December 2013

OSISKO
HAMMOND REEF GOLD

HAMMOND REEF GOLD PROJECT

Human Health and Ecological Risk Assessment Technical Support Document

VERSION 2

Submitted to:
Osisko Hammond Reef Gold Ltd.
155 University Avenue, Suite 1440
Toronto, Ontario M5H 3B7

Project Number: 13-1118-0010
Document Number: DOC020
Distribution:

Alexandra Drapack, Director Sustainable Development
Cathryn Moffett, Project Manager Sustainable Development

Golder Associates

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PART A

Introduction

Version 1 of the Human Health and Ecological Risk Assessment (HHERA) Technical Support Document (TSD) was published on February 15, 2013 as part of Osisko Hammond Reef Gold's (OHRG) Draft Environmental Impact Statement/Environmental Assessment (EIS/EA) Report.

The Draft EIS/EA Report underwent a seven week public review comment period after which, on April 5, 2013, OHRG received comments from the public, Aboriginal groups and the Government Review Team (GRT) seeking clarification and requesting new information.

Three comments regarding the HHERA TSD and the HHERA component of the EIS/EA Report were received from the GRT. Written responses were prepared for each comment received and are provided in Appendix 1.IV of the EIS/EA Report.

Version 1 of the HHERA TSD has not been revised. The methods used to define baseline conditions and assess the risks to human and ecological heath are technically defensible and based on standard industry practices. The conclusions and results presented in Version 1 of the HHERA TSD are sound based on the information presented therein. Where new information has since become available, updates have been made to the EIS/EA and this Version 2 of the HHERA TSD.

The EIS/EA Report has been revised and updated based on comments received. Version 2 of the HHERA TSD is comprised of the following:

- Part A: Introduction
- Part B: Supplemental Information Package (attached) that provides additional detail related to the HHERA component and the information presented in the HHERA TSD.
- Part C: Version 1 of the HHERA TSD. Part C was issued in February 2013, and is available online on OHRG's website; it has not been re-printed as part of this Version 2 of the HHERA TSD. The Version 1 document should be reviewed within the context of this Version 2 document, and associated updated information as presented in Part A or Part B should be considered as correct should it differ from the information presented in Version 1.

A summary of the information found in Part B is provided below. Throughout the EIS/EA Report, unless otherwise noted, all references made to the HHERA TSD are to Part C.

Figure Updates

Health Canada (IR-HC-3) indicated that the consideration of dust inhalation as a pathway was not clear in the presentation of the conceptual site model for human health receptors (Figure 4-1).

Figure 4-1 of the HHERA TSD has been revised to indicate that the inhalation of dust was considered in the assessment and is provided in the attached Supplemental Information Package.

The HHERA TSD assumed that "designated campsites" identified in the MNR land use data map layer were part of a commercial camping operation (i.e., campers would be assigned locations and amenities would be available) and, therefore, these campsites were identified as points of reception for consideration in the HHERA.

However, based on clarification from the Ministry of Natural Resources, OHRG now understands that these sites are Crown land and are simply suggested camping areas, which, just like any other Crown land, can be used for camping by anyone that chooses to do so. Based on this new understanding, the designated campsites have been removed as points of reception under the HHERA.

Figure 4-2 of the HHERA TSD has been revised to reflect the updated points of reception locations and is provided in the attached Supplemental Information Package.

Mitigation Measures

Version 1 of the HHERA TSD included a proposed mitigation measure to restrict access to identified designated campsites in close proximity to the Project site due to changes in noise levels and potential increase in particulate matter. OHRG was advised by MNR that restricting access to Crown Land would not be appropriate. Additionally, the "designated" campsites to which access was to be restricted are simply Crown land locations and, thus, have been removed as points of reception (as explained above). Therefore, restriction of access to these locations has been removed as a mitigation measure from the EIS/EA Report and replaced with a commitment to post signs advising potential campers of the mine operations and the potential for elevated noise levels should they chose to camp at these locations.

Supplemental Information

In response to a comment received from Health Canada that information related to the deposition of project-related emissions onto plants that may be consumed directly by people was not provided in the HHERA, additional work was carried out to model and predict potential chemical uptake in vegetation concentrations and compare the results to the measured existing concentrations. This information is provided as a response to IR-HC-4 in Appendix 1.IV of the EIS/EA Report and in the attached Supplemental Information Package.

Supplemental Information Provided in Part B

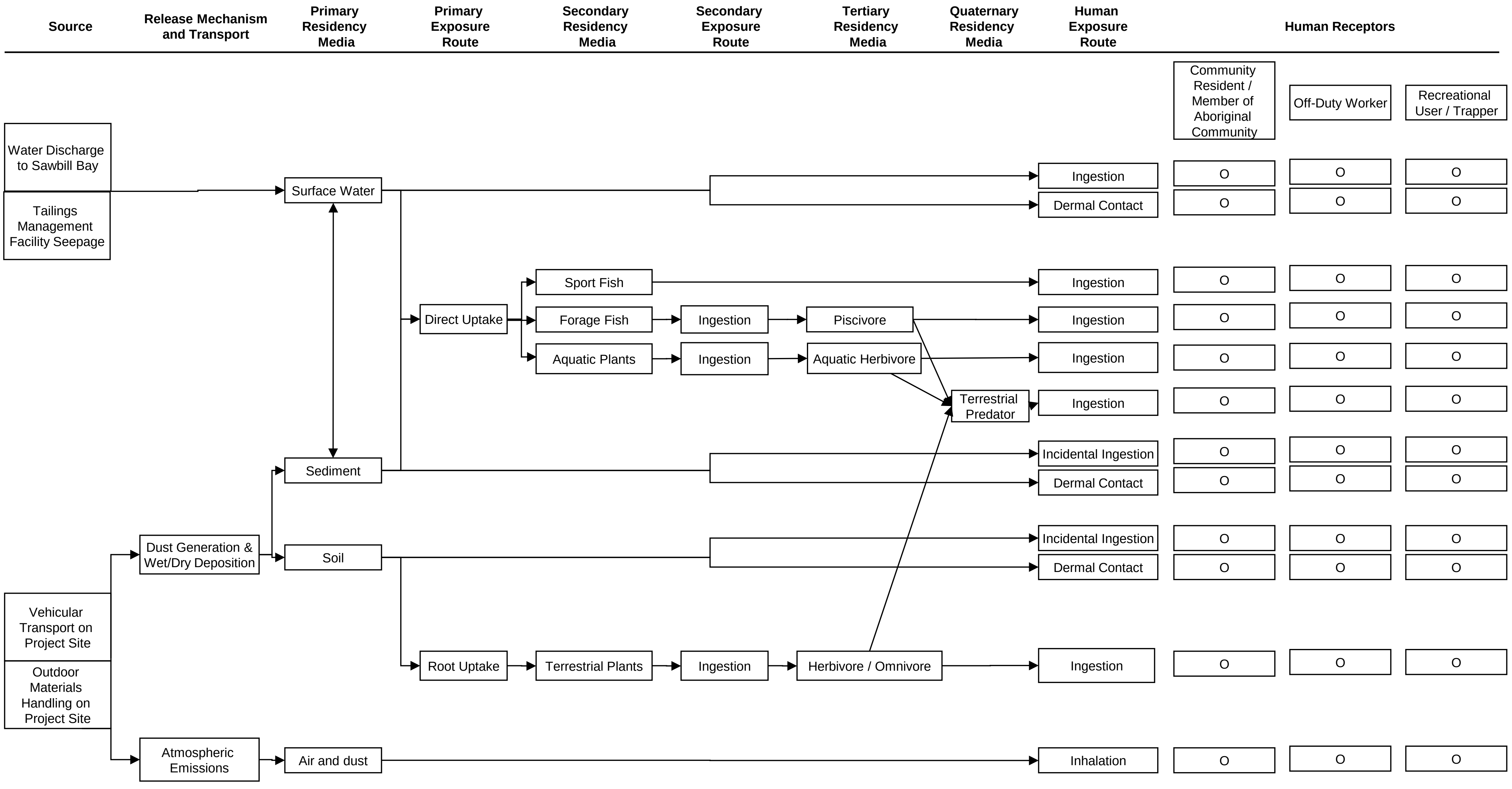
- Revised Figures 4-1 and 4-2
- Response to Information Request HC-4

