for tin available from the RAIS (2019) were used for screening. The predicted concentrations for tin were below all available surface water ecological benchmarks from RAIS.

Therefore, the above-noted parameters were not retained as COCs for aquatic life in Boot lake, East Lake or Lower Sewage Lake for the ERA.

Predicted phosphorus concentrations in Lower Sewage Lake were above the background concentration. To determine if phosphorus should be retained as a COC for aquatic life in Lower Sewage Lake, the guidance framework for phosphorus from the CCME (2004) was followed. First, the reference condition was defined. The reference (i.e., background) phosphorus concentration is 0.0080 mg/L (50th percentile mass loadings input). The reference condition was then used to select the trigger range to be used for comparison to the Lower Sewage Lake predicted phosphorus concentration. The trigger range is based on the trophic status of the reference

condition and is the desired concentration range for phosphorus. If the upper limit of the range is exceeded, it indicates a potential environmental problem, and therefore, “triggers” further investigation.

The reference phosphorus concentration for Lower Sewage Lake is indicative of an oligotrophic (0.004 – 0.01 mg/L) lake based on CCME (2004). Therefore, the trigger range for the reference condition for phosphorus for Lower Sewage Lake was selected to be 0.004 to 0.01 mg/L. The predicted phosphorus concentration for Lower Sewage Lake was then compared to the selected trigger range. The predicted phosphorus concentration for the Lower Sewage Lake based on the 50th percentile mass loadings inputs was 0.0084 microgram per litre (µg/L) and does not exceed the upper limit of the trigger range.

In the guidance framework, the CCME (2004) includes an additional step when phosphorus concentrations do not exceed the upper limit of the trigger range. In this step, up to a 50% increase in phosphorus concentrations above the reference condition is acceptable. This additional step is meant to address the general nature of the trigger values and the size of some of the defined phosphorus ranges. The predicted phosphorus concentration for Lower Sewage Lake of 0.0084 mg/L is less than a 50% increase from the reference condition (maximum reference concentration of 0.008 mg/L + 50% = 0.012 mg/L). Therefore, phosphorus was not identified as a COC for aquatic life in Lower Sewage Lake.

5.1.1.4 Characteristics of Contaminants of Concern

An understanding of the characteristics of COCs is important for the selection of relevant receptors, exposure pathways and endpoints. The transport and fate characteristics of a COC predict its behaviour in the environment and partitioning into various environmental media. The effects characteristics aid in the identification of sensitive species and health endpoints. A summary of the transport, fate and effects characteristics for the COCs identified for the ERA is provided in Table 5.9. It is noted that broad characteristics relevant to the key contaminant groups and receptors groups are provided. A more detailed effects assessment is provided as part of the effects/toxicity assessment of the ERA (Section 5.3).

5.1.2 Receptors of Concern

A ROC is any non-human individual, species, population, community, habitat or ecosystem that may be potentially exposed to COCs on a site (Environment Canada 2012). A ROC should be ecologically relevant to the site and should have a reasonable potential to be found on a site. The identification of ROCs for a site begins with the compilation of relevant site information, such as basic site characteristics, habitat types and species present on the site, including species at risk (SAR).

Once the site has been characterized with respect to its ecological attributes, ROCs for each receptor type are selected for assessment in the ERA. The selection of ROCs is based on many criteria (as discussed in Section 5.1.2.2) and considers the degree to which the ROC is representative and/or protective of other species that may be present on the site. The identification of ROCs to be evaluated by the ERA is described further in the following sections.

5.1.2.1 Description of Terrestrial and Aquatic Habitats and Species

No additional environmental assessments were completed to characterize the terrestrial and aquatic environments of the Site; therefore, the HHERA relies on the information provided in previous assessments (summarized in Section 1.2) to determine habitat types and species present, including SAR.

As described in Section 3.1, the Lupin Gold Mine is on the west shore of Contwoyto Lake, Nunavut in the southern arctic ecoregion. The Site is in the tundra zone of the Canadian Shield, an area of continuous permafrost. Terrain is generally low and undulating, ranging between 470 and 505 m elevation.

As described in Section 3.4, the Site is located within an area of sparse vegetation, in the barren land tundra of Nunavut. It is typified as having sparse low-lying vegetation which is extremely tolerant and well adapted to the climatic conditions. Some of the more prevalent types of habitat that can be found throughout the area include upland and lowland tundra, wet meadows and gentle slopes.

Throughout the Site there are diverse types of vegetation consisting of grasses and sedges, and ground cover such as mosses, Labrador tea, cranberry, bilberry, bearberry, and arctic white heather. In wet areas, predominant species include cotton grass, bog rush, and other aquatic grasses. Dwarf birch and willows populate trenches, and examples of colourful flowering plant species include fireweed, Lapland rosebay, azalea and saxifrage (Golder 2018).

Characteristic wildlife species include caribou, muskox, grizzly bear, hare, fox, wolf, raptors, shorebirds and waterfowl (Golder 2004).

As described in Section 3.2, Contwoyto Lake is the major water body in the region and has two outlets: the Burnside River on the northwest end of the lake towards Bathurst Inlet, and the Back River at the southeast end of the lake, which flows into Pellatt Lake (Golder 2004). The main body of Contwoyto Lake lies approximately 1.5 km to the east and south of the Site. To the north of the Site, the West Arm of the lake extends to the west and south, terminating in Sun Bay, which lies directly west of the Site (Golder 2004; Morrow 2006). There are a number of smaller waterbodies in the vicinity of the Site including East Lake, Boot Lake, Upper Sewage Lake and Lower Sewage Lake. All of the small lakes and ponds freeze to the bottom in winter (Morrow 2006). As a consequence, overwintering habitat for fish is limited primarily to the main body of Contwoyto Lake.

Species at Risk

A SAR assessment was completed in support of the Golder 2004 ERA (Golder 2004). Species lists compiled by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC (2002); SARA 2002) were consulted to determine whether any local species have been designated as sensitive or threatened. The following species were listed as species of special concern by COSEWIC in the Golder 2004 ERA:

- Grizzly bear (*Ursus arctos horribilis*); and
- Wolverine (*Gulo gulo*).

A more recent SAR assessment has not been completed for the Site, but the status of the grizzly bear and wolverine were confirmed (Government of Canada 2019b). This is a source of uncertainty, as noted in Section 5.5.

5.1.2.2 Selection of Receptors of Concern

Several factors were considered when selecting the ROCs for the ERA including the following:

- Species considered in the Golder 2004 ERA (Golder 2004);
- Potential for species to be present on the Site;
- Are important to human populations (i.e. used as a food source);

- Have economic and/or social value (i.e. animals that are trapped for furs, recreational value);
- Species that play important roles in community structure and function (e.g., major herbivores and top predators in terrestrial ecosystems);
- Potential for exposure (i.e., diet, habitat preferences and behaviours that make the species likely to contact the COCs) and sensitivity to COCs;
- Inclusion of the various trophic levels (e.g., primary producer, herbivore, carnivore) for species that could potentially use the Site;
- The availability of information on the species, including exposure-related and ecotoxicological data, as well as availability of laboratory toxicity testing; and
- SAR (e.g., special concern, threatened or endangered species).

As discussed in Section 5.1.2.1, terrestrial and aquatic habitats are present on the Site; therefore, ROCs for terrestrial and aquatic ecosystems were selected. The selected ROCs and rationale for selection are presented in Table 5.10 and 5.11 for the terrestrial and aquatic ecosystems, respectively, and briefly discussed below.

Aerial invertebrates were not evaluated because ground-dwelling invertebrates would be more exposed to COCs in soil than aerial invertebrates. In addition, there is a lack of ecotoxicological data for aerial invertebrates to conduct a quantitative risk assessment.

Carnivorous and omnivorous mammals and birds were identified as wildlife receptors in the Golder 2004 ERA (Golder 2004). These included the wolverine (*Gulo gulo*), fox (both red and arctic; *Vulpes vulpes* and *Vulpes lagopus*), wolf (*Canis lupus*), grizzly bear (*Ursus arctos horribilis*) and rough legged hawk (*Buteo lagopus*). However, the identified COCs (i.e., PHCs, metals and PAHs) do not bioaccumulate in animals and exposure via other pathways would be less than that for herbivorous mammals. As discussed in Section 4.1.3.1, a bioaccumulation screening was completed and no metals were considered to sufficiently bioaccumulate in mammals (Table 4.3). As per US EPA (2007a), the bioaccumulation of PAHs in mammals is expected to be negligible because of the rapid metabolism of these compounds following ingestion. Similarly, the CCME (2008) indicates that PHCs are readily metabolized and excreted by vertebrates and bioaccumulation would be similarly negligible. Therefore, only the wolverine and grizzly bear were selected as ROCs because they were identified as SAR for the Site in the Golder 2004 ERA (Golder 2004).

Due to the cold climate and permafrost conditions, reptiles and amphibians are not found on the Site. There are no reptiles in Nunavut (University of Guelph 2012). Only two species of amphibians are found in Nunavut: the American toad, limited to Akimiski Island in James Bay and the wood frog, found in the western portion of the territory. The geographic range for the wood frog (University of Guelph 2012) does not overlap with the Site (University of Guelph 2012). Therefore, reptiles and amphibians were not selected as ROCs.

Aquatic birds including the snipe (*Gallinago gallinago*) and duck (*Clangula hyemalis*) were identified as wildlife receptors in the Golder 2004 ERA (Golder 2004). However, these species were not selected as ROCs in the current ERA because no COCs were identified for the consumption of surface water pathway and sediment is not considered an environmental medium of concern for the ERA (discussed further in Section 5.1.3). Aquatic mammals were not evaluated for the same reasons.

As discussed in Section 5.1.2.1, fish habitat is present only in the main body of Contwoyto Lake. As Contwoyto Lake is not expected to be impacted by the Site (Section 3.9), fish were not selected as ROCs in the ERA.

5.1.3 Exposure Pathways

Exposure pathways are the means by which receptors come into contact with COCs. For an exposure pathway to exist, a contaminant source, a release mechanism, transport media and a receptor must be present. Incomplete (or inoperable) and/or negligible pathways were not evaluated in the ERA. Rationale for the inclusion or exclusion of potential pathways for each receptor group is provided in Tables 5.12 and 5.13 for the terrestrial and aquatic ecosystems, respectively.

5.1.4 Ecological Conceptual Site Model

A CSM was developed for ecological receptors to summarize the results of the problem formulation. The CSM illustrates the potential links between sources of COCs, exposure pathways and ROCs. Figure 11 provides the CSM for the terrestrial ecosystem and Figure 12 provides the CSM for the aquatic ecosystem.

The CSM for the terrestrial ecosystem (Figure 11) is described briefly below:

- Contaminants of concern were identified in soil.
 - Terrestrial plants and invertebrates may be exposed to COCs in soil via direct contact and this link was considered further in the ERA.
 - Wildlife (mammals and birds) may be exposed to COCs in soil via incidental ingestion of soil and via consumption of food items (plants and/or prey) that have accumulated COCs from soil and this link was considered further in the ERA.
- Contaminants of concern were identified in groundwater.
 - Terrestrial plants may be exposed to COCs in groundwater via direct contact and this link was considered further in the ERA.
 - Groundwater discharge to nearby surface water bodies is not expected (Section 3.4); therefore, all exposure pathways and ROCs associated with this contaminant transport pathway were not evaluated further in the ERA.
- Seeps are present around the perimeter of the Site. No COCs were identified in seepage surface water for consumption by wildlife (mammals and birds) and this link was not considered further in the ERA.
- Amphibians and reptiles do not occur on the Site and were not selected as terrestrial ROCs for the ERA.

The CSM for the aquatic ecosystem (Figure 12) is described briefly below:

- The proposed esker-covered waste rock dome is a potential source of ARD-impacted seepage. The ARD-impacted seepage may result in long-term impacts to surface water quality in receiving surface water bodies (Boot Lake, East Lake and Lower Sewage Lake). Impacts to surface water quality in Contwoyto Lake are expected to be negligible.
- Contaminants of concern were identified in surface water for direct contact by aquatic life (plants, pelagic invertebrates and benthic invertebrates) based on predicted concentrations for Boot Lake, East Lake and Lower Sewage Lake. This link was considered further in the ERA.

- No COCs were identified in surface water for consumption by wildlife (mammals and birds) based on predicted concentrations for Boot Lake, East Lake and Lower Sewage Lake and this link was not considered further in the ERA.
- Fish were not selected as aquatic ROCs because overwintering habitat for fish is only present in Contwoyto Lake. Amphibians and reptiles do not occur on the Site and were not selected as aquatic ROCs.
- The focus of the ERA was on ARD-impacted seepage and potential long-term impacts to surface water quality in the receiving water bodies. Potential impacts to sediment and all associated exposure pathways and ROCs were not considered further in the ERA.

5.2 Exposure Assessment

The exposure assessment estimates the amount of a COC to which each of the ROCs are exposed via each complete (or operable) pathway. Exposure was determined in two ways: 1) by direct measurement or prediction of COC concentrations in abiotic media (e.g., soil, groundwater and surface water); and 2) by calculation of total doses using a food chain model.

For terrestrial plants and soil invertebrates, exposure is expressed as the concentration of a COC in soil (mg/kg) and/or groundwater (mg/L). For aquatic life, including aquatic plants, pelagic and benthic invertebrates, exposure is expressed as the concentration of a COC in surface water (mg/L). This permits the evaluation of exposure relative to TRVs that are expressed in this way.

For mammals and birds, exposure is expressed as the total dose (mg/kg-d) from food, incidental ingestion of soil and water as determined through a food chain model. Again, this permits the evaluation of exposure relative to TRVs that are expressed in this way.

The exposure assumptions used in the assessment for each receptor class (i.e., terrestrial plants and soil invertebrates, terrestrial mammals and birds, and aquatic life), including details of the food chain model used in the assessment for mammals and birds, are provided in the following sections. The following sections also provide the exposure estimates for each ROC.

5.2.1 Concentrations in Soil, Groundwater, and Surface Water

5.2.1.1 Concentrations in Soil (Current Conditions)

Terrestrial plants and immobile soil invertebrates are considered sessile receptors and could be exposed to soil in the areas with the maximum measured concentrations of COCs. Considering exposure based on maximum measured concentrations is informative on the potential effects of COC concentrations on individual organisms. However, the protection goal for the ERA is maintenance of healthy communities and populations. As such, statistical measures were used where possible to assess exposure to terrestrial plants, soil invertebrates and wildlife (mammals and birds), specifically the 95% UCLM, as this statistic is informative on the potential effects of COCs on communities and populations. The 95% UCLM is a conservative estimate of mean exposure (i.e., there is a 95% probability that the true mean is below this value). This approach is consistent with the FCSAP ERA guidance (Environment Canada 2012).

ProUCLVersion 5.1.002, developed by the US EPA (2016a) was used to calculate 95% UCLMs for soil. Soil quality data from all environmental investigations (from Morrow 2006 and Golder 2017) and all depths were used. The approach for calculating and selecting the 95% UCLMs is described in Appendix B, along with the ProUCL

inputs and outputs for the ERA. The exposure concentrations for soil used in the assessment (i.e., maximum measured concentration or 95% UCLM) are presented in Table 5.14.

5.2.1.2 Concentrations in Groundwater (Current Conditions)

As described for soil, 95% UCLMs were used where possible to assess exposure to terrestrial plants from COCs in groundwater. Data from the most recent year of data available (2017) were included as no more recent sampling was conducted. The approach for calculating and selecting the 95% UCLMs is described in Appendix B, along with the ProUCL inputs and outputs for the ERA. The exposure concentrations for groundwater used in the assessment (i.e., maximum measured concentration or 95% UCLM) are presented in Table 5.15.

5.2.1.3 Concentrations in Surface Water

Predicted surface water quality was provided for Boot Lake, East Lake and Lower Sewage Lake based on 50th percentile mass loading inputs for the months of June, July, August and September. The highest concentration of the four months was used as the exposure concentration for the evaluation of risks to aquatic life. The surface water concentrations in the lakes were predicted using a model that incorporated the proposed risk management measures outlined in the FCRP (i.e., waste rock consolidation and placement of engineered cover). The exposure concentrations for surface water used in the assessment are presented in Table 5.16.

5.2.2 Food Chain Model for Terrestrial Mammals and Birds

A food chain model was used to calculate the total doses of COCs received by terrestrial mammals and birds from incidental soil ingestion and food consumption. In order to calculate a total dose, the following parameters are required for the food chain model:

- Receptor characteristics, including body weight, diet composition, soil, and food ingestion rates and home ranges;
- Concentrations of COCs in soil; and
- Concentrations of COCs in food items (i.e., terrestrial plants, soil invertebrates, mammals).

As discussed in Section 5.1.2, only herbivores were selected for evaluation in the ERA; therefore, ingestion of plants was the only applicable food item. The doses from incidental soil ingestion and food consumption were calculated for each terrestrial mammal and bird ROC using the following equation:

$$D_{\text{soil+food}} = AUF \times \left[\frac{(IR_{\text{soil}} \times C_{\text{soil}}) + (IR_{\text{plant}} \times C_{\text{plant}}) + (IR_{\text{mammals}} \times C_{\text{mammals}})}{BW} \right]$$

Where:

$D_{\text{soil+food}}$ is the estimated dose of the COC from incidental soil ingestion and food consumption (mg/kg-d);

AUF is the area use factor (unitless);

IR_{soil} is the soil ingestion rate (kilograms in dry weight per day [kg dw/d]);

C_{soil} is the COC concentration in the soil (milligrams per kilograms in dry weight [mg/kg dw]);

IR_{plant} is the plant ingestion rate (kg dw/d);

C_{plant} is the COC concentration in the plant (mg/kg dw);

IR_{mammals} is the small mammals ingestion rate (kg dw/d);

C_{mammals} is the COC concentration in small mammals (mg/kg dw); and

BW is the receptor's body weight (kg).

Calculations were done on a dry weight basis. Plant and mammal ingestion rates were calculated from the dry weight food ingestion rate, weighted by the proportion of that item in the receptor's diet.

Area use factors (AUFs) can be applied in exposure assessment when the home range of the receptor is larger than the size of the site (or impacted area of the site) to allow for the consideration that the receptor spends less than 100% of the time on-site or in the impacted area of the site. The area of impact was considered to include the area of the mine disturbance footprint that was sampled for metals, PAHs, PHCs and glycols (i.e., the COCs identified in soil for wildlife). This area was estimated to be 0.55 km². For the arctic hare, arctic ground squirrel and willow ptarmigan, the sizes of their home range are less than the size of the impacted area of the Site. Therefore, it was assumed that these ROCs would spend 100% of their time on the Site.

For the caribou, the home range was 36,124 km² based on the lowest of the post-calving and autumn seasonal ranges from 2006-2013 (Virgl et al. 2017). The post-calving and autumn seasonal range are critical periods in the caribou migration as calves are nursing and females need to gain enough energy to feed the calf and themselves in order to be healthy enough to become pregnant and carry the unborn calf to term the following spring. In addition, the autumn seasonal range overlaps with the Site more recently as a shift in the caribou range was observed. The home ranges from 2006-2013 were considered to be the most relevant as a decrease in abundance and the shift in range northwards to overlap with Site was the strongest. Considering the area of impact and the home range, the AUF for the caribou was calculated to be 0.000015.

For the muskox, the home range was 27 km² based on the winter and calving ranges (Elder 2005). These are considered to be the most critical periods in the muskox life history. The summer seasonal range averages 223 km². The AUF was calculated to be 0.02 based on the area of impact and the winter home range.

For the grizzly bear, the home range was selected as 700 km² based on the average for females in Canada (COSEWIC 2012). Studies cited by COSEWIC (2012) report grizzly bear home ranges for Nunavut as 2100 km² for females and 7245 km² for males. The use of a Canadian average in the calculation of the AUF is a conservative estimate for grizzly bear home ranges in Nunavut. Considering the area of impact and the home range, the AUF was calculated to be 0.001.

For the wolverine, home ranges for males can be between 600 and 1000 km² and for females between 50 and 350 km² (Patsy and Sygo 2009). The lower end of the range for females (50 km²) was used in the calculation of the AUF. The AUF was calculated to be 0.011.

5.2.2.1 Receptor Characteristics

Characteristics of the terrestrial mammal and bird ROCs evaluated in the ERA and the sources of those characteristics are provided in Table 5.17. Food ingestion rates were calculated based on allometric equations for mammals and birds provided by the US EPA (1993).

5.2.2.2 Concentrations in Soil

The concentrations of COCs in soil (current conditions) used in the food chain model are the exposure concentrations described in Section 5.2.1.1 and are provided in Table 5.14. It was assumed that COCs in soil were 100% bioavailable. This is considered a conservative approach.

5.2.2.3 Concentrations in Food Items

Terrestrial mammals and birds evaluated in the ERA consume various tissue types as food items (e.g., plants and mammals). Site-specific tissue concentrations were not available for plants so the concentrations in plants for the

food chain model were estimated using uptake equations and uptake factors from soil. Concentrations of COCs in plants were calculated based on 95% UCLM soil concentrations using uptake equations provided by the US EPA (2007b) or uptake factors provided by Baes et al. (1984) and are presented in Table 5.18. For COCs for which the Baes et al. (1984) uptake factors were used (e.g., molybdenum), the soil-to-plant concentration factor for vegetative parts was used as it provided a more conservative estimate of plant concentrations than that for reproductive parts. While the uptake of some metals into plants is influenced by soil pH, the uptake equations were still deemed appropriate to estimate COC concentrations in plants. This is because for those metals evaluated with respect to pH, the source of the uptake equations provided by the US EPA (Bechtel Jacobs Company 1998) recommends use of the single-variable regression or multiple regression with pH (with no preference given except for mercury). Given that areas of low and high pH have been identified on the Site, it was considered reasonable to apply the single-variable regression to provide an estimate of plant tissue concentrations reflective of the range in soil pH across the Site. As discussed in Section 5.5.3, this is considered to be a source of uncertainty in the ERA.

Studies have demonstrated that PHCs and PAHs are not readily absorbed or accumulated by plants (CCME 2008; CCME 2010). Therefore, exposure to terrestrial mammals and birds via ingestion of plants that have accumulated PHCs and PAHs from soil was assumed to be negligible in the ERA.

There is no available uptake equation or factor for cyanide. The CCME indicates that very few data are available on the uptake of cyanide from soil by plants and provides a BAF of 0.8 based on data for bush beans (CCME 1999c). Given the lack of data for cyanide it was conservatively assumed that the plant concentration was equivalent to the exposure concentration in soil.

Uptake equations have not been derived and plant concentrations were not estimated for sulphide, sulphate, tin and ethylene glycol because TRVs are not available to allow calculations of HQs.

As discussed in Section 4.1.3.1, a bioaccumulation screening was completed, and no metals were considered to sufficiently bioaccumulate in mammals (Table 4.3). As per US EPA (2007a), the bioaccumulation of PAHs in mammals is expected to be negligible because of the rapid metabolism of these compounds following ingestion. Similarly, the CCME (2008) indicates that PHCs are readily metabolized and excreted by vertebrates and bioaccumulation would be similarly negligible. Based on the above, bioaccumulation of metals, PHCs and PAHs in mammals is not expected. Therefore, exposure via ingestion of mammals was assumed to be zero.

Concentrations of COCs in food items (i.e., plants and mammals) are presented in Table 5.19.

5.2.2.4 *Estimated Total Doses*

For each terrestrial mammal and bird ROC evaluated, the doses from incidental soil ingestion and consumption of food items (plants and mammals) that have accumulated COCs from soil are provided in Table 5.20. A sample calculation is provided in Appendix F.

5.3 **Effects Assessment**

The effects assessment characterizes potential effects associated with COCs. It provides a basis for evaluating what is an acceptable exposure and what level of exposure may adversely affect the health of ROCs. This involves identification of the potentially toxic effects of the COCs and determining concentrations or doses that receptors can be exposed to without adverse effects. For terrestrial plants and soil invertebrates, this is expressed as an acceptable concentration in the media to which the ROC is exposed (i.e., soil or groundwater) and is referred to as the TRV. For aquatic life, this is also expressed as an acceptable concentration in the media to

which the ROC is exposed (i.e., surface water). For mammals and birds, this is expressed as an acceptable daily dose and is also referred to as a TRV. These values are used as thresholds for comparison with exposure concentrations (for terrestrial plants and soil invertebrates) and doses (for mammals and birds) during risk characterization.

The TRVs used for each receptor group are discussed in detail below.

5.3.1 Terrestrial Plants and Soil Invertebrates

Terrestrial plants and soil invertebrates were evaluated by the comparison of COC concentrations in soil and groundwater (for plants only) to literature-based TRVs for effects on survival, growth and reproduction. The TRVs used in the assessment for soil and groundwater are detailed in the following sections.

Terrestrial Plants and Soil Invertebrates - Soil

The CCME (1999a/2019; 2008), MECP (MOECC 2016), AEP (AEP 2019 and BC MECCS (BC MECCS 2019b) derived guidelines/standards for soil that are considered to be protective of direct contact by both terrestrial plants and soil invertebrates. These derivations involved the generation of extensive datasets of toxicity data and the identification of suitable toxicity data for guideline/standard development. The CCME SQGEs and CWS (for PHCs) for direct soil contact for agricultural land use and coarse-grained soil were used as the TRVs for COCs in soil for terrestrial plants and soil invertebrates. Where CCME SQGEs and CWSs were not available, TRVs were selected as the lowest guideline/standard from the MECP, AEP or BC MECCS.

In the absence of TRVs for tin from federal and provincial jurisdictions, the toxicological benchmark for plants from Efroymson et al. (1997) was used. No TRV was available for soil invertebrates; therefore, the effects of tin on soil invertebrates was evaluated qualitatively.

For fluorene, the TRV was selected as the lowest effect concentration for survival, growth and reproduction endpoints of the toxicity data considered by the CCME (2010) in the derivation of the SQGE. The selected value was based on an 10% effective concentration (EC₁₀) of 7.7 mg/kg for reproduction effects in springtail. No TRV was available for terrestrial plants; therefore, the effects of fluorene on terrestrial plants was evaluated qualitatively.

Soil pH was identified as a COC for terrestrial plants and soil invertebrates and is evaluated qualitatively in Section 5.4.1.

The selected TRVs for soil for terrestrial plants and soil invertebrates are presented in Table 5.21. This table also presents the basis of the selected TRVs.

Terrestrial Plants - Groundwater

The FCSAP FIGQGs (FCSAP 2016) for SODC (protective of direct contact with groundwater by plants and soil invertebrates) are considered protective of COCs in groundwater via root uptake by terrestrial plants on the Site. The FCSAP FIGQGs for SODC for agricultural land use and coarse-grained soil were used as the TRVs for COCs in groundwater for terrestrial plants. Where these values were not available, TRVs were selected from the following hierarchy of sources:

- AEP (2019), groundwater remediation guideline values for agricultural (coarse soil type) for direct groundwater contact (protective of plants);
- Efroymson et al. (1997), toxicological benchmarks for terrestrial plants for soil solution;

- MECP (MOECC 2016), GW3 component values (Table 7, groundwater components for shallow soil, non-potable scenario; the GW3 is a groundwater concentration protective of aquatic life from migration of groundwater to a downgradient surface water body but is considered to provide a sufficient degree of protection to terrestrial plants from direct contact exposure to shallow groundwater [MOE 2011a]);
- CCME (1999b/2019), WQG-PAL, Freshwater, Long-term, these guidelines are considered to be protective of aquatic plants; and
- BC MECCS (2019a) Approved WQGs, Aquatic Life, 30-day average, hardness 0-30 mg/L. These guidelines are considered to be protective of aquatic plants.

The selected TRVs for groundwater for plants are presented in Table 5.22. This table also provides the basis of the selected TRVs.

5.3.2 Mammals and Birds

Risks to mammals and birds were evaluated by the comparison of the estimated exposures to COCs (total doses from all exposure pathways) as determined using a food chain model to literature-based TRVs derived from toxicity studies for effects on survival, growth and reproduction. These types of TRVs are protective of species at an individual level and are most appropriate for SAR because impairment of individuals could imperil populations. Use of these TRVs for common species is considered to be a conservative approach.

In general, the default wildlife TRVs for mammals and birds published by FCSAP (FCSAP 2017) were used in the ERA, if available. These represent minimal to low level effects on survival, growth and reproduction and are based on an effect level of 25% or less. If not available, TRVs were determined based on the following hierarchy of sources:

- TRVs published by the CCME in the scientific supporting documents for the SQG_{ES} (CCME 1999a/2019);
- TRVs published by the MECP (MOE 2011a);
- TRVs published by the Oak Ridge National Laboratory (Sample et al. 1996);
- TRVs published by the US EPA in the Ecological Soil Screening Level (Eco-SSL) documents (US EPA 2019c); and
- TRVs published by the LANL (2017).

The TRVs that were adopted for the ERA are provided in Table 5.23. This table also provides the basis of the adopted TRVs.

There are no TRVs for mammals and birds for sulphide, sulphate, tin and ethylene glycol and no TRVs for PHC F2 and antimony for birds. Therefore, the assessment of risks to mammals and birds from these COCs has relied upon a qualitative assessment.

5.3.3 Aquatic Life

For aquatic life, risks were evaluated through the comparison of the predicted COC concentrations in surface water to literature-based TRVs for effects on survival, growth, reproduction, development and population changes (for aquatic plants only). The TRVs used in the assessment for surface water are described below and summarized in Table 5.24.

- The CCME WQG-PAL was selected as the TRV for cadmium. The WQG-PAL for cadmium was recently re-evaluated by the CCME (2014). The re-evaluation included a review of the toxicity data published for cadmium since the last time the guideline was derived and incorporated advances in the understanding of environmental toxicology. The guideline is based on hardness; therefore, it was adjusted as such. Hardness was not predicted for East Lake (the only lake for which cadmium was identified as a COC) so background hardness was used (50th percentile background hardness).
- There is currently no CCME WQG for cobalt to protect freshwater aquatic life. The FEQG for cobalt (Environment Canada 2017a) was not selected as the TRV because it is only applicable for hardness values between 52 and 396 mg/L as calcium carbonate (CaCO₃) and the document does not provide any guidance on how to apply the FEQG when hardness is outside the specified range. The MECP has derived an APV of 5.2 µg/L for cobalt based on a 28-day lowest observed effect level (LOEL) of 5.2 µg/L for effects on reproduction (number of progeny) in *Daphnia magna* (Kimball 1978; as cited in MOE 2011). The BC MECCS provides a long-term WQG for cobalt of 4 µg/L (BC MECCS 2019a). The WQG is based on the invertebrates *Daphnia magna* and *Ceriodaphnia dubia* that exhibited chronic effects when exposed to low concentrations of cobalt. A lowest observed effect concentration (LOEC; geometric mean) of about 8 µg/L total cobalt was determined to cause reproductive effects in these organisms. The WQG was developed by applying a safety factor of 2 to the LOEC. A lower (than 10) safety factor was justified because cobalt is essential in the synthesis of vitamin B₁₂ which is necessary for animal and human nutrition (BC MOE 2004). The lowest of the MECP and BC MECCS values (i.e., the BC MECCS WQG of 4 µg/L) was selected as the TRV for cobalt.
- The CCME WQG-PAL was selected as the TRV for copper. The guideline is dependent on water hardness (CCME 1999b/2019) so it was adjusted as such. Hardness was not predicted for East Lake (the only lake for which copper was identified as a COC) so background hardness was used (50th percentile background hardness).

5.4 Risk Characterization

5.4.1 Terrestrial Plants and Soil Invertebrates

COC concentrations in soil and groundwater (current conditions) were compared to literature-based TRVs for effects on survival, growth and reproduction of plants and soil invertebrates to determine HQs. An HQ of less than or equal to one was considered to represent a negligible risk to these ROCs from exposure to the COC. An HQ of greater than one was considered to represent a potential risk to these ROCs from exposure to the COC.

Soil (Current Conditions)

HQs calculated for terrestrial plants and soil invertebrates using the TRVs for soil are presented in Table 5.25. HQs were marginally greater than one for PHC F1 (HQ = 1.2) and greater than one for PHC F2, F3, cyanide, arsenic and naphthalene (HQ = 2.6 to 95).

Exceedances of the TRV (CCME CWS (soil contact)) for PHCs F1 to F3 are widespread across the Site. The TRVs are based on laboratory studies in which soils are amended with the bioavailable form of the contaminant (e.g., fresh versus weathered PHCs). Over time, PHCs undergo weathering whereby there is a change in the composition and bioavailability due to natural processes including volatilization, differential mobility, biodegradation and stabilization (CCME 2008). Therefore, the toxicities of PHC F1 and F3 are likely less than that for the amended soils used to derive the TRVs given the length of time that has passed since the contamination occurred. This likely overestimates risks to terrestrial plants and soil invertebrates that would be found on the Site.

Exceedances of the TRV (CCME SQGE (soil contact)) for cyanide in soil occur in only one location, with the remaining samples less than detection limits. The area of cyanide contamination is limited to BH05-03. The TRV for cyanide is based on a toxicity data set that includes effects to sensitive crop species that are likely not present on the Site. This may overestimate or underestimate risks to terrestrial plants and soil invertebrates that would be found on the Site.

Exceedances of the TRV (CCME SQGE (soil contact)) for arsenic in soil are widespread across the Site. The TRV for arsenic is based on a toxicity data set that includes effects to sensitive crop species that are likely not present on the Site. This may overestimate or underestimate risks to terrestrial plants and soil invertebrates that would be found on the Site.

Exceedances of the TRV (MOECC Table 2 Plants & Soil Org. component value (agricultural)) for naphthalene occur in five sampling locations in the central and western portion of the Site and are co-located with PHC impacts. The TRV for naphthalene is based on a toxicity data set that includes effects to sensitive crop species that are likely not present on the Site. This may overestimate or underestimate risks to terrestrial plants and soil invertebrates that would be found on the Site.

Despite the conservative assumptions discussed above, potential risks to terrestrial plants and soil invertebrates from exposure to PHC F1 to F3, cyanide, arsenic and naphthalene in soil cannot be ruled out. The remaining COCs with HQs less than one are considered to pose negligible risks to plants and soil invertebrates.

The TRV for tin is protective of plants only. Effects to soil invertebrate populations are not expected as tin concentrations were above the CCME SQGE for agricultural land use in three out of 68 samples and only detected above laboratory detection limits in six out of 68 samples. These exceedances are localized and would not impact the soil invertebrate population on the Site. Therefore, risks to soil invertebrates from tin in soil were considered to be negligible.

The TRV for fluorene is protective of soil invertebrates only. Effects to terrestrial plants are not expected as fluorene was detected above laboratory detection limits in only five out of 37 samples. These detected concentrations are localized and would not impact the terrestrial plant populations on the Site. Therefore, risks to terrestrial plants from fluorene in soil were considered to be negligible.

HQs could not be calculated for terrestrial plants and soil invertebrates for sulphate because a TRV for soil is not available. Concentrations of sulphate were detected in all three samples analyzed for this COC ranging from 348 to 821 mg/kg. Sulphate occurs naturally in the environment and is one of the least toxic anions (Health Canada 1994a). Based on the above, sulphate is unlikely to pose risks to plants and soil invertebrates.

Soil pH on the Site ranged from 2.7 to 12.5 which ranged both higher and lower than the background pH (4.13 to 5.67) and the CCME SQGE (6 to 8). Extreme pH values in themselves provide challenges to plants and soil invertebrates.

The ideal soil pH for plants is close to neutral and neutral soils are considered to fall within a range from a slightly acidic pH of 6.5 to a slightly alkaline pH of 7.5. This is because plant nutrients required for growth are optimally available to plants within this pH range. Environment Canada uses an optimal pH range of 6.5 to 7.5 for artificial soil in their biological test method for measuring emergence and growth of terrestrial plants exposed to contaminants in soil (Environment Canada 2005/2007). However, some plants prefer or can tolerate a lower or higher soil pH (Environment Canada 2005/2007). The acceptable range of soil pH was considered to be 4.13 to 8

based on the lower end of background and the upper end of the CCME SQGE. Those areas with soil pH outside the acceptable range are considered to pose potential risks to plants based on pH alone.

Jänsch et al. (2005) provides a pH threshold for earthworms of 4 to 9. Feisthauer et al. (2006) provides a tolerable pH range of 4.8 to 5.2 for earthworms. Environment Canada (Environment Canada 2004) uses an optimal pH range of 4 to 8 for artificial soil in their biological test method for tests for toxicity of contaminated soil to earthworms. Based on the above, the acceptable range of soil pH was considered to be 4 to 9. Those areas with soil pH outside the acceptable range are considered to pose potential risks to soil invertebrates based on pH alone. It is noted that the locations with lower pH and higher pH are co-located with exceedances for arsenic. Any remediation or risk management measures proposed to address risks to plants and soil invertebrates due to arsenic in soil would also address risks due to pH.

Groundwater (Current Conditions)

HQs calculated for terrestrial plants using the TRVs for groundwater are presented in Table 5.26. HQs were above one for all COCs, including PHC F2 (HQ = 36), aluminum (HQ = 10), arsenic (HQ = 350), cobalt (HQ = 5.0), iron (HQ = 3.7), zinc (HQ = 5.0) and sulphate (HQ = 4.5) suggesting potential risks to terrestrial plants from exposure to COCs in groundwater.

Concentrations of PHC F2 exceeded the TRV (FIGQG SODC) in four of 10 sampling locations.

Concentrations of aluminum exceeded the TRV (screening value from Efroymson et al. (1997)) in two of seven groundwater sampling locations. The TRV used in the assessment was based on laboratory studies including sensitive species that are likely not present at the Site.

Concentrations of arsenic exceeded the TRV (screening value from Efroymson et al. (1997)) in all seven groundwater sampling locations. The TRV used in the assessment was based on laboratory studies including sensitive species that are likely not present at the Site. In addition, there was some uncertainty in the value as there were a limited number of studies and species considered in the derivation of the TRV.

Concentrations of cobalt exceeded the TRV (screening value from Efroymson et al. (1997)) in two of seven groundwater sampling locations. The TRV used in the assessment was based on laboratory studies including sensitive species that are likely not present at the Site. In addition, there was some uncertainty in the value as there were a limited number of species considered in the derivation of the TRV.

Concentrations of iron exceeded the TRV (screening value from Efroymson et al. (1997)) in four of seven groundwater sampling locations. The TRV used in the assessment was based on laboratory studies including sensitive species that are likely not present at the Site. In addition, there was some uncertainty in the value as there were a limited number of studies considered in the derivation of the TRV.

Concentrations of zinc exceeded the TRV (screening value from Efroymson et al. (1997)) in one of seven groundwater sampling locations. The TRV used in the assessment was based on laboratory studies including sensitive species that are likely not present at the Site. In addition, there was some uncertainty in the value as there were a limited number of studies and species considered in the derivation of the TRV.

Sulphate concentrations exceed the TRV (BC MECCS WQG protective of aquatic life) of 128 mg/L in three out of seven groundwater sampling locations. The TRV used in the assessment was based on toxicity to aquatic invertebrates, which were more sensitive than the aquatic plants in the studies included in the WQG derivation (BC MECCS 2019a). This may overestimate the risks to terrestrial plants.