PART B

Supplemental Information Package

Conceptual Site Model for Hammond Reef Gold Project – Human Receptors

FIGURE 4-1



LEGEND

X Pathway incomplete and/or not evaluated

O Pathway complete and evaluated

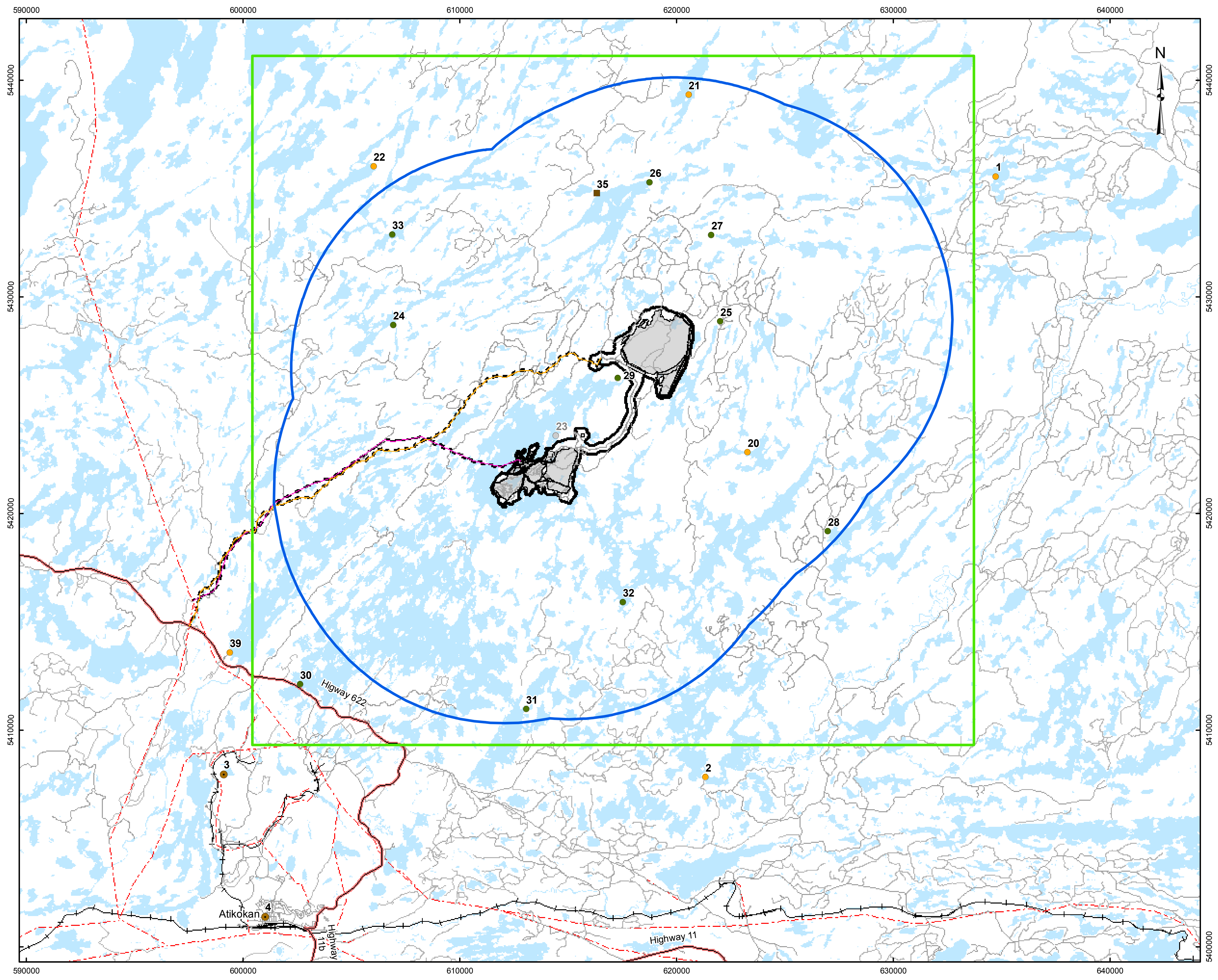
Date: May 2013

Project: 13-1118-0010

Version 2

CAD: GD

CKD: TRS



LEGEND

- Provincial Highway
- Road
- Existing Railway
- River/Stream
- Lake

Human Risk Assessment Receptor

- Community
- Cottage
- Tourism Establishment
- Trapper Cabin
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Project Transmission Line
- Project Facilities
- Air Local Study Area
- Air Regional Study Area
- Linear Infrastructure Study Area
- Mine Facility Study Area

REFERENCE

Base Data - Provided by OSISKO Hammond Reef Gold Project Ltd
Base Data - MNR NRVIS, obtained 2004
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2008
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15N

3 1.5 0 3 6 9
KILOMETRES

PROJECT

HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE

HUMAN RISK ASSESSMENT RECEPTOR LOCATIONS

Golder Associates
Mississauga, Ontario

PROJECT NO. 13-1118-0010			SCALE AS SHOWN	VERSION 2
DESIGN	CGE	14 Nov. 2008	FIGURE: 4-2	
GIS	JO	2 Dec. 2013		
CHECK	GD	2 Dec. 2013		
REVIEW	TRS	2 Dec. 2013		

G:\Projects\2013\13-1118-0010_Osisko_Hammond_Reef\GIS\MXDs\Reporting\Risk\HumanHealthAssessment.mxd

INFORMATION REQUEST – HC-4

Source: Health Canada

Summary of Comment

None

Potential Environmental Effects

The report did not include information related to the COPCs in country foods as part of the multi-media human health risk assessment. The clarification email provided by the proponent to Kitty Ma on March 12, 2013 addresses the issue of depositions affecting soil, and ensuring that soil concentrations do not exceed agricultural guideline levels. However, information related to the deposition of emissions onto plants which may be consumed directly by people during the operational phase of the project has not been provided. Since some harvesting of country foods is permitted in the local study area, it is appropriate to include as part of the multi-media assessment a discussion about the concentrations as a result of the project and the potential impact on human health.

Proposed Action

Given that the operational phase is used as a bounding scenario, please discuss whether monitoring data is needed during the post-closure phase to confirm the results of modelling where soil concentrations remain below the appropriate guideline.

Reference: Health Canada. 2010. Supplemental Guidance on Country Foods. (HHRAfoods) can be obtained at:

http://www.hc-sc.gc.ca/ewh-semt/pubs/contamsite/country_foods-aliments_locale/index-eng.php

Reference to EIS

HHERA TSD, Section 4.7

Response

The multimedia screening carried out for soil included a comparison of the predicted concentrations to the maximum existing concentrations (HHERA TSD, Appendix 3.II). For PAHs, all of the predicted soil concentrations were <0.6% above maximum existing concentrations and for metals, the predicted soil concentrations were <0.9% above maximum existing concentrations. As the deposition rates that were used to calculate soil concentrations would be the same deposition rates that would be used to calculate country food concentrations (e.g., for vegetation), it is expected that changes in country food concentrations as a result of the Project would be limited to less than 1%. Therefore, the change in exposure to COPCs in country foods as a result of the Project is expected to be negligible.

However, to demonstrate this quantitatively, chemical uptake in vegetation is modelled and predicted concentrations are compared to measured existing concentrations. In order to focus the assessment on a worst-case COPC, the chemicals with the highest percent increase in soil concentrations compared to baseline were identified; including barium, cadmium, calcium, potassium, sodium and strontium. Among this list, calcium, potassium, sodium and strontium were excluded as being generally non-toxic. Although cadmium was detected in baseline soil, it was not detected in baseline vegetation, meaning that a site-specific uptake factor could not be calculated. Barium, meanwhile, was detected in both soil and vegetation in all samples and site-specific uptake factors can be calculated. Therefore, barium was selected as a worst-case COPC to evaluate potential impacts on country foods.

In order to support the HHERA (see Section 3.1.1 of the HHERA TSD), blueberries and Labrador tea were collected from within the Regional Study Area (RSA), along with co-located soil samples. Both types of vegetation are known to be collected in the area and used for human consumption. Co-located soil samples were collected so that site-specific plant uptake factors could be calculated. An uptake factor is the vegetation concentration divided by the soil concentration. Existing barium concentrations in Labrador tea and blueberries (from HHERA TSD, Appendix 2.I) and calculated uptake factors are provided in Tables 1 and 2.

Table 1: Soil and Labrador Tea Concentrations and Uptake Factors for Barium

	S5C	**S22B**	**S6B**	**HR-LAB-01**	**HR-LAB-03**
Soil (µg/g)	28.0	63.0	48.0	na	na
Labrador Tea (µg/g)	22.0	**34.3**	29.3	22.7	18.2
Uptake Factor	**0.79**	0.54	0.61	-	-

Concentrations are reported on a dry weight basis; na = not analyzed; maximum values are in bold

Table 2: Soil and Blueberry Concentrations and Uptake Factors for Barium

	MBerry1	**Berry2**	**MBerry3**	**MBerry4-1**	**220**	**Blue 225**
Soil (µg/g)	26	78	24	21	30	47
Blueberry (µg/g)	2.4	3.8	4.0	4.2	4.2	**7.0**
Uptake Factor	0.09	0.05	0.17	**0.20**	0.14	0.15

Concentrations are reported on a dry weight basis; maximum values are in bold

Incremental plant concentrations incorporating the contribution of Project emissions were calculated based on plant exposure from direct deposition onto leaves or berries and chemical uptake from soil. The equations are provided in the table 3 below.

Table 3: Equations for Predicting Incremental Concentrations in Labrador Tea and Berries

Media	Equation
Total plant concentration	PC = Pd + Pr
	PC = incremental concentration (mg/kg dry wt) Pd = incremental concentrations due to air deposition (mg/kg dry wt) Pr = incremental concentration due to root uptake (mg/kg dry wt)
Plant concentration due to air deposition	Pd = 1,000 x [D_{yd} + (Fw x D_{wyd})] x Rp [1-exp(-kp x Tp)]/(Y_p x kp)
	Pd = incremental concentration due to air deposition (mg/kg dry wt) D_{yd} = dry particle deposition rate (g/m^2/y) Fw = Fraction of COPC wet deposition that adheres to plant surface D_{wyd} = wet deposition rate (g/m^2/y) Rp = interception fraction; represents portion of chemical deposition intercepted by plants Y_p = crop yield (kg dry wt/m^2) Tp = length of plant exposure to deposition per harvest (yr) kp = chemical removal from the plant surface by weathering (yr^{-1})
Plant concentration due to root uptake	Pr = SC x BAF
	Pr = incremental concentration due to root uptake (mg/kg dry wt) SC = predicted incremental soil concentration (mg/kg dry wt) BAF = bioaccumulation factor (unitless)

Source: U.S. EPA 2006.

Incremental plant concentration due to air deposition

The maximum dry and wet particle deposition rates for barium from all receptor locations were used (i.e., 1.1E-4 g/m^2/yr and 2.3E-6 g/m^2/yr). A value of 0.6 was used as the fraction of COPC wet deposition that adheres to plant surfaces (Fw), consistent with the U.S. EPA (2006) recommendation for cations. The default value of 0.39 for interception fraction (Rp) (U.S. EPA 2006) was determined to be sufficiently conservative for wild plants because the surface areas of fruit (e.g., tomatoes, apples) and leafy vegetables (e.g., lettuce, cabbage) are much greater than berries and Labrador tea leaves. The default value of 2.24 for crop yield (Yp) from U.S. EPA (2006) was used, and is considered a likely over-estimate of the crop yield for Labrador tea and berries in the RSA. Length of plant exposure (Tp) was estimated to be three months (0.25 yr) for blueberries and Labrador tea, given the growing season and length of snow-cover in the area. The default value of 18 yr^{-1} for kp was adopted from U.S. EPA (2006).

Incremental plant concentration due to root uptake

The maximum site-specific uptake factors (provided in Tables 1 and 2) for Labrador tea and blueberries were used, use of the maximum uptake factor is a conservative assumption that will generally over-estimate predicted plant concentrations.