Despite the conservative assumptions discussed above, potential risks to terrestrial plants and soil invertebrates from exposure to PHC F2, aluminum, arsenic, cobalt, iron, zinc and sulphate in groundwater cannot be ruled out.

5.4.2 Mammals and Birds (Current Conditions)

The estimated exposures to COCs (total doses from all exposure pathways) as determined using a food chain model were compared to literature-based TRVs for effects on survival, growth and reproduction to determine HQs. An HQ of less than or equal to one was considered to represent a negligible risk to a ROC from exposure to the COC, while an HQ of greater than one was considered to represent a potential risk to the ROC from exposure to the COC. A sample calculation is provided in Appendix F.

For each mammal and bird evaluated, the HQs for incidental soil ingestion and food consumption are provided in Table 5.27.

For the caribou, muskox, grizzly bear and wolverine, HQs for incidental soil ingestion and food consumption were less than the target HQ of one for all COCs. As such risks to these receptors from all COCs in soil are negligible.

For the arctic hare and the arctic ground squirrel, HQs for incidental soil ingestion and food consumption were higher than the target HQ of one for arsenic (HQ = 4.7 and 7.3, respectively). Arsenic was considered to be 100% bioavailable (i.e., no adjustment was made for possible limited bioavailability in soil and food), which is a conservative assumption. The TRV for arsenic for mammals is based on a NOAEL (a TRV based on a LOAEL was not available). The TRV used in the assessment has likely resulted in an overestimate of toxicity to the arctic hare.

Despite the conservative assumptions discussed above, the potential for risks to the arctic hare and arctic ground squirrel from arsenic cannot be ruled out.

For the willow ptarmigan, HQs for incidental soil ingestion and food consumption were higher than the target HQ of one for cyanide (HQ = 7.6) and arsenic (HQ = 1.5). Arsenic and cyanide were considered to be 100% bioavailable (i.e., no adjustment was made for possible limited bioavailability in soil and food), which is a conservative assumption. The TRV for arsenic for birds is based on a 20% effective concentration (EC₂₀) for reproduction, growth and mortality endpoints in birds. Uncertainty factors were applied to the EC₂₀ to account for short exposure durations and mortality endpoints. The TRV for cyanide for birds is based on an LD₅₀ and an uncertainty factor of 10 was applied. The arsenic and cyanide TRVs used in the assessment may have resulted in an overestimate of toxicity to the willow ptarmigan. Despite the conservative assumptions discussed above, the potential for risks to the willow ptarmigan from arsenic and cyanide cannot be ruled out.

Several COCs could not be quantitatively evaluated due to lack of an appropriate TRVs for mammals or birds. Risks due to these COCs were evaluated qualitatively below.

- Sulphides in the natural environment are converted to sulphates through oxidation reactions (BC MECCS 2013). Mammals and birds are exposed to sulphides (e.g. hydrogen sulphide) through inhalation exposure as sulphides readily volatilize into air (HSDB 2012a). Exposure by mammals and birds via the inhalation pathway is considered negligible as vapours would be rapidly mixed with ambient air and diluted, resulting in concentrations that would pose negligible risks to mammals and birds. This approach is consistent with that used by the US Department of Energy (DOE; Sample and Suter 1994) and the US EPA (2005) where inhalation of contaminants is considered negligible and exposure via this pathway is not assessed. There is a lack of toxicity data for mammals and birds for the oral route of exposure given that inhalation is the more relevant route of exposure. Based on this, sulphide is unlikely to pose risks to mammals and birds.

- Concentrations of sulphate were detected in all three soil samples analyzed, ranging from 348 to 821 mg/kg. Sulphate occurs naturally in the environment and is one of the least toxic anions (Health Canada 1994a). Health Canada (1994a) reports that the minimum lethal dose of magnesium sulphate in mammals is 200 mg/kg and the HSDB reports an oral LD₅₀ for the mouse of 5989 mg/kg for sodium sulphate (HSDB 2018). Based on the above, there are potential risks to mammals and birds due to sulphate concentrations at the Site. It is noted that the sulphate concentrations are co-located with arsenic exceedances. Any remediation or risk management measures proposed to address risks to mammals and birds due to arsenic in soil would also address risks due to sulphate.
- Concentrations of tin were greater than the CCME SQGE (5 mg/kg) and background (<5 mg/kg) in only two out of 68 samples analyzed for this COC (7.2 and 8.8 mg/kg), and the remaining samples were below the laboratory detection limits. The exposure concentration (95% UCLM of 1.6 mg/kg) was below the SQGE. Elemental tin is considered to be generally non-toxic by the oral route (WHO 2005). Inorganic tin compounds have low solubility, poor absorption, low accumulations in tissues and rapid excretion. Consequently, risks from these compounds are considered to be low (WHO 2005). Based on the above, tin is unlikely to pose risks to populations of mammals and birds.
- Concentrations of ethylene glycol were detected in only one sample out of 21 samples analyzed for this COC (11 mg/kg), which was only slightly above the laboratory detection limit (< 10 mg/kg). Based on this, ethylene glycol is unlikely to pose risks to mammals and birds.
- There was no TRV available for PHC F2 for birds. Concentrations of PHC F2 were greater than the screening value from AEP (2019; surface soil remediation values for Wildlife Soil and Food Ingestion) (9800 mg/kg) in one sample (14000 mg/kg). The exposure concentration (95% UCLM of 1545 mg/kg) is below the screening value. Based on this, PHC F2 is unlikely to pose risks to birds.
- There was no TRV available for antimony for birds. Concentrations of antimony were greater than the CCME SQGE (20 mg/kg) in one sample (171 mg/kg) and the majority of the 135 other samples were below the laboratory detection limit. Based on this, antimony is unlikely to pose risks to birds.

Given the considerations above, the following potential risks were identified for incidental ingestion of soil and consumption of food items that have accumulated COCs from soil under current conditions:

- Arsenic: arctic hare, arctic ground squirrel, willow ptarmigan;
- Cyanide: willow ptarmigan; and
- Sulphate: mammals and birds.

5.4.3 Aquatic Life (Predicted Future Lake Conditions)

The calculated HQs for COCs in surface water for aquatic life are provided in Table 5.28 and discussed further below.

Cadmium

The calculated HQ for cadmium (HQ = 1.0) in East Lake was at the target HQ of one. Based on this and the following discussion, there are expected to be negligible risks to aquatic life from cadmium in East Lake from the predicted future lake condition:

- The calculated HQ is based on the highest predicted concentration in East Lake for the 50th percentile scenario (0.000041 mg/L in August and September). Predicted concentrations in East Lake in June and July were below the applied screening value for aquatic life.
- The surface water quality model used a number of conservative assumptions that have likely overestimated the predicted concentrations in East Lake.
- The recently re-evaluated CCME WQG-PAL, Freshwater was adopted as the TRV for cadmium in the current assessment. The guideline is based on hardness; therefore, it was adjusted to account for hardness. While hardness, and specifically calcium and magnesium ions, plays an important role in mitigating the toxicity of cadmium to aquatic organisms, other water quality parameters also influence toxicity, including DOC. These mitigating parameters have not been considered in the current WQG-PAL, Freshwater. Acute biotic ligand models (BLMs) (see discussion provided below for the copper BLM) that take into account these mitigating factors are available for fish (rainbow trout and fathead minnow) and invertebrates (*C. dubia*); however, these models require further validation before they can be used to derive guidelines. As well, there is currently no chronic BLM available for cadmium. It is likely that risks to aquatic life from cadmium in East Lake have been overestimated given that the TRV does not account for all factors known to mitigate the toxicity of this metal to aquatic receptors.

Cobalt

The calculated HQ for cobalt (HQ = 1.2) in East Lake was slightly above the target HQ of one. Based on this and the following discussion, potential risks to aquatic life are expected to be low from the predicted future lake condition:

- The calculated HQ is based on the highest predicted concentration in East Lake for the 50th percentile scenario (0.0048 mg/L in August and September). Predicted concentrations in East Lake in June and July were below the TRV.
- The surface water quality model used a number of conservative assumptions that have likely overestimated the predicted concentrations in East Lake.
- The BC MECCS WQG was adopted as the TRV for cobalt. It is based on a LOEC for reproductive effects in invertebrates to which a safety factor of two was applied. Therefore, potential risks to aquatic life may have been overestimated by a factor of two.
- The predicted surface water concentrations in East Lake are less than the MECP APV for cobalt of 0.0052 mg/L.

Copper

The calculated HQ for copper (HQ = 1.9) in East Lake was slightly above the target HQ of one. Based on this and the following discussion, potential risks to aquatic life are expected to be low from the predicted future lake condition:

- The calculated HQ is based on the highest predicted concentration in East Lake for the 50th percentile scenario (0.0039 mg/L in August and September). The predicted concentration for June (0.00034 mg/L) results in an HQ of less than one (HQ = 0.17) and the predicted concentration for July (0.0032 mg/L) results in an HQ slightly above the target HQ of one (HQ = 1.6).

- The surface water quality model used a number of conservative assumptions that have likely overestimated the predicted concentrations in East Lake.
- The CCME WQG-PAL was adopted as the TRV for copper in the current assessment. Since development of the WQG-PAL, there have been advances in the understanding of copper toxicity and the factors that influence toxicity to aquatic life in fresh waters. While hardness, and specifically calcium and magnesium ions, plays an important role in mitigating the toxicity of copper to aquatic life, other water quality parameters also influence toxicity (e.g., pH and dissolved organic carbon [DOC]). In recognition of this, the US EPA revised the national recommended freshwater criteria for aquatic life for copper (US EPA 2007c). In the revision, a BLM-based approach was used in place of the formerly applied hardness-based approach to calculate water quality criteria for copper. The BLM-based approach offers an improvement over the hardness-based approach because in addition to water hardness, it incorporates the protective effects of other water quality parameters on copper toxicity, including the competitive influences of various cations (e.g., calcium, potassium, magnesium and sodium), as well as the influence of important complexing anions (e.g., DOC, sulphate and chloride). Copper toxicity predictions based on the BLM have been shown to agree well with measured values in published studies (US EPA 2007c). Because the BLM-based approach uses receiving waterbody quality to develop site-specific water quality criteria, it is considered by the US EPA to utilize the best available science for copper (US EPA 2007c). The CCME also recognizes the importance of the BLM in the derivation of water quality guidelines for metals such as copper for which bioavailability and toxicity are affected by several water quality parameters (CCME 2007). A draft federal water quality guideline for aquatic life for copper has been derived by ECCC (2019) using a BLM-based approach. It is likely that risks to aquatic life from copper in East Lake have been overestimated given that the TRV does not account for all factors known to mitigate the toxicity of this metal to aquatic receptors.

pH

The predicted pH in Boot Lake (5.6 to 6.6) and East Lake (5.0 to 6.6) is lower than the CCME WQG-PAL (6.5 to 9.0) and background (6.3 to 6.9). Based on this and the following discussion, potential risks to aquatic life are expected to be moderate from the predicted future lake conditions:

- The predicted pH in Boot Lake and East Lake falls below the CCME WQG-PAL in July, August and September but is above the WQG-PAL in June.
- The surface water quality model used a number of conservative assumptions that may have overestimated transport of acidity to Boot Lake and East Lake, resulting in low pH, as a consequence of ARD-impacted seepage from the proposed esker-covered waste rock dome.
- The CCME WQG-PAL of 6.5 to 9.0 is based on effects in fish. Fish were not identified as ROCs for the ERA.
- Aquatic plants have an extremely wide pH tolerance range and major shifts in pH (2-3 pH units) would not impact the community structure or production (BC MECCS 1991).
- Pelagic invertebrates may experience adverse effects at pH below 6.0. Environment Canada (1996) uses an optimal pH range of 6.0 to 8.5 for water for daphnids in their biological test methods. Values for pH within the range of 6.5 to 8.5 are preferred. Environment Canada (2007) uses an optimal range of 6.0 to 8.5 for water for *C. dubia* in their biological test methods. Values for pH within the range of 7.0 to 8.5 are preferred.

- Benthic invertebrates may experience adverse effects at pH below 6.0. Little information is available on how pH affects the survival of *H. azteca*. de March (1979) reported that survival of this species was optimum at pH values of 6 to 8, and that pH values ranging from 4 to 5 resulted in gradual mortalities. It is not known if there is any information on the effects of fresh water with differing pH values on the growth rates or reproductive success of this amphipod. Environment Canada (2017b) uses an optimal pH range of 6.0 to 8.0 for *H. azteca* in their biological test methods.

5.4.4 Uncertainty Assessment

Uncertainties related to each component of the ERA and the potential implications that these uncertainties may have on the interpretation of risks are detailed in Table 5.29. In general, the uncertainties result in a representative estimation to overestimation of risks to ecological receptors.

5.5 Site Specific Target Levels

For each contaminated medium (i.e., soil, groundwater and lake surface water) SSTLs for the protection of ecological receptors (ecological-based SSTLs) were derived for the COCs and ROCs for which potential risks were identified, as summarized below. The resulting ecological-based SSTLs are presented in Table 5.30.

5.5.1 Soil

To summarize, potential risks were identified for the following COCs and ROCs under current conditions:

- PHC F1 to F3 for direct contact with soil by plants and soil invertebrates;
- Cyanide for direct contact with soil by plants and soil invertebrates, and incidental ingestion of soil and consumption of food items that have accumulated cyanide from the soil by the willow ptarmigan;
- Arsenic for direct contact with soil by plants and soil invertebrates, and incidental ingestion of soil and consumption of food items that have accumulated arsenic from the soil by the arctic hare, arctic ground squirrel and willow ptarmigan;
- Naphthalene for direct contact with soil by plants and soil invertebrates;
- pH for plants and soil invertebrates; and
- Sulphate for direct contact with soil by mammals and birds.

For plants and soil invertebrates, the SSTLs for soil are simply the TRVs used in the assessment (Section 5.3.1). For wildlife, the SSTLs for soil were calculated iteratively by inputting the calculated soil concentrations into the equations used to calculate doses and HQs to obtain an HQ of one, consistent with CCME and FCSAP guidance. The lowest SSTL derived for soil for a COC and ROC was selected as the ecological-based SSTL for the Site.

For PHCs F1, F2 and F3, SSTLs were derived for the protection of plants and soil invertebrates. The SSTLs for plants and soil invertebrates (210 mg/kg, 150 mg/kg, 300 mg/kg, for PHC F1 to F3, respectively) were selected as the ecological-based SSTLs for the Site.

For cyanide, SSTLs were derived for the protection of plants and soil invertebrates and the willow ptarmigan. The receptor-specific SSTL for plants and soil invertebrates (0.9 mg/kg) was selected as the ecological-based SSTL for cyanide for the Site.

For arsenic, SSTLs were derived for the protection of plants and soil invertebrates, the arctic hare, the arctic ground squirrel and the willow ptarmigan. However, the lowest receptor-specific SSTL (17 mg/kg for plants and soil invertebrates) was below the background concentration (79 mg/kg). Therefore, the background concentration (79 mg/kg) was selected as the ecological-based SSTL for arsenic for the Site.

For naphthalene, an SSTL was derived for the protection of plants and soil invertebrates. The receptor-specific SSTL for plants and soil invertebrates (0.6 mg/kg) was selected as the ecological-based SSTL for naphthalene for the Site.

For pH, SSTLs were derived for the protection of plants and soil invertebrates. The lower end of the background range and the upper end of the receptor-specific SSTL for plants (4.13 to 9) was selected as the ecological-based SSTL for pH for the Site.

A SSTL was not developed for sulphate because there was no available background data or TRV. It is noted that the sulphate concentrations are co-located with arsenic exceedances. Any remediation or risk management measures proposed to address risks to mammals and birds due to arsenic in soil would also address risks due to sulphate.

5.5.2 Groundwater

Potential risks to plants from direct contact with groundwater were identified for PHC F2, aluminum, arsenic, cobalt, iron, zinc and sulphate under current conditions. Therefore, SSTLs for the protection of plants were calculated for these COCs in groundwater. The SSTLs are simply the TRVs for groundwater used in the assessment (Section 5.3.1). These values are as follows: PHC F2 (1.8 mg/L), aluminum (0.3 mg/L), arsenic (0.001 mg/L), cobalt (0.06 mg/L), iron (10 mg/L), zinc (0.4 mg/L) and sulphate (128 mg/L).

5.5.3 Lake Surface Water

Potential risks to aquatic life from direct contact with surface water in Boot Lake and East Lake were identified for pH under the predicted future conditions. Therefore, a SSTL for aquatic life was developed for this parameter for these water bodies.

As discussed in Section 5.4.3, aquatic life can experience adverse effects from low pH in surface water. The most sensitive species are pelagic and benthic invertebrates which may experience adverse effects at pH below 6.0. Considering the background concentration ranged from 6.3 to 6.9 (50th percentile of 6.6) and the CCME WQG-PAL is 6.5 to 9.0, the SSTL was set at 6.5 to 9.0 for Boot Lake and East Lake.

5.6 Summary and Conclusions

An ERA was completed to evaluate the potential risks to ecological receptors from contamination associated with the historical operation of the Site as a gold mine considering that no remediation or risk management has been implemented through the FCRP, with respect to soil, groundwater and surface water seepage (current conditions). The ERA also evaluated potential risks to ecological receptors from ARD-impacted seepage and impacts to surface water quality in the receiving water bodies from the esker-covered waste rock dome proposed in the FCRP (predicted future lake conditions). If risks were identified, SSTLs were derived which represent acceptable levels of risk to ecological receptors. The final SSTLs for the Site, which incorporate protection of both human health and the environment, were considered in Section 6.0 below to confirm whether the measures outlined in the FCRP for the Site are sufficiently protective of human health and the environment.

- The following summarizes the results and conclusions of the ERA: A number of parameters were identified as COCs in soil, groundwater, seepage surface water and lake surface water for assessment in the ERA.
- Primary producers (terrestrial plants), invertebrates, mammals (arctic hare and arctic ground squirrel), and birds (willow ptarmigan) were identified as receptor groups for the terrestrial ecosystem. Two SAR (grizzly bear and wolverine) were also identified as ROCs for the terrestrial ecosystem.
- Primary producers (aquatic plants), pelagic invertebrates and benthic invertebrates were identified as receptor groups for the aquatic ecosystem.
- The exposure pathways selected for the terrestrial ecosystem included the following:
 - Direct contact with soil by terrestrial plants and invertebrates;
 - Incidental ingestion of soil by mammals and birds;
 - Consumption of food items (plants and/or prey) that have accumulated COCs from soil by mammals and birds; and
 - Direct contact with shallow groundwater by terrestrial plants.
- The exposure pathways selected for the aquatic ecosystem included direct contact with surface water by aquatic plants, pelagic invertebrates and benthic invertebrates.
- Risks to ROCs were determined through the comparison of the estimated exposures to COCs to literature-based TRVs for effects on survival, growth and reproduction to calculate a HQ. An HQ of less than or equal to one was considered to represent a negligible risk to these ROCs from exposure to the COC. An HQ of greater than one was considered to represent a potential risk to these ROCs from exposure to the COC.
- Risks to terrestrial plants and soil invertebrates were identified for direct contact with soil (pH, PHCs F1 to F3, cyanide, arsenic and naphthalene) under current conditions.
- Risks to terrestrial plants were identified for direct contact with groundwater (PHC F2, aluminum, arsenic, cobalt, iron, zinc and sulphate) under current conditions.
- Risks to mammals and birds (arctic hare, arctic ground squirrel and willow ptarmigan) were identified for incidental ingestion of soil and consumption of food items (cyanide and arsenic) under current conditions.
- Potential risks to aquatic life in Boot Lake and East Lake from ARD-impacted seepage from the proposed esker-covered waste rock dome (predicted future lake conditions) were as follows:
 - There are expected to be negligible risks to aquatic life from cadmium in East Lake;
 - The potential risks to aquatic life are expected to be low for cobalt in East Lake;
 - The potential risks to aquatic life are expected to be low for copper in East Lake; and
 - The potential risks to aquatic life are expected to be moderate for pH in Boot Lake and East Lake.
- Given that unacceptable risks were identified, ecological-based SSTLs were calculated for soil for pH (4.13 to 9), PHCs F1 to F3 (210, 150 and 300 mg/kg, respectively), cyanide (0.9 mg/kg), arsenic (79 mg/kg) and naphthalene (0.6 mg/kg) for soil. Ecological-based SSTLs were calculated for groundwater for PHC F2 (1.8

mg/L), aluminum (0.3 mg/L), arsenic (0.001 mg/L), cobalt (0.06 mg/L), iron (10 mg/L), zinc (0.4 mg/L) and sulphate (128 mg/L). Ecological-based SSTLs were derived for surface water (Boot Lake and East Lake) for pH (6.5 to 9.0).

- A number of conservative assumptions were used in the ERA such that potential risks have likely been overestimated and consequently the SSTLs are sufficiently protective of ecological receptors.

Section 6.0 below defines areas requiring remediation and/or risk management to mitigate risks to human health and the environment based upon the derived SSTLs and confirms whether the measures outlined in the FCRP are sufficiently protective of human health and the environment.

6.0 OVERALL CONCLUSIONS AND RECOMMENDATIONS

The objectives of the HHRA were as follows:

- To evaluate the potential risks to human health and the environment from the contamination associated with the historical operation of the Site as a gold mine;
- If potential risks are present, to derive SSTLs for remediation and/or risk management that represent acceptable levels of risk to human health and the environment; and
- To define areas requiring remediation and/or risk management to mitigate risks to human health and the environment based upon the derived SSTLs, if applicable, and to confirm whether the measures outlined in the FCRP are sufficiently protective of human health and the environment.

A summary of the identified potential risks to human health and the environment, the proposed SSTLs for the Site, the areas requiring remediation and/or risk management based upon the derived SSTLs and the sufficiency of the FCRP to address the identified potential risks are discussed in the sections below.

6.1 Summary of Potential Risks

Potential risks to human health and the environment from the contamination associated with the historical operation of the Site as a gold mine were evaluated. The HHRA and ERA identified potential risks to the following receptors and COCs:

- Risks to the Site Visitor were identified for direct contact with soil and inhalation of soil particulates (arsenic and lead), and consumption of plants (arsenic);
- Risks to the Community Member were identified for consumption of plants (arsenic);
- Risks to terrestrial plants and soil invertebrates were identified for direct contact with soil (pH, PHCs F1 to F3, cyanide, arsenic and naphthalene);
- Risks to terrestrial plants were identified for direct contact with groundwater (PHC F2, aluminum, arsenic, cobalt, iron, zinc and sulphate);
- Risks to mammals and birds (arctic hare, arctic ground squirrel and willow ptarmigan) were identified for incidental ingestion of soil and consumption of food items (cyanide and arsenic); and
- Potential risks to aquatic life in Boot Lake and East Lake from ARD-impacted seepage from the proposed esker-covered waste rock dome were expected to be moderate for pH. However, the surface water quality model used a number of conservative assumptions that may have overestimated transport of acidity to Boot Lake and East Lake, resulting in low predicted pH.

6.2 Site Specific Target Levels

Human health-based SSTLs for soil were derived based on the results of the HHRA (Section 4.5) and ecological-based SSTLs for soil, groundwater and surface water were derived based on the results of the ERA (Section 5.6). SSTLs protective of both human health and the environment were derived for the Site as the lower of the human health-based SSTL and the ecological-based SSTL for those COCs for which both were derived. If only a human health-based SSTL or an ecological-based SSTL were derived, that SSTL was adopted as the SSTL for the Site. Arsenic in soil was the only COC with both a human health-based SSTL (98 mg/kg) and an ecological-based

SSTL (79 mg/kg) and the ecological-based SSTL of 79 mg/kg was selected as the SSTL for the Site. The SSTLs for the Site represent acceptable levels of risk to human health and the environment and are presented in Table 6.1.

As described in the FCRP (Golder 2018) and summarized in Section 1.3, arsenic concentrations above 4000 mg/kg will be ex-situ remediated and will be excavated and disposed of within the shafts or into open crown pillars for isolation. Soil exceeding the SSTLs will be risk-managed with the placement of a coarse-grained engineered cover.

6.3 Areas Requiring Remediation/Risk Management and Sufficiency of the Final Closure and Reclamation Plan

Locations where soil and groundwater concentrations are above the SSTLs for the Site and requiring remediation and/or risk management are indicated on Figures 13 and 14, respectively. As discussed previously, arsenic concentrations above 4000 mg/kg will be ex-situ remediated and will be excavated and disposed of within the shafts or into open crown pillars for isolation. The SSTLs can be used to guide the remediation and/or risk management of the impacted soil left in-place. Soil exceeding the SSTLs should be remediated to meet the SSTL or risk-managed with the placement of a coarse-grained engineered cover.

The FCRP (Golder 2018) outlines the remediation and risk management measures proposed to address contaminated soil and waste rock at the Site. Based on the results of the HHERA, the measures outlined in the FCRP were evaluated as to whether they are sufficiently protective of human health and the environment:

- Risks to human and ecological receptors from several COCs (pH, PHCs F1 to F3, cyanide, arsenic, lead and naphthalene) in soil were identified under current conditions. Exceedances of the SSTLs for soil (Figure 13) are located within the areas where waste rock will be removed or covered. The remediation and risk management measures outlined in the FCRP (e.g., placement of engineered cover) is considered sufficient to address these risks.
- Risks to ecological receptors (i.e., plants) from several COCs (PHC F2, aluminum, arsenic, cobalt, iron, zinc and sulphate) in groundwater were identified under current conditions. Exceedances of the SSTLs for groundwater (Figure 14) are located within the areas where waste rock will be removed or covered. The remediation and risk management measures outlined in the FCRP (e.g., placement of engineered cover) is considered sufficient to address these risks.
- Moderate risks to aquatic life from low pH were identified for Boot Lake and East Lake under predicted future lake conditions. Surface water quality modeling of receiving water bodies was completed to evaluate the performance of the proposed granular esker cover of the waste rock dome with respect to limiting generation of ARD-impacted seepage from the waste rock dome. Based on the identified risks to aquatic life, the proposed risk management measures outlined in the FCRP (i.e., waste rock consolidation and placement of engineered cover) may not be sufficient to fully address the potential risks from low pH in these lakes. The water quality model used a number of conservative assumptions that may have overestimated transport of acidity to Boot Lake and East Lake, resulting in low pH. Given this, water quality monitoring is recommended for Boot Lake, East Lake and Lower Sewage Lake. The results of the monitoring will be used to assess the current conditions, provide data to evaluate the conservatism of the water quality model and verify the conclusion of negligible risks to aquatic life from metals (cadmium, cobalt and copper). It is anticipated that the current water quality in these lakes would be improved with the implementation of the

FCRP (waste rock consolidation and placement of engineered cover). The recommended water quality monitoring is briefly described below. A more detailed monitoring program can be developed under a separate scope of work:

- Before implementation of the FCRP, it is recommended that one sample is collected from each water body and submitted for analysis of the following parameters: pH, hardness, DOC, temperature, alkalinity, anions, sulphate and metals.
- After implementation of the FCRP, monitoring at a frequency of two sampling events per season (one at freshet and one late in the thawed season) for three years is recommended to confirm pH and metal concentrations in the water bodies.
- Contingent on the results of the water quality monitoring in the lakes, other measures may need to be considered.

In summary, the measures outlined in the FCRP are sufficiently protective of human health and the environment with respect to soil and groundwater; however, additional measures should be considered with respect to ARD-impacted seepage from the proposed esker-covered waste rock dome and potential reductions in pH in Boot Lake and East Lake. Water quality monitoring is recommended to assess the current conditions, provide data to evaluate the conservatism of the water quality model and to confirm the conclusion of negligible/low risks to aquatic life from metals.

7.0 LIMITATIONS

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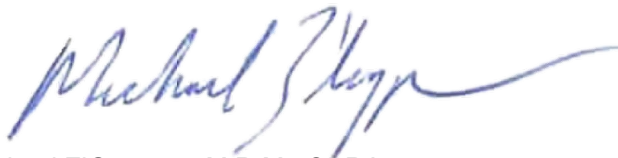


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Tables

Table 4.1
Exposure Durations and Frequencies
Lupin Mine, Nunavut

Parameter	Community Member		Composite Community Member ^(a)					Site Visitor	
	Adult	Toddler	Infant	Toddler	Child	Adolescent	Adult	Adult	Female ^(e)
Hours per day on Site ^(b)	NA	NA	NA	NA	NA	NA	NA	2	24
Days per week on Site ^(c)	NA	NA	NA	NA	NA	NA	NA	7	7
Weeks per year on Site ^(d)	NA	NA	NA	NA	NA	NA	NA	2	NA
Dermal exposure events (per day)	NA	NA	NA	NA	NA	NA	NA	1	1
Years exposed	60	4.5	0.5	4.5	7	8	60	60	80
Life expectancy	80	80	80	80	80	80	80	80	NA
Days per year ingesting plants ^(d)	365	365	365	365	365	365	365	14	365

Notes:

Based on Health Canada (2012) unless otherwise indicated.

NA – not applicable

(a) Composite receptor is exposed from the infant life stage through to and including adulthood, and is applicable for the community member.

(b) For the Site Visitor, assumed 2 hours (rounded from 121 minutes) per day playing on dirt, from Table 16-1 in US EPA (2011).

(c) For the Site Visitor, assumed 7 days per week could be spent visiting the Site.

(d) For the Site Visitor, assumed 2 weeks per year could be spent hunting/fishing on the Site.

(e) Lead and vanadium are considered developmental toxicants and as such, a Female Site Visitor was considered for the evaluation of non-carcinogenic risks.

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

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Prepared by: SG

Checked by: AF

Table 4.2
Receptor Characteristics
Lupin Mine, Nunavut

Parameter	Community Member		Composite Community Member ^(a)					Site Visitor	
	Adult	Toddler	Infant	Toddler	Child	Adolescent	Adult	Adult	Female ^(e)
Age	≥ 20 yrs	7 mo. - 4 yrs	0 mo. - 6 mo.	7 mo. - 4 yrs	5 to 11 yrs	12 to 19 yrs	≥ 20 yrs	≥ 20 yrs	≥ 20 yrs
Years at specific life stage	60	4.5	0.5	4.5	7	8	60	60	60
Body Weight (kg)	70.7	16.5	8.2	16.5	32.9	59.7	70.7	70.7	70.7
Soil ingestion rate (kg/d)	0.00002	0.00008	0.00002	0.00008	0.00002	0.00002	0.00002	0.00002	0.00002
Surface water ingestion rate (L/hr) ^(b)	NA	NA	NA	NA	NA	NA	NA	0.01	0.01
Inhalation rate (m ³ /day) ^(c)	NA	NA	NA	NA	NA	NA	NA	16.6	16.6
Ingestion rate - plants (kg/d) ^(d)	0.000434	0.000434	0	0.000434	0.000434	0.000434	0.000434	0.00434	0.00434
Skin Surface Area (cm²)									
Hands	890	430	320	430	590	800	890	890	890
Arms (upper and lower)	2500	890	550	890	1480	2230	2500	2500	2500
Legs (upper and lower)	5720	1690	910	1690	3070	4970	5720	5720	5720
Soil loading to exposed skin (kg/cm²/event)									
Hands	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07	1.00E-07
Surfaces other than hands	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-08

Notes:

Based on Health Canada (2012) unless otherwise indicated.

cm² = square centimetre; kg = kilogram; kg/cm²/event = kilogram per square centimetre per event; kg/d = kilogram per day; L/d = litres per day; L/hr = litres per hour; m³/day = cubic metre per day; mg/cm² = milligram per square centimetre; mL/hour = millilitre per hour; mo. = months; NA = not applicable; yrs = years

(a) Composite receptor is exposed from the infant life stage through to and including adulthood, and is applicable for the community member.

(b) Health Canada (2012b) reports an average water ingestion rate of 0.024 L/d for adults during swimming. As exposure via incidental ingestion of seepage is expected to be significantly less than during swimming, an ingestion rate of 0.01 L/d was assumed for the Site Visitor.

(c) Assumed the inhalation rate for the adult from Health Canada (2012).

(d) Assumed a plant ingestion rate of 0.00434 kg/d for all life stages based on traditional diet data from Saskatchewan (FNFNES, 2018). Calculated based on ingestion rates for bearberry, bilberry (includes blueberry), cranberry and Labrador tea. The plant ingestion rate for the Community Member was adjusted by a factor of 0.1 based on the assumption that 10% of the Community Member's intake of plants would come from the Site.

(e) Vanadium is considered a developmental toxicant and as such, a Female Site Visitor was considered for the evaluation of non-carcinogenic risks.

References:

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

Health Canada. 2012a. Guidelines for Canadian Recreational Water Quality. Third Edition. Water, Air and Climate Change Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario (Catalogue No H129-15/2012E). April 2012.

Prepared by: SG

Checked by: AF

Table 4.3
Bioaccumulation Screening of Metals and Glycols
Lupin Mine, Nunavut

Parameter	BAF ⁽¹⁾	BCF ⁽²⁾	Log K _{ow} ⁽³⁾⁽⁴⁾	Considered to Bioaccumulate? ⁽⁵⁾
Metals				
Sulphide	1 ⁽⁷⁾	--	--	No
Sulphate	--	0.5	--	No
Total Cyanide	1 ⁽⁷⁾	--	--	No
Total Antimony (Sb)	--	2 to 9	--	No
Total Arsenic (As)	0.0025	--	--	No
Total Barium (Ba)	0.0566	--	--	No
Total Beryllium (Be)	NA	NA	NA	No
Total Cadmium (Cd)	0.3333	--	--	No
Total Chromium (Cr)	0.0846	--	--	No
Total Cobalt (Co)	0.0205	--	--	No
Total Copper (Cu)	0.1963	--	--	No
Total Lead (Pb)	0.1054	--	--	No
Total Mercury (Hg)	0.0543	--	--	No
Total Molybdenum (Mo)	1 ⁽⁷⁾	--	--	No
Total Nickel (Ni)	0.2488	--	--	No
Total Selenium (Se)	NA	NA	NA	No
Total Silver (Ag)	0.004	--	--	No
Total Thallium (Tl)	NA	NA	NA	No
Total Tin (Sn)	1 ⁽⁷⁾	--	--	No
Total Uranium (U)	0.0001 to 0.1 ⁽⁶⁾	--	--	No
Total Vanadium (V)	0.0123	--	--	No
Total Zinc (Zn)	0.7717	--	--	No
Glycols				
Diethylene glycol	--	3	--	No
Ethylene glycol	--	10	--	No
Propylene glycol	--	3	--	No
Triethylene glycol	--	3	--	No

Notes:

Tables should be read in conjunction with the accompanying document.

-- = no value available; BAF = bioaccumulation factor; BCF = bioconcentration factor; Log K_{ow} = log of the octanol-water coefficient; NA = not applicable, parameter was not detected above background concentration.

⁽¹⁾ Sample, B.E., Beauchamp, J.J., Efroymson, R.A. and Suter II, G.W. 1998. Development and Validation of Bioaccumulation Models for Small Mammals. Prepared for the US Department of Energy, Office of Environmental Management. ES/ER/TM-219. February 1998.

⁽²⁾ Hazardous Substances Data Bank (HSDB). 2019. Available online at <https://toxnet.nlm.nih.gov/newtoxnet/hsdb.htm>

⁽³⁾ Risk Assessment Information System (RAIS). 2019. Chemical Parameters. Available online at <https://rais.ornl.gov/>

⁽⁴⁾ Ontario Ministry of Environment and Climate Change (MOECC). 2016. Modified Generic Risk Assessment Approved Model. November 2016.

⁽⁵⁾ As per CEPA (1999), a parameter was considered to bioaccumulate if the BAF (or BCF in the absence of a BAF) is > 5000. If neither a BAF nor BCF is determined, a substance is considered to bioaccumulate if the log K_{ow} is > 5.

CEPA (Canadian Environmental Protection Act). 1999. Persistence and Bioaccumulation Regulations. Current to June 20, 2019. Published by the Minister of Justice at: <http://laws-lois.justice.gc.ca>

⁽⁶⁾ Canadian Council of Ministers of the Environment (CCME). 2007. Canadian Soil Quality Guidelines for Uranium: Environmental and Human Health. Scientific Supporting Document.

⁽⁷⁾ In the absence of a BAF, BCF or log K_{ow}, a BAF of one was assumed as per the protocol developed by the Environmental Restoration Division (ERD) of the Savannah River Site (SRS) (US DOE, 1999).