The incremental plant concentration calculations for barium for Labrador tea and blueberries are presented below. The maximum predicted incremental soil concentration from all receptor locations (HHERA TSD, Appendix 3.II) of 0.057 mg/kg for barium was used.

Pd = 1,000 x [D_{yd} + (Fw x D_{wyd})] x Rp [1-exp(-kp x Tp)]/(Y_p x kp)

Pd = 1,000 mg/g x [0.00011 g/m^2/yr + (0.6 x 0.0000023 g/m^2/yr)] x 0.39[1-exp(-18/yr x 0.25yr)] / (2.24 kg/m^2 x 18 yr^{-1})

Pd = 0.00107 mg/kg

Pr (Labrador tea) = SC x BAF = 0.057 mg/kg x 0.79 = 0.045 mg/kg

PC (Labrador tea) = Pd + Pr = 0.00107 mg/kg + 0.045 mg/kg = **0.046 mg/kg**

Pr (blueberries) = SC x BAF = 0.057 mg/kg x 0.20 = 0.0114 mg/kg

PC (blueberries) = Pd + Pr = 0.00107 mg/kg + 0.0114 mg/kg = **0.012 mg/kg**

The predicted incremental concentration for Labrador tea (0.046 mg/kg) represents a 0.1% increase above the maximum measured existing concentration (34.3 mg/kg). The predicted incremental concentration for blueberries (0.012 mg/kg) represents a 0.2% increase above the maximum measured existing concentration (7.0 mg/kg). Overall, the Project contribution to vegetation concentrations in the RSA is considered to be negligible. This is supported by a quantitative evaluation for barium, a chemical with among the highest incremental changes in soil concentrations and detected uptake into Labrador tea and blueberries.

Given the conservative nature of the predicted Project-related emissions that are applied in the multi-media screening and the negligible incremental change in vegetation concentration, monitoring data is not required during post-closure.

References

U.S. EPA. 2005. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities. U.S. EPA Office of Solid Waste. EPA520-R-05-006. Washington, D.C.

PART C

Human Health and Ecological Risk Assessment Technical Support Document, Version 1

February 2013

HAMMOND REEF GOLD PROJECT

Human Health and Ecological Risk Assessment Technical Support Document

VERSION 1

Submitted to:
Osisko Hammond Reef Gold Ltd.
155 University Avenue, Suite 1440
Toronto, Ontario M5H 3B7

Project Number: 10-1118-0020
Document No.: 2012-036
Distribution:

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Cathryn Moffett, Project Manager Sustainable Development

Hammond Reef Gold Project
Human Health and Ecological Risk Assessment Technical Support Document

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Supporting Tables for Human Health Multi-Media Assessment

APPENDIX 4.I
Supporting Tables for Ecological Multi-Media Assessment

APPENDIX 4.II
Biotic Ligand Model for Copper

1.0 INTRODUCTION

Osisko Hammond Reef Gold Ltd. (OHRG) proposes the development of an open pit gold mine in north-western Ontario, herein referred to as the Hammond Reef Gold Project (Project). This Technical Support Document (TSD) is one of a series of reports in support of the Project's Environmental Impact Statement/Environmental Assessment Report (EIS/EA Report).

The following reports have been prepared to support the EIS/EA Report:

- Atmospheric Environment TSD.
- Geochemistry, Geology and Soil TSD.
- Hydrogeology TSD.
- Hydrology TSD.
- Water and Sediment Quality TSD.
- Site Water Quality TSD.
- Lake Water Quality TSD.
- Aquatic Environment TSD.
- Terrestrial Ecology TSD.
- Aboriginal Interests TSD.
- Cultural Heritage Resources TSD.
- **Human Health and Ecological Risk Assessment TSD.**
- Socio-economic Environment TSD.
- Alternatives Assessment Report.
- Conceptual Closure and Rehabilitation Plan

The EIS/EA Report will summarize the findings of this TSD and of the above-listed supporting reports.

1.1 Purpose and Scope

The purpose of this TSD is to fulfill the assessment scope outlined in the Project's Terms of Reference (ToR) approved by the Ontario Minister of the Environment (July 2012), and in the Environmental Impact Statement Guidelines (EIS Guidelines) published by the Canadian Environmental Assessment Agency (CEA Agency) (December 2011).

1.2 Report Organization

This TSD is structured as follows:

- Section 2 presents the purpose and scope of the TSD, provides an overview of the Project and describes the general assessment approach, valued ecosystem components, and assessment boundaries of the TSD.
- Section 3 describes the existing human health conditions in the vicinity of the Project.
- Section 4 assesses potential effects of the Project on human health.
- Section 5 addresses the potential effects of the Project on ecological health.
- Section 6 outlines the requirements of the monitoring program to help determine if effects are occurring to human and ecological health during the Project's life cycle.
- Section 7 summarizes the findings of this TSD.

2.0 PROJECT OVERVIEW

The Project overview and Project description are provided in Chapter 5 of the EIS/EA Report. Project aspects that influence the human health and ecological risk assessment are described in Sections 2.1 through 2.9.

2.1 Project Location

The Project is set within the Thunder Bay Mining District in north-western Ontario, approximately 170 kilometres (km) west of Thunder Bay and 23 km northeast of the town of Atikokan (Figure 2-1).

Access to the Hammond Reef property is presently via two routes: the Premier Lake Road, a gravel road that intersects Highway 623 near Sapawe and the Hardtack-Sawbill Road, a gravel road that intersects Highway 622 northwest of the Town of Atikokan. The exploration camp is located at the northern end of Sawbill Bay in Upper Marmion Reservoir. The property is also accessible by water from the southwest end of the Upper Marmion Reservoir at its access point from Highway 622. The existing Hardtack-Sawbill road located to the north of Finlayson Lake has been upgraded to provide an improved and more direct linkage to the Project Site in support of the expanded exploration program.

The Hammond Reef deposit is located mainly on a peninsula of land extending into the north end of the Upper Marmion Reservoir. The peninsula containing the deposit is surrounded by the Upper Marmion Reservoir on three sides with Sawbill Bay to the northwest and Lynxhead Bay to the southeast. The property also contains a number of smaller lakes. Mitta Lake is a small, steep-sided waterbody located atop mineralized zones of the deposit. Due to its location, the proposed Mine will encompass Mitta Lake.

2.2 Climate

The Project is located in a typical boreal climate region, which is characterized by long, usually very cold winters, and short, cool to mild summers. The annual temperature average is 1.6 degrees Celsius (°C) for Atikokan with a seasonal maximum of 16.2°C (average) for summer and a minimum of minus 15.4°C (average) for winter. Temperatures lower than minus 37°C have been recorded during the fall and winter. The annual normal total for precipitation is 788 millimetres (mm) (568 mm of rainfall and 220 mm of snowfall) for Atikokan with a seasonal maximum of 299 mm for the summer period.