Prepared by: SG

Checked by: AF/SG

Table 4.4
Screening of Soil for Human Health
Lupin Mine, Nunavut

Parameter	Unit	Background Concentration ⁽¹⁾	Screening Values				Maximum Measured Concentration - All depths ⁽⁵⁾	Retain as a COC for Direct Contact with and/or Ingestion of Soil Pathway? ⁽⁶⁾	Retain as a COC for Consumption of Plants? ⁽⁷⁾	Retain as a COC for Consumption of Wild Game? ⁽⁸⁾	
			CCME SQGHH ⁽²⁾ /CCME CWS ⁽³⁾			Other Guidelines/Standards ⁽⁴⁾					
			Soil Ingestion	Soil Dermal Contact	Produce, Meat and Milk or Generic SQG ⁽¹⁶⁾						
Petroleum Hydrocarbons (PHCs) and BTEX											
Benzene	mg/kg	--	110	250	--	NR	<0.8 (0.494)	No	No ⁽²²⁾	No ⁽²³⁾	
Ethylbenzene	mg/kg	--	10000	58000	--	NR	7.8	No	No ⁽²²⁾	No ⁽²³⁾	
Toluene	mg/kg	--	22000	220000	--	NR	8.3	No	No ⁽²²⁾	No ⁽²³⁾	
m,p-Xylenes	mg/kg	--	--	--	--	--	24	No (See Xylenes, Total)	No (See Xylenes, Total)	No (See Xylenes, Total)	
o-Xylene	mg/kg	--	--	--	--	--	15	No (See Xylenes, Total)	No (See Xylenes, Total)	No (See Xylenes, Total)	
Xylenes, Total	mg/kg	--	150000	NA	--	NR	92	No	No ⁽²²⁾	No ⁽²³⁾	
Petroleum Hydrocarbons - F1 (C6-C10)	mg/kg	--	12000		--	NR	4701	No	No ⁽²²⁾	No ⁽²³⁾	
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	mg/kg	--	12000		--	NR	2650	No	No ⁽²²⁾	No ⁽²³⁾	
Petroleum Hydrocarbons - F2 (C10-C16)	mg/kg	--	6800		--	NR	14000	Yes	No ⁽²²⁾	No ⁽²³⁾	
Petroleum Hydrocarbons - F3 (C16-C34)	mg/kg	--	15000		--	NR	4400	No	No ⁽²²⁾	No ⁽²³⁾	
Petroleum Hydrocarbons - F4 (C34-C50)	mg/kg	--	21000		--	NR	2700	No	No ⁽²²⁾	No ⁽²³⁾	
Metals and Physical Parameters											
pH	pH	4.13 to 5.67	6 to 8			NR	2.7 to 12.5	No ⁽¹⁷⁾	No ⁽¹⁷⁾	No ⁽¹⁷⁾	
Sulphide	mg/kg	--	--	--	--	--	21.9	No ⁽¹⁸⁾	No ⁽¹⁸⁾	No ⁽²⁴⁾	
Sulphate	mg/kg	--	--	--	--	--	821	No ⁽¹⁹⁾	No ⁽¹⁹⁾	No ⁽²⁴⁾	
Total Cyanide	mg/kg	--	29 ⁽⁹⁾	--	0.9	NR	21.9	No	Yes	No ⁽²⁴⁾	
Total Antimony (Sb)	mg/kg	<10	20 ⁽¹⁰⁾			NR	171	Yes	Yes	No ⁽²⁴⁾	
Total Arsenic (As)	mg/kg	79	12 ⁽¹¹⁾	--	12 ⁽¹¹⁾	NR	11700	Yes	Yes	No ⁽²⁴⁾	
Total Barium (Ba)	mg/kg	46	6800		750	NR	558	No	No	No ⁽²⁴⁾	
Total Beryllium (Be)	mg/kg	<0.5	75		4	NR	<0.5 (0.41)	No	No	No	
Total Cadmium (Cd)	mg/kg	1.3	1.4	--	1.4	NR	6.4	Yes	Yes	No ⁽²⁴⁾	
Total Chromium (Cr)	mg/kg	24	220	--	64	NR	94.3	No	Yes	No ⁽²⁴⁾	
Total Cobalt (Co)	mg/kg	7.0	40 ⁽¹⁰⁾			NR	34.9	No	No	No ⁽²⁴⁾	
Total Copper (Cu)	mg/kg	28	1100	--	63	NR	480	No	Yes	No ⁽²⁴⁾	
Total Lead (Pb)	mg/kg	<30	140	--	70	NR	3410	Yes	Yes	No ⁽²⁴⁾	
Total Mercury (Hg)	mg/kg	0.042	6.6 ⁽¹²⁾	--	6.6 ⁽¹²⁾	NR	0.1	No	No	No ⁽²⁴⁾	
Total Molybdenum (Mo)	mg/kg	<4	5 ⁽¹⁰⁾			NR	22.8	Yes	Yes	No ⁽²⁴⁾	
Total Nickel (Ni)	mg/kg	20	200		45	NR	67.3	No	Yes	No ⁽²⁴⁾	
Total Selenium (Se)	mg/kg	<2	80		1	NR	<2	No	No	No	
Total Silver (Ag)	mg/kg	<2	20 ⁽¹⁰⁾			NR	2.5	No	No	No ⁽²⁴⁾	
Total Thallium (Tl)	mg/kg	<1	1 ⁽¹⁰⁾			NR	<1 (0.34)	No	No	No	
Total Tin (Sn)	mg/kg	<5	5 ⁽¹⁰⁾			NR	9.3	Yes	Yes	No ⁽²⁴⁾	
Total Uranium (U)	mg/kg	--	23		23	NR	3.8	No	No	No ⁽²⁴⁾	
Total Vanadium (V)	mg/kg	22	--	--	130	39	65.6	Yes	No	No ⁽²⁴⁾	
Total Zinc (Zn)	mg/kg	54	10000		250	NR	1570	No	Yes	No ⁽²⁴⁾	
Polycyclic Aromatic Hydrocarbons (PAHs)											
Acenaphthene	mg/kg	--	--	--	--	78	<1.5	No	No ⁽²²⁾	No ⁽²³⁾	
Acenaphthylene	mg/kg	--	--	--	--	7.8	<1	No	No ⁽²²⁾	No ⁽²³⁾	
Anthracene	mg/kg	--	--	--	--	5400	<1.9	No	No ⁽²²⁾	No ⁽²³⁾	
Benz[a]anthracene	mg/kg	--	--	--	--	NR	< 0.5	No ⁽²⁰⁾	No ⁽²²⁾	No ⁽²³⁾	
Benzo[a]pyrene	mg/kg	--	--	--	--	NR	< 0.5	No ⁽²⁰⁾	No ⁽²²⁾	No ⁽²³⁾	
Benzo[b]fluoranthene	mg/kg	--	--	--	--	NR	< 0.5	No ⁽²⁰⁾	No ⁽²²⁾	No ⁽²³⁾	
Benzo[g,h,i]perylene	mg/kg	--	--	--	--	NR	< 0.5	No ⁽²⁰⁾	No ⁽²²⁾	No ⁽²³⁾	
Benzo[k]fluoranthene	mg/kg	--	--	--	--	NR	< 0.5	No ⁽²⁰⁾	No ⁽²²⁾	No ⁽²³⁾	
Chrysene	mg/kg	--	--	--	--	NR	< 0.5	No ⁽²⁰⁾	No ⁽²²⁾	No ⁽²³⁾	
Dibenz[a,h]anthracene	mg/kg	--	--	--	--	NR	< 0.5	No ⁽²⁰⁾	No ⁽²²⁾	No ⁽²³⁾	
Fluoranthene	mg/kg	--	--	--	--	7.8	<0.5 (0.113)	No	No ⁽²²⁾	No ⁽²³⁾	
Fluorene	mg/kg	--	--	--	--	720	4.53	No	No ⁽²²⁾	No ⁽²³⁾	
Indeno[1,2,3-cd]pyrene	mg/kg	--	--	--	--	NR	< 0.5	No ⁽²⁰⁾	No ⁽²²⁾	No ⁽²³⁾	
Naphthalene	mg/kg	--	--	--	--	360	10.1	No	No ⁽²²⁾	No ⁽²³⁾	
Phenanthrene	mg/kg	--	--	--	--	5400 ⁽¹⁴⁾	3.74	No	No ⁽²²⁾	No ⁽²³⁾	
Pyrene	mg/kg	--	--	--	--	78	<0.5 (0.318)	No	No ⁽²²⁾	No ⁽²³⁾	
Benzo[a]pyrene TPE ⁽²⁵⁾	mg/kg	--	5.3			NR	1.2	No	No ⁽²²⁾	No ⁽²³⁾	
Glycols											
Diethylene glycol	mg/kg	--	--	--	--	15000	<10	No ⁽²¹⁾	No ⁽²¹⁾	No ⁽²¹⁾	
Ethylene glycol	mg/kg	--	--	--	960	73000	11	No	No	No ⁽²⁴⁾	
Propylene glycol	mg/kg	--	--	--	960 ⁽¹³⁾	260000 ⁽¹⁵⁾	<10	No	No	No ⁽²¹⁾	
Triethylene glycol	mg/kg	--	--	--	960 ⁽¹³⁾	150000	<10	No	No	No ⁽²¹⁾	

Table 4.4
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Notes:

Tables should be read in conjunction with the accompanying document.

COC = contaminant of concern; BTEX = benzene, toluene, ethylbenzene, and xylene; mg/kg = milligram per kilogram; NA = calculated guideline > 1,000,000 mg/kg; NR = not required (provincial screening values only used in absence of federal screening values); < = parameter not detected above method detection limit; -- = no screening value available; UCLM = upper confidence limit of the mean; TPE = total potency equivalent; HHRA = human health risk assessment.

⁽¹⁾ Calculated as the 95% UCLM of the site-specific background samples: SS76, 51171, 51172, 51173, 51174, 51175, 51176, 51177, 51178, 51179, 51180, 51181, 51182, 51183, 51184, 51185, 51186, 51187, 51188, 51189, 51190. For parameters with too few detected samples to calculate a 95% UCLM, the maximum concentration was used as the background concentration.

⁽²⁾ Canadian Council of Ministers of the Environment (CCME), 2010. Canadian Soil Quality Guidelines (SQGs) for the Protection of Human Health (SQGHH), Surface Soil, coarse grained soil, agricultural land use. Values based on incremental risk of 1.0 x 10⁻⁵ where applicable.

⁽³⁾ Canadian Council of Ministers of the Environment (2008) Canadian-Wide Standards (CWS) for Petroleum Hydrocarbons in Soil: Scientific Rationale. Supporting Technical Document. January 2008. Table 5.2 and 5.3 Tier 1 Levels (mg/kg soil) for PHC for Agricultural land use. Direct Contact (Ingestion + Dermal Contact). Coarse grained soil standards were used.

⁽⁴⁾ In the absence of federal guidelines/standards, the lowest of the available provincial guidelines/standards from the following regulatory bodies was selected:

Ontario Ministry of the Environment and Climate Change (MOECC). 2016. Modified Generic Risk Assessment "Approved Model". Soil Components for Table 2 - Full Depth, Potable Water Scenario, coarse textured soil, agricultural land use, soil contact S1 risk.

Alberta Environment and Parks (AEP). 2019. Alberta Tier 1 Soil and Groundwater Remediation Guidelines. Land Policy Branch, Policy and Planning Division. Table A-2: Surface Soil Remediation Guideline Values for Agricultural Land Use - Direct Soil Contact.

British Columbia Ministry of the Environment and Climate Change Strategy (BC MECCS). 2019. Environmental Management Act. Contaminated Sites Regulation (BC Reg. 175/96). Schedule 3.1 - Part 1: Numerical Soil Standards (Matrix 1 to 40) - Intake of Contaminated Soil. Column 4: Agricultural. Consolidation current to March 19, 2019.

⁽⁵⁾ Maximum measured concentrations for screening exposure by a Site Visitor and Community Member were calculated from soil samples of all depths. Values in brackets are the maximum detected concentration. The soil concentrations used in the HHRA represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).

⁽⁶⁾ Parameters were retained as COCs for direct contact and/or ingestion of soil by a Site Visitor if the maximum concentration exceeded the screening value and the background concentration.

⁽⁷⁾ In the absence of pathway-specific CCME guidelines/component values for consumption of plants, parameters were retained for the Site Visitor and Community Member if the maximum concentratoin exceeded the agricultural CCME SQG.

⁽⁸⁾ Parameters were retained as COCs for consumption of wild game by a Site Visitor and Community Member if the maximum soil concentration exceeded the background concentration and was considered to bioaccumulate as per Canadian Environmental Protection Act (CEPA, 1999).

⁽⁹⁾ Guideline is for free cyanide.

⁽¹⁰⁾ Screening value is the CCME Soil Quality Guideline (SQG) for the Protection of Environmental and Human Health. Agricultural land use.

⁽¹¹⁾ Guideline is for inorganic arsenic.

⁽¹²⁾ Guideline is for inorganic mercury.

⁽¹³⁾ The CCME SQG agricultural for ethylene glycol was used as a surrogate for other glycols.

⁽¹⁴⁾ Anthracene was used as a surrogate based on structural similarity and similar physical/chemical properties in the absence of federal, provincial or international guidelines/standards.

⁽¹⁵⁾ In the absence of federal or provincial guidelines/standards, a screening value was obtained from United States Environmental Protection Agency (US EPA). 2019. Regional Screening Levels (RSL) for Resident Soil (THQ=0.1), May 2019. Screening values for non-carcinogens were multiplied by 2 to adjust to a hazard quotient of 0.2 to be consistent with federal guidance.

⁽¹⁶⁾ In the absence of a Produce, Meat and Milk component value, the CCME SQG (surface soil, coarse grained soil, agricultural land use) was used for the screening of the consumption of plants pathway.

⁽¹⁷⁾ Given that the human stomach has a pH of between approximately 1 and 3, the soil pH is not expected to be of importance with respect to ingestion and absorption of COCs by human receptors. Soil pH may influence the transport of metals to other media such as plants and game. Given the lack of measured tissue concentrations, metals concentrations in these tissues have been calculated using literature uptake factors. This may under or overestimate the concentrations of some metals and is a source of uncertainty, as discussed in Section 6.7.

⁽¹⁸⁾ The daily intake of sulphides by Canadians has not been estimated (Health Canada, 1987b). In England, the maximum likely daily intake of dimethyl sulphide from artificially flavoured candies, soft drinks, creams and jellies was estimated to be 1.7 mg. Sulphides are present in a wide range of foods, including milk, beer, ale, meat and vegetables so the daily intake of sulphides is likely higher than that estimated based on only candies, soft drinks, creams and jellies. Based on a soil ingestion rate of 0.0002 kg/d for a Site Visitor and the maximum concentration for sulphide (21.9 mg/kg), the maximum daily intake would be about 0.004 mg/d. It has been estimated that an oral dose of 10,000 to 15,000 mg of sodium sulphide would be fatal to humans (Health Canada, 1987b). The maximum daily intake of a Site Visitor is well below the intake considered to be toxic. Therefore, sulphide was not retained for quantitative evaluation of direct contact by human receptors in the HHRA.

⁽¹⁹⁾ The estimated average daily dietary intake of sulphate from food, water and air is 500 mg (Health Canada, 1994). Given the soil ingestion rates of 0.0002 kg/d for a Site Visitor and the maximum concentration of sulphate (821 mg/kg), the maximum daily intakes would be 0.16 mg/d, which is well below the average daily dietary intake.

⁽²⁰⁾ Benzo[a]pyrene total potency equivalent concentration is below the screening value, therefore individual carcinogenic PAHs were not retained in the HHRA.

⁽²¹⁾ No guideline and not-detected.

⁽²²⁾ As PHCs and BTEX parameters do not tend to bioaccumulate in plants (Landsell and McConnell, 2003; CCME, 2008), they were not retained for further evaluation for consumption of plants. In addition, as plants exhibit very limited ability to accumulate PAHs from soils, and to translocate PAHs from root tissue into aboveground biomass (Simonich and Hites 1995; as cited by CCME, 2010), PAHs were not considered for the consumption of plants pathway.

⁽²³⁾ As per US EPA (2007), the bioaccumulation of PAHs in mammals and birds is expected to be negligible because of the rapid metabolism of these compounds following ingestion. Similarly, the CCME (2008) indicates that PHCs are readily metabolized and excreted by vertebrates and bioaccumulation would be similarly negligible. Therefore, the concentrations of PAHs and PHCs in wild game (e.g. caribou) were assumed to be zero and the consumption of wild game pathway was not assessed for these parameter groups.

⁽²⁴⁾ Parameter not considered to bioaccumulate or biomagnify as per CEPA (1999), therefore it was not retained for quantitative evaluation of consumption of wild game by human receptors in the HHRA.

⁽²⁵⁾ Benzo[a]pyrene TPE was calculated for potentially carcinogenic PAHs by multiplying their concentrations in soil by the following Benzo[a]pyrene potency equivalence factors and then summing the products: benz[a]anthracene= 0.1; benzo[a]pyrene = 1; benzo[b+j+k]fluoranthene = 0.1; chrysene = 0.01; benzo[g,h,i]perylene = 0.01; dibenz[a,h]anthracene = 1; indeno[1,2,3-cd]pyrene = 0.1.

Grey and bold	Indicates exceedances of applied screening value and above background concentration.
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Prepared by: SG/AF

Checked by: TD

Table 4.5
Screening of Seepage Surface Water for Human Health
Lupin Mine, Nunavut

Parameter	Unit	Background Concentration ⁽¹²⁾	Screening Values			Maximum Measured Concentration ⁽⁴⁾	Retain as a COC for Incidental Ingestion of Seepage Surface Water Pathway?
			HC CDWQ Guidelines ⁽¹⁾	Other Guidelines/Standards ⁽²⁾	Screening Value x60 (or x100) ⁽³⁾		Site Visitor ⁽⁵⁾
Petroleum Hydrocarbons							
Benzene	mg/L	<0.00040	0.005	NR	0.3	0.023	No
Toluene	mg/L	<0.00040	0.06	NR	3.6	0.023	No
Ethylbenzene	mg/L	<0.00040	0.14	NR	8.4	0.002	No
Xylenes	mg/L	<0.00080	0.09	NR	5.4	0.029	No
F1 (C6-C10) - BTEX	mg/L	<0.1	--	0.82	49	0.19	No
F2 (C10-C16)	mg/L	<0.1	--	0.30	18	1.3	No
Metals							
Total Aluminum (Al)	mg/L	0.0604	≤ 0.1 ⁽⁷⁾	9.5	570	10.9	No
Total Antimony (Sb)	mg/L	<0.00010	0.006	NR	0.36	0.022	No
Total Arsenic (As)	mg/L	0.00108	0.01	NR	0.6	0.364	No
Total Barium (Ba)	mg/L	0.00684	1	NR	60	0.0652	No
Total Beryllium (Be)	mg/L	<0.00010	--	0.004	0.24	0.00289	No
Total Bismuth (Bi)	mg/L	<0.000050	--	--	--	0.000067	No ⁽¹⁰⁾
Total Boron (B)	mg/L	<0.010	5	NR	300	0.693	No
Total Cadmium (Cd)	mg/L	0.0000154	0.005	NR	0.3	0.0042	No
Total Calcium (Ca)	mg/L	2.97	--	--	--	270	No ⁽¹⁰⁾
Total Cesium (Cs)	mg/L	0.000024	--	--	--	0.0038	No ⁽¹⁰⁾
Total Chromium (Cr)	mg/L	0.00018	0.05	NR	3	0.0145	No
Total Cobalt (Co)	mg/L	0.00113	--	0.003	0.18	0.422	Yes
Total Copper (Cu)	mg/L	0.00191	2	NR	120	0.173	No
Total Iron (Fe)	mg/L	0.167	≤ 0.3 ⁽⁸⁾	0.3	18	9.67	No
Total Lead (Pb)	mg/L	<0.000050	0.005	NR	0.3	0.0289	No
Total Lithium (Li)	mg/L	0.0036	--	0.008 ⁽⁶⁾	0.8	0.16	No
Total Magnesium (Mg)	mg/L	1.85	--	--	--	44.5	No ⁽¹⁰⁾
Total Manganese (Mn)	mg/L	0.0127	0.12	NR	7.2	3.77	No
Total Mercury (Hg)	mg/L	<0.0000050	0.001	NR	0.06	<0.0000050	No
Total Molybdenum (Mo)	mg/L	<0.000050	--	0.07	4.2	0.00252	No
Total Nickel (Ni)	mg/L	0.00795	--	0.10	6	1.06	No
Total Phosphorus (P)	mg/L	<0.050	--	--	--	0.126	No ⁽¹⁰⁾
Total Potassium (K)	mg/L	0.458	--	--	--	20.1	No ⁽¹⁰⁾
Total Rubidium (Rb)	mg/L	0.00149	--	--	--	0.0325	No ⁽¹⁰⁾
Total Selenium (Se)	mg/L	<0.000050	0.05	NR	3	0.000497	No
Total Silicon (Si)	mg/L	0.88	--	--	--	17.6	No ⁽¹⁰⁾
Total Silver (Ag)	mg/L	<0.000010	--	0.10	6	0.000045	No
Total Sodium (Na)	mg/L	1.58	≤ 200 ⁽⁸⁾	200	12000	32	No
Total Strontium (Sr)	mg/L	0.017	--	2.6 ⁽⁶⁾	260	1.31	No
Total Sulphur (S)	mg/L	4.86	--	--	--	309	No ⁽¹⁰⁾
Total Tellurium (Te)	mg/L	<0.00020	--	--	--	0.00022	No ⁽¹⁰⁾
Total Thallium (Tl)	mg/L	<0.000010	--	0.002	0.12	0.000158	No
Total Thorium (Th)	mg/L	<0.00010	--	--	--	0.00092	No ⁽¹⁰⁾
Total Tin (Sn)	mg/L	<0.00010	--	2.5 ⁽⁶⁾	250	0.00023	No
Total Titanium (Ti)	mg/L	<0.00030	--	--	--	0.254	No ⁽¹⁰⁾
Total Tungsten (W)	mg/L	<0.00010	--	0.003 ⁽⁶⁾	0.3	0.00086	No
Total Uranium (U)	mg/L	0.00003	0.02	NR	1.2	0.0262	No
Total Vanadium (V)	mg/L	<0.00050	--	0.0062	0.37	0.0107	No
Total Zinc (Zn)	mg/L	0.0048	≤ 5 ⁽⁸⁾	3	180	1.99	No
Total Zirconium (Zr)	mg/L	<0.00020	--	0.00032 ⁽⁶⁾	0.032	0.00063	No
Routine Physical and Chemical Parameters							
Anion Sum	meq/L	0.35	--	--	--	23	No ⁽⁹⁾
Cation Sum	meq/L	0.43	--	--	--	25	No ⁽⁹⁾
Hardness (CaCO3)	mg/L	16	--	--	--	1200	No ⁽⁹⁾
Ion Balance (% Difference)	%	11	--	--	--	6.6	No ⁽⁹⁾
Dissolved Nitrate (NO3)	mg/L	0.28	45	NR	2700	12	No
Nitrate plus Nitrite (N)	mg/L	0.0107	--	10	600	0.807	No
Dissolved Nitrite (NO2)	mg/L	<0.033	3	NR	180	0.17	No
Total Dissolved Solids	mg/L	49	≤ 500 ⁽⁸⁾	500	30000	1400	No
Conductivity	µS/cm	44	--	--	--	1660	No ⁽⁹⁾
Strong Acid Dissoc. Cyanide (CN)	mg/L	<0.0050	0.2	NR	12	<0.005	No
pH	pH	6.58	7.0 -10.5	NR	NA	8.27	No
Acidity (as CaCO3)	mg/L	2.7	--	--	--	68.4	No ⁽⁹⁾
Alkalinity, Bicarbonate (as CaCO3)	mg/L	2.7	--	--	--	123	No ⁽⁹⁾
Alkalinity, Carbonate (as CaCO3)	mg/L	<1.0	--	--	--	<1	No ⁽⁹⁾
Alkalinity, Hydroxide (as CaCO3)	mg/L	<1.0	--	--	--	<1	No ⁽⁹⁾
Alkalinity (PP as CaCO3)	mg/L	<2.0	--	--	--	<2	No ⁽⁹⁾
Alkalinity (Total as CaCO3)	mg/L	2.7	--	--	--	123	No ⁽⁹⁾
Bicarbonate (HCO3)	mg/L	6.7	--	--	--	140	No ⁽⁹⁾
Carbonate (CO3)	mg/L	<0.50	--	--	--	<0.50	No ⁽⁹⁾
Hydroxide (OH)	mg/L	<0.50	--	--	--	<0.50	No ⁽⁹⁾
Dissolved Sulphate (SO4)	mg/L	14.8	≤ 500 ⁽⁸⁾	NR	30000	840	No
Dissolved Chloride (Cl)	mg/L	0.97	≤ 250 ⁽⁸⁾	250	15000	36.4	No
Ammonia, Total (as N)	mg/L	<0.0050	--	--	--	2.26	No ⁽⁹⁾
Bromide (Br)	mg/L	<0.050	--	--	--	<0.50	No ⁽⁹⁾
Fluoride (F)	mg/L	0.039	1.5	1.5	90	1.11	No

Notes:

Tables should be read in conjunction with the accompanying document.

BTEX = Benzene, toluene, ethylbenzene, and xylene; COC = contaminant of concern; mg/L = milligrams per litre; meq/L = milliequivalents per litre; $\mu\text{S}/\text{cm}$ = microsiemens per centimeter; < = parameter not detected above laboratory method detection limit; $\leq$ = less than or equal to; -- = no screening value available; NR = not required (provincial screening value only used in absence of federal screening values); NA = not applicable; HHRA = human health risk assessment.

⁽¹⁾ Health Canada. 2019. Guidelines for Canadian Drinking Water Quality (HC CDWQ Guidelines) Summary Table. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. June 2019. When available, maximum allowable concentrations (MAC) were used.

⁽²⁾ In the absence of federal guidelines/standards, the lowest of the available provincial guidelines/standards from the following regulatory bodies was selected:

Ontario Ministry of the Environment and Climate Change (MOECC). 2016. Modified Generic Risk Assessment "Approved Model". Groundwater Components for Potable Water Scenario (Table 2), coarse textured soil, GW1. Alberta Environment and Parks (AEP). 2019. Alberta Tier 1 Soil and Groundwater Remediation Guidelines. Land Policy Branch, Policy and Planning Division. Table B-2: Groundwater Remediation Guidelines for Agricultural Land - Potable.

British Columbia Ministry of the Environment and Climate Change Strategy (BC MECCS). 2019. Environmental Management Act. Contaminated Sites Regulation (BC Reg. 175/96). Schedule 3.2 - Generic Numerical Water Standards. Column 6: Drinking Water. Consolidation current to March 19, 2019.

⁽³⁾ Adjustment factor of 60 is based on average water ingestion rates during recreational activities such as swimming from Health Canada (2012a). Health Canada assumes adults could be ingesting an average value of 0.024 L/d while swimming, which is approximately 60 times lower than the daily drinking water rate of an adult (1.5 L/d). Given that exposure by splashing and hand-to-mouth contact is far lower than would occur swimming, an adjustment factor of 60 was considered reasonable. The US EPA RSLs were derived based on an ingestion rate of 2.5 L/day for an adult, which is approximately 100 times higher than the ingestion rate while swimming. Therefore, the RSLs were adjusted by a factor of 100.

⁽⁴⁾ Maximum measured concentrations were calculated from 2019 data where available as it is considered to be most representative of current conditions. For parameters that were not analyzed in 2019, the 2017 data was used. The seepage surface water concentrations used in the HHRA represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).

⁽⁵⁾ For the Site Visitor, maximum measured concentrations were compared to the HC GCDWQ guidelines x60. If federal screening values were not available, the lowest of the available provincial guidelines/standards x60 were used.

⁽⁶⁾ In the absence of federal and provincial guidelines/standards, a screening value was obtained from United States Environmental Protection Agency (U.S. EPA) 2017, Regional Screening Levels (RSL) for tapwater (THQ=0.1), May 2019. Screening values for carcinogens was multiplied by 10 to adjust to a target cancer risk of 10^{-6} to be consistent with federal guidance. Screening values for non-carcinogens were multiplied by 2 to adjust to a hazard quotient of 0.2 to be consistent with federal guidance. The RSLs were derived based on an ingestion rate of 2.5 L/day for an adult, which is approximately 100 times higher than the ingestion rate while swimming. Therefore, the RSLs were adjusted by a factor of 100.

⁽⁷⁾ Operational guideline; applies to treatment plants using aluminum-based coagulants, it does not apply to naturally occurring aluminum found in groundwater. Operational guidelines were not used in the screening.

⁽⁸⁾ Aesthetic objective; based on taste. The aesthetic objectives were not used in the screening with the exception of sulphate. The aesthetic objective of 500 mg/L for sulphate is also protective of gastrointestinal effects in humans.

⁽⁹⁾ Physical water quality parameter and not directly toxic.

⁽¹⁰⁾ Ubiquitous in the environment, essential and/or non-toxic to humans (except when ingested in extreme quantities). See Section 4.1.3.2 in the text for discussion of each parameter.

⁽¹¹⁾ No guidelines and not detected.

⁽¹²⁾ Background concentration is measured surface water concentration from one sample collected in a creek north of the Site considered not to be impacted by the mine site. The data from 2019 was used where available as it is considered to be most representative of current conditions. For parameters that were not analyzed in 2019, the 2017 data was used.

Grey and bold Indicates exceedance of applied screening value.

Prepared by: SG/KL/AF

Checked by: TD/SG

Table 4.6
Relative Absorption Factors (RAFs)
Lupin Mine, Nunavut

COC	RAF _{Oral}	RAF _{Derm}	RAF _{Inh}
Soil			
Petroleum Hydrocarbons - F2 (C10-C16)	1 ^(b)	0.2 ^(a)	1 ^(a)
Cyanide	1 ^(b)	NA	NA
Antimony	1 ^(b)	0.1 ^(b)	1 ^(a)
Arsenic	0.5 ^(b) or 1 ^(e)	0.03 ^(a)	1 ^(a)
Cadmium	1 ^(b)	0.01 ^(a)	1 ^(a)
Chromium	1 ^(b)	NA	NA
Copper	1 ^(b)	NA	NA
Lead	1 ^(b)	1 ^(b)	1 ^(a)
Molybdenum	1 ^(b)	0.01 ^(a)	1 ^(a)
Nickel	1 ^(b)	NA	NA
Tin	1 ^(c)	1 ^(c)	1 ^(a)
Vanadium	1 ^(b)	0.1 ^(b)	1 ^(a)
Zinc	1 ^(b)	NA	NA
Surface Water^(d)			
Cobalt	1 ^(b)	0.01 ^(b)	NA

Notes:

All values based on Health Canada (2010) unless otherwise indicated

COC = Contaminant of concern; MOECC = Ministry of Environment and Climate Change; RAF_{Oral} = relative absorption factor from the gastrointestinal tract; RAF_{Derm} = relative dermal absorption factor; RAF_{Inh} = relative absorption factor for inhalation; NA = not applicable (pathway is incomplete).

(a) Health Canada (2010)

(b) MOECC 2016

(c) Value was conservatively assumed to be 1 in absence of guidance from Health Canada and the Ontario MOECC

(d) RAFs for surface water were adopted from groundwater values.

(e) A RAF of 0.5 is only applicable to soil exposures, therefore a RAF of 1 was used for the consumption of plants pathway.

References:

Health Canada, 2010. Federal Contaminated Site Risk Assessment In Canada: Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, version 2.

MOECC (Ministry of the Environment and Climate Change). 2016. Modified Generic Risk Assessment "Approved Model". November, 2016.

Prepared by: SG

Checked by: DL/KL

Table 4.7
Exposure Point Concentrations for COCs in Soil for Evaluation of Direct Contact and Consumption of Plants Pathways
Lupin Mine, Nunavut

COC	General Statistics					Exposure Concentration		Selected EPC ^{(d)(e)}
	Maximum Concentration ^(a)	N ^(b)	Minimum	Mean ^(c)	SD ^(c)	95% UCLM	Selected UCL Distribution	
Community Member and Site Visitor								
Petroleum Hydrocarbons - F2 (C10-C16)	14000	89	<10	1953	2880	1590	95% BCA Bootstrap UCL ^(f)	1590
Aliphatic C10-C12	--	--	--	--	--	--	--	572
Aliphatic C12-C16	--	--	--	--	--	--	--	700
Aromatic C10-C12	--	--	--	--	--	--	--	143
Aromatic C12-C16	--	--	--	--	--	--	--	175
Cyanide	21.9	14	<3	--	--	--	--	21.9
Antimony	171	91	<0.5	41	72.79	10.51	95% KM Approximate Gamma UCL	10.51
Arsenic	11700	91	4.8	1236	1989	1615	95% KM Approximate Gamma UCL	1615
Arsenic (total minus background)	--	--	--	--	--	--	--	1536
Cadmium	6.4	91	<0.05	0.605	1.474	0.442	95% BCA Bootstrap UCL ^(f)	0.442
Chromium	94.3	91	15	52.86	22.54	56.79	95% Student's-t UCL	56.79
Copper	480	91	8.8	44.31	68.1	61.38	95% BCA Bootstrap UCL ^(f)	61.38
Lead	3410	91	1.5	153.1	588.9	186.4	95% BCA Bootstrap UCL ^(f)	186.4
Molybdenum	22.8	91	<0.4	3.571	5.475	2.7	95% BCA Bootstrap UCL ^(f)	3
Nickel	67.3	91	9.7	34.4	17.53	37.49	95% BCA Bootstrap UCL ^(f)	37.49
Tin	9.3	91	<1	5.82	3.662	1.587	95% KM (t) UCL	1.587
Vanadium	65.6	91	12.2	36.44	14.57	38.98	95% Modified-t UCL ^(g)	38.98
Zinc	1570	91	13	68.47	163.8	130	95% BCA Bootstrap UCL ^(f)	130

Notes:

COC = contaminant of concern; EPC = exposure point concentration; N = total observations; SD = standard deviation; UCL = upper confidence limit; UCLM = upper confidence limit of the mean; µg/g = micrograms per gram; -- = not available; % = percent; < = less than reportable detection limit.

All values in µg/g unless otherwise indicated.

(a) Maximum concentration in soil corresponds to all soil depths. The soil concentrations used in the HHERA represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).

(b) Total observations (detected and non-detected)

(c) Mean and SD includes only detected values

(d) Selected EPC is the 95% UCLM.

(e) EPCs for petroleum hydrocarbon fractions were calculated using the percent compositions in Table 6.10.

(f) Suggested UCL was not considered reliable. The bias-corrected and accelerated bootstrap UCL was chosen as it is the preferred method to calculate 95% UCLM by Helsel and Gilroy (2012). See text Section 6.2.4.1.

(g) Two UCLs were generated by the program and the higher value was selected as a conservative approach.

Statistics were calculated using ProUCL software (US EPA, 2016). Output worksheets are presented in Appendix C.

References:

Helsel, D.R., and Gilroy, E.J. 2012. The Unofficial User's Guide to ProUCL 4. Practical Stats. 66 pp.

United States Environmental Protection Agency (US EPA), June 2016. ProUCL Version 5.1 Statistical Software for Environmental Applications of Data Sets With and Without Non-detect Observations

Prepared by: SG

Checked by: TD/KL

Table 4.8
Petroleum Hydrocarbon (PHC) Fraction Composition
Lupin Mine, Nunavut

COC	Proportion in Soil
Petroleum Hydrocarbons - F2 (C10-C16)	1
Aliphatic C10-C12	0.36
Aliphatic C12-C16	0.44
Aromatic C10-C12	0.09
Aromatic C12-C16	0.11

Notes:

All values based on Health Canada (2011) unless otherwise indicated
 COC = Contaminant of concern

References:

Health Canada, 2011. Federal Contaminated Site Risk Assessment Part IV: Spreadsheet Tool for Human Health Preliminary Quantitative Risk Assessment (PQRA). Spreadsheet designed and programmed by Meridian Environmental Inc. July 13, 2011.

Prepared by: SG

Checked by: TD

Table 4.9
Exposure Point Concentrations for COCs in Plants
Lupin Mine, Nunavut

COC	Soil EPC ^(a)	Uptake Equation	Calculated EPC in Plants Using Uptake Equation
Community Member and Site Visitor			
Cyanide	21.9	$C_p = C_s$	(d) 21.9
Antimony	10.51	$\ln(C_p) = 0.938 * \ln(C_s) - 3.233$	(c) 0.36
Arsenic	1615	$C_p = 0.03752 * C_s$	(c) 61
Arsenic (total minus background)	1536	$C_p = 0.03752 * C_s$	(c)€ 58
Cadmium	0.442	$\ln(C_p) = 0.546 * \ln(C_s) - 0.475$	(c) 0.40
Chromium	56.79	$C_p = 0.041 * C_s$	(c) 2.33
Copper	61.38	$\ln(C_p) = 0.394 * \ln(C_s) + 0.668$	(c) 9.88
Lead	186.4	$\ln(C_p) = 0.561 * \ln(C_s) - 1.328$	(c) 5.0
Molybdenum	2.7	$C_p = 0.25 * C_s$	(b) 0.68
Nickel	37.49	$\ln(C_p) = 0.748 * \ln(C_s) - 2.223$	(c) 1.63
Tin	1.587	$C_p = 0.030 * C_s$	(b) 0.048
Zinc	130	$\ln(C_p) = 0.554 * \ln(C_s) + 1.575$	(c) 71.64

Notes:

COC = contaminant of concern; EPC = exposure point concentration; mg/kg dry w = milligrams per kilogram dry weight; C_p = concentration in plants; C_s = concentration in soil

All values in mg/kg dry w unless otherwise indicated.

(a) Soil EPC is the 95% Upper Confidence Limit of the Mean. The soil concentrations used in the HHERA represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).

(b) Baes et al. 1984. Uptake equation uses the soil-to-plant concentration factor which is the ratio of activity concentration in plant parts usually associated with vegetative functions (leaves, stems, straw, etc.) in dry weight to the dry weight activity concentration in root zone at edible maturity or time of harvest.

(c) US EPA, 2007

(d) The CCME indicates that very few data are available on the uptake of cyanide from soil by plants and provides a BAF of 0.8 based on data for bush beans (CCME, 1997). Given the lack of data for cyanide it was conservatively assumed that the plant concentration was equivalent to the exposure concentration in soil.

(e) For arsenic, uptake into plants was also calculated based on the total concentration (1615 mg/kg) minus the background concentration (79 mg/kg)

References:

Baes III, C. F., Sharp, R. D., Sjoreen, A. L., & Shor, R. W. (1984). Review and analysis of parameters for assessing transport of environmentally released radionuclides through agriculture (No. ORNL-5786). Oak Ridge National Lab., TN (USA). Soil-to-plant elemental transfer coefficient for vegetative portions of food crops and feed plants.

CCME (Canadian Council of Ministers of the Environment). 1997. A Framework for Ecological Risk Assessment: Technical Appendices. The National Contaminated Sites Remediation Program. Winnipeg, MB.

United States Environmental Protection Agency (US EPA), 2007. Guidance for Developing Ecological Soil Screening Levels (Eco-SSL). Attachment 4-1. OSWER Directive 9285.7-55. Table 4a. Uptake Equations for Inorganics. Revised April 2007.

Prepared by: SG

Checked by: TD/KL

Table 4.10
Estimated Daily Intakes for Soil and Consumption of Plants
Lupin Mine, Nunavut

COC	Ingestion of Soil	Dermal Contact with Soil	Inhalation of Soil Particulates	Total Estimated Daily Intake of Soil	Consumption of Plants
Non-Carcinogens					
Adult Site Visitor					
Petroleum Hydrocarbons - F2 (C10-C16)				1.2E-03	NA
Aliphatic C10-C12	1.6E-04	2.8E-04	8.5E-09	4.4E-04	NA
Aliphatic C12-C16	2.0E-04	3.4E-04	1.0E-08	5.4E-04	NA
Aromatic C10-C12	4.0E-05	6.9E-05	2.1E-09	1.1E-04	NA
Aromatic C12-C16	4.9E-05	8.5E-05	2.6E-09	1.3E-04	NA
Antimony	3.0E-06	2.5E-06	1.6E-10	5.5E-06	8.4E-07
Arsenic	8.8E-06	4.5E-06	9.2E-10	1.3E-05	1.4E-04
Cadmium	1.3E-07	1.1E-08	6.6E-12	1.4E-07	9.4E-07
Lead ^(a)	5.3E-05	4.5E-04	3.3E-08	5.0E-04	3.1E-04
Molybdenum	7.6E-07	6.5E-08	4.0E-11	8.3E-07	1.6E-06
Tin	4.5E-07	3.8E-06	2.4E-11	4.3E-06	1.1E-07
Vanadium ^(a)	1.1E-05	9.4E-06	7.0E-09	2.0E-05	1.2E-05
Toddler Community Member					
Cyanide	NA	NA	NA	NA	5.8E-04
Antimony	NA	NA	NA	NA	9.4E-06
Arsenic	NA	NA	NA	NA	1.6E-03
Cadmium	NA	NA	NA	NA	1.0E-05
Chromium	NA	NA	NA	NA	6.1E-05
Copper	NA	NA	NA	NA	2.6E-04
Lead	NA	NA	NA	NA	1.3E-04
Molybdenum	NA	NA	NA	NA	1.8E-05
Nickel	NA	NA	NA	NA	4.3E-05
Tin	NA	NA	NA	NA	1.3E-06
Zinc	NA	NA	NA	NA	1.9E-03
Adult Community Member					
Cyanide	NA	NA	NA	NA	1.3E-04
Antimony	NA	NA	NA	NA	2.2E-06
Arsenic	NA	NA	NA	NA	3.7E-04
Cadmium	NA	NA	NA	NA	2.4E-06
Chromium	NA	NA	NA	NA	1.4E-05
Copper	NA	NA	NA	NA	6.1E-05
Lead	NA	NA	NA	NA	3.1E-05
Molybdenum	NA	NA	NA	NA	4.1E-06
Nickel	NA	NA	NA	NA	1.0E-05
Tin	NA	NA	NA	NA	2.9E-07
Zinc	NA	NA	NA	NA	4.4E-04
Carcinogens					
Adult Site Visitor					
Arsenic	6.6E-06	3.4E-06	6.9E-10	1.0E-05	1.1E-04
Arsenic (total minus background) ^(b)	6.3E-06	3.2E-06	6.6E-10	9.5E-06	1.0E-04
Cadmium	NA	NA	1.2E-09	1.2E-09	NA
Composite Community Member					
Arsenic	NA	NA	NA	NA	4.8E-04
Arsenic (total minus background) ^(b)	NA	NA	NA	NA	4.6E-04

Notes:

All values are in milligrams per kilogram per day (mg/kg-day)

COC = contaminant of concern; NA = not applicable

The soil concentrations used in the HHERA represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).