2.3 Project Phases

The Project comprises four phases: construction, operations, closure and post-closure. The predicted emissions from the operations phase of the Project were used to represent the Project as assessed in the HHRA. The operations phase was identified as the bounding case for the other phases of the Project (i.e., construction, operations, closure, and post-closure) and the predictive air modelling (Atmospheric Environment TSD) and water quality modelling (Site Water Quality TSD, Lake Water Quality TSD) were carried out for the operations phase. Therefore, the operations phase is anticipated to be the bounding scenario for health risks associated with changes in air and surface water quality. The post-closure phase was evaluated separately for water quality.

REFERENCE

Base Data - Provided by OSISKO Hammond Reef Gold Project Ltd.;
Base Data - MNR NRVIS, obtained 2004. Produced by Golder Associates Ltd
under licence from Ontario Ministry of Natural Resources, © Queens Printer 2012
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15N

100 0 100 200 300 400
SCALE 1:10,000,000 KILOMETRES

Golder Associates
Mississauga, Ontario

DATE	February, 2013	TITLE	PROJECT LOCATION
DESIGN	CGE		
GIS	JO		
PROJECT No. 10-1118-0020	CHECK PB	PROJECT HAMMOND REEF GOLD PROJECT ATIKOKAN, ONTARIO, CANADA	FIGURE: 2-1
SCALE AS SHOWN VERSION 1	REVIEW PB		

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Activities expected to have the greatest influence are those that impact the atmospheric environment and surface water including:

- Mining and material handling activities.
- Vehicle exhaust emissions.
- Vehicle movement, which creates fugitive dust and noise.
- Existing hydrologic environment of the Marmion basin.
- Discharge from the Project Site.
- Discharge from the accommodation camp.
- Possibility of seepage and runoff from other Project Site locations during operations, closure and post-closure.
- Flooding and overflow of the open pit at closure and post-closure.

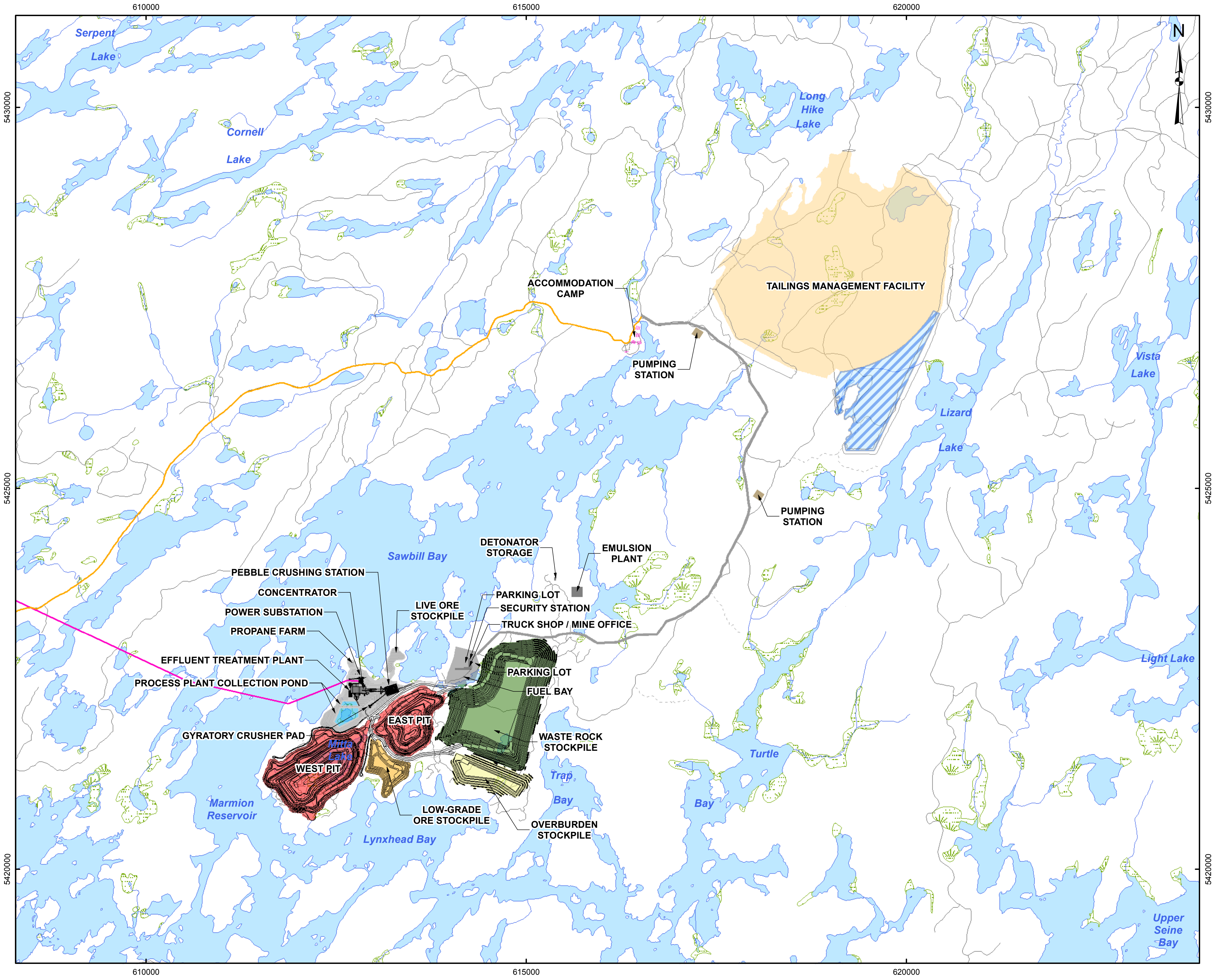
Additional details regarding activities expected to take place in each phase of the Project are provided in Chapter 5 of the EIS/EA Report.

2.4 Project Components

The Project consists of the following eight main components:

- Mine, including two open pits (i.e., east pit and west pit).
- Waste Rock Management Facility.
- Ore Processing Facility.
- Tailings Management Facility.
- Support and Ancillary Infrastructure.
- Water Management System.
- Linear Infrastructure.
- Borrow Sites.

Of these, the key Project components related to the assessment of human and ecological health are those that impact atmospheric and surface water quality, specifically the Mine, the Waste Rock Management Facility, and the Ore Processing Facility. Project components are shown in Figure 2-2. A detailed description of Project components is provided in Chapter 5 of the EIS/EA Report.