^(a) Daily intake presented is for female receptor

^(b) Daily intakes for arsenic were also calculated based on the total concentration (1615 mg/kg) minus the background concentration (79 mg/kg)

Prepared by: SG

Checked by: AF/KL

Table 4.11
Exposure Point Concentrations for COCs in Seepage Surface Water for Evaluation of Incidental Ingestion Pathway
Lupin Mine, Nunavut

COC	General Statistics					Exposure Concentration		Selected EPC ^(d)
	Maximum Concentration ^(a)	N ^(b)	Minimum	Mean ^(c)	SD ^(c)	95% UCLM	Selected UCL Distribution	
Site Visitor								
Cobalt	0.422	13	0.00105	0.167	0.147	0.24	95% Student's-t UCL	0.24

Notes:

COC = contaminant of concern; EPC = exposure point concentration; N = total observations; SD = standard deviation; UCL = upper confidence limit; UCLM = upper confidence limit of the mean; mg/L = milligrams per litre.

All values in mg/L unless otherwise indicated.

(a) Maximum concentration in seepage surface water corresponds to data from 2019. The seepage surface water concentrations used in the HHERA represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).

(b) Total observations (detected and non-detected)

(c) Mean and SD includes only detected values

(d) Selected EPC is the 95% UCLM for the site visitor, unless otherwise indicated.

Statistics were calculated using ProUCL software (US EPA, 2016). Output worksheets are presented in Appendix C.

References:

United States Environmental Protection Agency (US EPA), June 2016. ProUCL Version 5.1 Statistical Software for Environmental Applications of Data Sets With and Without Nondetect Observations.

Prepared by: SG

Checked by: TD

Table 4.12
Estimated Daily Intakes for Surface Water
Lupin Mine, Nunavut

COC	Ingestion of Surface Water	Dermal Contact with Surface Water	Total Estimated Daily Intake
Non-Carcinogens			
Adult Site Visitor			
Cobalt	3.39E-05	7.17E-06	4.11E-05

Notes:

All values are in milligrams per kilogram per day (mg/kg-day)

COC = contaminant of concern

The seepage surface water concentrations used in the HHERA represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).

Prepared by: SG

Checked by: AF

Table 4.13a
Carcinogenicity Classification Systems
Lupin Mine, Nunavut

Health Canada	US EPA	IARC	Description
Group I	Group A	Group 1	Human carcinogen
Group II	Group B	Group 2A	Probable human carcinogen
--	Group B1	--	Limited human evidence available
--	Group B2	--	Inadequate human evidence, sufficient animal evidence
Group III	Group C	Group 2B	Possible human carcinogen
Group IV	--	--	Unlikely human carcinogen
Group VI	Group D	Group 3	Unclassifiable as to human carcinogenicity
Group V	Group E	Group 4	Probably not carcinogenic to humans

Notes:

US EPA = United States Environmental Protection Agency; IARC = International Agency for Research on Cancer.

-- = carcinogenicity group not classified by agency.

Prepared by: TMG

Checked by: AA

Table 4.13b
Carcinogenicity Classifications for Contaminants of Concern
Lupin Mine, Nunavut

COC	Health Canada Classification ^(a)	US EPA Classification ^(b)	IARC Classification ^(c)	Assessed as a Carcinogen?
Petroleum Hydrocarbons - F2 (C10-C16)	NA	NA	NA	No
Cyanide	Group VI	Group D	NA	No
Antimony	NA	NA	NA	No
Arsenic	Group I	Group A	Group 1	Yes
Cadmium	Group II (inhalation)	Group B1	Group 1	Yes (inhalation)
Chromium	Group I (inhalation)	Group A (CrVI) Group D (CrIII)	Group 1 (CrVI) Group 3 (CrIII)	No ^(f)
Cobalt	NA	NA	Group 2B	No
Copper	NA ^(d)	Group D	NA	No
Lead	NA	Group B2	Group 2A	No
Molybdenum	NA ^(e)	NA	NA	No
Nickel	Group 1	NA	Group 1	No ^(f)
Tin	NA	NA	NA	No
Vanadium	NA	NA	NA	No
Zinc	NA ^(e)	Group D	NA	No

Notes:

NA = not available; COC = contaminant of concern; IARC = International Agency for Research on Cancer; US EPA = United States Environmental Protection Agency.

^(a) Health Canada (2010).

^(b) US EPA (2019).

^(c) IARC (2019).

^(d) IOM (Institute of Medicine of the National Academies), 2001 "There is little convincing evidence indicating that copper is causally associated with the development of cancer in humans"

^(e) IOM does not consider molybdenum or zinc carcinogenic to humans

^(f) Chromium and nickel are considered carcinogenic for inhalation exposure. Since chromium and nickel were only identified as COCs for plant consumption, it was not assessed as a carcinogen.

References:

Health Canada. 2010. Federal Contaminated Site Risk Assessment in Canada, Part V: Guidance on Human Health Detailed Quantitative Risk Assessment for Chemicals (DQRACChem). Dated September 2010.

IARC (International Agency for Research on Cancer). 2019. IARC Monographs on the Identification of Carcinogenic Hazards to Humans. Available online: <https://monographs.iarc.fr/agents-classified-by-the-iarc/>. Accessed January 2019.

US EPA (United States Environmental Protection Agency). 2019. Integrated Risk Information System (IRIS). National Center for Environmental Assessment, Office of Research and Development. Available Online: <https://www.epa.gov/iris>. Accessed August 2019.

Prepared by: SG

Checked by: DL/KL

Table 4.14: Toxicity Reference Values for Human Health Risk Assessment
Lupin Mine, Nunavut

COC	TDI (mg/kg/d)	Critical Effect	Study Duration	Principal Study	Reference	Oral Cancer Slope Factor (mg/kg-d) ⁻¹	Critical Effect	Study Duration	Principal Study	Reference
Petroleum Hydrocarbons - F2 (C10-C16)										
Aliphatic C10-C12	0.1	Hepatic and hematological changes	Chronic	TPHCWG (1997); CCME (2000)	MOECC, 2016	NA	NA	NA	NA	NA
Aliphatic C12-C16	0.1	Hepatic and hematological changes	Chronic	TPHCWG (1997); CCME (2000)	MOECC, 2016	NA	NA	NA	NA	NA
Aromatic C10-C12	0.04	Decreased body weight	Chronic	TPHCWG (1997); CCME (2000)	MOECC, 2016	NA	NA	NA	NA	NA
Aromatic C12-C16	0.04	Decreased body weight	Chronic	TPHCWG (1997); CCME (2000)	MOECC, 2016	NA	NA	NA	NA	NA
Cyanide	0.02	Decreased weight gain, thyroxin levels and myelin degeneration	Chronic	CCME, 1996 (based on Howard and Hanzal, 1955)	Health Canada, 2010	NA	NA	NA	NA	NA
Antimony	0.0004	Longevity, blood glucose, and cholesterol	Chronic	US EPA IRIS (1991)	MOECC, 2016	NA	NA	NA	NA	NA
Arsenic	0.0003	Hyperpigmentation, keratosis, possible vascular complications	Chronic	US EPA IRIS (1993); CalEPA ChREL (2000); ATSDR (2005, draft)	MOECC, 2016	1.8	Bladder, lung, liver	Chronic	Morales et al., 2000	Health Canada, 2010
Cadmium	0.001	Renal tubular dysfunction (proximal tubule epithelial cell damage), manifested by low molecular weight proteinuria	Chronic	HC (1986); Based on WHO (1972) and Friberg et al (1971)	Health Canada, 2010	42	Lung	Chronic	HC (1996); HC/EC (1994); Based on Takenaka et al (1983); Oldiges et al (1984)	Health Canada, 2010
Chromium	0.001	hepatotoxicity, irritation, or corrosion of the gastrointestinal mucosa, encephalitis	Chronic	Health Canada, 1979 (updated 1986)	Health Canada, 2010	NA	NA	NA	NA	NA
Cobalt	0.001	Polycythemia (disease state in which the volume percentage of red blood cells in the blood is elevated)	Chronic	Modified from ATSDR (2004)	MOECC, 2016	NA	NA	NA	NA	NA
Copper	0.091 (0-6 mo.)	hepatotoxicity, gastrointestinal effects	Subchronic	IOM, 2001 (based on Pratt et al., 1985; O'Donohue et al., 1993)	Health Canada, 2010	NA	NA	NA	NA	NA
	0.091 (7 mo.- 4 yrs)									
	0.11 (5-11 yrs)									
	0.126 (12-19 yrs)									
	0.141 (20+ yrs)									
Lead	0.0013 (a)	Cardiovascular effects (increase in systolic blood pressure of 1 mmHg)	Chronic	WHO, 2011	WHO, 2011	NA	NA	NA	NA	NA
Molybdenum	0.028	Reproductive effects	Subchronic	IOM (2001); Based on Fungwe et al (1990)	Health Canada, 2010	NA	NA	NA	NA	NA
Nickel	0.011	post-implantation perinatal lethality	Chronic	WHO, 2005 (based on SLI, 2000)	Health Canada, 2010	NA	NA	NA	NA	NA
Tin	0.6	Kidney and liver lesions	Chronic	NTP (1982); US EPA (1986); US EPA (1987)	HEAST, 2019	NA	NA	NA	NA	NA
Vanadium	0.0021 (a)	Developmental effects	Chronic	CalEPA DW (2000)	MOECC, 2016	NA	NA	NA	NA	NA
Zinc	0.5 (0-6 mo.)	Increased growth of infant: length, weight, and head circumference	Chronic	Walravens and Hambidge, 1976	Health Canada, 2010	NA	NA	NA	NA	NA
	0.5 (7 mo.- 4 yrs)									
	0.5 (5-11 yrs)									
	0.5 (12-19 yrs)									
	0.6 (20+ yrs)									

Notes:

TDI = tolerable daily intake; mg/kg-d = milligrams per kilogram per day; COC = contaminant of concern; NA = not applicable; HC = Health Canada; EC = Environment Canada; IOM = Institute of Medicine of the National Academies; WHO = World Health Organization; mo. = months; yrs = years.

(a) Lead and vanadium are considered developmental toxicants and as such, a Female Site Visitor was considered for the evaluation of non-carcinogenic risks.

References:

Health Canada, 2010. Federal Contaminated Site Risk Assessment In Canada: Part II: Health Canada Toxicological Reference Values (TRVs).
HEAST (Health Effects Assessment Summary Tables). 2019. Oak Ridge National Laboratory. Accessed August 2019. Available at: <https://epa-heast.oerl.gov/heast.php>
MOECC (Ministry of Environment and Climate Change). 2016. Modified Generic Risk Assessment (MGRA) "Approved" Model. November 2016.
US EPA (United States Environmental Protection Agency). 2001. Integrated Risk Information System (IRIS) Toxicological Profile for Quinoline. Available at: <https://www.epa.gov/iris>. Accessed January 2019.
WHO (World Health Organization). 2011. WHO Food Additive Series: 64 - Safety Evaluation of Certain Food Additives and Contaminants. Prepared by the seventy-third meeting of JECFA. Joint FAO/WHO Expert Committee on Food Additives. ISBN 978 924 166064 8.

Prepared by: SG
Checked by: DL

Table 4.15
Hazard Quotients for Soil
Lupin Mine, Nunavut

COC	Hazard Quotient ^(a)				
	Ingestion of Soil	Dermal Contact with Soil	Inhalation of Soil Particulates	Total Hazard Quotient for Soil	Consumption of Plants
Adult Site Visitor					
Petroleum Hydrocarbons - F2 (C10-C16)				1.6E-02	NA
Aliphatic C10-C12	1.6E-03	2.8E-03	8.5E-08	4.4E-03	NA
Aliphatic C12-C16	2.0E-03	3.4E-03	1.0E-07	5.4E-03	NA
Aromatic C10-C12	1.0E-03	1.7E-03	5.3E-08	2.7E-03	NA
Aromatic C12-C16	1.2E-03	2.1E-03	6.5E-08	3.4E-03	NA
Antimony	7.4E-03	6.4E-03	3.9E-07	1.4E-02	2.1E-03
Arsenic	2.9E-02	1.5E-02	3.1E-06	4.4E-02	4.8E-01
Cadmium	1.3E-04	1.1E-05	6.6E-09	1.4E-04	9.4E-04
Lead ^(b)	4.1E-02	3.5E-01	2.6E-05	3.9E-01	2.4E-01
Molybdenum	2.7E-05	2.3E-06	1.4E-09	3.0E-05	5.7E-05
Tin	7.5E-07	6.4E-06	3.9E-11	7.2E-06	1.9E-07
Vanadium ^(b)	5.3E-03	4.5E-03	3.3E-06	9.7E-03	5.5E-03
Toddler Community Member					
Cyanide	NA	NA	NA	NA	2.9E-02
Antimony	NA	NA	NA	NA	2.4E-02
Arsenic	NA	NA	NA	NA	5.3E+00
Cadmium	NA	NA	NA	NA	1.0E-02
Chromium	NA	NA	NA	NA	6.1E-02
Copper	NA	NA	NA	NA	2.9E-03
Lead	NA	NA	NA	NA	1.0E-01
Molybdenum	NA	NA	NA	NA	6.3E-04
Nickel	NA	NA	NA	NA	3.9E-03
Tin	NA	NA	NA	NA	2.1E-06
Zinc	NA	NA	NA	NA	3.8E-03
Adult Community Member					
Cyanide	NA	NA	NA	NA	6.7E-03
Antimony	NA	NA	NA	NA	5.5E-03
Arsenic	NA	NA	NA	NA	1.2E+00
Cadmium	NA	NA	NA	NA	2.4E-03
Chromium	NA	NA	NA	NA	1.4E-02
Copper	NA	NA	NA	NA	4.3E-04
Lead	NA	NA	NA	NA	2.4E-02
Molybdenum	NA	NA	NA	NA	1.5E-04
Nickel	NA	NA	NA	NA	9.1E-04
Tin	NA	NA	NA	NA	4.9E-07
Zinc	NA	NA	NA	NA	7.3E-04

Notes:

COC = contaminant of concern; HQ = hazard quotient; PHC = petroleum hydrocarbon; NA = not applicable, pathway not evaluated for this receptor

(a) The risks calculated based on soil concentrations represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).

(b) Daily intake presented is for female receptor

Bold and shaded Indicates an exceedance of target HQ of 0.2 (or 0.5 for PHCs F2)

Prepared by: SG

Checked by: AF/KL

Table 4.16
Incremental Lifetime Cancer Risks for Soil
Lupin Mine, Nunavut

COC	Incremental Lifetime Cancer Risk ^(c)				
	Ingestion of Soil	Dermal Contact with Soil	Inhalation of Soil Particulates	Total ILCR for Direct Contact with Soil	Consumption of Plants
Adult Site Visitor					
Arsenic ^(b)	1.2E-05	6.1E-06	1.2E-09	1.8E-05	1.9E-04
Arsenic (total minus background) ^(a)	1.1E-05	5.8E-06	1.2E-09	1.7E-05	1.8E-04
Cadmium	NA	NA	5.1E-08	5.1E-08	NA
Composite Community Member					
Arsenic ^(b)	NA	NA	NA	NA	8.7E-04
Arsenic (total minus background) ^(a)	NA	NA	NA	NA	8.3E-04

Notes:

COC = contaminant of concern; ILCR = incremental lifetime cancer risk; NA = not applicable, the exposure pathway/COC was not evaluated

^(a) Risks for arsenic were also calculated based on the total concentration (1615 mg/kg) minus the background concentration (79 mg/kg)

^(b) Risks for total concentrations of arsenic are provided for informational purposes only.

^(c) The risks calculated based on soil concentrations represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).

Bold and shaded Indicates an exceedance of target ILCR of 1E-05

Prepared by: SG
 Checked by: AF/KL

Table 4.17
Hazard Quotients for Surface Water
Lupin Mine, Nunavut

COC	Hazard Quotients ^(a)		Total Hazard Quotients
	Ingestion of Surface Water	Dermal Contact with Surface Water	
Adult Site Visitor			
Cobalt	3.4E-02	7.2E-03	4.1E-02

Notes:

COC = contaminant of concern; HQ = hazard quotient

Bold and shaded Indicates an exceedance of target HQ of 0.2

^(a) The risks calculated based on seepage surface water concentrations represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).

Prepared by: SG

Checked by: AF

Table 4.18
Uncertainty Assessment for the Human Health Risk Assessment
Lupin Mine

Assumption	Uncertainty	Over/Under Estimate Risk	Rationale
Problem Formulation			
Receptor selection	Low	Neutral	Receptors considered most likely to frequent the Site based on the future land use scenario (agricultural land use, considered to represent natural areas). Other receptors were considered to be less exposed. Therefore, the selected receptors are likely representative of those likely to use the Site and the level of uncertainty is low.
Receptor characteristics, exposure durations and frequencies	Low	Neutral/Overestimate	Receptor characteristics and exposure durations and frequencies were generally based on those provided by Health Canada. The use of Health Canada assumptions is considered to be conservative. Exposure amortization was not considered for COCs where there was no risk resulting from the comparison of the unamortized exposure to the chronic TRV. This is consistent with Health Canada (2016) guidance and is considered to be an overly conservative approach. Exposure amortization was appropriate for arsenic given that it does not persist in the body and is rapidly eliminated. Following oral exposure, urinary excretion is the primary route of excretion with whole-body clearance occurring within 1-3 days in humans and no expected retention in the body (ATSDR, 2007). Site specific assumptions are considered to be conservative and overestimate risk.
Body weights, soil ingestion rates, soil loading to exposed skin, inhalation rate	Low	Neutral	Assumptions were based on those provided by Health Canada. The use of the Health Canada assumptions is considered to provide realistic receptor characteristic assumptions as they are based on the Canadian population.
Ingestion rates for plants	Moderate	Overestimate	The plant ingestion rate was calculated based on traditional diet data from First Nations Food, Nutrition and Environment Study for Saskatchewan (Chan et al., 2018). The plant ingestion rate was calculated based on similar plants species that are present on the Site. The CCME (2006) considers that 10% and 50% of produce ingested is grown on-Site for residential land use and agricultural land use scenarios, respectively. Given the distance between the Site and the closest community, it was assumed that 10% of the plants ingested by the community member come from the Site. It was assumed that 100% of the plants the Site Visitor ingests would be from the Site.
Surface water ingestion rate	Low	Overestimate	Surface water ingestion rates were determined based on ingestion rates during swimming activities reported by Health Canada. As incidental ingestion of seepage surface water is expected to be far lower than would occur during swimming, the ingestion rate is considered to be conservative.
In the absence of screening values for incidental contact with surface water, screening for direct contact with seepage surface water was completed by using the drinking water screening values adjusted by a factor of 60.	Low	Overestimate	Health Canada (2012) assumes adults could be ingesting an average value of 0.024 L/d while swimming, which is approximately 60 times lower than the daily drinking water rate of an adult (1.5 L/d). Given that exposure by splashing and hand-to-mouth contact is far lower than would occur swimming, an adjustment factor of 60 was considered reasonable.
Exposure Assessment			
The 95% UCLMs of COCs in soil and seepage surface water were used to estimate exposure point concentrations.	Low	Overestimate	Health Canada (2010) describes the use of the 95% UCLM or the mean to calculate the exposure point concentration when data are sufficiently numerous and rigorous (i.e., when at least 4 detectable concentrations were available for a given dataset). Sufficient samples were collected to calculate a 95% UCLM for all COCs. The 95% UCLMs are conservative estimates of exposure. Where 95% UCLMs could not be computed, maximum concentrations were used.
Literature uptake equations were used to estimate COC concentrations in plants.	Low	Under- or overestimate	Uptake of metals into plants is influenced by soil pH. As the Site has a wide range of soil pH (i.e., 2.7 to 12.5), the use of literature uptake equations may under or overestimate risk. While the uptake of some metals into plants is influenced by soil pH, the uptake equations were still deemed appropriate to estimate COC concentrations in plants. This is because for those metals evaluated with respect to pH, the source of the uptake equations provided by the US EPA (Bechtel Jacobs Company 1998) recommends use of the single-variable regression or multiple regression with pH (with no preference given except for mercury). Given that areas of low and high pH have been identified on the Site, it was considered reasonable to apply the single-variable regression to provide an estimate of plant tissue concentrations reflective of the range in soil pH across the Site. For arsenic, under low pH conditions the risks to human receptors via consumption of plants may be overestimated. Under high pH conditions the risks via this pathway may be underestimated. For lead, under low pH conditions the risks to human receptors via consumption of plants may be underestimated. Under high pH conditions the risks via this pathway may be overestimated.
Toxicity Assessment			
Toxicity reference values used in the assessment from Health Canada	Low	Neutral or overestimate	TRVs used in the assessment were preferentially selected from Health Canada (2010). TRVs are often derived from animal studies. Uncertainty factors are applied to the TRV derived from the studies to account for inter- and intraspecies variability as well as other factors.
TRVs based on chronic exposure for Site Visitors	Low	Overestimate	Site Visitors are assumed to visit the Site 14 days per year (i.e., less than chronic exposure). For the non-carcinogenic assessment, unamortized exposures for all COCs, with the exception of arsenic, were compared to TRVs based on chronic exposure. This may overestimate potential risks to these receptors.

Notes:
COC = contaminant of concern; TRV = toxicity reference value; UCLM = upper confidence limit of the mean.

References:

ATSDR (Agency for Toxic Substances and Disease Registry). 2007. Toxicological Profile for Arsenic. U.S. Department of Health and Human Services. Public Health Service. August 2007.

Betchel Jacobs Company (Betchtel Jacobs Company LLC). 1998. Empirical Models for Uptake of Inorganic Chemicals from Soil by Plants. Prepared for the U.S. Department of Energy, Office of Environmental Management. September 1998. Online: <https://rais.ornl.gov/documents/bjcor-133.pdf>

Chan, L., Receveur, O., Batal, M., Sadik, T., Schwartz, H., Ing, A., Fediuk, K., Tikhonov, C. 2018. First Nations Food, Nutrition and Environment Study (FNFNES). Results from Saskatchewan 2015. Ottawa: University of Ottawa.

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

Health Canada. 2016. Memorandum: A Primer for Evaluating Human Health Risk at Contaminated Sites for Chronic and Less-than-Chronic Exposures to Chemicals. October 2016.

Health Canada. 2012. Guidelines for Canadian Recreational Water Quality. Third Edition. Water, Air and Climate Change Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario (Catalogue No H129-15/2012E). April 2012.

Table 4.19
Human Health Site Specific Target Levels for Metals
Lupin Mine, Nunavut

Land Use	COC	Threshold Effects				Non-Threshold Effects			Background ^(b)	SSTL ^(c)
		Direct Contact by a Site Visitor ^(a)	Consumption of Plants by a Site Visitor	Consumption of Plants by a Toddler Community Member	Consumption of Plants by an Adult Community Member	Direct Contact by a Site Visitor ^(a)	Consumption of Plants by a Site Visitor	Consumption of Plants by a Site Visitor		
Soil										
Agricultural Land Use	Arsenic	--	759	139	339	979	164	98	79	98
	Lead	95	140	--	--	--	--	--	<30	95

Notes:

All values in milligrams per kilogram (mg/kg)

COC = Contaminant of concern; SSTL = site specific target level; < = less than detection limit

(a) Direct contact for soil includes ingestion, dermal contact and inhalation of soil particulates.

(b) 95% UCLM of background locations.

(c) The SSTL was based on the lowest calculated SSTL of the exposure pathways and endpoints (threshold versus non-threshold) for the Site Visitor. If the lowest calculated SSTL was lower than the background concentration, then the background concentration was selected as the SSTL.

Prepared by: SG

Checked by: AA

Table 5.1a
Screening of Soil for Ecological Receptors - Plants and Soil Invertebrates
Lupin Mine, Nunavut

Parameter	Unit	Background Concentration ⁽¹⁾	Screening Value				Maximum Measured Concentration ⁽⁶⁾	Retain as a COC for Terrestrial Plants and Soil Invertebrates?
			Terrestrial Plants and Soil Invertebrates					
			CCME SQG _e ⁽²⁾ / CCME CWS ⁽³⁾ Soil contact	MOECC Table 2 ^(4,5) Plants & Soil Org.	AEP ^(4,6) Direct Soil Contact	BC MECCS ^(4,7) Toxicity to Soil Invertebrates and Plants		
Petroleum Hydrocarbons and BTEX								
Benzene	mg/kg	--	31	NR	NR	NR	<0.8 (0.494)	No
Ethylbenzene	mg/kg	--	55	NR	NR	NR	7.8	No
Toluene	mg/kg	--	75	NR	NR	NR	8.3	No
m,p-Xylenes	mg/kg	--	--	--	--	--	24	No (see Xylenes, Total)
o-Xylene	mg/kg	--	--	--	--	--	15	No (see Xylenes, Total)
Xylenes, Total	mg/kg	--	95	NR	NR	NR	92.4	No
Petroleum Hydrocarbons - F1 (C6-C10)	mg/kg	--	--	--	--	--	4701	No (see PHC F1-BTEX)
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	mg/kg	--	210	NR	NR	NR	2650	Yes
Petroleum Hydrocarbons - F2 (C10-C16)	mg/kg	--	150	NR	NR	NR	14000	Yes
Petroleum Hydrocarbons - F3 (C16-C34)	mg/kg	--	300	NR	NR	NR	4400	Yes
Petroleum Hydrocarbons - F4 (C34-C50)	mg/kg	--	2800	NR	NR	NR	2700	No
Metals and Physical Parameters								
pH	pH	4.13 to 5.67	6 to 8	5 to 9	NR	NR	2.7 to 12.5	Yes
Sulphide	mg/kg	--	--	--	--	--	21.9	No ⁽¹⁵⁾
Sulphate	mg/kg	--	--	--	--	--	821	Yes
Total Cyanide	mg/kg	--	0.9 ⁽¹¹⁾	NR	NR	NR	21.9	Yes
Total Antimony (Sb)	mg/kg	<10	20 ⁽¹⁰⁾	NR	NR	NR	171	Yes
Total Arsenic (As)	mg/kg	79	17 ⁽¹²⁾	NR	NR	NR	11700	Yes
Total Barium (Ba)	mg/kg	46	--	750	750	700	558	No
Total Beryllium (Be)	mg/kg	<0.5	--	4	5	150	<0.5 (0.41)	No
Total Cadmium (Cd)	mg/kg	1.3	10	NR	NR	NR	6.4	No
Total Chromium (Cr)	mg/kg	24	64	NR	NR	NR	94.3	Yes
Total Cobalt (Co)	mg/kg	7.0	40 ⁽¹⁰⁾	NR	NR	NR	34.9	No
Total Copper (Cu)	mg/kg	28	63	NR	NR	NR	480	Yes
Total Lead (Pb)	mg/kg	<30	300	NR	NR	NR	3410	Yes
Total Mercury (Hg)	mg/kg	0.042	12 ⁽¹³⁾	NR	NR	NR	0.1	No
Total Molybdenum (Mo)	mg/kg	<4	5 ⁽¹⁰⁾	NR	NR	NR	22.8	Yes
Total Nickel (Ni)	mg/kg	20	45	NR	NR	NR	67.3	Yes
Total Selenium (Se)	mg/kg	<2	1	NR	NR	NR	<2	No
Total Silver (Ag)	mg/kg	<2	20 ⁽¹⁰⁾	NR	NR	NR	2.5	No
Total Thallium (Tl)	mg/kg	<1	1.4	NR	NR	NR	<1 (0.34)	No
Total Tin (Sn)	mg/kg	<5	5 ⁽¹⁰⁾	NR	NR	NR	9.3	Yes
Total Uranium (U)	mg/kg	--	500	NR	NR	NR	3.8	No
Total Vanadium (V)	mg/kg	22	130	NR	NR	NR	65.6	No
Total Zinc (Zn)	mg/kg	54	250	NR	NR	NR	1570	Yes
Polycyclic Aromatic Hydrocarbons								
Acenaphthene	mg/kg	--	--	--	2.5	--	<1.5	No
Acenaphthylene	mg/kg	--	--	--	--	--	<1	No ⁽⁹⁾
Anthracene	mg/kg	--	2.5	NR	NR	NR	<1.9	No
Benzo[a]anthracene	mg/kg	--	--	0.5	--	--	< 0.5	No
Benzo[a]pyrene	mg/kg	--	20	NR	NR	NR	< 0.5	No
Benzo[b]fluoranthene	mg/kg	--	--	--	--	--	< 0.5	No ⁽⁹⁾
Benzo[g,h,i]perylene	mg/kg	--	--	6.6	--	--	< 0.5	No
Benzo[k]fluoranthene	mg/kg	--	--	7.6	--	--	< 0.5	No
Chrysene	mg/kg	--	--	7	--	--	< 0.5	No
Dibenz[a,h]anthracene	mg/kg	--	--	--	--	--	< 0.5	No ⁽⁹⁾
Fluoranthene	mg/kg	--	50	NR	NR	NR	<0.5 (0.113)	No
Fluorene	mg/kg	--	--	0.6 ⁽¹⁴⁾	--	--	4.53	Yes
Indeno[1,2,3-cd]pyrene	mg/kg	--	--	0.38	--	--	< 0.5	No
Naphthalene	mg/kg	--	--	0.6	--	0.6	10.1	Yes
Phenanthrene	mg/kg	--	--	6.2	--	--	3.74	No
Pyrene	mg/kg	--	--	--	--	10 ⁽¹⁶⁾	<0.5 (0.318)	No
Glycols								
Diethylene glycol	mg/kg	--	--	--	1000	--	<10	No
Ethylene glycol	mg/kg	--	1100	NR	NR	NR	11	No
Propylene glycol	mg/kg	--	--	--	--	--	<10	No ⁽⁹⁾
Triethylene glycol	mg/kg	--	--	--	5000	--	<10	No

Notes:
Tables should be read in conjunction with the accompanying document.
COC = contaminant of concern; BTEX = benzene, toluene, ethylbenzene, and xylene; ERA = ecological risk assessment; mg/kg= milligram per kilogram; NR = not required (provincial screening values only used in absence of federal screening values); < = parameter not detected above method detection limit; -- = no screening value available.
⁽¹⁾ Calculated as the 95% UCLM of the site-specific background samples: SS76, 51171, 51172, 51173, 51174, 51175, 51176, 51177, 51178, 51179, 51180, 51181, 51182, 51183, 51184, 51185, 51186, 51187, 51188, 51189, 51190. For parameters with too few detected samples to calculate a 95% UCLM, the maximum concentration was used as the background concentration.
⁽²⁾ Canadian Council of Ministers of the Environment (CCME), 1999/2019. Canadian Soil Quality Guidelines (SQGs) for the Protection of Environmental Health (SQG_e), agricultural land use, coarse textured soil, surface soil.
⁽³⁾ Canadian Council of Ministers of the Environment (2008). Canadian-Wide Standards (CWS) for Petroleum Hydrocarbons (PHCs) in Soil: Scientific Rationale. Supporting Technical Document, January 2008. Table 5.2 and 5.3 Tier 1 Levels for PHC, agricultural land use, coarse grained soil.
⁽⁴⁾ In the absence of CCME guidelines/standards, the lowest of the available Canadian provincial guidelines/standards were selected (Ontario, Alberta, British Columbia). The selected guideline/standard is shown in underlined text.
⁽⁵⁾ Ontario Ministry of the Environment and Climate Change (MOECC). 2016. Modified Generic Risk Assessment "Approved Model". Soil Components for Table 2 - Full Depth, Potable Water Scenario, Agricultural Land Use, coarse grained soil.
⁽⁶⁾ Alberta Environment and Parks (AEP). 2019. Alberta Tier 1 Soil and Groundwater Remediation Guidelines. Land Policy Branch. Policy and Planning Division. Table A-2: Surface Soil Remediation Guideline Values for Agricultural Land Use - Direct Soil Contact, coarse grained soil.
⁽⁷⁾ British Columbia Ministry of Environment and Climate Change Strategy (BC MECCS). 2019. Contaminated Sites Regulation. Schedule 3.1 Numerical Soil Standards, Agricultural. Toxicity to soil invertebrates and plants.
⁽⁸⁾ Maximum measured concentrations were selected from soil samples of all depths. Values in brackets are the maximum detected concentration. The soil concentrations used in the ERA represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).
⁽⁹⁾ No screening value and not detected.
⁽¹⁰⁾ Screening value is the CCME Soil Quality Guideline (SQG) for the Protection of Environmental and Human Health. Agricultural land use.
⁽¹¹⁾ Guideline is for free cyanide.
⁽¹²⁾ Guideline is for inorganic arsenic.
⁽¹³⁾ Guideline is for inorganic mercury.
⁽¹⁴⁾ Value for naphthalene used as a surrogate for low molecular weight PAHs when PAH-specific values were not available.
⁽¹⁵⁾ Sulphur is in essential nutrient for plants and soil invertebrates. It is only available for absorption by plants and soil invertebrates when it is in its biologically available form, sulphate. Therefore, sulphide was not retained as a COC for plants and soil invertebrates.
⁽¹⁶⁾ Los Alamos National Laboratory (LANL). September 2017. "ECORISK Database (Release 4.1)", LA-UR-17-26376, Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2017, 602538).

Grey and bold Indicates exceedances of applied screening value and background concentration, or no screening value and above background concentration.

Prepared by: SG/AF
Checked by: TD

Table 5.1b
Screening of Soil for Ecological Receptors - Wildlife
Lupin Mine, Nunavut

Parameter	Unit	Background Concentration ⁽¹⁾	Screening Value			Maximum Measured Concentration ⁽⁷⁾	Retain as a COC for Wildlife?
			Mammals and Birds				
			CCME SQGE ⁽²⁾ / CCME CWS ⁽³⁾ Soil and Food Ingestion	MOECC Table 2 ^(4,5) Mammals & Birds	AEP ^(4,6) Wildlife Soil and Food Ingestion		
Petroleum Hydrocarbons and BTEX							
Benzene	mg/kg	--	25	NR	NR	<0.8 (0.494)	No
Ethylbenzene	mg/kg	--	910	NR	NR	7.8	No
Toluene	mg/kg	--	1400	NR	NR	8.3	No
m,p-Xylenes	mg/kg	--	--	--	--	24	No (see Xylenes, Total)
o-Xylene	mg/kg	--	--	--	--	15	No (see Xylenes, Total)
Xylenes, Total	mg/kg	--	3700	NR	NR	92.4	No
Petroleum Hydrocarbons - F1 (C6-C10)	mg/kg	--	--	--	--	4701	No (see PHC F1-BTEX)
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	mg/kg	--	--	--	11000	2650	No
Petroleum Hydrocarbons - F2 (C10-C16)	mg/kg	--	--	--	9800	14000	Yes
Petroleum Hydrocarbons - F3 (C16-C34)	mg/kg	--	--	--	16000	4400	No
Petroleum Hydrocarbons - F4 (C34-C50)	mg/kg	--	--	--	8400	2700	No
Metals and Physical Parameters							
pH	pH	4.13 to 5.67	6 to 8	NR	NR	2.7 to 12.5	No ⁽¹¹⁾
Sulphide	mg/kg	--	--	--	--	21.9	Yes
Sulphate	mg/kg	--	--	--	--	821	Yes
Total Cyanide	mg/kg	--	11	NR	NR	21.9	Yes
Total Antimony (Sb)	mg/kg	<10	20 ⁽⁹⁾	NR	NR	171	Yes
Total Arsenic (As)	mg/kg	79	380	NR	NR	11700	Yes
Total Barium (Ba)	mg/kg	46	--	390	--	558	Yes
Total Beryllium (Be)	mg/kg	<0.5	--	13	--	<0.5 (0.41)	No
Total Cadmium (Cd)	mg/kg	1.3	3.8	NR	NR	6.4	Yes
Total Chromium (Cr)	mg/kg	24	--	160	--	94.3	No
Total Cobalt (Co)	mg/kg	7.0	40 ⁽⁹⁾	NR	NR	34.9	No
Total Copper (Cu)	mg/kg	28	300	NR	NR	480	Yes
Total Lead (Pb)	mg/kg	<30	70	NR	NR	3410	Yes
Total Mercury (Hg)	mg/kg	0.042	19 ⁽¹⁰⁾	NR	NR	0.1	No
Total Molybdenum (Mo)	mg/kg	<4	5 ⁽⁹⁾	NR	NR	22.8	Yes
Total Nickel (Ni)	mg/kg	20	528	NR	NR	67.3	No
Total Selenium (Se)	mg/kg	<2	4.5	NR	NR	<2	No
Total Silver (Ag)	mg/kg	<2	20 ⁽⁹⁾	NR	NR	2.5	No
Total Thallium (Tl)	mg/kg	<1	1	NR	NR	<1 (0.34)	No
Total Tin (Sn)	mg/kg	<5	5 ⁽⁹⁾	NR	NR	9.3	Yes
Total Uranium (U)	mg/kg	--	33	NR	NR	3.8	No
Total Vanadium (V)	mg/kg	22	--	18	--	65.6	Yes
Total Zinc (Zn)	mg/kg	54	960	NR	NR	1570	Yes
Polycyclic Aromatic Hydrocarbons							
Acenaphthene	mg/kg	--	21.5	NR	NR	<1.5	No
Acenaphthylene	mg/kg	--	--	--	--	<1	No ⁽⁸⁾
Anthracene	mg/kg	--	61.5	NR	NR	<1.9	No
Benz[a]anthracene	mg/kg	--	6.2	NR	NR	< 0.5	No
Benzo[a]pyrene	mg/kg	--	0.6	NR	NR	< 0.5	No
Benzo[b]fluoranthene	mg/kg	--	6.2	NR	NR	< 0.5	No
Benzo[g,h,i]perylene	mg/kg	--	--	--	--	< 0.5	No ⁽⁸⁾
Benzo[k]fluoranthene	mg/kg	--	6.2	NR	NR	< 0.5	No
Chrysene	mg/kg	--	6.2	NR	NR	< 0.5	No
Dibenz[a,h]anthracene	mg/kg	--	--	--	--	< 0.5	No ⁽⁸⁾
Fluoranthene	mg/kg	--	15.4	NR	NR	<0.5 (0.113)	No
Fluorene	mg/kg	--	15.4	NR	NR	4.53	No
Indeno[1,2,3-cd]pyrene	mg/kg	--	--	--	--	< 0.5	No ⁽⁸⁾
Naphthalene	mg/kg	--	8.8	NR	NR	10.1	Yes
Phenanthrene	mg/kg	--	43	NR	NR	3.74	No
Pyrene	mg/kg	--	7.7	NR	NR	<0.5 (0.318)	No
Glycols							
Diethylene glycol	mg/kg	--	--	--	--	<10	No ⁽⁸⁾
Ethylene glycol	mg/kg	--	--	--	--	11	Yes
Propylene glycol	mg/kg	--	--	--	--	<10	No ⁽⁸⁾
Triethylene glycol	mg/kg	--	--	--	--	<10	No ⁽⁸⁾

Notes:
Tables should be read in conjunction with the accompanying document.
COC = contaminant of concern; BTEX = benzene, toluene, ethylbenzene, and xylene; ERA = ecological risk assessment; mg/kg= milligram per kilogram; NR = not required (provincial screening values only used in absence of federal screening values); < = parameter not detected above method detection limit; -- = no screening value available.
⁽¹⁾ Calculated as the 95% UCLM of the site-specific background samples: SS76, 51171, 51172, 51173, 51174, 51175, 51176, 51177, 51178, 51179, 51180, 51181, 51182, 51183, 51184, 51185, 51186, 51187, 51188, 51189, 51190. For parameters with too few detected samples to calculate a 95% UCLM, the maximum concentration was used as the background concentration.
⁽²⁾ Canadian Council of Ministers of the Environment (CCME), 1999/2019. Canadian Soil Quality Guidelines (SQGs) for the Protection of Environmental Health (SQGE), agricultural land use, coarse textured soil, surface soil.
⁽³⁾ Canadian Council of Ministers of the Environment (2008). Canadian-Wide Standards (CWS) for Petroleum Hydrocarbons (PHCs) in Soil: Scientific Rationale. Supporting Technical Document. January 2008. Table 5.2 and 5.3 Tier 1 Levels for PHC, agricultural land use, coarse grained soil.
⁽⁴⁾ In the absence of CCME guidelines/standards, the lowest of the available Canadian provincial guidelines/standards were selected (Ontario, Alberta, British Columbia).
⁽⁵⁾ Ontario Ministry of the Environment and Climate Change (MOECC). 2016. Modified Generic Risk Assessment "Approved Model". Soil Components for Table 2 - Full Depth, Potable Water Scenario, Agricultural Land Use, coarse grained soil.
⁽⁶⁾ Alberta Environment and Parks (AEP). 2019. Alberta Tier 1 Soil and Groundwater Remediation Guidelines. Land Policy Branch, Policy and Planning Division. Table A-2: Surface Soil Remediation Guideline Values for Agricultural Land Use - Wildlife Soil and Food Ingestion, coarse grained soil.
⁽⁷⁾ Maximum measured concentrations were selected from soil samples of all depths. Values in brackets are the maximum detected concentration. The soil concentrations used in the ERA represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).
⁽⁸⁾ No screening value and not detected.
⁽⁹⁾ Screening value is the CCME Soil Quality Guideline (SQG) for the Protection of Environmental and Human Health. Agricultural land use.
⁽¹⁰⁾ Guideline is for organic mercury.

⁽¹¹⁾ pH is less important for soils/food that are incidentally ingested by wildlife given that gut physiology (including gastric and intestinal pH) is an important parameter influencing metal bioavailability. Therefore, soil pH was not retained as a COC for mammals and birds.

Grey and bold	Indicates exceedances of applied screening value and background concentration, or no screening value and above background concentration.
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Prepared by: SG/AF
Checked by: TD

Table 5.2
Screening of Groundwater for Ecological Receptors - Terrestrial Plants
Lupin Mine, Nunavut

Parameter	Unit	Screening Value				Maximum Measured Concentration ⁽⁷⁾	Retain as a COC for Terrestrial Plants?
		FCSAP FIGQG ^(1,2) SODC	AEP Eco Soil Contact ^(3,4)	Efroymson et al. 1997 ^(3,5)	MOECC Table 7 ⁽⁶⁾ GW3		
Petroleum Hydrocarbons and BTEX							
Benzene	mg/L	61	NR	NR	NR	0.058	No
Toluene	mg/L	59	NR	NR	NR	0.22	No
Ethylbenzene	mg/L	20	NR	NR	NR	0.079	No
m & p-Xylene	mg/L	--	NR	NR	NR	0.36	See Xylenes
o-Xylene	mg/L	--	NR	NR	NR	0.29	See Xylenes
Xylenes	mg/L	31	NR	NR	NR	0.65	No
F1 (C6-C10)	mg/L	7.1	NR	NR	NR	3.3	See F1 (C1-C10) - BTEX
F1 (C6-C10) - BTEX	mg/L	7.1	NR	NR	NR	2.5	No
F2 (C10-C16)	mg/L	1.8	NR	NR	NR	64	Yes
Metals							
Dissolved Aluminum (Al)	mg/L	--	--	0.3	NR	3	Yes
Dissolved Antimony (Sb)	mg/L	--	--	--	16	0.004	No
Dissolved Arsenic (As)	mg/L	--	--	0.001	NR	0.35	Yes
Dissolved Barium (Ba)	mg/L	--	--	--	23	0.06	No
Dissolved Beryllium (Be)	mg/L	--	--	0.5	NR	<0.0010	No
Dissolved Boron (B)	mg/L	--	--	1	NR	0.56	No
Dissolved Cadmium (Cd)	mg/L	--	--	0.1	NR	0.004	No
Dissolved Calcium (Ca)	mg/L	--	--	--	--	290	No ⁽⁹⁾
Dissolved Chromium (Cr)	mg/L	--	--	0.05	NR	0.0046	No
Dissolved Cobalt (Co)	mg/L	--	--	0.06	NR	0.3	Yes
Dissolved Copper (Cu)	mg/L	--	--	0.06	NR	0.03	No
Dissolved Iron (Fe)	mg/L	--	--	10	NR	54	Yes
Dissolved Lead (Pb)	mg/L	--	--	0.02	NR	0.0028	No
Dissolved Lithium (Li)	mg/L	--	--	3	NR	0.11	No
Dissolved Magnesium (Mg)	mg/L	--	--	--	--	61	No ⁽⁹⁾
Dissolved Manganese (Mn)	mg/L	--	--	4	NR	2.4	No
Dissolved Molybdenum (Mo)	mg/L	--	--	0.5	NR	0.0046	No
Dissolved Nickel (Ni)	mg/L	--	--	0.5	NR	0.37	No
Dissolved Phosphorus (P)	mg/L	--	--	--	--	0.24	No ^(9,12)
Dissolved Potassium (K)	mg/L	--	--	--	--	38	No ⁽⁹⁾
Dissolved Selenium (Se)	mg/L	--	--	0.7	NR	0.0016	No
Dissolved Silicon (Si)	mg/L	--	--	--	--	18	No ⁽⁹⁾
Dissolved Silver (Ag)	mg/L	--	--	0.1	NR	<0.00010	No
Dissolved Sodium (Na)	mg/L	--	--	--	1800	66	No
Dissolved Strontium (Sr)	mg/L	--	--	--	10.7 ⁽¹³⁾	1.2	No
Dissolved Sulphur (S)	mg/L	--	--	--	--	290	No ⁽¹¹⁾
Dissolved Thallium (Tl)	mg/L	--	--	0.05	NR	<0.00020	No
Dissolved Tin (Sn)	mg/L	--	--	100	NR	<0.0010	No
Dissolved Titanium (Ti)	mg/L	--	--	0.06	NR	0.0057	No
Dissolved Uranium (U)	mg/L	--	--	40	NR	0.0011	No
Dissolved Vanadium (V)	mg/L	--	--	0.2	NR	0.006	No
Dissolved Zinc (Zn)	mg/L	--	--	0.4	NR	2	Yes
Routine Physical and Chemical Parameters							
Anion Sum	meq/L	--	--	--	--	23	No ⁽⁸⁾
Cation Sum	meq/L	--	--	--	--	23	No ⁽⁸⁾
Hardness (CaCO3)	mg/L	--	--	--	--	960	No ⁽⁸⁾
Ion Balance (% Difference)	%	--	--	--	--	30	No ⁽⁸⁾
Dissolved Nitrate (NO3)	mg/L	13 ⁽²⁾	NR	NR	NR	1.1	No
Nitrate plus Nitrite (N)	mg/L	--	--	--	--	0.27	See results for Nitrate and Nitrite
Dissolved Nitrite (NO2)	mg/L	0.197 ⁽²⁾	NR	NR	NR	0.15	No
Total Dissolved Solids	mg/L	--	--	--	--	1500	No ⁽⁸⁾
Conductivity	µS/cm	--	--	--	--	2300	No ⁽⁸⁾
Strong Acid Dissoc. Cyanide (CN)	mg/L	--	--	--	0.052	<0.0020	No
pH	pH	6.5 to 9 ⁽²⁾	NR	NR	NR	6.82	No
Alkalinity (PP as CaCO3)	mg/L	--	--	--	--	<0.50	No ⁽⁸⁾
Alkalinity (Total as CaCO3)	mg/L	--	--	--	--	44	No ⁽⁸⁾
Bicarbonate (HCO3)	mg/L	--	--	--	--	54	No ⁽⁸⁾
Carbonate (CO3)	mg/L	--	--	--	--	<0.50	No ⁽⁸⁾
Hydroxide (OH)	mg/L	--	--	--	--	<0.50	No ⁽⁸⁾
Dissolved Sulphate (SO4)	mg/L	--	--	--	128 ⁽¹⁴⁾	800	Yes ⁽¹¹⁾
Dissolved Chloride (Cl)	mg/L	--	--	--	1800	200	No
Glycols							
Ethylene Glycol	mg/L	192 ⁽²⁾	NR	NR	NR	<3.0	No
Diethylene Glycol	mg/L	--	--	--	--	<5.0	No ⁽¹⁰⁾
Triethylene Glycol	mg/L	--	--	--	--	<5.0	No ⁽¹⁰⁾
Tetraethylene Glycol	mg/L	--	--	--	--	<5.0	No ⁽¹⁰⁾
Propylene Glycol	mg/L	500 ⁽²⁾	NR	NR	NR	<5.0	No

Notes:

Tables should be read in conjunction with the accompanying document.

COC = contaminant of concern; BTEX = benzene, toluene, ethylbenzene, and xylene; ERA = ecological risk assessment; mg/L = milligram per litre; meq/L = milliequivalents per litre; µS/cm = microsiemens per centimetre; < = parameter not detected above method detection limit; -- = no screening value available; NR = not required (provincial screening values only used in absence of federal screening values).

⁽¹⁾ Government of Canada. 2016. Federal Contaminated Sites Action Plan (FCSAP), Federal Interim Groundwater Quality Guidelines (FIGQG) for Federal Contaminated Sites. Table 1 Federal Interim Groundwater Quality Guidelines, Generic Guidelines for Agricultural Land Use, Soil Organisms Direct Contact (SODC), coarse textured soil.

⁽²⁾ Canadian Council of Ministers of the Environment (CCME). 2018. Canadian Water Quality Guidelines (CWQG) for the Protection of Aquatic Life (PAL), Freshwater, Long-term. In the absence guidelines/standards specifically for groundwater contact with terrestrial plants, the CCME CWQG PAL were used as these are protective of aquatic plants.

⁽³⁾ In the absence of federal guidelines/standards, provincial screening values (i.e., AEP 2019) was used. In the absence of federal or provincial guidelines/standards Efroymson et al. (1997) was selected for screening given that these values are directly applicable to terrestrial plants.

⁽⁴⁾ Alberta Environment and Parks (AEP). 2019. Alberta Tier 1 Soil and Groundwater Remediation Guidelines. Land Policy Branch, Policy and Planning Division. 198 pp. Table B-2: Groundwater Remediation Guideline Values for Agricultural Land - Eco Soil Contact. The coarse grained soil guidelines were used.

⁽⁵⁾ Efroymson et al. 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Prepared for the U.S. Department of Energy. November 1997.

⁽⁶⁾ Ontario Ministry of the Environment and Climate Change (MOECC). 2016. Modified Generic Risk Assessment "Approved Model". Groundwater Components for Shallow Soil Scenario (Table 7), Non-potable Scenario, GW3. In absence of federal or provincial values and values from Efroymson, Table 7 GW3 values were used.

⁽⁷⁾ Maximum measured concentrations were calculated using the 2017 groundwater monitoring data. The groundwater concentrations used in the ERA represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).

⁽⁸⁾ Routine physical water quality parameter and not directly toxic.

⁽⁹⁾ These parameters are ubiquitous in the environment and non-toxic (except at extreme concentrations). Calcium, magnesium, phosphorus, and potassium are essential elements of living organisms.

⁽¹⁰⁾ No guideline and not detected.

⁽¹¹⁾ Sulphur is an essential nutrient for plants and is only available for absorption when it is in the form of sulphate (Holobrá, 1981). Given this, sulphur has not been retained as a COC for further evaluation for uptake from groundwater by plants, but sulphate has been retained.

⁽¹²⁾ For phosphorus, concerns with this parameter are related to aesthetics (i.e., algal blooms) and effects to aquatic life rather than adverse effects to terrestrial plants.

⁽¹³⁾ In the absence of screening guidelines/standards for groundwater contact with terrestrial plants, surface water screening values protective of aquatic life (including aquatic plants) were used. For strontium, the chronic effects benchmark for aquatic life of 10.7 mg/L was used (McPherson et al. 2014).

⁽¹⁴⁾ British Columbia Ministry of Environment and Climate Change Strategy (BC MECCS). 2019. British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture Summary Report. Water Protection & Sustainability Branch. August 2019. The guideline for sulphate of 128 mg/L was used (based on water hardness of 0-30 mg/L). This is considered to be protective of aquatic plants.

Grey and Bold

Indicates exceedance of applied screening value, or no screening value and detectable concentration.

Prepared by: SG/AF
Checked by: TD

Table 5.3
Calculation of Toxicological Benchmarks
for Water for Wildlife - Ingestion of Drinking Water
Lupin Mine, Nunavut

Parameter	Mammal TRV (mg/kg-d) ^(c)	Bird TRV (mg/kg-d) ^(c)	Toxicological Benchmark for Water Ingestion (mg/L) ^(c)								Toxicological Benchmark for Water Ingestion (mg/L) ^(c)								Toxicological Benchmark for Water Ingestion (mg/L) ^(c)		
			Short-tailed Shrew	Little Brown Bat	Meadow Vole	White-footed Mouse	Eastern Cottontail	Mink	Red Fox	White-tailed Deer	American Robin	Rough-winged Swallow	American Woodcock	Wild Turkey	Belted Kingfisher	Great Blue Heron	Barred Owl	Barn Owl	Cooper's Hawk	Red-tailed Hawk	Osprey
Aluminum	19.3	109.7	88	121	142	64	200	195	229	295	797	471	1086	3349	1015	2478	1674	1461	1416	1930	2137
Antimony	1.25	NV	5.7	7.8	9.2	4.2	13	13	15	19	--	--	--	--	--	--	--	--	--	--	--
Arsenic	1.26	12.84	5.7	7.9	9.2	4.2	13	13	15	19	93	55	127	392	119	290	196	171	166	226	250
Barium	19.8	41.7	90	124	145	66	205	200	234	302	303	179	413	1273	386	942	636	555	538	734	812
Beryllium	0.66	NV	3.0	4.1	4.8	2.2	6.8	6.7	7.8	10	--	--	--	--	--	--	--	--	--	--	--
Bismuth	1000	NV	4545.5	6250.0	7333.3	3333.3	10344.8	10101.0	11842.1	15270	--	--	--	--	--	--	--	--	--	--	--
Cadmium	10	20	45	63	73	33	103	101	118	153	145	86	198	611	185	452	305	266	258	352	390
Calcium	NV	NV	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chromium	13.14	5	60	82	96	44	136	133	156	201	36	21	50	153	46	113	76	67	65	88	97
Cobalt	8.8	7.8	40	55	65	29	91	89	104	134	57	34	77	238	72	176	119	104	101	137	152
Copper	15.14	61.7	69	95	111	50	157	153	179	231	448	265	611	1883	571	1394	941	821	797	1086	1202
Iron	NV	NV	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lead	80	11.3	364	500	587	267	828	808	947	1222	82	49	112	345	105	255	172	150	146	199	220
Lithium	18.8	NV	85	118	138	63	194	190	223	287	--	--	--	--	--	--	--	--	--	--	--
Magnesium	NV	NV	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Manganese	284	977	1291	1775	2083	947	2938	2869	3363	4337	7097	4198	9672	29824	9037	22070	14904	13008	12615	17189	19032
Mercury	1.0	0.9	5	6	7	3	10	10	12	15	7	4	9	27	8	20	14	12	12	16	18
Molybdenum	2.6	35.3	12	16	19	9	27	26	31	40	256	152	349	1078	327	797	539	470	456	621	688
Nickel	80	107	364	500	587	267	828	808	947	1222	777	460	1059	3266	990	2417	1632	1425	1382	1883	2084
Phosphorus	NV	NV	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Potassium	NV	NV	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Silicon	NV	NV	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Silver	190	54.4	864	1188	1393	633	1966	1919	2250	2901	395	234	539	1661	503	1229	830	724	702	957	1060
Sodium	NV	NV	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Strontium	263	NV	1195	1644	1929	877	2721	2657	3114	4016	--	--	--	--	--	--	--	--	--	--	--
Sulphur	NV	NV	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Thallium	0.074	3.5	0.34	0.46	0.54	0.25	0.77	0.75	0.88	1.1	25	15	35	107	32	79	53	47	45	62	68
Tin	NV	NV	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Titanium	158	NV	718	988	1159	527	1634	1596	1871	2413	--	--	--	--	--	--	--	--	--	--	--
Uranium	6.13	780	28	38	45	20	63	62	73	94	5666	3352	7722	23811	7215	17620	11899	10385	10071	13723	15195
Vanadium	2.1	11.4	10	13	15	7	22	21	25	32	83	49	113	348	105	258	174	152	147	201	222
Zinc	320	131	1455	2000	2347	1067	3310	3232	3789	4886	952	563	1297	3999	1212	2959	1998	1744	1691	2305	2552
Zirconium	1.74	NV	8	11	13	6	18	18	21	27	--	--	--	--	--	--	--	--	--	--	--
Body Weight (kg) ^(b)			0.015	0.0075	0.044	0.022	1.2	1.0	4.5	56.5	0.077	0.0159	0.198	5.8	0.148	2.39	0.717	0.466	0.439	1.126	1.5
Water Intake (L/d) ^(b)			0.0033	0.0012	0.006	0.0066	0.116	0.099	0.38	3.7	0.0106	0.0037	0.02	0.19	0.016	0.1058	0.047	0.035	0.034	0.064	0.077

Notes:
mg/L - milligram per litre; TRV = toxicity reference value; mg/kg-d = milligrams per kilogram per day; kg = kilogram; L/d = litres per day; NV = no value; "--" = not calculated because no TRV available; LOAEL = lowest observed adverse effect level; NOAEL = no observed adverse effect level.

^(a) TRVs were taken from Sample et al. (1996). In the absence of a TRV from Sample et al. (1996), TRVs were taken from Los Alamos National Laboratory (LANL, 2017; silver, thallium, titanium, uranium) or Ontario Ministry of Environment, Conservation and Parks (MOE, 2011; cobalt) or Sano et al (2005; bismuth). Where available, LOAEL-based TRVs were used. Where lacking, NOAEL-based TRVs were used.

^(b) Body weights and water intakes were taken from Sample et al. (1996).

^(c) Toxicological benchmarks were calculated as follows: LOAEL of test species (in mg/kg/d) x body weight of wildlife species (in kg) / water intake of wildlife species (in L/d).

Prepared by: SG/AF
Checked by: TD

Table 5.4
Screening of Surface Water for Ecological Receptors from Seepage - Wildlife
Lupin Mine, Nunavut

Parameter	Units	Background Concentration ⁽¹⁾	Screening Value			Seepage Maximum Measured Concentration ⁽⁷⁾	Retain as a COC for Wildlife?
			Provincial Guideline/Standard - Wildlife Water ⁽²⁾⁽³⁾⁽⁴⁾	Sample et al. (1996) Toxicological Benchmark ⁽⁵⁾	CCME CWQG ⁽⁶⁾ Livestock Water		
Petroleum Hydrocarbons and BTEX							
Benzene	mg/L	<0.00040	0.076 ⁽³⁾	NR	NR	0.023	No
Toluene	mg/L	<0.00040	4.25 ⁽³⁾	NR	NR	0.023	No
Ethylbenzene	mg/L	<0.00040	2.77 ⁽³⁾	NR	NR	0.0016	No
Xylenes	mg/L	<0.00080	11.3 ⁽³⁾	NR	NR	0.029	No
F1 (C6-C10) - BTEX	mg/L	<0.1	46.4 ⁽³⁾	NR	NR	0.19	No
F2 (C10-C16)	mg/L	<0.1	42.6 ⁽³⁾	NR	NR	1.3	No
Metals							
Total Aluminum (Al)	mg/L	0.0604	--	64	NR	10.9	No
Total Antimony (Sb)	mg/L	<0.00010	--	4.2	NR	0.022	No
Total Arsenic (As)	mg/L	0.00108	--	4.2	NR	0.364	No
Total Barium (Ba)	mg/L	0.00684	--	66	NR	0.0652	No
Total Beryllium (Be)	mg/L	<0.00010	--	2.2	NR	0.00289	No
Total Bismuth (Bi)	mg/L	<0.000050	--	3333	NR	0.000067	No
Total Boron (B)	mg/L	<0.010	5 ⁽⁴⁾	NR	NR	0.693	No
Total Cadmium (Cd)	mg/L	0.0000154	--	33	NR	0.0042	No
Total Calcium (Ca)	mg/L	2.97	--	--	1000	270	No
Total Cesium (Cs)	mg/L	0.000024	--	--	--	0.0038	No ⁽⁸⁾
Total Chromium (Cr)	mg/L	0.00018	--	21	NR	0.0145	No
Total Cobalt (Co)	mg/L	0.00113	--	29	NR	0.422	No
Total Copper (Cu)	mg/L	0.00191	--	50	NR	0.173	No
Total Iron (Fe)	mg/L	0.167	--	--	--	9.67	No ⁽¹⁰⁾
Total Lead (Pb)	mg/L	<0.000050	--	49	NR	0.0289	No
Total Lithium (Li)	mg/L	0.0036	--	63	NR	0.16	No
Total Magnesium (Mg)	mg/L	1.85	--	--	--	44.5	No ⁽⁸⁾
Total Manganese (Mn)	mg/L	0.0127	--	947	NR	3.77	No
Mercury	mg/L	<0.0000050	--	3	NR	<0.0000050	No
Total Molybdenum (Mo)	mg/L	<0.000050	--	9	NR	0.00252	No
Total Nickel (Ni)	mg/L	0.00795	--	267	NR	1.06	No
Total Phosphorus (P)	mg/L	<0.050	--	--	--	0.126	No ^(8,14)
Total Potassium (K)	mg/L	0.458	--	--	--	20.1	No ⁽⁸⁾
Total Rubidium (Rb)	mg/L	0.00149	--	--	--	0.0325	No ⁽⁸⁾
Total Selenium (Se)	mg/L	<0.000050	0.002 ⁽⁴⁾	NR	NR	0.000497	No
Total Silicon (Si)	mg/L	0.88	--	--	--	17.6	No ⁽¹¹⁾
Total Silver (Ag)	mg/L	<0.000010	--	233.8	NR	0.000045	No
Total Sodium (Na)	mg/L	1.58	--	--	--	32	No ⁽⁸⁾
Total Strontium (Sr)	mg/L	0.017	--	877	NR	1.31	No
Total Sulphur (S)	mg/L	4.86	--	--	--	309	See result for sulphate ⁽¹⁷⁾
Total Tellurium (Te)	mg/L	<0.00020	--	--	--	0.00022	No ⁽⁸⁾
Total Thallium (Tl)	mg/L	<0.000010	--	0.25	NR	0.000158	No
Total Thorium (Th)	mg/L	<0.00010	--	--	--	0.00092	No ⁽⁸⁾
Total Tin (Sn)	mg/L	<0.00010	--	--	--	0.00023	No ⁽⁸⁾
Total Titanium (Ti)	mg/L	<0.00030	--	527	NR	0.254	No
Total Tungsten (W)	mg/L	<0.00010	--	--	--	0.00086	No ⁽⁸⁾
Total Uranium (U)	mg/L	0.00003	--	20	NR	0.0262	No
Total Vanadium (V)	mg/L	<0.00050	--	7.0	NR	0.0107	No
Total Zinc (Zn)	mg/L	0.0048	--	563	NR	1.99	No
Total Zirconium (Zr)	mg/L	<0.00020	--	6	NR	0.00063	No
Routine Physical and Chemical Parameters							
Anion Sum	meq/L	0.35	--	--	--	23	No ⁽⁹⁾
Cation Sum	meq/L	0.43	--	--	--	25	No ⁽⁹⁾
Hardness (CaCO3)	mg/L	16	--	--	--	1200	No ⁽⁹⁾
Ion Balance (% Difference)	%	11	--	--	--	6.6	No ⁽⁹⁾
Dissolved Nitrate (NO3)	mg/L	0.28	--	--	--	12	See result for Nitrate plus Nitrite
Nitrate plus Nitrite (N)	mg/L	0.0107	--	--	100	0.807	
Dissolved Nitrite (NO2)	mg/L	<0.033	--	--	32.8	0.17	No
Total Dissolved Solids	mg/L	49	--	--	3000	1400	No
Conductivity	µS/cm	44	--	--	--	1660	No ⁽⁹⁾
Strong Acid Dissoc. Cyanide (CN)	mg/L	<0.0050	--	--	--	<0.005	No ⁽¹²⁾
pH	pH	6.58	--	--	--	3.79 to 8.27	No ⁽¹³⁾
Acidity (as CaCO3)	mg/L	2.7	--	--	--	68.4	No ⁽⁹⁾
Alkalinity, Bicarbonate (as CaCO3)	mg/L	2.7	--	--	--	123	No ⁽⁹⁾
Alkalinity, Carbonate (as CaCO3)	mg/L	<1.0	--	--	--	<1	No ⁽⁹⁾
Alkalinity, Hydroxide (as CaCO3)	mg/L	<1.0	--	--	--	<1	No ⁽⁹⁾
Alkalinity (PP as CaCO3)	mg/L	<2.0	--	--	--	<2	No ⁽⁹⁾
Alkalinity (Total as CaCO3)	mg/L	2.7	--	--	--	123	No ⁽⁹⁾
Bicarbonate (HCO3)	mg/L	6.7	--	--	--	140	No ⁽⁹⁾
Carbonate (CO3)	mg/L	<0.50	--	--	--	<0.50	No ⁽⁹⁾
Hydroxide (OH)	mg/L	<0.50	--	--	--	<0.50	No ⁽⁹⁾
Dissolved Sulphate (SO4)	mg/L	14.8	--	--	1000	840	No
Dissolved Chloride (Cl)	mg/L	0.97	600 ⁽⁴⁾	--	--	36.4	No
Ammonia, Total (as N)	mg/L	<0.0050	84 ⁽¹⁵⁾	--	--	2.26	No
Bromide (Br)	mg/L	<0.050	--	--	--	<0.50	No ⁽¹²⁾
Fluoride (F)	mg/L	0.039	--	--	2 ⁽¹⁶⁾	1.11	No

Notes:
Tables should be read in conjunction with the accompanying document.
COC = contaminant of concern; BTEX = benzene, toluene, ethylbenzene, and xylene; ERA = ecological risk assessment; mg/L = milligram per litre; meq/L = milliequivalents per litre; < = parameter not detected above method detection limit; -- = no screening standard available; NR = not required; µS/cm = microsiemens per centimetre.

⁽¹⁾ Background concentration is measured surface water concentration from one sample collected in a creek north of the Site considered not to be impacted by the mine site. The data from 2019 was used, where available, as it is considered to be most representative of current conditions. For parameters that were not analyzed in 2019, the 2017 data was used.

⁽²⁾ The provincial guideline/standard was selected as the lowest of the AEP SWQG wildlife water, or the BC MECCS water quality guideline for wildlife, unless otherwise noted.

⁽³⁾ Alberta Environment and Parks (AEP). 2019. Alberta Tier 1 Soil and Groundwater Remediation Guidelines. Land Policy Branch, Policy and Planning Division. 198 pp. Table C-11 Surface Water Quality Guidelines (SWQG) - Wildlife Water. □

⁽⁴⁾ British Columbia Ministry of Environment & Climate Change Strategy (BC MECCS). 2018. British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife and Agriculture, Summary Report, Water Protection & Sustainability Branch, Ministry of Environment & Climate Change Strategy, March 2018.

⁽⁵⁾ In the absence of provincial guidelines for wildlife water from AEP or MECCS, toxicity benchmarks were calculated using Sample et al. (1996).
Sample et al. 1996. Toxicological Benchmarks for Wildlife: 1996 Revision, June 1996. United States Department of Energy. Most conservative of the available toxicity benchmarks was selected as screening. Calculation the toxicity benchmarks is presented in Table 7.3.

⁽⁶⁾ In the absence of provincial guidelines and Sample et al. toxicity benchmarks, guidelines from the CCME (2019) for livestock water were selected.
Canadian Council of Ministers of the Environment (CCME). 2019. Canadian Water Quality Guidelines (CWQG) for the Protection of Agricultural Uses, Livestock Water.

⁽⁷⁾ Maximum measured concentrations were calculated using the 2019 data. In the absence of 2019 data, 2017 data were used. The seepage surface water concentrations used in the ERA represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).

⁽⁸⁾ Naturally occurring, essential and/or generally considered non-toxic (except when ingested in extreme quantities). See Section 5.1.1.3.1 for further description.

⁽⁹⁾ Routine physical water quality parameter and not directly toxic.

⁽¹⁰⁾ Iron is an essential nutrient for mammals and birds and relevant toxicity reference values have not been published for these receptors. The US EPA (2006) published a toxicity reference value based on the geomean of the lowest observed adverse effect levels for decreased body weight in rats; however, the effect was attributed to the decreased palatability of water as opposed to the toxicity of iron itself.

⁽¹¹⁾ Silicon is the second most abundant element and makes up 25.7% of the earth's crust (HSDB, 2011). Silicon is fundamentally non-toxic. No short-term or long-term toxicity data in either humans or laboratory animals were found on the potential oral toxicity of elemental silicon (HSDB, 2011). Therefore, silicon was not retained as a COC for wildlife.

⁽¹²⁾ Less than or equal to background concentration.

⁽¹³⁾ The stomach pH of wildlife is naturally lower than the lowest pH measured in surface water.

⁽¹⁴⁾ For phosphorus, concerns with this parameter are related to aesthetics (i.e., algal blooms) and effects to aquatic life rather than adverse effects to wildlife.

⁽¹⁵⁾ The CCME water quality guideline for aquatic life (freshwater) for ammonia was selected in the absence of wildlife guideline from AEP, toxicity benchmark from Sample et al. or livestock value from CCME and AEP. The aquatic life value is considered protective of wildlife merely ingesting the seepage surface water. The aquatic life guideline is based on pH and temperature. The average pH in seepage surface water is 5.6, therefore the lowest pH available for the guideline calculation (6.0) was selected. The maximum temperature in background surface water from Fingers Lake (12 degrees Celsius) was also selected in order use aquatic life guideline for total ammonia of 84 mg/L as N (102 mg/L NH3).

⁽¹⁶⁾ The CCME livestock value for fluoride is 2 mg/L where the feed of livestock does not contain fluoride, and 1 mg/L where feed does contain fluoride. As the livestock values are being applied to wildlife which does not ingest supplied feed, the non-fluoride added value of 2 mg/L was selected.

⁽¹⁷⁾ For sulphur, the result for sulphate was used as it is the more biologically relevant parameter and there are screening values available.

Grey and bold Indicates exceedance of applied screening value.

Prepared by: SG/TD/AF
Checked by: TD

Table 5.5
Screening of Surface Water for Ecological Receptors from Lakes - Wildlife
Lupin Mine, Nunavut

Parameter	Units	Background Concentration - 50th Percentile ⁽¹⁾	Screening Value			Boot Lake	East Lake	Lower Sewage Lake	Retain as a COC for Wildlife?
			Provincial Guideline/Standard - Wildlife Water ⁽²⁾⁽³⁾⁽⁴⁾	Sample et al. (1996) Toxicological Benchmark ⁽⁵⁾	CCME CWQG ⁽⁶⁾ Livestock Water	50th Percentile ⁽⁷⁾	50th Percentile ⁽⁷⁾	50th Percentile ⁽⁷⁾	
Metals									
Total Aluminum (Al)	mg/L	0.016	--	64	NR	0.0029	0.040	0.0022	No
Total Antimony (Sb)	mg/L	0.000015	--	4.2	NR	0.000019	0.000019	0.000042	No
Total Arsenic (As)	mg/L	0.0013	--	4.2	NR	0.0016	0.0015	0.0016	No
Total Barium (Ba)	mg/L	0.0019	--	66	NR	0.0020	0.0024	0.0039	No
Total Beryllium (Be)	mg/L	0.00010	--	2.2	NR	0.000068	0.00013	0.000025	No
Total Boron (B)	mg/L	0.0022	5 ⁽⁴⁾	NR	NR	0.0027	0.0031	0.019	No
Total Cadmium (Cd)	mg/L	0.0000085	--	33	NR	0.000015	0.000041	0.000023	No
Total Calcium (Ca)	mg/L	1.1	--	--	1000	1.6	2.6	11	No
Total Chromium (Cr)	mg/L	0.000079	--	21	NR	0.000061	0.000083	0.000040	No
Total Cobalt (Co)	mg/L	0.000069	--	29	NR	0.0010	0.0048	0.0015	No
Total Copper (Cu)	mg/L	0.00030	--	50	NR	0.00042	0.0039	0.00047	No
Total Iron (Fe)	mg/L	0.028	--	--	--	0.0052	0.024	0.00069	No ⁽¹⁰⁾
Total Lead (Pb)	mg/L	0.000025	--	49	NR	0.000048	0.000061	0.000027	No
Total Magnesium (Mg)	mg/L	0.60	--	--	--	0.68	0.93885354	2.1	No ⁽⁸⁾
Total Manganese (Mn)	mg/L	0.0029	--	947	NR	0.010	0.026	0.063	No
Total Mercury (Hg)	mg/L	0.000010	--	3	NR	0.000011	0.000016	0.000026	No
Total Molybdenum (Mo)	mg/L	0.000030	--	9	NR	0.000037	0.000031	0.00011	No
Total Nickel (Ni)	mg/L	0.00044	--	267	NR	0.0023	0.011	0.0077	No
Total Phosphorus (P)	mg/L	0.0080	--	--	--	0.0073	0.0077	0.0084	No ^(8,14)
Total Potassium (K)	mg/L	0.40	--	--	--	0.45	0.5	1.2	No ⁽⁸⁾
Total Selenium (Se)	mg/L	0.000050	0.002 ⁽⁴⁾	NR	NR	0.000052	0.000055	0.000063	No
Total Silicon (Si)	mg/L	0.0025	--	--	--	0.019	0.13	0.22	No ⁽¹¹⁾
Total Silver (Ag)	mg/L	0.000050	--	233.8	NR	0.000050	0.00005	0.000049	No
Total Sodium (Na)	mg/L	0.43	--	--	--	0.64	0.73	3.9	No ⁽⁸⁾
Total Strontium (Sr)	mg/L	0.0048	--	877	NR	0.0065	0.010	0.039	No
Total Thallium (Tl)	mg/L	0.000015	--	0.25	NR	0.000015	0.000017	0.000019	No
Total Tin (Sn)	mg/L	0.000050	--	--	--	0.000086	0.00005	0.000063	No ⁽⁸⁾
Total Uranium (U)	mg/L	0.000025	--	20	NR	0.000053	0.000065	0.00017	No
Total Vanadium (V)	mg/L	0.000025	--	7.0	NR	0.000061	0.000036	0.000056	No
Total Zinc (Zn)	mg/L	0.00040	--	563	NR	0.0018	0.0083	0.015	No
Routine Physical and Chemical Parameters									
pH	pH	6.60	--	--	--	6.55	6.56	6.94	No ⁽¹³⁾
Alkalinity (Total as CaCO3)	mg/L	2.5	--	--	--	2.4	2.4	6.3	No ⁽⁹⁾
Dissolved Sulphate (SO4)	mg/L	2.5	--	--	1000	4.3	9.2	35	No
Dissolved Chloride (Cl)	mg/L	0.5	600 ⁽⁴⁾	--	NR	1.4	1.3	2.8	No
Dissolved Nitrate (N)	mg/L as N	0.003	100 ⁽¹²⁾	--	NR	0.0059	0.0040	0.00048	No

Notes:

Tables should be read in conjunction with the accompanying document.

COC = contaminant of concern; mg/L = milligram per litre; -- = no screening value available; NR = not required.

⁽¹⁾ Background concentrations are calculated as the total metal concentrations based on 50th percentile mass loading inputs from data collected at Fingers Lake between 2005 and 2016.

⁽²⁾ The provincial guideline/standard was selected as the lowest of the AEP SWQG wildlife water, or the BC MECCS water quality guideline for wildlife, unless otherwise

⁽³⁾ Alberta Environment and Parks (AEP). 2019. Alberta Tier 1 Soil and Groundwater Remediation Guidelines. Land Policy Branch, Policy and Planning Division. 198 pp. Table C-11 Surface Water Quality Guidelines (SWQG) - Wildlife Water.

□

⁽⁴⁾ British Columbia Ministry of Environment & Climate Change Strategy (BC MECCS). 2018. British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife and Agriculture, Summary Report, Water Protection & Sustainability Branch, Ministry of Environment & Climate Change Strategy, March 2018.

⁽⁵⁾ In the absence of guidelines from AEP, toxicity benchmarks were calculated using Sample et al. (1996).

Sample et al. 1996. Toxicological Benchmarks for Wildlife: 1996 Revision, June 1996. United States Department of Energy. Most conservative of the available toxicity benchmarks was selected as screening. Calculation the toxicity benchmarks is presented in Table 7.3.

⁽⁶⁾ In the absence of AEP guidelines and Sample et al. toxicity benchmarks, guidelines from the CCME (2019) were selected.

Canadian Council of Ministers of the Environment (CCME). 2019. Canadian Water Quality Guidelines (CWQG) for the Protection of Agricultural Uses, Livestock Water.