LEGEND

- Road
- Trail
- River/Stream
- Lake
- Wetland
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Project Transmission Line
- Accommodation Camp
- Laydown Area
- Office and Truck Shop, Explosives Storage and Processing Plant
- Open Pits
- Ore Stockpile
- Overburden Stockpile
- Process Plant Collection Pond
- Pump Station
- Tailings Management Facility
- Tailings Management Facility Reclaim Pond
- Waste Rock Stockpile

REFERENCE

Base Data - Provided by OSISKO Hammond Reef Gold Project Ltd.
Base Data - MNR NRVIS, obtained 2004
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2008
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15N

500 0 500 1,000 1,500 2,000 2,500
SCALE 1:50,000 METERS

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
SITE LAYOUT

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008	**FIGURE: 2-2**	
GIS	JO	8 Feb. 2013		
CHECK	GD	8 Feb. 2013		
REVIEW	TRS	8 Feb. 2013		

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2.5 Risk Assessment Framework and General Approach

2.5.1 Risk Assessment Framework

Human and ecological health will be evaluated using a risk assessment approach. Risk assessment (RA) is a scientific tool used to characterize the nature and magnitude of potential risks, if any, associated with the exposure of receptors (e.g., humans, wildlife and aquatic life) to substances. For there to be a potential risk, the following three conditions must be met:

- A chemical must be present at levels that could be harmful.
- A receptor must be present.
- There must be an exposure pathway by which the receptor can come into contact with the chemical.

These three conditions are illustrated in Figure 2-3, where risk is anticipated to occur when the three necessary conditions are met.

To determine whether these conditions are present, the RA framework used in Canada typically involves four components, as described below and depicted in Figure 2-4:

i) Problem Formulation: The Problem Formulation involves developing a focused understanding of how environmental quality might affect the health of receptors (e.g., humans, wildlife and aquatic life) near the proposed project. The problem formulation identifies the following:

  - A representative set of receptors (e.g., humans, wildlife and aquatic life) that may be present in the vicinity of the Project.
  - Substances that may be present at levels that may be harmful to receptors (termed Chemicals of Potential Concern [COPCs]).
  - Pathways by which receptors may be exposed to COPCs (e.g., inhalation of COPCs in ambient air by people, incidental ingestion of soil by wildlife and direct contact with surface water by aquatic life).

  The information from the Problem Formulation is summarized in a Conceptual Site Model (CSM) which illustrates the pathways of the COPCs from their sources, through the relevant environmental media and to the identified receptors.

ii) Exposure Assessment: For humans and wildlife, the exposure assessment involves estimating the daily dose of a COPC received by the receptors for each relevant exposure pathway and COPC identified in the Problem Formulation. This value is called the Estimated Daily Intake (EDI) and is typically expressed as milligrams (mg) of a chemical per kilogram (kg) of body weight per day (mg/kg/d). The EDI is calculated from site-specific concentrations of COPCs (i.e., chemical characterization) in environmental media (e.g., water, sediment, fish, air, soil, or vegetation), the amount of time the receptor spends in the study area and receptor-specific parameters such as body weight, ingestion rate, and dietary preferences (i.e., receptor characterization). For aquatic life, exposure is expressed as the concentrations of the COPCs in water and/or sediment. This permits evaluation of exposure relative to environmental guidelines and toxicity benchmarks for aquatic life that are expressed in the same way.

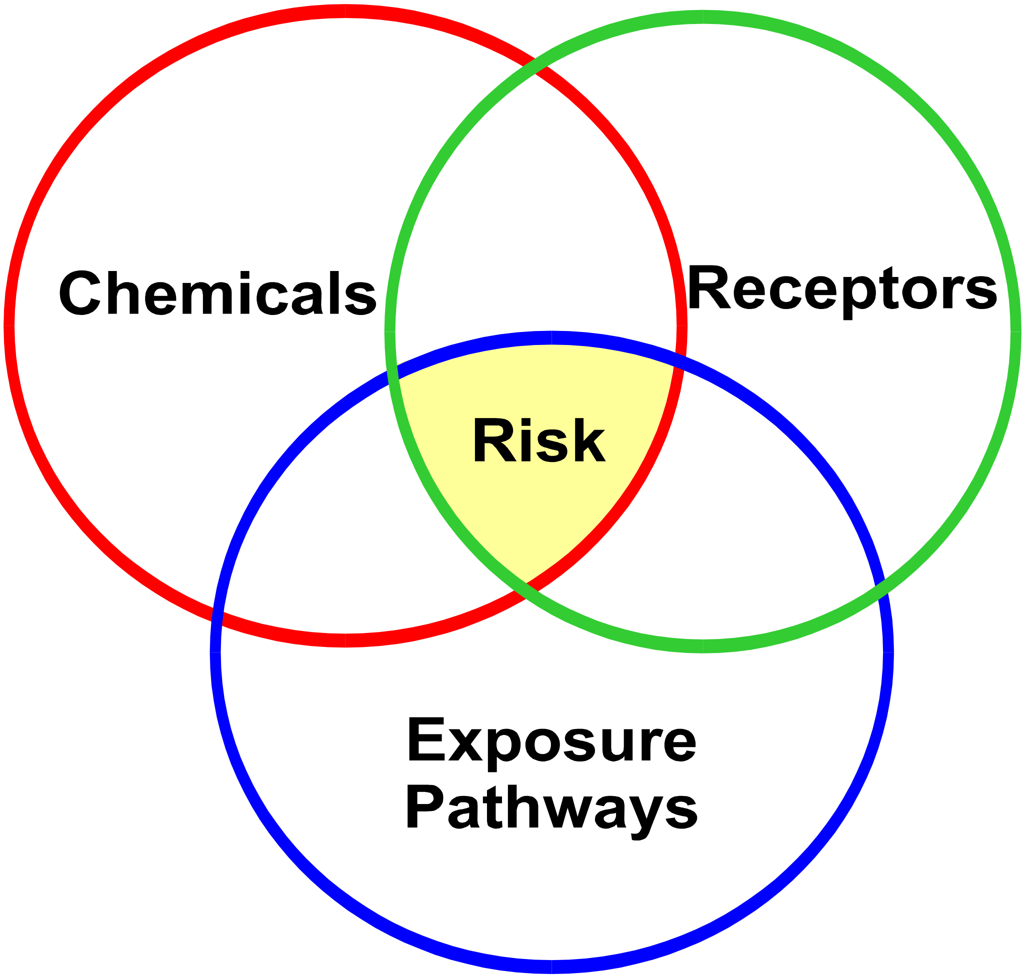
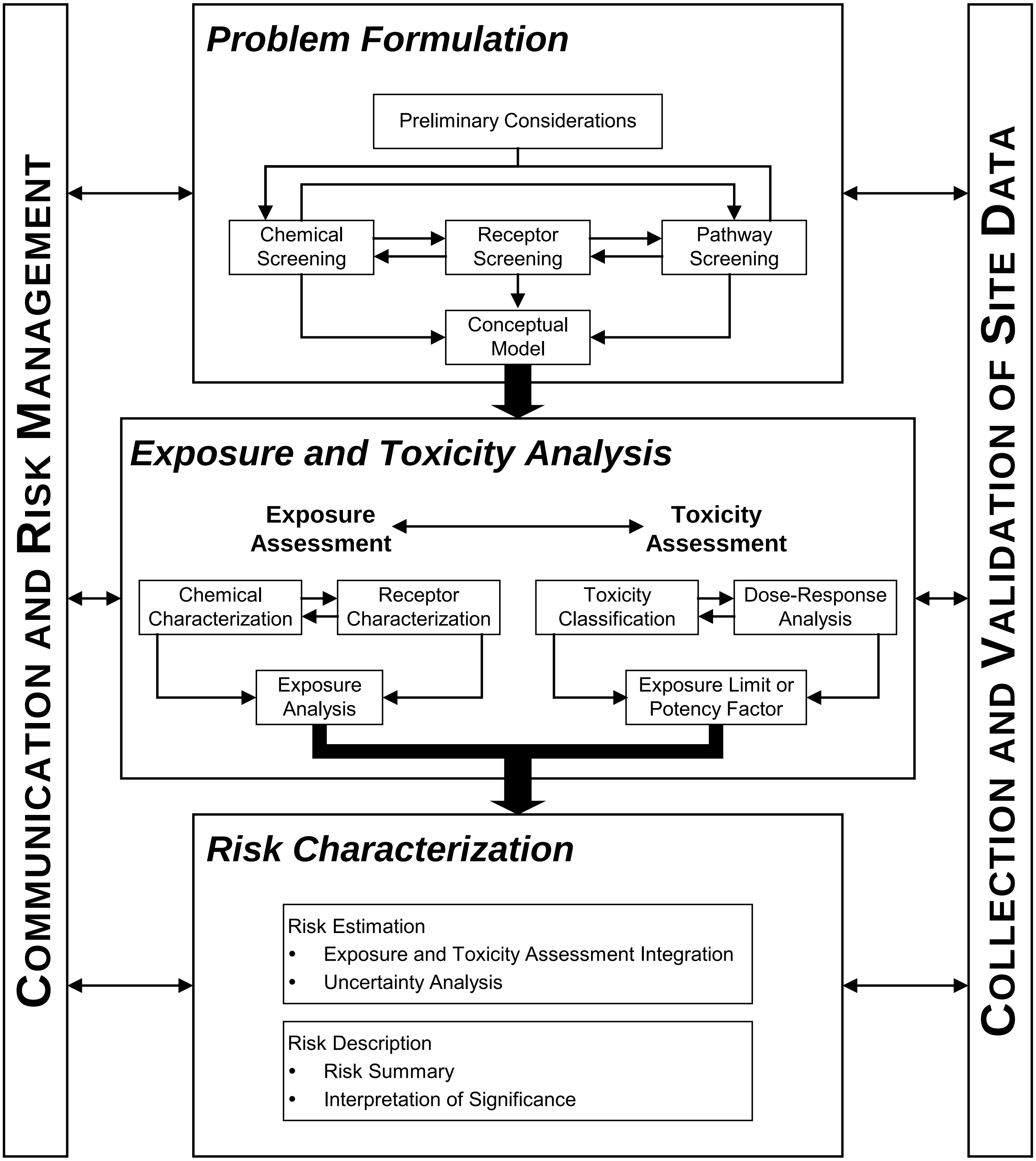