⁽⁷⁾ Highest predicted surface water concentration based on the 50th percentile mass loading inputs of water quality predictions for June, July, August and September. The surface water concentrations in the lakes were predicted using a model that incorporated the proposed risk management measures outlined in the Final Closure and Reclamation Plan (i.e., waste rock consolidation and placement of engineered cover).

⁽⁸⁾ Naturally occurring, essential and/or generally considered non-toxic (except when ingested in extreme quantities). See Section 5.1.1.3.1 for further description.

⁽⁹⁾ Routine physical water quality parameter and not directly toxic.

⁽¹⁰⁾ Iron is an essential nutrient for mammals and birds and relevant toxicity reference values have not been published for these receptors. The US EPA (2006) published a toxicity reference value based on the geomean of the lowest observed adverse effect levels for decreased body weight in rats; however, the effect was attributed to the decreased palatability of water as opposed to the toxicity of iron itself.

⁽¹¹⁾ Silicon is the second most abundant element and makes up 25.7% of the earth's crust (HSDB, 2011). Silicon is fundamentally non-toxic. No short-term or long-term toxicity data in either humans or laboratory animals were found on the potential oral toxicity of elemental silicon (HSDB, 2011). Therefore, silicon was not retained as a COC for wildlife.

⁽¹²⁾ British Columbia Ministry of Environment . 2009. Water Quality Guidelines for Nitrogen (Nitrate, Nitrite, and Ammonia) Overview Report Update. Water Stewardship Division, Ministry of Environment, Province of British Columbia. September 2009.

⁽¹³⁾ The stomach pH of wildlife is naturally lower than the lowest pH measured in surface water.

⁽¹⁴⁾ For phosphorus, concerns with this parameter are related to aesthetics (i.e., algal blooms) and effects to aquatic life rather than adverse effects to wildlife.

Grey and bold

Indicates exceedance of applied screening value and background concentration, or no screening value and detectable concentration and above background concentration.

Prepared by: SG
Checked by: TD

Table 5.6
Screening of Boot Lake Surface Water for Ecological Receptors - Aquatic Life
Lupin Mine, Nunavut

Parameter	Units	Background Concentration - 50th Percentile ⁽¹⁾	Screening Value		Highest Predicted Concentration ⁽⁶⁾	Retain as a COC for Aquatic Life?
			CCME CWQG-PAL ⁽²⁾ or FEQG ^(3,4)	Other Guidelines/Standards ⁽⁵⁾	50th Percentile	
Physical and Chemical Parameters						
pH	-	6.3 to 6.9	6.5 to 9.0	NR	5.6 to 6.6	Yes
Alkalinity	mg/L CaCO3	2.5	--	--	2.4	No ⁽¹³⁾
Nitrate	mg/L N	0.0030	3	NR	0.0059	No
Chloride	mg/L	0.50	120	NR	1.4	No
Sulphate	mg/L	2.5	--	128 ⁽¹⁰⁾	4.3	No
Metals						
Silver	mg/L	0.000050	0.00025	NR	0.000050	No
Aluminum	mg/L	0.016	0.1 ⁽⁷⁾	NR	0.0029	No
Arsenic	mg/L	0.0013	0.005	NR	0.0016	No
Boron	mg/L	0.0022	1.5	NR	0.0027	No
Barium	mg/L	0.0019	--	2.3	0.0020	No
Beryllium	mg/L	0.00010	--	0.0053	0.000068	No
Calcium	mg/L	1.1	--	--	1.6	No ⁽¹⁴⁾
Cadmium	mg/L	0.000009	0.00004 ⁽⁸⁾	NR	0.000015	No
Cobalt	mg/L	0.000069	0.00078 ⁽³⁾	NR	0.0010	Yes
Chromium	mg/L	0.000079	0.001	NR	0.000061	No
Copper	mg/L	0.00030	0.002 ⁽⁸⁾	NR	0.00042	No
Iron	mg/L	0.028	0.3	NR	0.0052	No
Mercury	mg/L	0.000010	0.000026	NR	0.000011	No
Potassium	mg/L	0.40	--	--	0.45	No ⁽¹⁴⁾
Magnesium	mg/L	0.60	--	--	0.68	No ⁽¹⁴⁾
Manganese	mg/L	0.0029	--	0.767 ⁽¹¹⁾	0.010	No
Molybdenum	mg/L	0.000030	0.073	NR	0.000037	No
Sodium	mg/L	0.43	--	180	0.64	No
Nickel	mg/L	0.00044	0.025 ⁽⁸⁾	NR	0.0023	No
Phosphorus	mg/L	0.0080	--	--	0.0073	No ⁽¹⁵⁾
Lead	mg/L	0.000025	0.001 ⁽⁸⁾	NR	0.000048	No
Antimony	mg/L	0.000015	--	1.6	0.000019	No
Selenium	mg/L	0.000050	0.001	NR	0.000052	No
Silicon	mg/L	0.0025	--	--	0.019	No ⁽¹⁶⁾
Tin	mg/L	0.000050	--	--	0.000086	No ⁽¹⁷⁾
Strontium	mg/L	0.0048	--	10.7 ⁽¹²⁾	0.0065	No
Thallium	mg/L	0.000015	0.0008	NR	0.000015	No
Uranium	mg/L	0.000025	0.015	NR	0.000053	No
Vanadium	mg/L	0.000025	0.120 ⁽⁴⁾	--	0.000061	No
Zinc	mg/L	0.00040	15.08 ⁽⁹⁾	NR	0.0018	No

Notes:
Tables should be read in conjunction with the accompanying document.
COC = contaminant of concern; mg/L = milligram per litre; -- = no screening value available; NR = not required (provincial screening values only used in absence of federal screening values)

⁽¹⁾ Background concentrations are calculated as the total metal concentrations based on 50th percentile mass loading inputs from data collected at Fingers Lake between 2005 and 2016. Background pH is the range of pH measured from Fingers Lake.

⁽²⁾ Canadian Council of Ministers of the Environment (CCME). 1999/2019. Canadian Water Quality Guidelines (CWQG) for the Protection of Aquatic Life (PAL), Freshwater.

⁽³⁾ Environment Canada. 2017. Federal Environmental Quality Guideline (FEQG) For Cobalt. May 2017. Freshwater aquatic life. Calculated based on the lowest hardness in the range for which the guideline is applicable (52 mg/L)

⁽⁴⁾ Environment and Climate Change Canada. 2016. Federal Environmental Quality Guideline (FEQG) for Vanadium. May 2016. Freshwater aquatic life.

⁽⁵⁾ In the absence of federal standards/guidelines, the lowest of the available provincial values from the following regulatory bodies was selected for screening:
British Columbia Ministry of Environment and Climate Change Strategy (BC MECCS). 2019. British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture Summary Report. Water Protection & Sustainability Branch. August 2019.
Alberta Environment and Parks (AEP). 2019. Alberta Tier 1 Soil and Groundwater Remediation Guidelines. Land Policy Branch, Policy and Planning Division. 198 pp. Table C-11 Surface Water Quality Guidelines (SWQG) - Aquatic Life.
Ontario Ministry of the Environment and Climate Change (MOECC). 2016. Modified Generic Risk Assessment "Approved Model". Aquatic Protection Values.

⁽⁶⁾ Highest predicted surface water concentration based on the 50th percentile mass loading inputs of water quality predictions for June, July, August and September. The surface water concentrations in the lakes were predicted using a model that incorporated the proposed risk management measures outlined in the Final Closure and Reclamation Plan (i.e., waste rock consolidation and placement of engineered cover).

⁽⁷⁾ Aluminium guideline= 0.1 mg/L at pH ≥ 6.5, based on predicted pH of 6.55 (based on 50th percentile mass loading inputs)

⁽⁸⁾ CCME guideline based on surface water hardness as [CaCO3] = 5 mg/L (background 50th percentile mass loading inputs)

⁽⁹⁾ CCME guideline based on surface water hardness, pH and dissolved organic carbon. The lowest applicable hardness for which the CCME equation is valid was used (23.4 mg/L). Predicted pH of 6.55 was used (50th percentile). Background (50th percentile) dissolved organic carbon concentration of 3.00 mg/L was used.

⁽¹⁰⁾ The AEP & BC MOECCS guideline for sulphate of 128 mg/L was used (based on water hardness of 0-30 mg/L).

⁽¹¹⁾ The BC MOECCS guideline for manganese of 0.767 mg/L was used (BC MOE, 1999). Calculated based on the lowest hardness in the range for which the guideline is applicable (37 mg/L)

⁽¹²⁾ In the absence of federal or provincial screening guidelines/standards for aquatic life, the chronic effects benchmark for aquatic life of 10.7 mg/L was used (McPherson et al. 2014).

McPherson, C.A., Lawrence, G.S., Elphick, J.R., Chapman, P.M. 2014. Development of a Strontium Chronic Effects Benchmark for Aquatic Life in Freshwater. Environmental Toxicology and Chemistry. 33:2472-2478.

⁽¹³⁾ Routine water quality parameter and not directly toxic.

⁽¹⁴⁾ Naturally occurring, essential and generally considered non-toxic. Calcium, magnesium and potassium are not expected to result in adverse health effects to aquatic life. Major ions such as these can effectively reduce metal toxicity in aquatic biota through competitive interactions at uptake sites (US EPA, 2007). As such, an increase in the concentration of these parameters above reference concentrations would not necessarily constitute a potential adverse effect but would serve to ameliorate metal toxicity to aquatic biota.

US EPA. 2007. Aquatic Life Ambient Freshwater Quality Criteria – Copper: 2007 Revision (CAS Registry Number 7440-50-8). Office of Water, Office of Science and Technology. Washington, DC. EPA-822-R-07-001. February 2007.

⁽¹⁵⁾ Less than or equal to background concentration.

⁽¹⁶⁾ Silicon is ubiquitous in the environment and fundamentally non-toxic.

⁽¹⁷⁾ In the absence of federal or provincial guidelines/standards; the ecological benchmarks for tin available from the Risk Assessment Information System (RAIS, 2019) was used for screening. The highest predicted concentrations for tin were below all available surface water ecological benchmarks available from RAIS.

Risk Assessment Information System (RAIS). 2019. Ecological Benchmark Tool. Current to October 1, 2019.

Grey and bold

Indicates exceedance of applied screening value and background concentration, or no screening value and detectable concentration and above background concentration.

Prepared by: KL/AF
Checked by: SG

Table 5.7
Screening of East Lake Surface Water for Ecological Receptors - Aquatic Life
Lupin Mine, Nunavut

Parameter	Units	Background Concentration - 50th Percentile ⁽¹⁾	Screening Value		Highest Predicted Concentration ⁽⁶⁾	Retain as a COC for Aquatic Life?
			CCME CWQG-PAL ⁽²⁾ or FEQG ^(3,4)	Other Guidelines/Standards ⁽⁵⁾	50th Percentile	
Physical and Chemical Parameters						
pH	-	6.3 to 6.9	6.5 to 9.0	NR	5.0 to 6.6	Yes
Alkalinity	mg/L CaCO3	2.5	--	--	2.4	No ⁽¹³⁾
Nitrate	mg/L N	0.0030	3	NR	0.0040	No
Chloride	mg/L	0.50	120	NR	1.3	No
Sulphate	mg/L	2.5	--	128 ⁽¹⁰⁾	9.2	No
Metals						
Silver	mg/L	0.000050	0.00025	NR	0.00005	No
Aluminum	mg/L	0.016	0.1 ⁽⁷⁾	NR	0.040	No
Arsenic	mg/L	0.0013	0.005	NR	0.0015	No
Boron	mg/L	0.0022	1.5	NR	0.0031	No
Barium	mg/L	0.0019	--	2.3	0.0024	No
Beryllium	mg/L	0.00010	--	0.0053	0.00013	No
Calcium	mg/L	1.1	--	--	2.6	No ⁽¹⁴⁾
Cadmium	mg/L	0.000009	0.00004 ⁽⁸⁾	NR	0.000041	Yes
Cobalt	mg/L	0.000069	0.00078 ⁽³⁾	NR	0.0048	Yes
Chromium	mg/L	0.000079	0.001	NR	0.000083	No
Copper	mg/L	0.00030	0.002 ⁽⁸⁾	NR	0.0039	Yes
Iron	mg/L	0.028	0.3	NR	0.024	No
Mercury	mg/L	0.000010	0.000026	NR	0.000016	No
Potassium	mg/L	0.40	--	--	0.5	No ⁽¹⁴⁾
Magnesium	mg/L	0.60	--	--	0.9	No ⁽¹⁴⁾
Manganese	mg/L	0.0029	--	0.767 ⁽¹¹⁾	0.026	No
Molybdenum	mg/L	0.000030	0.073	NR	0.000031	No
Sodium	mg/L	0.43	--	180	0.73	No
Nickel	mg/L	0.00044	0.025 ⁽⁸⁾	NR	0.011	No
Phosphorus	mg/L	0.0080	--	--	0.0077	No ⁽¹⁵⁾
Lead	mg/L	0.000025	0.001 ⁽⁸⁾	NR	0.000061	No
Antimony	mg/L	0.000015	--	1.6	0.000019	No
Selenium	mg/L	0.000050	0.001	NR	0.000055	No
Silicon	mg/L	0.0025	--	--	0.13	No ⁽¹⁶⁾
Tin	mg/L	0.000050	--	--	0.00005	No ⁽¹⁷⁾
Strontium	mg/L	0.0048	--	10.7 ⁽¹²⁾	0.010	No
Thallium	mg/L	0.000015	0.0008	NR	0.000017	No
Uranium	mg/L	0.000025	0.015	NR	0.000065	No
Vanadium	mg/L	0.000025	0.120 ⁽⁴⁾	--	0.000036	No
Zinc	mg/L	0.00040	14.90 ⁽⁹⁾	NR	0.0083	No

Notes:
Tables should be read in conjunction with the accompanying document.
COC = contaminant of concern; mg/L = milligram per litre; -- = no screening value available; NR = not required (provincial screening values only used in absence of federal screening values)

⁽¹⁾ Background concentrations are calculated as the total metal concentrations based on 50th percentile mass loading inputs from data collected at Fingers Lake between 2005 and 2016. Background pH is the range of pH measured from Fingers Lake.

⁽²⁾ Canadian Council of Ministers of the Environment (CCME). 2018. Canadian Water Quality Guidelines (CWQG) for the Protection of Aquatic Life (PAL), Freshwater.

⁽³⁾ Environment Canada. 2017. Federal Environmental Quality Guideline (FEQG) For Cobalt. May 2017. Freshwater aquatic life. Calculated based on the lowest hardness in the range for which the guideline is applicable (52 mg/L)

⁽⁴⁾ Environment and Climate Change Canada. 2016. Federal Environmental Quality Guideline (FEQG) for Vanadium. May 2016. Freshwater aquatic life.

⁽⁵⁾ In the absence of federal standards/guidelines, the lowest of the available provincial values from the following regulatory bodies was selected for screening:
British Columbia Ministry of Environment and Climate Change Strategy (BC MECCS). 2019. British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture Summary Report. Water Protection & Sustainability Branch. August 2019.
Alberta Environment and Parks (AEP). 2019. Alberta Tier 1 Soil and Groundwater Remediation Guidelines. Land Policy Branch, Policy and Planning Division. 198 pp. Table C-11 Surface Water Quality Guidelines (SWQG) - Aquatic Life.
Ontario Ministry of the Environment and Climate Change (MOECC). 2016. Modified Generic Risk Assessment "Approved Model". Aquatic Protection Values.

⁽⁶⁾ Highest predicted surface water concentration based on the 50th percentile mass loading inputs of water quality predictions for June, July, August and September. The surface water concentrations in the lakes were predicted using a model that incorporated the proposed risk management measures outlined in the Final Closure and Reclamation Plan (i.e., waste rock consolidation and placement of engineered cover).

⁽⁷⁾ Aluminium guideline= 0.1 mg/L at pH ≥ 6.5, based on predicted pH of 6.55 (based on 50th percentile mass loading inputs)

⁽⁸⁾ CCME guideline based on surface water hardness as [CaCO3] = 5 mg/L (background 50th percentile mass loading inputs)

⁽⁹⁾ CCME guideline based on surface water hardness, pH and dissolved organic carbon. The lowest applicable hardness for which the CCME equation is valid was used (23.4 mg/L). Predicted pH of 6.55 was used (50th percentile). Background (50th percentile) dissolved organic carbon concentration of 3.00 mg/L was used.

⁽¹⁰⁾ The AEP & BC MOECCS guideline for sulphate of 128 mg/L was used (based on water hardness of 0-30 mg/L).

⁽¹¹⁾ The BC MOECCS guideline for manganese of 0.767 mg/L was used (BC MOE, 1999). Calculated based on the lowest hardness in the range for which the guideline is applicable (37 mg/L)

⁽¹²⁾ In the absence of federal or provincial screening guidelines/standards for aquatic life, the chronic effects benchmark for aquatic life of 10.7 mg/L was used (McPherson et al. 2014).
McPherson, C.A., Lawrence, G.S., Elphick, J.R., Chapman, P.M. 2014. Development of a Strontium Chronic Effects Benchmark for Aquatic Life in Freshwater. Environmental Toxicology and Chemistry. 33:2472-2478.

⁽¹³⁾ Routine water quality parameter and not directly toxic.

⁽¹⁴⁾ Naturally occurring, essential and generally considered non-toxic. Calcium, magnesium and potassium are not expected to result in adverse health effects to aquatic life. Major ions such as these can effectively reduce metal toxicity in aquatic biota through competitive interactions at uptake sites (US EPA, 2007). As such, an increase in the concentration of these parameters above reference concentrations would not necessarily constitute a potential adverse effect but would serve to ameliorate metal toxicity to aquatic biota.

US EPA. 2007. Aquatic Life Ambient Freshwater Quality Criteria – Copper: 2007 Revision (CAS Registry Number 7440-50-8). Office of Water, Office of Science and Technology. Washington, DC. EPA-822-R-07-001. February 2007.

⁽¹⁵⁾ Less than or equal to background concentration.

⁽¹⁶⁾ Silicon is ubiquitous in the environment and fundamentally non-toxic.

⁽¹⁷⁾ In the absence of federal or provincial guidelines/standards; the ecological benchmarks for tin available from the Risk Assessment Information System (RAIS, 2019) was used for screening. The highest predicted concentrations for tin were below all available surface water ecological benchmarks available from RAIS.

Risk Assessment Information System (RAIS). 2019. Ecological Benchmark Tool. Current to October 1, 2019.

Grey and bold

Indicates exceedance of applied screening value and background concentration, or no screening value and detectable concentration and above background concentration.

Prepared by: KL/AF
Checked by: SG

Table 5.8
Screening of Lower Sewage Lake Surface Water for Ecological Receptors - Aquatic Life
Lupin Mine, Nunavut

Parameter	Units	Background Concentration - 50th Percentile ⁽¹⁾	Screening Value		Highest Predicted Concentration ⁽⁶⁾	Retain as a COC for Aquatic Life?
			CCME CWQG-PAL ⁽²⁾ or FEQG ^(3,4)	Other Guidelines/Standards ⁽⁵⁾	50th Percentile	
Physical and Chemical Parameters						
pH	-	6.3 to 6.9	6.5 to 9.0	NR	6.5 to 6.9	No
Alkalinity	mg/L CaCO3	2.5	--	--	6.3	No ⁽¹³⁾
Nitrate	mg/L N	0.0030	3	NR	0.00048	No
Chloride	mg/L	0.50	120	NR	2.8	No
Sulphate	mg/L	2.5	--	128 ⁽¹⁰⁾	35	No
Metals						
Silver	mg/L	0.000050	0.00025	NR	0.000049	No
Aluminum	mg/L	0.016	0.1 ⁽⁷⁾	NR	0.0022	No
Arsenic	mg/L	0.0013	0.005	NR	0.0016	No
Boron	mg/L	0.0022	1.5	NR	0.019	No
Barium	mg/L	0.0019	--	2.3	0.0039	No
Beryllium	mg/L	0.00010	--	0.0053	0.000025	No
Calcium	mg/L	1.1	--	--	11	No ⁽¹⁴⁾
Cadmium	mg/L	0.0000085	0.00004 ⁽⁸⁾	NR	0.000023	No
Cobalt	mg/L	0.000069	0.00078 ⁽³⁾	NR	0.0015	Yes
Chromium	mg/L	0.000079	0.001	NR	0.000040	No
Copper	mg/L	0.00030	0.002 ⁽⁸⁾	NR	0.00047	No
Iron	mg/L	0.028	0.3	NR	0.00069	No
Mercury	mg/L	0.000010	0.000026	NR	0.000026	No
Potassium	mg/L	0.40	--	--	1.2	No ⁽¹⁴⁾
Magnesium	mg/L	0.60	--	--	2.1	No ⁽¹⁴⁾
Manganese	mg/L	0.0029	--	0.767 ⁽¹²⁾	0.063	No
Molybdenum	mg/L	0.000030	0.073	NR	0.00011	No
Sodium	mg/L	0.43	--	180	3.9	No
Nickel	mg/L	0.00044	0.025 ⁽⁸⁾	NR	0.0077	No
Phosphorus	mg/L	0.0080	0.004-0.010 ⁽¹⁷⁾	--	0.0084	No ⁽¹⁸⁾
Lead	mg/L	0.000025	0.001 ⁽⁸⁾	NR	0.000027	No
Antimony	mg/L	0.000015	--	1.6	0.000042	No
Selenium	mg/L	0.000050	0.001	NR	0.000063	No
Silicon	mg/L	0.0025	--	--	0.22	No ⁽¹⁵⁾
Tin	mg/L	0.000050	--	--	0.000063	No ⁽¹⁶⁾
Strontium	mg/L	0.0048	--	10.7 ⁽¹³⁾	0.039	No
Thallium	mg/L	0.000015	0.0008	NR	0.000019	No
Uranium	mg/L	0.000025	0.015	NR	0.00017	No
Vanadium	mg/L	0.000025	0.120 ⁽⁴⁾	--	0.000056	No
Zinc	mg/L	0.00040	10.93 ⁽⁹⁾	NR	0.015	No

Notes:
Tables should be read in conjunction with the accompanying document.
COC = contaminant of concern; mg/L = milligram per litre; -- = no screening value available; NR = not required (provincial screening values only used in absence of federal screening values)

⁽¹⁾ Background concentrations are calculated as the total metal concentrations based on 50th percentile mass loading inputs from data collected at Fingers Lake between 2005 and 2016. Background pH is the range of pH measured from Fingers Lake.

⁽²⁾ Canadian Council of Ministers of the Environment (CCME). 2018. Canadian Water Quality Guidelines (CWQG) for the Protection of Aquatic Life (PAL), Freshwater.

⁽³⁾ Environment Canada. 2017. Federal Environmental Quality Guideline (FEQG) For Cobalt. May 2017. Freshwater aquatic life. Calculated based on the lowest hardness in the range for which the guideline is applicable (52 mg/L)

⁽⁴⁾ Environment and Climate Change Canada. 2016. Federal Environmental Quality Guideline (FEQG) for Vanadium. May 2016. Freshwater aquatic life.

⁽⁵⁾ In the absence of federal standards/guidelines, the lowest of the available provincial values from the following regulatory bodies was selected for screening: British Columbia Ministry of Environment and Climate Change Strategy (BC MECCS). 2019. British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture Summary Report. Water Protection & Sustainability Branch. August 2019.

Alberta Environment and Parks (AEP). 2019. Alberta Tier 1 Soil and Groundwater Remediation Guidelines. Land Policy Branch, Policy and Planning Division. 198 pp. Table C-11 Surface Water Quality Guidelines (SWQG) - Aquatic Life.

Ontario Ministry of the Environment and Climate Change (MOECC). 2016. Modified Generic Risk Assessment "Approved Model". Aquatic Protection Values.

⁽⁶⁾ Highest predicted surface water concentration based on the 50th percentile mass loading inputs of water quality predictions for June, July, August and September. The surface water concentrations in the lakes were predicted using a model that incorporated the proposed risk management measures outlined in the Final Closure and Reclamation Plan (i.e., waste rock consolidation and placement of engineered cover).

⁽⁷⁾ Aluminium guideline= 0.1 mg/L at pH ≥ 6.5, based on predicted pH of 6.55 (based on 50th percentile mass loading inputs)

⁽⁸⁾ CCME guideline based on surface water hardness as [CaCO3] = 5 mg/L (background 50th percentile mass loading inputs)

⁽⁹⁾ CCME guideline based on surface water hardness, pH and dissolved organic carbon. The lowest applicable hardness for which the CCME equation is valid was used (23.4 mg/L). Predicted pH of 6.94 was used (50th percentile). Background (50th percentile) dissolved organic carbon concentration of 3.00 mg/L was used.

⁽¹⁰⁾ The AEP & BC MOECCS guideline for sulphate of 128 mg/L was used (based on water hardness of 0-30 mg/L).

⁽¹¹⁾ The BC MOECCS guideline for manganese of 0.767 mg/L was used (BC MOE, 1999). Calculated based on the lowest hardness in the range for which the guideline is applicable (37 mg/L)

⁽¹²⁾ In the absence of federal or provincial screening guidelines/standards for aquatic life, the chronic effects benchmark for aquatic life of 10.7 mg/L was used (McPherson et al. 2014). McPherson, C.A., Lawrence, G.S., Elphick, J.R., Chapman, P.M. 2014. Development of a Strontium Chronic Effects Benchmark for Aquatic Life in Freshwater. Environmental Toxicology and Chemistry. 33:2472-2478.

⁽¹³⁾ Routine water quality parameter and not directly toxic.

⁽¹⁴⁾ Naturally occurring, essential and generally considered non-toxic. Calcium, magnesium and potassium are not expected to result in adverse health effects to aquatic life. Major ions such as these can effectively reduce metal toxicity in aquatic biota through competitive interactions at uptake sites (US EPA, 2007). As such, an increase in the concentration of these parameters above reference concentrations would not necessarily constitute a potential adverse effect but would serve to ameliorate metal toxicity to aquatic biota.

US EPA. 2007. Aquatic Life Ambient Freshwater Quality Criteria – Copper: 2007 Revision (CAS Registry Number 7440-50-8). Office of Water, Office of Science and Technology. Washington, DC. EPA-822-R-07-001. February 2007.

⁽¹⁵⁾ Silicon is ubiquitous in the environment and fundamentally non-toxic.

⁽¹⁶⁾ In the absence of federal or provincial guidelines/standards; the ecological benchmarks for tin available from the Risk Assessment Information System (RAIS, 2019) was used for screening. The highest predicted concentrations for tin were below all available surface water ecological benchmarks available from RAIS.

Risk Assessment Information System (RAIS). 2019. Ecological Benchmark Tool. Current to October 1, 2019.

⁽¹⁷⁾ The background phosphorus concentration of 0.008 mg/L sets the trigger range of 0.004-0.010 mg/L for oligotrophic lakes. The phosphorus concentration in Lower Sewage Lake is within the desired trigger range for the trophic status of the lake, therefore phosphorus was not retained as a COC.

Grey and bold

Indicates exceedance of applied screening value and background concentration, or no screening value and detectable concentration and above background concentration.

Prepared by: KL/AF
Checked by: SG

Table 5.9
Characteristics of Contaminants of Concern
Lupin Mine, Nunavut

COC	Transport and Fate	Effects
Metals	The information provided below on the behaviour, transport and fate of metals in soil was taken from McLean and Bledsoe (1992). In soil, metals are associated with one or more “pools”, as follows: (1) dissolved in the soil solution; (2) occupying exchange sites on inorganic soil constituents; (3) adsorbed on inorganic soil constituents; (4) associated with insoluble soil organic matter; (5) precipitated as pure or mixed solids; (6) present in the structure of secondary minerals; and/or, (7) present in the structure of primary materials. Native metals can be associated with any of the seven pools but metals resulting from anthropogenic activities are only associated with the first five pools. Metals in soil solution, or in equilibrium with the soil solution, are generally considered to be most important with respect to leaching to groundwater, plant and invertebrate uptake and volatilization. Metals in soil solution exist as: (1) free (uncomplexed) metal ions (e.g., Cd^{2+}, Zn^{2+}); (2) soluble complexes with inorganic or organic ligands (e.g., CdSO_4, ZnCl_2); and/or, (3) associated with mobile inorganic and organic colloidal material. The total concentration of metal in the soil solution is the sum of the free ion concentration, the concentration of soluble organic and inorganic metal complexes and the concentration of metals associated with mobile colloidal material. The free metal ion is generally the most mobile, bioavailable and toxic form of the metal. The free metal ion concentration in the soil solution is determined by a number of controls, including complex formation, redox reaction, ion exchange and adsorption, precipitation and dissolution of solids and acid-base reaction. These controls are in turn affected by soil properties such as pH, redox potential, clay, soil organic matter, iron and manganese hydroxides and calcium carbonate content. For example, several metals exist in soils in more than one oxidation state (e.g., chromium, hexavalent chromium and trivalent chromium). The oxidation state determines their mobility, bioavailability and toxicity. Hexavalent chromium is toxic, weakly adsorbed by soils and relatively mobile while trivalent chromium is less toxic, relatively insoluble and strongly adsorbs to surfaces and relatively immobile. In general, oxidizing conditions favor retention of metals in soils while reducing conditions favor mobility. Of particular note for the Site is the effect of pH on metal mobility in soils. In general, the adsorption of cationic metals (e.g., lead, nickel, cadmium, copper, lead, silver, zinc) to soil increases with pH and the adsorption of anions (e.g., arsenic, selenium) decreases with pH. As in soil, the free metal ion is generally the most bioavailable and toxic form of a metal in water and sediment (ICMM, 2007). In water, several factors influence the bioavailability and toxicity of metals through their interactions either directly or indirectly with metal ions. These include: pH and redox potential, alkalinity, ionic strength and complexing ligands (organic and inorganic ligands) (ICMM, 2007). For example, various ions (e.g., calcium, magnesium, sodium and potassium) can reduce bioavailability and metal toxicity to aquatic biota through competitive interactions with the metal ion at uptake sites on the aquatic organism. Complexing ligands (e.g., dissolved organic carbon and chloride) can reduce the bioavailable portion of a metal and thus metal toxicity to aquatic biota through complexation with the metal ion in the water column. In sediment, sulfides, organic matter concentration, redox potential and iron and manganese oxides affect the bioavailability and toxicity of metals to aquatic life (ICMM, 2007). Metals are considered to be persistent because they are elements and cannot be further degraded; however, they do undergo speciation based on environmental conditions (e.g., pH, redox). Most metals are absorbed from soil but are not biomagnified in the food chain. Mercury and selenium may be biomagnified in the aquatic food chain.	Metals are most bioavailable in dissolved form. The bioavailability and toxicity of cationic metals generally increases with decreasing pH ($\text{pH}<6$) while the bioavailability and toxicity of anionic metals generally increases with increasing pH. The effects of metals on ecological receptors depend on the metal and on the receptor group. In general, exposure to metals by ecological receptors can result in effects on reproduction, survival and growth. Physiological, biochemical and pathological effects have also been documented. When multiple COCs are present in an exposure medium (e.g., soil), they may produce antagonistic, additive and synergistic effects. The assessment relied solely on a literature-based toxicity assessment for each individual COC, and there is uncertainty regarding whether a combination of the COCs might have the potential to result in negative health effects. Although a number of COCs were identified in the assessment, not all these COCs have the same exposure pathways and mechanisms for effect and therefore the potential for interactions is reduced.

COC	Transport and Fate	Effects
Glycols (Ethylene glycol)	Glycols are used in deicing fluids and antifreeze mixtures and manufacturing processes. Ethylene glycol is a clear, colourless, odourless, relatively non-volatile, viscous liquid (CCME 1999a). If released to air, vapour phase ethylene glycol undergoes photodegradation, with a half-life estimated as 2 days (HSDB 2012). If released to soil, ethylene glycol is expected to have high mobility (based on the K_{oc} of 0.2) and has high potential to leach into groundwater (HSDB 2012). The low K_{ow} and high water solubility of ethylene glycol indicate a low potential for soil and sediment adsorption. Volatilization from surfaces is not expected as indicated by low vapour pressure and Henry's law constant. If released to water, glycols (ethylene glycol) is miscible in water and will move through surface water (CCME 1999a). Hydrolysis is not expected this compound lacks functional groups that hydrolyze under environmental conditions (HSDB 2012). Ethylene glycol is not considered persistent as it undergoes biodegradation and phototransformation (HSDB 2012). Biodegradation has been reported under aerobic and anaerobic conditions in soils, sediments and sludge. Ethylene glycol has a BCF of 10 for fish, suggesting the potential for bioconcentration in aquatic organisms is low (HSDB 2012). While low pH at the Site can affect the bioavailability and toxicity of some parameter groups (i.e., metals), low pH is not expected to affect bioavailability or toxicity of glycols.	Toxicity data for terrestrial plants and soil invertebrates are limited. Studies by Environment Canada found the lowest concentrations at which adverse effects occurred were 5300 and 9000 mg/kg in soil, resulting in a 25% reduction in seedling emergence for radishes and lettuce, respectively (Environment Canada 1995, as cited by CCME 1999a). The lowest concentration resulting in adverse effects for earthworms is 20000 mg/kg, resulting in 25% mortality (Environment Canada 1995, as cited by CCME 1999a). Ethylene glycol itself is not toxic, however the intermediary oxidation products (glycoaldehyde, glycolic acid, glyoxylic acid, and glycolate) are active toxicants (CCME, 1999a). Ethylene glycol has low acute toxicity in experimental animals following oral, inhalation and dermal exposure (HSDB 2012). Effects in mammals may include metabolic acidosis, coma, cardiopulmonary collapse and death. Effects in birds may include drowsiness, ataxia, dyspnea and death.
BTEX	BTEX (benzene, toluene, ethylbenzene and xylenes) are volatile organic compounds (VOCs) that are typically found in petroleum products such as gasoline and diesel fuel. Xylenes are a mixture of three isomers: 2(o)-xylene, 3(m)-xylene and 4(p)-xylene. The information provided below on the fate and transport of BTEX in air, soil and water was taken from the Hazardous Substances Data Bank (HSDB, 2014a,b,c,d). If released to air, BTEX will exist solely as a vapour in the atmosphere based on its vapour pressures. Vapour-phase BTEX will be degraded in the atmosphere primarily by reaction with photochemically-produced hydroxyl radicals. If released to soil, BTEX is expected to have moderate to very high mobility based on its K_{ocs}. Volatilization is expected to be an important fate process based upon its vapour pressures and Henry's Law constants. BTEX is also expected to biodegrade in soils. If released to water, benzene, toluene and xylenes are not expected to adsorb to suspended solids and sediment based upon their K_{oc} values. Ethylbenzene may adsorb to suspended solids and sediment. Volatilization is expected to be an important fate process for BTEX in water based upon its Henry's Law constant. Benzene, toluene and xylenes are biodegraded in water. Ethylbenzene is biodegraded in water and sediment. BTEX are not considered persistent as half-lives are below persistence criteria established under the Canadian Environmental Protection Act (Minister of Justice, 2018). The uptake of BTEX in animals may occur via many routes, including oral, inhalation and dermal absorption (CCME, 2004a,b,c,d). In ecological risk assessment, the majority of uptake of contaminants by wildlife is typically attributed to the oral route of uptake (Sample and Suter, 1994). BTEX is absorbed and rapidly distributed throughout an animal's body (CCME, 2004a,b,c,d). It is preferentially stored in adipose tissue but also accumulates in the kidneys, liver and brain. The major route of elimination from the body is excretion in the urine. BTEX are not considered bioaccumulative because BAFs and BCFs for algae, fish, mussels and plants are less than bioaccumulation criteria established under the Canadian Environmental Protection Act (Minister of Justice, 2018). While low pH at the Site can affect the bioavailability and toxicity of some parameter groups (i.e., metals), low pH is not expected to affect bioavailability or toxicity of BTEX.	Toxicity data for terrestrial plants and soil invertebrates is limited. Studies were commissioned by the CCME in support of development of the soil quality guidelines for BTEX (CCME, 2004a,b,c,d). These studies included a 14-day study that examined the effects of BTEX on root and shoot length and biomass of Northern wheatgrass and alfalfa and a 14-day test that investigated the effects of BTEX on survival of springtails and earthworms. Benzene is metabolized in mammals, and intermediates in the metabolic pathway are the primary cause of benzene toxicity. The primary effect of chronic exposure to benzene by mammals is effects on blood cells. Benzene is also a known carcinogen in mammals. Observed effects in laboratory studies of BTEX using experimental animals include central nervous systems effects, neurological effects and liver and kidney damage (CCME, 2004a,b,c,d).

COC	Transport and Fate	Effects
PHCs	Petroleum hydrocarbons (PHCs) are a mixture of organic compounds that come from crude oil. PHCs are divided into four fractions based on carbon number as follows: F1 (C6 to C10), F2 (>C10 to C16), F3 (>C16 to C34) and F4 (C34+). Lighter constituents (i.e., <C12) are water soluble and volatile while heavier constituents (i.e., >C21) are not soluble and non-volatile. Lighter compounds are likely present in air. Heavier compounds are more likely to be found bound to particulates in air, soil, suspended solids in water and sediment. PHCs adsorb onto sediment. Biodegradation is a major fate process for PHCs as most soils and sediments have populations of bacteria and other organisms capable of degrading PHCs (Williams et al., 2006). Biodegradability is affected by organic matter content, moisture, temperature, pH, and biological activity (Leahy and Colwell, 1990). Lighter compounds (aliphatic and aromatic hydrocarbons <C26) have half-lives below persistence criteria, while heavier compounds (>C30) are considered persistent based on modelled degradation rates (Environment Canada and Health Canada, 2013). PHCs are not readily taken up and accumulated by plants (CCME, 2008), invertebrates, or mammals (Landsell and McConnell, 2003). In wildlife, PHCs do not tend to accumulate in tissues because they are readily metabolized and excreted (CCME, 2008). As a result, ingestion of contaminated media rather than consumption of food items (plants or other animals) is the major route of exposure to wildlife from PHCs. Dermal contact and ingestion of petroleum product may also be important. For example, oiling of feathers can lead to hypothermia in waterfowl, and petroleum product may be ingested by wildlife during preening of fur and feathers (CCME, 2008). Based on Canadian Environmental Protection Act criteria (Minister of Justice, 2018), some PHCs are bioaccumulative. Bioaccumulation of hydrocarbons increases with K_{ow}, which tends to increase with molecular weight for PHCs (MADEP, 2007). BAFs/BCFs above 5000 have been reported for some PHCs (Environment Canada and Health Canada, 2013). There is no evidence to suggest that these PHCs biomagnify in terrestrial and aquatic food chains (Environment Canada and Health Canada, 2013). While low pH at the Site can affect the bioavailability and toxicity of some parameter groups (i.e., metals), low pH is not expected to affect bioavailability or toxicity of PHCs.	Toxicity varies by fractions (F1 through F4). The toxicity of PHCs is affected by soil texture and weathering processes. The CCME has developed soil quality guidelines for the protection of terrestrial plants and soil invertebrates (CCME, 2008). The guidelines for F1 through F4 are based on acute and chronic toxicity data for several plant and soil invertebrate species and include survival, growth and reproduction endpoints. Critical effects for aliphatic and aromatic hydrocarbons observed in studies with laboratory animals include neurological, kidney and liver effects, and hematological changes (CCME, 2008).