Figure 2-3: Venn Diagram Showing the Three Conditions that Must Occur for Risk to Exist



Source: Health Canada [unpublished] 1995.

Figure 2-4: Risk Assessment Framework

iii) Toxicity Assessment: The Toxicity Assessment provides the basis for assessing what is an acceptable exposure and what exposure level may adversely affect the health of receptors. This involves identification of the potentially toxic effects of a COPC (i.e. toxicity classification) and determination of the dose (for humans and wildlife) or concentration (aquatic life) to which a receptor can be exposed without experiencing adverse health effects (i.e., dose-response analysis). This value is called the Toxicity Reference Value (TRV). For humans and wildlife, the TRV is expressed as milligrams of a COPC per kilogram of body weight per day (mg/kg/d). For aquatic life, for which daily dose calculations are not possible, the TRV is expressed as an acceptable concentration of the chemical in the media to which the receptor is exposed (i.e., surface water or sediment concentration).

iv) Risk Characterization: The final component of an RA determines the potential for adverse health effects to occur. This is determined by comparing the estimated exposure received by the receptors (i.e., the EDI for humans and wildlife and the surface water/sediment concentration for aquatic life from the exposure assessment) with the level of exposure that is determined to be acceptable (i.e., the TRV from the toxicity assessment). The characterization of risks includes consideration of the uncertainty and conservatism in the RA.

2.5.2 Conceptual Site Model

A CSM is developed in a RA to understand which substances (i.e., substances present at concentrations in excess of the applicable guidelines/standards or COPCs) are present in the study area, how receptors may use the areas, and the pathways of contact that are possible between these substances and the receptors. These substances, receptors, and pathways (the environmental risk components) are examined in detail to identify the "reasonably anticipated" combinations corresponding to potentially complete exposure pathways. Incomplete pathways are eliminated from further consideration or are "screened out". The combinations of the environmental components that remain subsequent to the screening process, form the basis of the conceptual model, and are used to focus the RA.

The CSM addresses the following questions to characterize the effect of COPCs on receptors:

- Which substances are present at elevated levels relative to site-specific and/or literature-based provincial background levels? Which substances are a result of Project-related emissions and which are related to natural sources?
- Which substances are present at elevated levels relative to applicable guidelines/standards?
- In which environmental media are the substances located (e.g., soil, groundwater, surface water, air, vegetation)?
- Is there a potential for the substances to migrate?
- In what concentrations are the substances present in the environmental media?
- Who are the receptors (current and future users)?
- How is and/or will the Project Site be used?
- How can the receptors come into contact with the substances?

Where exposure scenarios can be reasonably assumed to be complete, a more detailed examination or quantification of potential risks is required. The detailed assessment involves the remaining stages of the RA including exposure assessment, toxicity assessment, and risk characterization.

2.6 Incorporation of Traditional Knowledge

Identifying issues and predicting impacts are strengthened when traditional knowledge of local resource users is properly identified and when a broad spectrum of the public can participate in the consultation process. Traditional knowledge in combination with other information sources is valuable in achieving a better understanding of the Project's potential effects on the biophysical and socio-economic environment. It also contributes to the description of the existing biophysical and human environment, natural cycles, resource distribution and abundance, and the use of land and water resources. A detailed discussion on traditional knowledge is included in the Aboriginal Interests TSD.

Relevant to human and ecological health, the Aboriginal considerations that must be identified and assessed if potentially affected by the Project as stated in the ToR and EIS Guidelines are as follows:

- Past, current and known planned land uses.
- Traditional land use, including areas where camping, travel, hunting, fishing, trapping, planting and harvesting currently occur.
- Traditional dietary habits and dependence on country foods.
- Harvesting of plants for other purposes, including medicine.
- Commercial, recreational and subsistence lake and stream fisheries.