COC	Transport and Fate	Effects
PAHs	PAHs are a group of organic compounds composed of two or more benzene rings. Sources of PAHs in the environment include anthropogenic sources but they are also produced naturally. PAHs are divided into two categories: (1) low molecular weight (LMW) PAHs having fewer than four rings; and, (2) high molecular weight (HMW) PAHs having four or more rings. PAHs are non-polar, hydrophobic compounds, which do not ionize. As a result, they have low solubilities in water. The solubilities of PAHs in water increase as the molecular weight (and number of rings) decreases, as the temperature increases and in the presence of dissolved organics. Because of their hydrophobicity and low water solubilities, HMW PAHs tend to tightly sorb to soils, suspended particulates in water and sediments. LMW PAHs volatilize from soil and water and are predominantly present in the vapour phase in air. PAHs are subject to microbial degradation in soil, water and sediment under both aerobic and anaerobic conditions (CCME, 1999b; CCME, 2010). Resistance to microbial degradation in soils and water increases with molecular weight and number of rings (CCME, 1999b; CCME, 2010). In aquatic systems, photodegradation is also an important process for HMW PAHs and can lead to the formation of compounds that are more toxic than the parent compound (CCME, 1999b). Based on Canadian Environmental Protection Act criteria (Minister of Justice, 2018), naphthalene is not considered persistent but most of the other LMW-PAHs are considered persistent, including acenaphthene, fluorene, phenanthrene, anthracene and fluoranthene. The HMW-PAHs are also considered persistent. They have half-lives above persistence criteria in air, soil and sediment but below persistence criteria in water. Terrestrial plants may take up LMW-PAHs from soils and translocate the PAHs from the roots to various plant parts, however, they do not appear to accumulate or magnify the concentrations relative to those in soil (CCME, 2010). HMW-PAHs may sorb to plant roots but are not expected to translocate to other plant parts or accumulate in the plant (CCME, 2010). Gaseous phase transfer or deposition of particle-bound PAHs from the atmosphere to plant surfaces is the primary route of uptake of PAHs by terrestrial plants (US EPA, 2007). Earthworms take up PAHs primarily by direct contact (epidermal uptake) with soil pore water (US EPA, 2007). Animals may be exposed to PAHs in soil as the result of direct ingestion or indirect ingestion of food items (US EPA, 2007). Similar pathways of exposure apply to surface water and sediment. PAHs have limited ability to bioaccumulate in most animals because they are readily metabolized (ATSDR, 1995). The mixed-function oxygenase (MFO) enzyme systems are responsible for the biotransformation and ultimate detoxification of PAHs in animals. The process includes the generation of toxic intermediate products before formation of nontoxic end products. Based on Canadian Environmental Protection Act criteria (Minister of Justice, 2018), LMW- and HMW-PAHs are bioaccumulative for some aquatic species. In fish and crustaceans, BCFs have been reported in the range of 10 to 10,000 (ATSDR, 1995). In general, bioconcentration is greater for HMW- than LMW-PAHs. There is a high degree of variability in bioconcentration between species, depending on their ability to metabolize PAHs. Algae, mollusks and other species cannot metabolize PAHs rapidly and exhibit the highest BCFs, while fish and many crustaceans, which readily metabolize PAHs, generally have lower BCFs (CCME, 1999b). Fish have enzymes capable of metabolically transforming PAHs, thus concentrations of PAHs in tissues are typically close to or below analytical detection limits (e.g., Varanasi and Stein, 1991). While low pH at the Site can affect the bioavailability and toxicity of some parameter groups (i.e., metals), low pH is not expected to affect bioavailability or toxicity of PAHs.	Plant toxicity data for PAHs is limited but available data for crop species suggest that growth is the most sensitive endpoint for chronic exposure to PAHs by plants (US EPA, 2007; CCME, 2010). The primary mode of toxicity of PAHs to soil invertebrates is non-polar narcosis (epidermal uptake of PAHs from soil pore water and/or dietary intake and partitioning into body lipid) (US EPA, 2007; CCME, 2010). Reproductive impairment is the most sensitive endpoint for chronic exposure to PAHs by soil invertebrates (US EPA, 2007; CCME, 2010). Possible effects of PAHs on wildlife include mortality, reductions in growth, reproductive impairment, teratogenesis, endocrine disruption, liver and kidney damage, neurobehavioural changes, altered thermoregulatory ability and cancer (CCME, 2010).

Notes:
BAF = bioaccumulation factor; BCF = bioconcentration factor; BTEX = Benzene, Toluene, Ethylbenzene and Xylenes; CCME = Canadian Council of Ministers of the Environment; COC = contaminant of concern; HMW = high molecular weight; Koc = soil organic carbon partition coefficient; Kow = octanol-water partition coefficient; LMW = low molecular weight; MFO = mixed-function oxygenase; PAH = polycyclic aromatic hydrocarbon; PHC = petroleum hydrocarbon; VOC = volatile organic compound.

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Table 5.10
Terrestrial Receptors of Concern
Lupin Mine, Nunavut

Terrestrial Receptor Group	Terrestrial Receptor Type	Included in ERA? (Yes/No)	Rationale	Surrogate ROC	Rationale
Primary Producer (Plant)	Moss/Grass/Shrub/Tree/Forb	Yes	A number of plant communities and species of plants have been identified on the Site. As primary producers, plants play a critical role in terrestrial ecosystems. High potential for exposure to COCs because of root contact with soil and shallow groundwater. Food source for humans and wildlife (mammals and birds).	Plant community	n/a
Invertebrate	Ground-dwelling	Yes	Invertebrates (e.g., bumblebees, flies, mosquitos, moths, butterflies, beetles, spiders, worms, mites) are known to occur in the tundra (Hinterland Who's Who, 2012). Food source for mammals and birds.	Ground-dwelling invertebrate community	n/a
	Aerial	No	Ground-dwelling invertebrates would be more exposed to COCs in soil than aerial invertebrates. There is a lack of ecotoxicological data for aerial invertebrates to conduct a quantitative risk assessment.	n/a	n/a
Mammal	Herbivorous	Yes	Herbivorous mammals may be found on the Site and may be exposed to COCs in soil.	Arctic hare (<i>Lepus arcticus</i>)	Evaluated in the 2004 ERA (Golder, 2004). The Arctic hare is found throughout Nunavut. Plays a key role in the food web (component of the diet of larger mammals, such as wolves and grizzly bears). High potential for exposure to COCs due to small home range. Representative of small herbivores.
				Arctic ground squirrel (<i>Spermophilus parryii</i>)	Evaluated in the 2004 ERA (Golder, 2004). The arctic ground squirrel is found in the southern portion of the Kitikmeot region of Nunavut. Plays a key role in the food web (component of the diet of larger mammals, such as foxes). Ground squirrels are trapped by local Inuit residents. Representative of small herbivores.
				Caribou (<i>Rangifer tarandus</i>)	Evaluated in the 2004 ERA (Golder, 2004). Ecologically important species in the north. Important prey item for wolves and grizzly bears and are an important food item for people. Thousands of caribou can pass through or near the Lupin mine while travelling to and from their calving grounds. Representative of large herbivores.
				Muskoxen (<i>Ovibos moschatus</i>)	Evaluated in the 2004 ERA (Golder, 2004). Arctic dwelling animal with relatively small home range. Muskoxen are slow-moving animals that must dig through snow to consume vegetation. Important prey item for wolves. Observed occasionally near Lupin mine. Representative of large herbivores.
	Insectivorous	No	Only one insectivorous mammal occurs in Nunavut, the masked (or common) shrew and its geographical range does not overlap with the Site (Anand-Wheeler, 2002). The ERA focussed on mammals that are herbivores or that prey on herbivores given the typical food web of the arctic tundra.	n/a	n/a

Terrestrial Receptor Group	Terrestrial Receptor Type	Included in ERA? (Yes/No)	Rationale	Surrogate ROC	Rationale
	Carnivorous	Yes	Carnivorous mammals may occur on the Site but the identified COCs (i.e., PHCs, metals and PAHs) do not bioaccumulate in animals and exposure via other pathways would be less than that for herbivorous mammals. However, the carnivorous wolverine, a SAR, may be found on the Site and may be exposed to COCs in soil. Special consideration is to be given to SAR in ecological risk assessment to protect and conserve rare flora and fauna.	Wolverine (<i>Gulo gulo</i>)	Evaluated in the 2004 ERA. The wolverine is primarily a scavenger rather than a hunter and is usually dependent on other carnivores, such as wolves, to kill the animals for it to eat. Some individual wolverines can become good hunters and can kill young and adult ungulates, such as caribou, if the prey is in poor physical condition or if the wolverine has manoeuvred it into a disadvantaged position. Therefore, plays a key role in the wood web. Listed as a species of special concern by COSEWIC.
	Omnivorous	Yes	Evaluation of other mammals that feed almost exclusively on plants, invertebrates and small mammals (i.e., herbivorous, insectivorous and carnivorous mammals) is protective of omnivorous mammals whose diets are comprised of smaller portions of each of these food items. Insectivorous mammals do not occur on the Site. In addition, the identified COCs (i.e., PHCs, metals and PAHs) do not bioaccumulate in animals. Therefore, exposure by insectivorous and carnivorous mammals would be less than that for herbivorous mammals. However, the omnivorous grizzly bear, a SAR, may be found on the Site and may be exposed to COCs in soil. Special consideration is to be given to SAR in ecological risk assessment to protect and conserve rare flora and fauna.	Grizzly bear (<i>Ursus arctos Horribilis</i>)	Evaluated in the 2004 ERA. Socially important species. Listed as a species of special concern by COSEWIC.
Bird	Herbivorous	Yes	Herbivorous birds may be found on the Site and may be exposed to COCs in soil.	Willow ptarmigan (<i>Lagopus lagopus</i>)	Evaluated in the 2004 ERA (Golder, 2004). The willow ptarmigan is found throughout Nunavut. Spends most of its life on the ground so high potential for exposure to COCs in soil. Important prey item for wildlife such as wolves. One of a few species of birds that have a small home range. Source of food for people.
	Insectivorous	No	Only a few species of birds are present in Nunavut all year long (herbivorous, omnivorous and carnivorous species); however, several species of insectivorous birds migrate to Nunavut for breeding. Given the types of invertebrates found in Nunavut (e.g., bumblebees, flies, mosquitos, moths, butterflies, beetles, spiders, worms, mites), there is limited potential for exposure of these invertebrates to COCs in soil. The ERA focussed on birds that are herbivores or that prey on herbivores given the typical food web of the arctic tundra.	n/a	n/a
	Carnivorous	No	Carnivorous birds may occur on the Site (e.g., rough legged hawk); however, the identified COCs (i.e., PHCs, metals and PAHs) do not bioaccumulate in animals and exposure via other routes would be less than that for herbivorous birds.	n/a	n/a
	Omnivorous	No	Evaluation of other birds that feed almost exclusively on plants, soil invertebrates and small mammals (i.e., herbivorous, insectivorous and carnivorous mammals) is protective of omnivorous mammals whose diets are comprised of smaller portions of each of these food items. Insectivorous birds do not occur on the Site. In addition, the identified COCs (i.e., PHCs, metals and PAHs) do not bioaccumulate in animals. Therefore, exposure by insectivorous and carnivorous mammals would be less than that for herbivorous birds.	n/a	n/a
Amphibian	Carnivorous	No	Only two species of amphibians are found in Nunavut: the American toad, limited to Akimiski Island in James Bay and the wood frog, found in the western portion of the territory ((University of Guelph, 2012). The geographic range for the wood frog does not overlap with the Site.	n/a	n/a
Reptile	Carnivorous	No	There are no reptiles in Nunavut (University of Guelph, 2012).	n/a	n/a

Notes:
COC = contaminant of concern
ERA = ecological risk assessment
n/a = not applicable
PAHs = polycyclic aromatic hydrocarbons
PHCs = petroleum hydrocarbons
ROC = receptor of concern
COSEWIC = Committee on the Status of Endangered Wildlife in Canada
SAR = species at risk

Table 5.11
Aquatic Receptors of Concern
Lupin Mine, Nunavut

Aquatic Receptor Group	Aquatic Receptor Type	Included in ERA? (Yes/No)	Rationale	Surrogate ROC	Rationale
Primary Producer (Plant)	Phytoplankton Periphyton Macrophyte	Yes	Plants would be present in Contwoyto Lake, Boot Lake, East Lake and Lower Sewage Lake.	Plant community	n/a
Pelagic Invertebrate	Zooplankton	Yes	Pelagic invertebrates would be present Contwoyto Lake, Boot Lake, East Lake and Lower Sewage Lake.	Pelagic invertebrate community	n/a
Benthic Invertebrate	Epifauna Infauna	Yes	Benthic invertebrates would be present Contwoyto Lake, Boot Lake, East Lake and Lower Sewage Lake.	Benthic invertebrate community	n/a
Fish	Benthivorous Planktivorous Piscivorous	No	Fish habitat is present only in the main body of Contwoyto Lake. As surface water quality in Contwoyto Lake is not expected to be impacted by the Site, fish were not identified as ROCs.	n/a	n/a
Mammal	Herbivorous	No	No COCs were identified in surface water for mammals and birds.	n/a	n/a
	Piscivorous	No	No COCs were identified in surface water for mammals and birds.	n/a	n/a
	Omnivorous	No	No COCs were identified in surface water for mammals and birds.	n/a	n/a
Bird	Herbivorous	No	No COCs were identified in surface water for mammals and birds.	n/a	n/a
	Insectivorous	No	No COCs were identified in surface water for mammals and birds.	n/a	n/a
	Piscivorous	No	No COCs were identified in surface water for mammals and birds.	n/a	n/a
	Omnivorous	No	No COCs were identified in surface water for mammals and birds.	n/a	n/a
Amphibian	Carnivorous	No	Only two species of amphibians are found in Nunavut: the American toad, limited to Akimiski Island in James Bay and the wood frog, found in the western portion of the territory ((University of Guelph, 2012). The geographic range for the wood frog does not overlap with the Site.	n/a	n/a
Reptile	Omnivorous	No	There are no reptiles in Nunavut (University of Guelph, 2012).	n/a	n/a

Notes:
COC = contaminant of concern
ROC = receptor of concern

Table 5.12
Exposure Pathway Selection for Terrestrial Receptors of Concern
Lupin Mine, Nunavut

Receptor Group	Exposure Pathway	Included (yes/no)	Rationale
Primary Producer (Plant)	Direct Contact (Soil)	Yes	Plants are rooted in soil. COCs were identified in soil.
	Direct Contact (Groundwater)	Yes	Groundwater is within the rooting depth of plants in some parts of the Site (based on the 2017 monitoring results, the groundwater table in the shallow monitoring wells ranged from near surface to 1.75 mbgs). COCs were identified in groundwater.
Invertebrate	Direct Contact (Soil)	Yes	Some invertebrates live and feed in soil. COCs were identified in soil.
	Direct Contact (Groundwater)	No	Exposure via this pathway is likely to be negligible because invertebrates are expected to reside in unsaturated shallow soil.
Mammal	Water Consumption	No	No COCs were identified in seepage surface water on the Site for this exposure pathway. No COCs were identified in surface water in Boot Lake, East Lake or Lower Sewage Lake for this exposure pathway. Surface water quality in Lake Contwoyto is not expected to be impacted by the Site.
	Food Consumption	Yes	COCs in soil may be taken up by plants that are food items for mammals. Consumption of these food items would expose mammals to COCs in soil. COCs in groundwater may be taken up by plants that are food items for mammals. However, this pathway was not considered given the lack of uptake factors/equations for groundwater to plants. This is considered to be a source of uncertainty in the ERA.
	Incidental Soil Ingestion	Yes	Some mammals incidentally ingest soil during feeding.
	Dermal Exposure	No	This pathway is expected to be negligible because the presence of fur on mammals limits dermal contact with soil (US EPA 2005; Sample and Suter, 1994). Furthermore, the data necessary to evaluate dermal contact exposure is often lacking (US EPA, 1993; Sample and Suter, 1994), or if available, based on studies in which the chemical is applied directly to the skin by shaving the fur from laboratory rodents (US EPA, 2005), a type of exposure that would not occur in the natural environment. This approach is consistent with that used by the Ontario MECP in the development of the generic site condition standards where dermal exposure by mammals was considered but an assessment was not completed because there is currently not enough information to perform such an assessment (MOE, 2011a).
	Inhalation	No	This pathway is considered negligible as vapours would be rapidly mixed with ambient air and diluted, resulting in concentrations that would pose negligible risks to mammals. This approach is consistent with that used by the US DOE (Sample and Suter, 1994) and the US EPA (2005) where inhalation of contaminants is considered negligible and exposure via this pathway is not assessed. Some of the COCs can sorb to dust and be inhaled by mammals, however, exposure via this pathway is expected to be negligible in comparison to exposure from direct soil ingestion (US EPA, 2005). This approach with respect to inhalation exposure is consistent with that used by the Ontario MECP in the development of the site condition standards where inhalation exposure by mammals was considered but an assessment was not completed because there is currently not enough information to perform such an assessment (MOE 2011a).

Receptor Group	Exposure Pathway	Included (yes/no)	Rationale
Bird	Water Consumption	No	No COCs were identified in seepage surface water on the Site for this exposure pathway. No COCs were identified in surface water in Boot Lake, East Lake or Lower Sewage Lake for this exposure pathway. Surface water quality in Lake Contwoyto is not expected to be impacted by the Site.
	Food Consumption	Yes	COCs in soil may be taken up by plants that are food items for birds. Consumption of these food items would expose birds to COCs in soil. COCs in groundwater may be taken up by plants that are food items for birds. However, this pathway was not considered given the lack of uptake factors/equations for groundwater to plants. This is considered to be a source of uncertainty in the ERA.
	Incidental Soil Ingestion	Yes	Some birds incidentally ingest soil during feeding.
	Dermal Exposure	No	This pathway is expected to be negligible as the presence of feathers of birds limits dermal contact with soil (US EPA, 2005; Sample and Suter, 1994). Furthermore, the data necessary to evaluate dermal contact exposure is often lacking (US EPA 1993; Sample and Suter 1994), or if available, based on studies in which the chemical is applied directly to the skin by shaving the fur from laboratory rodents (US EPA 2005), a type of exposure that would not occur in the natural environment. This approach is consistent with that used by the Ontario MECP in the development of the generic site condition standards where dermal exposure by birds was considered but an assessment was not completed because there is currently not enough information to perform such an assessment (MOE, 2011a).
	Inhalation	No	This pathway is considered negligible as vapours would be rapidly mixed with ambient air and diluted, resulting in concentrations that would pose negligible risks to birds. This approach is consistent with that used by the US DOE (Sample and Suter, 1994) and the US EPA (2007) where inhalation of contaminants is considered negligible and exposure via this pathway is not assessed. Some of the COCs can sorb to dust and be inhaled by birds, however, exposure via this pathway is expected to be negligible in comparison to exposure from direct soil ingestion (US EPA, 2005). This approach with respect to inhalation exposure is consistent with that used by the Ontario MECP in the development of the site condition standards where inhalation exposure by birds was considered but an assessment was not completed because there is currently not enough information to perform such an assessment (MOE, 2011a).

Notes:
COC = contaminant of concern
mbgs = metres below ground surface
ERA = Ecological risk assessment
MOE = Ministry of the Environment
US DOE = United States Department of Energy
US EPA = Unites States Environmental Protection Agency
MECP = Ministry of the Environment, Conservation and Parks

Table 5.13
Exposure Pathway Selection for Aquatic Receptors of Concern
Lupin Mine, Nunavut

Receptor Group	Exposure Pathway	Included (yes/no)	Rationale
Primary Producer (Plant)	Direct Contact (Water)	Yes	Plants may be exposed to COCs in surface water in Boot Lake, East Lake or Lower Sewage Lake. Surface water quality in Lake Contwoyto is not expected to be impacted by the Site.
	Direct Contact (Sediment)	No	The focus of the ERA was on impacts to surface water quality of the receiving water bodies from generation of ARD-impacted waters from the waste rock dome.
Pelagic Invertebrate	Direct Contact (Water)	Yes	Pelagic invertebrates may be exposed to COCs in surface water in Boot Lake, East Lake or Lower Sewage Lake. Surface water quality in Lake Contwoyto is not expected to be impacted by the Site.
Benthic Invertebrate	Direct Contact (Water)	Yes	Benthic invertebrates may be exposed to COCs in surface water in Boot Lake, East Lake or Lower Sewage Lake. Surface water quality in Lake Contwoyto is not expected to be impacted by the Site.
	Direct Contact (Sediment)	No	The focus of the ERA was on impacts to surface water quality of the receiving water bodies from generation of ARD-impacted waters from the waste rock dome.
	Food Consumption (for macrofauna)	No	Benthic invertebrates may be exposed to substances in surface water in Boot Lake, East Lake or Lower Sewage Lake via uptake from the diet; however, uptake from the water is expected to be the dominant uptake route for most of the parameters predicted for surface water. For those substances for which uptake from the diet may be important (mercury and selenium), predicted concentrations in surface water were not much above reference conditions and are not expected to drive uptake by benthic invertebrates.

Notes:
COC = contaminant of concern.

Table 5.14
Exposure Concentrations for Contaminants of Concern in Soil for Evaluation of Ecological Receptors
Lupin Mine, Nunavut

COC	General Statistics					Exposure Concentration		Selected Exposure Concentration ^{(d),(f)}
	Maximum Concentration ^(a)	N ^(b)	Minimum	Mean ^(c)	SD ^(c)	95% UCLM	Selected UCL Distribution	
Terrestrial Plants and Soil Invertebrates								
Petroleum Hydrocarbons - F1 (C6-C10)	2650	72	<10	374.6	670.6	260.2	95% BCA Bootstrap UCL ^(e)	260.2
Petroleum Hydrocarbons - F2 (C10-C16)	14000	89	<10	1953	2880	1545	95% BCA Bootstrap UCL ^(e)	1545
Petroleum Hydrocarbons - F3 (C16-C34)	4400	89	<50	781.6	1074	787.3	95% BCA Bootstrap UCL ^(e)	787.3
Sulphate	821	3	348	--	--	--	-- ^(g)	821
Cyanide	21.9	14	<3	--	--	--	-- ^(g)	21.9
Antimony	171	91	<0.5	41	72.79	10.51	95% KM Approximate Gamma UCL	10.51
Arsenic	11700	91	4.8	1243	1990	1621	95% KM Approximate Gamma UCL	1621
Chromium	94.3	91	15	52.86	22.54	56.79	95% Student's-t UCL	56.79
Copper	480	91	8.8	44.31	68.1	62.25	95% BCA Bootstrap UCL ^(e)	62.25
Lead	3410	91	1.5	153.1	588.9	188.7	95% BCA Bootstrap UCL ^(e)	188.7
Molybdenum	22.8	91	<0.4	3.571	5.475	2.778	95% BCA Bootstrap UCL ^(e)	2.778
Nickel	67.3	91	9.7	34.4	17.53	37.25	95% BCA Bootstrap UCL ^(e)	37.25
Tin	9.3	91	<1	5.82	3.662	1.587	95% KM (t) UCL	1.587
Zinc	1570	91	13	68.47	163.8	120.7	95% BCA Bootstrap UCL ^(e)	120.7
Fluorene	4.53	28	<0.05	2.017	2.145	0.805	95% KM (t) UCL	0.805
Naphthalene	10.1	28	<0.05	3.599	4.19	1.628	95% KM (t) UCL	1.628
Wildlife								
Petroleum Hydrocarbons - F2 (C10-C16)	14000	89	<10	1953	2880	1545	95% BCA Bootstrap UCL ^(e)	1545
PHC F2 (aliphatic C>10-12)	--	--	--	--	--	--	--	556
PHC F2 (aliphatic C>12-16)	--	--	--	--	--	--	--	680
PHC F2 (aromatic C>10-12)	--	--	--	--	--	--	--	139
PHC F2 (aromatic C>12-16)	--	--	--	--	--	--	--	170
Sulphide	21.9	47	0.29	2.704	4.58	3.179	95% BCA Bootstrap UCL ^(e)	3.179
Sulphate	821	3	348	--	--	--	-- ^(g)	821
Cyanide	21.9	14	<3	--	--	--	-- ^(g)	21.9
Antimony	171	91	<0.5	41	72.79	10.51	95% KM Approximate Gamma UCL	10.51
Arsenic	11700	91	4.8	1243	1990	1621	95% KM Approximate Gamma UCL	1621
Barium	558	91	16	121.6	86.34	137.1	95% BCA Bootstrap UCL ^(e)	137
Cadmium	6.38	91	<0.05	0.605	1.474	0.407	95% BCA Bootstrap UCL ^(e)	0.407
Copper	480	91	8.8	44.31	68.1	62.25	95% BCA Bootstrap UCL ^(e)	62.25
Lead	3410	91	1.5	153.1	588.9	188.7	95% BCA Bootstrap UCL ^(e)	188.7
Molybdenum	22.8	91	<0.4	3.571	5.475	2.778	95% BCA Bootstrap UCL ^(e)	2.778
Tin	9.3	91	<1	5.82	3.662	1.587	95% KM (t) UCL	1.587
Vanadium	65.6	91	12.2	36.44	14.57	38.98	95% Modified-t UCL	38.98
Zinc	1570	91	13	68.47	163.8	120.7	95% BCA Bootstrap UCL ^(e)	120.7
Naphthalene	10.1	28	<0.05	3.599	4.19	1.628	95% KM (t) UCL	1.628
Ethylene glycol	11	21	<10	--	--	--	-- ^(g)	11

Notes:

COC = Contaminant of concern; N = total observations; SD = standard deviation; UCL = upper confidence limit; UCLM = upper confidence limit of the mean; µg/g = micrograms per gram; % = percent; < = less than reportable detection limit; BTEX = benzene, toluene, ethylbenzene, xylene; PHC = petroleum hydrocarbon; -- = not applicable; ERA = ecological risk assessment.

All values in µg/g unless otherwise indicated.

(a) Maximum concentration in soil corresponds to samples collected from all soil depths (up to 2.0 metres below ground surface). The soil concentrations used in the ERA represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).

(b) Total observations (detected and non-detected)

(c) Mean and SD includes only detected values

(d) Selected exposure concentration is the 95% UCLM, unless otherwise indicated.

(e) Suggested UCL was not considered reliable. The bias-corrected and accelerated bootstrap UCL was chosen as it is the preferred method to calculate 95% UCLM by Helsel and Gilroy (2012). See Appendix B.

(f) Exposure concentrations for petroleum hydrocarbon fractions were calculated using the percent compositions in Table 6.7.

(g) Insufficient number of detections (i.e., less than 4) to calculate a 95% UCLM, therefore the maximum concentration was selected as the EPC.

Statistics were calculated using ProUCL software (US EPA, 2016). Input and output worksheets are presented in Appendix B.

References:

Helsel, D.R., and Gilroy, E.J. 2012. The Unofficial User's Guide to ProUCL 4. Practical Stats. 66 pp.

United States Environmental Protection Agency (US EPA), June 2016. ProUCL Version 5.1 Statistical Software for Environmental Applications of Data Sets With and Without Nondetect Observations.

Prepared by: SG

Checked by: TD

Table 5.15
Exposure Concentrations for Contaminants of Concern in Groundwater for Evaluation of Ecological Receptors
Lupin Mine, Nunavut

COC	General Statistics					Exposure Concentration		Selected Exposure Concentration ^(d, e)
	Maximum Concentration ^(a)	N ^(b)	Minimum	Mean ^(c)	SD ^(c)	95% UCLM	Selected UCL Distribution	
Terrestrial Plants								
Petroleum Hydrocarbons - F2 (C10-C16)	64	9	0.054	13.66	25.02	102.1	95% KM Bootstrap t UCL ^(f)	64
Dissolved Aluminum (Al)	3	7	0.015	0.623	1.062	3.68	95% Adjusted Gamma UCL	3
Dissolved Arsenic (As)	0.35	7	0.01	0.109	0.12	0.399	95% Adjusted Gamma UCL	0.35
Dissolved Cobalt (Co)	0.3	7	0.0041	0.076	0.111	0.421	95% Adjusted Gamma UCL	0.30
Dissolved Iron (Fe)	54	7	0.16	22.07	20.79	37.33	95% Student's-t UCL	37
Dissolved Zinc (Zn)	2	7	0.0031	0.315	0.744	3.555	95% Adjusted Gamma UCL	2.0
Dissolved Sulphate (SO4)	800	6	16	314.8	318.2	576.6	95% Student's-t UCL	577

Notes:

COC = Contaminant of concern; N = total observations; SD = standard deviation; UCL = upper confidence limit; UCLM = upper confidence limit of the mean; mg/L = milligrams per litre; % = percent; < = less than reportable detection limit; ERA = ecological risk assessment.

All values in mg/L unless otherwise indicated.

(a) Maximum concentration in groundwater based on most recent year of data available (2017). The groundwater concentrations used in the ERA represent the current environmental conditions

(b) Total observations (detected and non-detected)

(c) Mean and SD includes only detected values

(d) Selected exposure concentration is the 95% UCLM, unless otherwise indicated.

(e) In instances where the calculated 95% UCLM was greater than the maximum measured concentration, the maximum measured concentration was selected as the exposure concentration

(f) Two UCLs generated by the program and the higher value was selected as a conservative approach.

Statistics were calculated using ProUCL software (US EPA, 2016). Input and output worksheets are presented in Appendix B.

References:

United States Environmental Protection Agency (US EPA), June 2016. ProUCL Version 5.1 Statistical Software for Environmental Applications of Data Sets With and Without Nondetect Observations.

Prepared by: TD/AF

Checked by: SG

Table 5.16
Exposure Concentrations for Contaminants of Concern in Surface Water for Evaluation of Ecological Receptors
Lupin Mine, Nunavut

COC	Exposure Point Concentration ^(a)		
	Boot Lake	East Lake	Lower Sewage Lake
Aquatic Life			
Cadmium	--	0.000041	--
Cobalt	0.0010	0.0048	0.0015
Copper	--	0.0039	--

Notes:

COC = Contaminant of concern; mg/L = milligrams per litre; -- = not a COC for this waterbody

All values in mg/L unless otherwise indicated.

(a) Exposure point concentration corresponds to the highest predicted surface water concentration based on the 50th percentile mass loading inputs of water quality predictions for June, July, August and September. The surface water concentrations in the lakes were predicted using a model that incorporated the proposed risk management measures outlined in the Final Closure and Reclamation Plan (i.e., waste rock consolidation and placement of engineered cover).

Prepared by: SG

Checked by: AF

Table 5.17
Receptor Characteristics for Terrestrial Mammals and Birds
Lupin Mine, Nunavut

Receptor Characteristic	Arctic hare (<i>Lepus arcticus</i>) ^(a)	Arctic ground squirrel (<i>Spermophilus parryii</i>) ^(b)	Caribou (<i>Rangifer tarandus</i>) ^(c)	Muskox (<i>Ovibos moschatus</i>) ^(d)	Grizzly Bear (<i>Ursus arctos horribilis</i>) ^(a)	Wolverine (<i>Gulo gulo</i>) ^(f)	Willow Ptarmigan (<i>Lagopus lagopus</i>) ^(g)
Feeding Guild	Mammalian small herbivore	Mammalian small herbivore	Mammalian large herbivore	Mammalian large herbivore	Mammalian large omnivore	Mammalian small carnivore	Avian herbivore
Diet Composition	Woody plants such as saxifrage, crowberry, dwarf willow. Leaves, roots, wood, bark, stems, fruit	Plants (foliage, roots, seeds, flowers, fruits), invertebrates, small vertebrates	Leaves of willows and birches, mushrooms, cotton grass, sedges, lichens	Grasses, leafy plants, sedges, mosses, shrubs, herbs, willow, roots, lichen	Large (i.e., caribou) and small (i.e., lemmings, voles, squirrels) mammals including aquatic mammals (i.e., seals, beached whales), fish, berries, grasses	Birds, small (i.e., squirrels, hares, marmots) to large (i.e., ungulates) mammals, eggs, carrion	Willow buds, grass shoots, flowers, seeds, berries, insects, caterpillars, beetles
Body Weight (kg)	4.81	0.75	108	280	139	10	0.56
Food Ingestion Rate (kg dw/d) ^{(h)(i)}	0.25	0.054	3.2	7.1	4	0.5	0.04
Proportion of Plant Material in Diet	1	1	1	1	0.5	0	1
Plant Ingestion Rate (kg dw/d) ⁽ⁱ⁾	0.25	0.054	3.2	7.1	2	0	0.04
Proportion of Earthworms in Diet	0	0	0	0	0	0	0
Earthworm Ingestion Rate (kg dw/d)	0	0	0	0	0	0	0
Proportion of Misc. Animals in Diet	0	0	0	0	0.5	1	0
Small Mammal Ingestion Rate (kg dw/d)	0	0	0	0	2.0	0.5	0
Proportion of Soil in Diet	2% of food ingestion	2.7% of food ingestion	2% of food ingestion	6.8% of food ingestion	2% of food ingestion	2% of food ingestion	2% of food ingestion
Soil Ingestion Rate (kg dw/d) ⁽ⁱ⁾	0.005	0.0015	0.064	0.48	0.08	0.009	0.0008
Home Range (km ²)	0.52	0.002	36124	27	700	50	0.067
Area Use Factor ^(k)	1	1	0.000015	0.02	0.001	0.011	1

Notes:

kg = kilogram; kg dw/d = kilogram dry weight per day; km² = square kilometre

- (a) Arctic hare body weight is from Silva and Downing 1995; home range and diet composition is from Betzler, 2015; proportion of soil in diet assumed to be 2% (Beyer et al. 1994).
- (b) Arctic ground squirrel body weight is from Silva and Downing 1995 as cited by Golder, 2004; home range and diet composition is from Torre, 2013; proportion of soil in diet assumed to be 2.7% based on the white-tailed prairie dog as a surrogate (Beyer et al. 1994).
- (c) Caribou body weight is from Silva and Downing 1995 as cited by Golder, 2004 and Government of Northwest Territories, 2019a.; home range is based on Virgl et al. 2017 (lowest range from post-calving and autumn); diet composition is from Shefferly 2000; proportion of soil in diet assumed to be 2% (Beyer et al. 1994).
- (d) Muskox body weight is from Silva and Downing 1995 as cited by Golder, 2004, RWED 2004; home range and diet composition is from Elder, 2005; proportion of soil in diet assumed to be 6.8% based on the bison as a surrogate (Beyer et al. 1994).
- (e) Grizzly bear body weight is from Silva and Downing 1995 as cited by Golder, 2004; home range (smaller range for females selected) from COSEWIC, 2012; diet composition is from Government of Nunavut, 2019b; proportion of soil in diet assumed to be 2% (Beyer et al. 1994).
- (f) Wolverine body weight is from Silva and Downing 1995 as cited by Golder, 2004; home range (lower end of range selected) and diet composition is from Patsy and Sygo, 2009; proportion of soil in diet assumed to be 2% (Beyer et al. 1994).
- (g) Willow ptarmigan body weight is from Dunning 1993 (average of male and female); home range and diet composition is from Morland 2011; proportion of soil in diet assumed to be 2% (Beyer et al. 1994).
- (h) Using the equation from US EPA 1993, the food ingestion rate for mammals was calculated using the following equation: Food ingestion rate (kg dw/d) = 0.0687* BW^{0.822}, where BW is the body weight in kg.
- (i) Using the equation from US EPA 1993, the food ingestion rate for birds was calculated using the following equation: Food ingestion rate (kg dw/d) = 0.0582* BW^{0.661}, where BW is the body weight in kg.
- (j) Calculated by the proportion of respective media in diet multiplied by the dry food ingestion rate
- (k) The area use factor was calculated based on the area of contamination at Lupin Mine (0.55 km²) divided by the home range (in km²). For receptors with home ranges less than the area of contamination, an AUF of 1 was used.

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Prepared by: SG/AF
Checked by: TD

Table 5.18
Uptake Factors/Equations for Contaminants of Concern in Food Items for Terrestrial Mammals and Birds
Lupin Mine, Nunavut

COC	Soil to Plants	
	Equation	Source
Petroleum Hydrocarbons (PHCs) and BTEX		
Petroleum Hydrocarbons - F2 (C10-C16)	--- (a)	---
Metals		
Sulphide	--- (b)	---
Sulphate	--- (b)	---
Cyanide	$C_p = C_s$	Assumed (c)
Antimony	$\ln(C_p) = 0.938 * \ln(C_s) - 3.233$	U.S. EPA, 2007
Arsenic	$C_p = 0.03752 * C_s$	U.S. EPA, 2007
Barium	$C_p = 0.156 * C_s$	U.S. EPA, 2007
Cadmium	$\ln(C_p) = 0.546 * \ln(C_s) - 0.475$	U.S. EPA, 2007
Copper	$\ln(C_p) = 0.394 * \ln(C_s) + 0.668$	U.S. EPA, 2007
Lead	$\ln(C_p) = 0.561 * \ln(C_s) - 1.328$	U.S. EPA, 2007
Molybdenum	$C_p = 0.25 * C_s$ (vegetative parts, e.g., leaves) $C_p = 0.06 * C_s$ (reproductive parts, e.g., fruits and seeds)	Baes et al., 1984
Tin	--- (b)	---
Vanadium	$C_p = 0.00485 * C_s$	U.S. EPA, 2007
Zinc	$\ln(C_p) = 0.554 * \ln(C_s) + 1.575$	U.S. EPA, 2007
Polycyclic Aromatic Hydrocarbons (PAHs)		
Naphthalene	(d)	---
Glycols		
Ethylene glycol	--- (b)	---

Notes:

Values reported on a dry weight (dw) basis.

COC = Contaminant of concern; BTEX = benzene, toluene, ethylbenzene, xylene; mg/kg = milligram per kilogram; BAF = bioaccumulation factor

C_p = Concentration in plants (mg/kg dw)

C_s = Concentration in soil (mg/kg dw)

(a) Uptake equations for PHCs were not derived as PHCs are not readily absorbed or accumulated by plants (CCME 2008; CCME 2010)

(b) Uptake equations have not been derived, or plant concentrations estimated, for sulphide, sulphate, tin and ethylene glycol because TRVs are not available to allow calculations of HQs.

(c) The CCME indicates that very few data are available on the uptake of cyanide from soil by plants and provides a BAF of 0.8 based on data for bush beans (CCME, 1997). Given the lack of data for cyanide it was conservatively assumed that the plant concentration was equivalent to the exposure concentration in soil.

(d) Studies have demonstrated that PAHs are not readily absorbed or accumulated by plants (CCME 2010). Therefore, exposure to terrestrial mammals and birds via ingestion of plants that have accumulated COCs from soil was assumed to be negligible in the ERA.

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Prepared by: SG

Checked by: TD

Table 5.19
Concentrations of Contaminants of Concern in Food Items
Lupin Mine, Nunavut

COC	Concentration in Plants (mg/kg dw) ^(a)	Concentration in small mammals (mg/kg dw)
Metals		
Cyanide	22	NA
Antimony	0.36	NA
Arsenic	61	NA
Barium	21	NA
Cadmium	0.38	NA
Copper	10	NA
Lead	5.0	NA
Molybdenum	0.69	NA
Vanadium	0.19	NA
Zinc	69	NA

Notes:

COC = Contaminant of concern; mg/kg dw = milligram per kilogram dry weight; NA = not applicable as these COCs are not considered to bioaccumulate

(a) The soil concentrations used to calculate uptake into plants represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).

Prepared by: SG

Checked by: TD

Table 5.20
Estimated Doses from Incidental Soil Ingestion and Food Consumption for Terrestrial Mammals and Birds
Lupin Mine, Nunavut

COC	Arctic hare (<i>Lepus arcticus</i>)	Arctic ground squirrel (<i>Spermophilus parryi</i>)	Caribou (<i>Rangifer tarandus</i>)	Muskox (<i>Ovibos moschatus</i>)	Grizzly Bear (<i>Ursus arctos horribilis</i>)	Wolverine (<i>Gulo gulo</i>)	Willow Ptarmigan (<i>Lagopus lagopus</i>)
Petroleum Hydrocarbons (PHCs) and BTEX							
Petroleum Hydrocarbons - F2 (C10-C16)	1.6E+00	3.0E+00	1.4E-05	5.4E-02	6.9E-04	1.5E-02	2.2E+00
Metals							
Sulphide	3.3E-03	6.2E-03	2.9E-08	1.1E-04	1.4E-06	3.2E-05	4.5E-03
Sulphate	8.5E-01	1.6E+00	7.5E-06	2.9E-02	3.7E-04	8.2E-03	1.2E+00
Cyanide	1.2E+00	1.6E+00	1.0E-05	1.2E-02	2.6E-04	2.2E-04	1.6E+00
Antimony	3.0E-02	4.6E-02	2.6E-07	5.5E-04	8.7E-06	1.1E-04	4.1E-02
Arsenic	4.8E+00	7.6E+00	4.2E-05	8.8E-02	1.4E-03	1.6E-02	6.6E+00
Barium	1.3E+00	1.8E+00	1.1E-05	1.6E-02	3.0E-04	1.4E-03	1.7E+00
Cadmium	2.0E-02	2.8E-02	1.8E-07	2.1E-04	4.5E-06	4.1E-06	2.8E-02
Copper	5.8E-01	8.4E-01	5.1E-06	7.3E-03	1.4E-04	6.2E-04	8.0E-01
Lead	4.6E-01	7.3E-01	4.0E-06	9.2E-03	1.4E-04	1.9E-03	6.3E-01
Molybdenum	3.9E-02	5.6E-02	3.4E-07	4.5E-04	9.0E-06	2.8E-05	5.3E-02
Tin	1.6E-03	3.1E-03	1.4E-08	5.5E-05	7.1E-07	1.6E-05	2.3E-03
Vanadium	5.0E-02	9.0E-02	4.4E-07	1.5E-03	2.0E-05	3.9E-04	6.9E-02
Zinc	3.7E+00	5.2E+00	3.2E-05	4.0E-02	8.3E-04	1.2E-03	5.1E+00
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	1.7E-03	3.2E-03	1.5E-08	5.7E-05	7.3E-07	1.6E-05	2.3E-03
Glycols							
Ethylene glycol	1.1E-02	2.1E-02	1.0E-07	3.8E-04	4.9E-06	1.1E-04	1.6E-02

Notes:

All values in milligrams per kilogram per day (mg/kg-d)

BTEX = benzene, toluene, ethylbenzene, xylenes; COC = contaminant of concern; ERA = ecological risk assessment

The soil concentrations used in the ERA represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).

Prepared by: SG/AF

Checked by: TD

Table 5.21
Toxicity Reference Values for Terrestrial Plants and Soil Invertebrates in Soil
Lupin Mine, Nunavut

COC	TRV for Plants and Soil Invertebrates (mg/kg)	Reference
Petroleum Hydrocarbons (PHCs) and BTEX		
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	210	CCME CWS (Soil Contact)
Petroleum Hydrocarbons - F2 (C10-C16)	150	CCME CWS (Soil Contact)
Petroleum Hydrocarbons - F3 (C16-C34)	300	CCME CWS (Soil Contact)
Metals and Physical Parameters		
Sulphate	NV	NA
Cyanide	0.9	CCME SQG _E (soil contact)
Antimony	20	MOECC Table 2 (Plants & Soil Org.)
Arsenic	17	CCME SQG _E (soil contact)
Chromium	64	CCME SQG _E (soil contact)
Copper	63	CCME SQG _E (soil contact)
Lead	300	CCME SQG _E (soil contact)
Molybdenum	40	MOECC Table 2 (Plants & Soil Org.)
Nickel	45	CCME SQG _E (soil contact)
Tin	50	Efroymsen et al. 1997 ^(a)
Zinc	250	CCME SQG _E (soil contact)
Polycyclic Aromatic Hydrocarbons (PAHs)		
Fluorene	7.7	CCME 2010 ^(b)
Naphthalene	0.6	MOECC Table 2 (Plants & Soil Org.)

Notes:

BTEX = benzene, toluene, ethylbenzene, xylenes; COC = Contaminant of concern; mg/kg = milligrams per kilogram; CCME CWS = Canadian Council of Ministers of the Environment Canada Wide Standard; CCME SQG_E = Canadian Council of Ministers of the Environment Soil Quality Guideline for Environmental Health; MOECC = Ministry of the Environment and Climate Change; TRV = toxicity reference value; NV = no value; NA = not applicable

^(a) TRV is protective of plants only. Effects on soil invertebrates were evaluated qualitatively.

^(b) TRV for fluorene was selected as the lowest effective concentration for survival, growth and reproduction endpoints of the toxicity data considered by the CCME (2010) in the derivation of the SQG_E. Selected value was based on an EC10 of 7.7 mg/kg for reproduction effects in springtail. TRV is protective of soil invertebrates only. Effects on terrestrial plants were evaluated qualitatively.

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Ontario Ministry of the Environment and Climate Change (MOECC). 2016. Modified Generic Risk Assessment "Approved Model". Soil Components for Table 2 - Full Depth, Potable Water Scenario, Agricultural Land Use, coarse grained soil.

Prepared by: TD/SG

Checked by: SG/TD

Table 5.22
Toxicity Reference Values for Terrestrial Plants in Groundwater
Lupin Mine, Nunavut

COC	TRV for Terrestrial Plants (mg/L)	Reference
<i>Petroleum Hydrocarbons (PHCs) and BTEX</i>		
Petroleum Hydrocarbons - F2 (C10-C16)	1.8	FCSAP FIGQG SODC
<i>Metals</i>		
Dissolved Aluminum (Al)	0.3	Efroymson et al. 1997
Dissolved Arsenic (As)	0.001	Efroymson et al. 1997
Dissolved Cobalt (Co)	0.06	Efroymson et al. 1997
Dissolved Iron (Fe)	10	Efroymson et al. 1997
Dissolved Zinc (Zn)	0.4	Efroymson et al. 1997
<i>Routine Physical and Chemical Parameters</i>		
Dissolved Sulphate (SO ₄)	128	BC MECCS (2019) Approved Water Quality Guideline; based on a water hardness of 0-30 mg/L

Notes:

BTEX = benzene, toluene, ethylbenzene, xylenes; COC = Contaminant of concern; mg/L= milligrams per litre; FCSAP = Federal Contaminated Sites Action Plan; FIGQG = Federal Interim Groundwater Quality Guideline; SODC = Soil organisms direct contact; MOECC = Ministry of the Environment and Climate Change; GW3 = exposure pathway to aquatic biota via groundwater discharge to surface water; TRV = toxicity reference value; NV = no value; NA = not applicable.

References:

British Columbia Ministry of Environment and Climate Change Strategy (BC MECCS). 2019. British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture Summary Report. Water Protection & Sustainability Branch. August 2019. The guideline for sulphate of 128 mg/L was used (based on water hardness of 0-30 mg/L). This is considered to be protective of aquatic plants.

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Prepared by: TD/AF

Checked by: SG

Table 5.23
Toxicity Reference Values for Mammals and Birds
Lupin Mine, Nunavut

COC	Toxicity Reference Value (mg/kg-d)						
	Mammals	Principal Study	Reference	Birds	Principal Study	Reference	Notes
Petroleum Hydrocarbons (PHCs)							
Petroleum Hydrocarbons - F2 (C10-C16)	44.7	AENV (2002) and CCME (2008)	FCSAP, 2017	NV	NA	NA	<u>Mammals:</u> The TRV is based on a LOAEL for behavioural, blood chemistry and liver functioning endpoints in cattle exposed to crude oil via food. No uncertainty factors were applied.
Metals							
Sulphide	NV	NA	NA	NV	NA	NA	NA
Sulphate	NV	NA	NA	NV	NA	NA	NA
Cyanide	69	Tewe and Maner 1981 as cited in Sample et al. 1996	MOE, 2011	0.21	Weimeyer et al. 1986 as cited in CCME, 1996	MOE, 2011	<u>Mammals:</u> The TRV is the chronic NOEL for reproduction endpoints in rats. <u>Birds:</u> The TRV was derived based on the LD50 for American kestrel. An uncertainty factor of 10 was applied.
Antimony	1.25	Schroeder et al. 1968 as cited in Sample et al. 1996	MOE, 2011	NV	NA	NA	<u>Mammals:</u> The TRV is the chronic LOAEL for longevity endpoints in mice.
Arsenic	1.04	US EPA (2005)	FCSAP, 2017	4.4	CEAEQ, 2012	FCSAP, 2017	<u>Mammals:</u> The TRV is based on the highest bound NOAEL below the lowest bound LOAEL from a dataset of 55 toxicological studies for relevant biological endpoints (survival, growth, and reproduction). The highest bound NOAEL corresponds to a study on the effects of growth in beagle dogs exposed to 0, 1, 2 and 4 mg sodium arsenite/kg bw/day. No uncertainty factors were applied. <u>Birds:</u> The TRV is based on the second lowest EC20 of eight different studies reporting reproduction, growth and mortality endpoints for mallard ducks, chickens, and quails. The toxicity study underlying this EC20 observed reduced growth rates in chickens exposed to arsenic via ingestion for 16 days. Uncertainty factors were applied to the EC20s to account for short exposure durations and mortality endpoints.
Barium	51.8	US EPA (2005)	FCSAP, 2017	51.3	CEAEQ, 2012	FCSAP, 2017	<u>Mammals:</u> The TRV was derived based on the geometric mean of eight NOAELs for growth or reproduction, from toxicity studies with mice or rats. Exposure routes consisted of gavage, food or drinking water and durations ranged from acute to chronic. No uncertainty factors were applied. <u>Birds:</u> The TRV was derived using Weibull statistical methods to model a dose-response curve for mortality from barium toxicity to chickens over a 4-week exposure to barium hydroxide int he diet. No allometric scaling was used but an uncertainty factor of 10 was applied to account for mortality endpoint and acute exposure.
Cadmium	0.77	US EPA (2005)	FCSAP, 2017	2.1	CEAEQ, 2012	FCSAP, 2017	<u>Mammals:</u> The TRV is based on the highest bound NOAEL below the lowest bound LOAEL from a dataset of 145 toxicological studies for survival, growth and reproduction endpoints. The highest bound NOAEL corresponds to effects on growth in rats exposed to cadmium acetate in drinking water. No uncertainty factors were applied. <u>Birds:</u> The TRV was derived using Weibull statistical methods to model a dose-response curve for mortality from six toxicological studies on four species (quails, chickens, pheasants, and mallard ducks). The dose corresponding to the EC20 was interpolated from dose-response curves for each of the six studies. Uncertainty factors were applied to the EC20s. The lowest resulting EC20 was for effects to juvenile quail growth of a 4-week exposure to cadmium in food.
Copper	5.6	US EPA (2007)	FCSAP, 2017	4.5	CEAEQ, 2012	FCSAP, 2017	<u>Mammals:</u> The TRV is based on the highest bound NOAEL below the lowest bound LOAEL from a large dataset (278 results from 97 studies) for survival, growth and reproduction endpoints including multiple mammalian species. It is considered to be representative of all mammals. The experimental design is reflective of actual environmental conditions because of the exposure pathways of contaminated food and water, relevant chemical forms (copper sulfate, copper chloride, cupric carbonate, and copper acetate), and a range of acute and chronic exposure durations (15 days to 2 years). No allometric scaling or uncertainty factors were applied. <u>Birds:</u> The TRV was derived using Weibull statistical methods to model dose-response curves for five different studies on reproductive endpoints in chickens exposed to copper in the diet. The dose corresponding to an EC20 was interpolated from dose-response curves for each of these five studies. An uncertainty factor of 2 was applied to account for exposure duration (14-70 days). The lowest EC20 was selected based on an endpoint of number of eggs laid by checks in a 48-day test.
Lead	4.7	US EPA (2005)	FCSAP, 2017	1.63	US EPA (2005)	FCSAP, 2017	<u>Mammals:</u> The TRV is based on the highest bound NOAEL below the lowest bound LOAEL from a dataset of 219 toxicological studies for survival, growth and reproduction endpoints on a variety of mammalian species, therefore the TRV is considered representative of all mammals. No allometric scaling or uncertainty factors were applied. <u>Birds:</u> The TRV is based on the highest bound NOAEL below the lowest bound LOAEL from a dataset of 54 studies for reproduction, growth and mortality endpoints. The dataset includes toxicity tests conducted on a variety of avian species (chicken, mallard, kestrel, zebra finch and quail). No allometric scaling or uncertainty factors were applied.
Molybdenum	2.6	Schroeder and Mitchner 1971 as cited in Sample et al. 1996	MOE, 2011	35	Lepore and Miller 1965 as cited in Sample et al. 1996	MOE, 2011	<u>Mammals:</u> The TRV is based on the chronic LOEL for reproduction endpoints in mice. <u>Birds:</u> The TRV is based on the chronic LOEL for reproduction endpoints in chickens.
Tin	NV	NA	NA	NV	NA	NA	NA
Vanadium	4.16	US EPA (2005)	FCSAP, 2017	0.344	US EPA (2005)	FCSAP, 2017	<u>Mammals:</u> The TRV is based on the highest bound NOAEL below the lowest bound LOAEL for survival, growth and reproduction endpoints from a dataset of 101 results (from 48 studies). Test species included rat, mouse, rabbit, pig and sheep, therefore the TRV is considered representative of all mamals. No allometric scaling or uncertainty factors were applied. <u>Birds:</u> The TRV is based on the highest bound NOAEL below the lowest bound LOAEL for reproductive, growth and survival endpoints from 36 studies on birds (chicken, duck, Japanese quail). The resulting TRV is based on a study with juvenile female chickens exposed to vanadium for 5 weeks in the diet and evaluated effects on growth.
Zinc	75.4	US EPA (2007)	FCSAP, 2017	66.1	US EPA (2007)	FCSAP, 2017	<u>Mammals:</u> The TRV was derived based on the geometric mean of 69 NOAELs for growth or reproduction, from 99 toxicity studies with mouse, rat, sheep, pig, hamster and cattle. Therefore the TRV is considered representative of all mammals. Exposure routes consisted of gavage, food or drinking water and durations ranged from acute to chronic. No allometric scaling or uncertainty factors were applied. <u>Birds:</u> The TRV was derived based on the geometric mean of 43 NOAELs for reproduction or growth. The dataset included toxicity tests conducted on a variety of avian species (chicken, duck, turkey, and quail), and typically involved exposure in the diet. No uncertainty factors were applied.
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	14.3	LANL, 2014	FCSAP, 2017	7.7	Klasing, 2007	FCSAP, 2017	<u>Mammals:</u> The TRV was derived based on the geometric mean of nine chronic NOAELs for reproduction, development, growth and survival endpoints, from toxicity studies with mice, rats or rabbits. Some NOAELs were the result of application of an uncertainty factor, while others were the result of dividing an unbound experimental LOAEL by a factor of 10. Chronic NOAELs were calculated from acute or subchronic NOAELs by dividing by uncertainty factors of 100 or 10, respectively. <u>Birds:</u> The TRV is the NOAEL for growth in Japanese quail following exposure to naphthalene in the diet for 14 weeks. No allometric scaling or uncertainty factors were used.
Glycols							
Ethylene glycol	NV	NA	NA	NV	NA	NA	NA

Notes:
COC = Contaminant of concern; mg/kg-d = milligrams per kilogram per day; EC20 = 20% effect concentration; LOAEL = Lowest observed adverse effect level; LOEL = Lowest observed effect level; NOAEL = No observed adverse effect level; NOEL = No observed effect level; TRV = Toxicity reference value; NV = No value available; NA = Not applicable

References:
FCSAP (Federal Contaminated Site Action Plan). 2017. Ecological Risk Assessment Guidance. Module 7: Default Wildlife Toxicity Reference Values (TRVs) Recommended for use at FCSAP Sites. Draft Version, December 20, 2017.
Ministry of the Environment (MOE). 2011. Rationale for the Development of Soil and Groundwater Standards for Use at Contaminated Sites in Ontario. Ministry of the Environment. April 15, 2011.

Prepared by: SG
Checked by: TD

Table 5.24
Toxicity Reference Values for Aquatic Life in Surface Water
Lupin Mine, Nunavut

COC	TRV (mg/L)	Reference	Notes
Metals			
Cadmium	0.00004	CCME CWQG-PAL (1999/2019)	CCME WQG-PAL adjusted to background water hardness based on 50th percentile mass loading inputs (5.0 mg/L CaCO ₃)
Cobalt	0.004	BC MECCS (2019)	Long-term water quality guideline for aquatic life, freshwater
Copper	0.002	CCME WQG-PAL (1999/2019)	CCME WQG-PAL adjusted to background water hardness based on 50th percentile mass loading inputs (5.0 mg/L CaCO ₃)

Notes:

COC = Contaminant of concern; mg/L = milligrams per litre; TRV = toxicity reference value; CaCO₃ = calcium carbonate

References:

Canadian Council of Ministers of the Environment (CCME). 1999/2019. Canadian Water Quality Guidelines (CWQG) for the Protection of Aquatic Life (PAL), Freshwater.

BC MECCS (British Columbia Ministry of Environment & Climate Change Strategy). 2019. British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife and Livestock. Summary Report. Water Protection & Sustainability Branch, Ministry of Environment & Climate Change Strategy. August 2019. Online: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/wqg_summary_aquaticlife_wildlife_agri.pdf

Prepared by: SG

Checked by: AF

Table 5.25
Hazard Quotients for Terrestrial Plants and Soil Invertebrates for Soil Direct Contact
Lupin Mine, Nunavut

COC	HQ for Terrestrial Plants and Soil Invertebrates ^(a)	
<i>Petroleum Hydrocarbons (PHCs) and BTEX</i>		
Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	1.2	
Petroleum Hydrocarbons - F2 (C10-C16)	10	
Petroleum Hydrocarbons - F3 (C16-C34)	2.6	
<i>Metals and Physical Parameters</i>		
Sulphate	NC	
Cyanide	24	
Antimony	0.5	
Arsenic	95	
Chromium	0.89	
Copper	0.99	
Lead	0.63	
Molybdenum	0.07	
Nickel	0.83	
Tin	0.03	(b)
Zinc	0.48	
<i>Polycyclic Aromatic Hydrocarbons</i>		
Fluorene	0.1	(c)
Naphthalene	2.7	

Notes:

BTEX = benzene, toluene, ethylbenzene and xylenes; COC = Contaminant of concern; HQ = hazard quotient; NC = not calculated due to lack of toxicity reference value

^(a) The risks calculated based on soil concentrations represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).

^(b) TRV for tin is protective of plants only. Effects on soil invertebrates were evaluated qualitatively.

^(c) TRV for fluorene is protective of soil invertebrates only. Effects on terrestrial plants were evaluated qualitatively.

Screening:

Bold and Shaded Indicates an exceedance of the target HQ of 1

Prepared by: SG

Checked by: TD

Table 5.26
Hazard Quotients for Terrestrial Plants for Groundwater Direct Contact
Lupin Mine, Nunavut

COC	HQ for Terrestrial Plants ^(a)
<i>Petroleum Hydrocarbons (PHCs) and BTEX</i>	
Petroleum Hydrocarbons - F2 (C10-C16)	36
<i>Metals</i>	
Dissolved Aluminum (Al)	10
Dissolved Arsenic (As)	350
Dissolved Cobalt (Co)	5.0
Dissolved Iron (Fe)	3.7
Dissolved Zinc (Zn)	5.0
<i>Routine Physical and Chemical Parameters</i>	
Dissolved Sulphate (SO ₄)	4.5

Notes:

BTEX = benzene, toluene, ethylbenzene and xylenes; COC = Contaminant of concern; HQ = hazard quotient; NC = not calculated due to lack of toxicity reference value

^(a) The risks calculated based on groundwater concentrations represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).

Screening:

Bold and Shaded

Indicates an exceedance of the target HQ of 1

Prepared by: SG/AF

Checked by: TD

Table 5.27

Hazard Quotients for Incidental Soil Ingestion and Food Consumption for Terrestrial Mammals and Birds
Lupin Mine, Nunavut

COC	Arctic hare (<i>Lepus arcticus</i>)	Arctic ground squirrel (<i>Spermophilus parryii</i>)	Caribou (<i>Rangifer tarandus</i>)	Muskox (<i>Ovibos moschatus</i>)	Grizzly Bear (<i>Ursus arctos horribilis</i>)	Wolverine (<i>Gulo gulo</i>)	Willow Ptarmigan (<i>Lagopus lagopus</i>)
Petroleum Hydrocarbons (PHCs) and BTEX							
Petroleum Hydrocarbons - F2 (C10-C16)	3.6E-02	6.7E-02	3.1E-07	1.2E-03	1.6E-05	3.5E-04	NC
Metals							
Sulphide	NC	NC	NC	NC	NC	NC	NC
Sulphate	NC	NC	NC	NC	NC	NC	NC
Cyanide	1.7E-02	2.4E-02	1.5E-07	1.7E-04	3.7E-06	3.2E-06	7.6E+00
Antimony	2.4E-02	3.7E-02	2.1E-07	4.4E-04	7.0E-06	8.4E-05	NC
Arsenic	4.7E+00	7.3E+00	4.1E-05	8.4E-02	1.4E-03	1.6E-02	1.5E+00
Barium	2.4E-02	3.5E-02	2.1E-07	3.0E-04	5.8E-06	2.7E-05	3.4E-02
Cadmium	2.6E-02	3.7E-02	2.3E-07	2.7E-04	5.8E-06	5.3E-06	1.3E-02
Copper	1.0E-01	1.5E-01	9.1E-07	1.3E-03	2.5E-05	1.1E-04	1.8E-01
Lead	9.7E-02	1.6E-01	8.5E-07	1.9E-03	3.0E-05	4.0E-04	3.8E-01
Molybdenum	1.5E-02	2.1E-02	1.3E-07	1.7E-04	3.5E-06	1.1E-05	1.5E-03
Tin	NC	NC	NC	NC	NC	NC	NC
Vanadium	1.2E-02	2.2E-02	1.1E-07	3.5E-04	4.7E-06	9.4E-05	2.0E-01
Zinc	4.9E-02	6.9E-02	4.3E-07	5.2E-04	1.1E-05	1.6E-05	7.7E-02
Polycyclic Aromatic Hydrocarbons (PAHs)							
Naphthalene	1.2E-04	2.2E-04	1.0E-09	4.0E-06	5.1E-08	1.1E-06	3.0E-04
Glycols							
Ethylene glycol	NC	NC	NC	NC	NC	NC	NC

Notes:

BTEX = benzene, toluene, ethylbenzene and xylenes; COC = Contaminant of concern; hydrocarbon; NC = not calculated due to lack of toxicity reference value

The risks calculated based on soil concentrations represent the current environmental conditions without the implementation of the measures proposed in the Final Closure and Reclamation Plan (e.g., placement of engineered cover).

Screening:

Bold and Shaded Indicates an exceedance of the target HQ of 1

Prepared by: SG/AF

Checked by: TD

Table 5.28
Hazard Quotients for Aquatic Life for Surface Water Direct Contact
Lupin Mine, Nunavut

COC	HQ for Aquatic Life - Boot Lake	HQ for Aquatic Life - East Lake	HQ for Aquatic Life - Lower Sewage Lake
Metals			
Cadmium	--	1.0	--
Cobalt	0.2	1.2	0.4
Copper	--	1.9	--

Notes:

COC = Contaminant of concern; HQ = hazard quotient; -- = not a COC for this waterbody

The risks based on predicted surface water concentrations in the lakes incorporate the proposed risk management measures outlined in the Final Closure and Reclamation Plan (i.e., waste rock consolidation and placement of engineered cover).

Screening:

Bold and Shaded Indicates an exceedance of the target HQ of 1

Prepared by: SG

Checked by: AF

Table 5.29
Uncertainty Assessment for the Ecological Risk Assessment
Lupin Mine, Nunavut

Source of Uncertainty	Overestimate, Neutral or Underestimate of Risk
Problem Formulation	
Ecological component values (termed screening values) from the CCME, Ontario MECP, AEP, BC MECCS and other suitable international regulatory agencies were used to identify COCs in soil, groundwater, and seepage and lake surface water for ecological receptors. In general, these screening values are considered to be conservative for PHCs, PAHs and glycols.	Overestimate
Soil pH was higher and lower than the CCME SQG (6 to 8) and MECP range (surface soil; 5 to 9). In general, the bioavailability and toxicity of cationic metals (e.g., antimony, barium, beryllium, cadmium, cobalt, copper, lead, nickel, and zinc) in soil tend to increase with decreasing pH, whereas the bioavailability and toxicity of anionic metals (e.g., arsenic, chromium, selenium and vanadium) in soil tend to decrease with decreasing pH (US EPA 1992; Wang et al. 2009). Metals were screened using the CCME and MECP guideline/standards; however, this approach may underestimate potential risks to plants and soil invertebrates from some metals under low and high soil pH conditions.	Underestimate
There were no screening values available for terrestrial plants and soil invertebrates for fluorene in soil; therefore, the screening value for naphthalene were used given the similarities in structure and physical/chemical properties between the two parameters.	Underestimate, neutral or overestimate
The screening values used in the screening for aquatic life do not address uptake from the diet (i.e., food consumption) by aquatic life. However, uptake from the water is expected to be the dominant uptake route for most of the parameters in surface water. For those parameters for which uptake from the diet may be important (mercury and selenium), predicted concentrations in the lakes were not much above reference conditions and are not expected to drive uptake by aquatic life.	Underestimate or neutral
For screening groundwater for direct contact by terrestrial plants, the CCME WGQ-PALs, MECP APVs and other guidelines/standards protective of aquatic life were used for the following parameters: nitrate, nitrite, pH, ethylene glycol, propylene glycol, antimony, barium, sodium, strontium, cyanide, sulphate and chloride. These values are protective of aquatic plants.	Underestimate, neutral or overestimate
For screening consumption of surface water by wildlife, the CCME WQG-PALs were used for the following parameters: ammonia. This was considered protective of wildlife consuming the surface water as they would be less exposed than aquatic life fully immersed in the water.	Overestimate
For screening consumption of surface water by wildlife, the CCME WQG for livestock watering were used for the following parameters: calcium, nitrate plus nitrite, nitrite, total dissolved solids, sulphate and fluoride.	Underestimate, neutral or overestimate
Terrestrial plants, soil invertebrates, mammals and birds are generally considered to come into contact with surface soil (0 to 1.5 mbgs). As analytical data for soil was only collected from the top 2.0 m at the Site, as a conservative approach data from all sampling depths were used in the comparison to screening values and background.	Neutral or overestimate
The consumption of plants that have accumulated COCs from groundwater by mammals and birds was not evaluated due to the lack of uptake factors/regression equations for estimating uptake from this pathway. This may result in uncertainty in the total doses from consumption of plants as the estimated concentrations in plants only considered uptake of COCs from soil.	Underestimate
Dermal exposure by soil by mammals and birds was considered to be negligible because the presence of fur, and feathers limits dermal contact with soil.	Underestimate
Inhalation of volatile compounds from soil by mammals, and birds was considered to be negligible because these compounds rapidly volatilize to air where they are rapidly diluted and dispersed.	Underestimate
Inhalation of soil dust by mammals and birds was considered to be negligible because aerial suspension of dust is expected to be minimal and inhalation of dust is expected to be minimal.	Underestimate
A recent SAR assessment has not been completed for the Site. The current ERA relies on the information provided in the 2004 ERA (Golder 2004).	Underestimate, neutral or overestimate
Exposure Assessment	
95% UCLMs were used as the exposure concentrations in soil and groundwater (where possible) for all ROCs. This is considered to be a conservative approach and may overestimate exposure in some cases (e.g., when only one exceedance is measured in a dataset). However, using the 95% UCLM is a practical approach given that the variability of the dataset is incorporated into this statistic. Use of this statistic assumes that ROCs could spend most of their time on the Site close to the highest measured concentrations.	Overestimate
Exposure concentrations for lake surface water used in the assessment are based on the highest concentration of the 50 th percentile predicted surface water concentrations for each water body. The water quality model was developed based on conservative assumptions.	Overestimate
The receptor characteristics for mammals and birds were taken various literature sources. In general, these characteristics are considered to provide reasonable estimates of exposure.	Neutral
The home range and resulting AUF for the grizzly bear was based on the Canadian average home range. This may be conservative for Nunavut given that reported home ranges specific to Nunavut were 3 to 10 times greater than the Canadian average.	Overestimate
Food ingestion rates for mammals and birds were calculated using allometric equations from the US EPA (1993). Allometric equations estimate food ingestion rates based on animal body weight using models derived from taxonomically similar species.	Underestimate, neutral or overestimate
The proportion of soil consumed by herbivores was assumed to be 2%. This value is taken from Beyer et al. (1994). This value was based on the lowest soil ingestion rate recorded in the study as <2% rather than as a precise value. Individual species may have higher or lower soil ingestion rates.	Underestimate, neutral or overestimate

Source of Uncertainty	Overestimate, Neutral or Underestimate of Risk
It was assumed that the arctic hare, arctic ground squirrel, caribou, muskox and willow ptarmigan diet consists of 100% plants; however, their diets may be comprised of invertebrates or small mammals in smaller proportions.	Overestimate
An AUF of one was used for the arctic hare, arctic ground squirrel, and willow ptarmigan which assumes that the ROCs reside and forage exclusively within the contaminated area of the Site.	Neutral
Studies have demonstrated that PHCs and PAHs are not readily absorbed or accumulated by plants (CCME 2008; CCME 2010). Therefore, exposure to terrestrial mammals and birds via ingestion of plants that have accumulated COCs from soil was assumed to be negligible.	Neutral
Equations provided by the US EPA (2007) were used to estimate concentrations in plants from soil. The US EPA (2007) indicates that these equations are neither conservative nor anti-conservative and are not expected to over-predict concentrations.	Neutral
While the uptake of some metals into plants is influenced by soil pH, the uptake equations were still deemed appropriate to estimate COC concentrations in plants. This is because for those metals evaluated with respect to pH, the source of the uptake equations provided by the US EPA (Bechtel Jacobs Company 1998) recommends use of the single-variable regression or multiple regression with pH (with no preference given except for mercury). Given that areas of low and high pH have been identified on the Site, it was considered reasonable to apply the single-variable regression to provide an estimate of plant tissue concentrations reflective of the range in soil pH across the Site.	Underestimate, neutral or overestimate
It was assumed that all COCs were 100% bioavailable (i.e., no adjustment was made for possible limited bioavailability of COCs in soil and food). This is a conservative assumption because TRVs are typically based on laboratory studies in which soils are amended with a bioavailable form of the contaminant (e.g., fresh versus weathered PHCs/PAHs). The contaminants in soil on the Site are likely weathered given that they may have been present in the soil for up to 35 years. Over time, PHCs/PAHs undergo weathering whereby there is a change in the composition and bioavailability due to natural processes including volatilization, differential mobility, biodegradation and stabilization (CCME 2008). Therefore, the bioavailability and toxicity of the COCs are likely less than that for the amended soils used to derive the TRVs.	Overestimate
Toxicity Assessment	
Given that there were no TRVs, a quantitative assessment could not be completed for the following COCs and ROCs: pH and sulphate for plants and soil invertebrates; sulphide, sulphate, and ethylene glycol for mammals; PHC F2, sulphide, sulphate, antimony and ethylene glycol for birds.	Neutral
The TRVs used in the toxicity assessment for PHCs for plants and soil invertebrates are typically based on laboratory studies in which soils are amended with the bioavailable form of the contaminant (e.g., fresh versus weathered PHCs). Over time, PHCs undergo weathering whereby there is a change in the composition and bioavailability due to natural processes including volatilization, differential mobility, biodegradation and stabilization (CCME, 2008). Therefore, the toxicities of PHC F1 and F3 are likely less than that for the amended soils used to derive the TRVs given the length of time that has passed since the contamination occurred.	Overestimate
The TRVs used in the toxicity assessment for mammals and birds are sometimes based on toxicity studies using laboratory/domestic species and not wildlife species. Wildlife species may be more or less sensitive than laboratory/domestic species.	Underestimate, neutral or overestimate
Risk Characterization	
Individual level endpoints of survival, growth and reproduction were used for ROCs and extrapolated to population-level effects (population level effects are considered to be ecologically relevant). However, individual-level endpoints do not necessarily translate to population-level effects which could overestimate risks for these ROCs.	Overestimate

Notes:
AEP = Alberta Environment and Parks; AUF = area use factor; BC MECCS = British Columbia Ministry of Environment and Climate Change Strategy; CCME = Canadian Council of Ministers of the Environment; COC = contaminant of concern; ERA = ecological risk assessment; MECP = Ministry of the Environment, Conservation and Parks; PAH = polycyclic aromatic hydrocarbon; PHC = petroleum hydrocarbon; ROC = receptor of concern; SAR = species at risk; TRV = toxicity reference value; UCLM = upper confidence limit of the mean; US EPA = United States Environmental Protection Agency.

Table 5.30
Ecological Site Specific Target Levels for Soil and Groundwater
Lupin Mine, Nunavut

Media	COC	Receptor	Receptor-Specific SSTL ^(a)	Source/Rationale	SSTL _{Eco}	Notes
Soil	Petroleum Hydrocarbons - F1 (C6-C10)-BTEX	Plants and Soil Invertebrates	210 mg/kg	CCME CWS (Soil Contact)	210 mg/kg	CCME CWS (Soil Contact)
	Petroleum Hydrocarbons - F2 (C10-C16)	Plants and Soil Invertebrates	150 mg/kg	CCME CWS (Soil Contact)	150 mg/kg	CCME CWS (Soil Contact)
	Petroleum Hydrocarbons - F3 (C16-C34)	Plants and Soil Invertebrates	300 mg/kg	CCME CWS (Soil Contact)	300 mg/kg	CCME CWS (Soil Contact)
	Cyanide	Plants and Soil Invertebrates	0.9 mg/kg	CCME SQGE (soil contact)	0.9 mg/kg	CCME SQGE (soil contact)
		Willow ptarmigan	2.9 mg/kg	Calculated iteratively ^(a)		
	Arsenic	Plants and Soil Invertebrates	17 mg/kg	CCME SQGE (soil contact)	79 mg/kg	The receptor-specific SSTL was lower than the background concentration. The background concentration was selected as the SSTL _{Eco} .
		Arctic Hare	348 mg/kg	Calculated iteratively ^(a)		
		Arctic ground squirrel	224 mg/kg	Calculated iteratively ^(a)		
		Willow ptarmigan	1075 mg/kg	Calculated iteratively ^(a)		
	Naphthalene	Plants and Soil Invertebrates	0.6 mg/kg	MOECC Table 2 (Plants & Soil Org.)	0.6 mg/kg	MOECC Table 2 (Plants & Soil Org.)
	pH	Plants	4.13 to 8.0 unitless	Lower end of background range; upper end of CCME SQG	4.13 to 9.0	Based on the lower end of background range and the upper end of the receptor-specific SSTL for soil invertebrates
		Soil Invertebrates	4 to 9.0 unitless	Jansch et al. (2005)		
Groundwater	Petroleum Hydrocarbons - F2 (C10-C16)	Plants	1.8 mg/L	FCSAP FIGQG SODC	1.8 mg/L	FCSAP FIGQG SODC
	Aluminum	Plants	0.3 mg/L	Efroymson et al. 1997	0.3 mg/L	Efroymson et al. 1997
	Arsenic	Plants	0.001 mg/L	Efroymson et al. 1997	0.001 mg/L	Efroymson et al. 1997
	Cobalt	Plants	0.06 mg/L	Efroymson et al. 1997	0.06 mg/L	Efroymson et al. 1997
	Iron	Plants	10 mg/L	Efroymson et al. 1997	10 mg/L	Efroymson et al. 1997
	Zinc	Plants	0.4 mg/L	Efroymson et al. 1997	0.4 mg/L	Efroymson et al. 1997
	Sulphate	Plants	128 mg/L	BC MECCS (2019)	128 mg/L	BC MECCS (2019) Approved Water Quality Guideline; based on a water hardness of 0-30 mg/L
Surface Water (Boot Lake and East Lake)	pH	Aquatic Life	6.5 to 9.0 unitless	CCME WQG-PAL (1999/2019)	6.5 to 9.0	CCME WQG-PAL (1999/2019)

Notes:

COC = Contaminant of concern; SSTL = Site Specific Target Level; mg/kg = milligrams per kilogram; mg/L = milligrams per litre; EPC = exposure point concentration; HQ = hazard quotient

(a) The receptor-specific SSTLs for wildlife were calculated iteratively by inputting the calculated soil concentrations into the equations used to calculate doses and HQs to obtain an HQ of one.

Prepared by: SG

Checked by: AF

Table 6.1
Site Specific Target Levels for the Site
Lupin Mine, Nunavut

COC	Health-based SSTL	Ecological-based SSTL	Overall SSTL ^(a)
Soil (mg/kg)			
PHC F1	--	210	210
PHC F2	--	150	150
PHC F3	--	300	300
Cyanide	--	0.9	0.9
Arsenic	98	79	79
Lead	95	--	95
Naphthalene	--	0.6	0.6
pH	--	4.13 to 9.0	4.13 to 9.0
Groundwater (mg/L)			
PHC F2	--	1.8	1.8
Aluminum	--	0.3	0.3
Arsenic	--	0.001	0.001
Cobalt	--	0.06	0.06
Iron	--	10	10
Zinc	--	0.4	0.4
Sulphate	--	128	128
Surface Water (Boot Lake and East Lake)			
pH	--	6.5 to 9.0	6.5 to 9.0

Notes:

COC = contaminant of concern; PHC = petroleum hydrocarbon; SSTL = site specific target level; mg/kg = milligram per kilogram; mg/L = milligram per litre; -- = not applicable

^(a) The overall SSTL for the Site was selected as the lower of the health-based SSTL and ecological-based SSTL.

Prepared by: SG

Checked by: AF