The Aboriginal Interests TSD describes the Traditional Knowledge and Traditional Land Use studies that were carried out for the Project. Aboriginal considerations were used in the human health and ecological risk assessment to identify and characterize receptors and identify receptor locations.

2.7 Precautionary Approach

Environmental assessments are forward-looking planning tools, used in early stages of project development. As such, environmental assessments are based on a precautionary approach. This approach is guided by judgement, based on regulatory and stakeholder-based values, and intended to address uncertainties in the assessment. This approach is consistent with the Canadian government's framework for applying precaution in decision-making processes.

2.8 Selection of Valued Ecosystem Components

The purpose of this TSD is to determine whether the Project will have effects on human or ecological health, the extent to which the Project may affect health, and to identify means by which potential effects can be mitigated. While all aspects of human and ecological health are important, it is neither practicable nor necessary to assess every potential effect of the Project on every aspect of the environment. In order to focus the assessment on those components that are of greatest relevance in terms of value and sensitivity, Valued Ecosystem Components (VECs) have been identified and selected as endpoints for the assessment.

The CEA Agency describes VECs as:

"Any part of the environment that is considered important by the proponent, public, scientists and government involved in the assessment process. Importance may be determined on the basis of cultural values or scientific concerns" (Hegmann et al. 1999).

The VECs are typically selected through an issues scoping exercise that identifies the particular components of the environment for which there is public, Aboriginal, regulatory or scientific concern. The VECs provide structure and focus for the environmental assessment and ensure that the likely effects of a project are considered.

Since the VECs are assessment endpoints, it is important that the selected VECs can be used to meaningfully measure the potential effects of the Project. The VECs for this TSD were selected based on the following considerations:

1) Review of Project information and mapping.

2) Consideration of the EIS Guidelines and Terms of Reference for this Project.

3) Identification of land uses (e.g., hunting, trapping, fishing) within the area.

4) Professional experience and understanding of human and ecological health issues pertaining to other environmental assessments in Ontario.

5) Input from regulatory and public consultation, and engagement with Aboriginal communities.

The VECs selected for human health are shown in Table 2-1. Indicators represent the key properties that should be protected for VECs, while measures are quantifiable expressions of changes to indicators.

Table 2-1: VECs Selected for Human Health

VEC	Rationale for Selection	Indicators	Measures
Off-duty worker	There is an accommodation camp on the Project Site where some workers will reside.	■ Protection of air quality and noise with respect to human health. ■ Continued opportunity for use of surface water, fish, vegetation and traditional foods for traditional and non-	■ Noise Levels ■ Chemical concentrations in air, water, sediment, fish, soil, vegetation and traditional foods
Trapper	There are several trapper cabins located near the Project Site.		
Recreational User	The area around the Project Site has several designated camping sites and tourism establishments.		

Table 2-1: VECs Selected for Human Health (Continued)

VEC	Rationale for Selection	Indicators	Measures
Member of Aboriginal Community	Members of the nearby Aboriginal communities may use the area surrounding the Project Site for plant harvesting, fishing and hunting.	traditional human use.	
Community Resident	Residents of nearby Steep Rock Lake and Atikokan may use the area surrounding the Project Site for recreational purposes including fishing and hunting.		

The VECs for ecological health were selected based on the following considerations:

- Wildlife and aquatic life identified in the EIS Guidelines for the Project.
- VECs selected by the Terrestrial Ecology and Aquatic Environment TSDs.
- Plants, wildlife and aquatic life that reflect the interests of Aboriginal groups and communities.
- Wildlife and aquatic life observed in the Project area.
- Species at risk.
- Sensitivity to substances.
- Availability of ecotoxicological and exposure related data.
- Ecological relevance (species that play important roles in community structure or function [e.g., top predators, major herbivores, key prey species]).
- Potential for exposure to substances (diet, habitat preferences and behaviours that make species likely to come into contact with substances).

Table 2-2 provides the VECs selected for ecological health, the rationale for their selection and the proposed indicators and measures.

Table 2-2: VECs Selected for Ecological Health

Valued Ecosystem Component	Rationale for Selection	Indicators	Measures
Wild rice	Traditional use plant	Survival, growth and reproduction	Comparison of surface water concentrations to literature-derived values without deleterious effects on growth and reproduction

Table 2-2: VECs Selected for Ecological Health (Continued)

Valued Ecosystem Component	Rationale for Selection	Indicators	Measures
Moose	Ungulates identified in the EIS Guidelines for the Project; moose selected as a VEC by the Terrestrial Ecology TSD; observed in the Project area, important subsistence and cultural species; play a key role in the food web (prey for large carnivores)	Survival, growth and reproduction	Comparison of modelled dietary doses to literature-derived values without deleterious effects on survival, growth and reproduction
Furbearers *(beaver, muskrat, otter, pine marten, fisher, Canada lynx, short-tailed weasel, mink, snowshoe hare, red fox)*	Identified in the EIS Guidelines for the Project; selected as a VEC by the Terrestrial Ecology TSD; observed in the Project area; play a key role in the food web (prey for carnivores or top predators); traditional and non-traditional uses		
Small mammals	Identified in the EIS Guidelines for the Project; documented in the Project area; play a key role in the food web (prey for carnivores); high potential for exposure to substances due to life history		
Raptors (*bald eagle*)	Raptors identified in the EIS Guidelines for the Project; bald eagle selected as a VEC in the Terrestrial Ecology TSD; observed in the Project area; cultural significance, species at risk; top predators may accumulate substances		
Waterbirds	Waterfowl and other birds identified in the EIS Guidelines for the Project; documented in the Project area; some species are important for subsistence		
Upland breeding birds (*common nighthawk, Canada warbler*)	Common nighthawk and Canada warbler selected as VECs in the Terrestrial Ecology TSD; documented in the Project area; species at risk		
Fish (*walleye, small mouth bass, northern pike, baitfish*)	Identified in the EIS Guidelines for the Project; selected as a VEC in the Aquatic Environment TSD; socio-economic importance; traditional resource use (e.g., walleye); baitfish are an important food resource for large fish species (e.g., walleye); long lived, top predator species (e.g., walleye, northern pike) may accumulate substances		Comparison of surface water concentrations to literature-derived values without deleterious effects on survival, growth and reproduction

Table 2-2: VECs Selected for Ecological Health (Continued)

Valued Ecosystem Component	Rationale for Selection	Indicators	Measures
Benthic invertebrates	Benthic invertebrates identified in the EIS Guidelines for the Project; play a vital role in nutrient cycling and the breakdown of detritus in the aquatic environment; important food source for fish; sensitive to contamination		

Reptiles and amphibians were identified in the EIS Guidelines for the Project. The snapping turtle was selected as a VEC in the Terrestrial Ecology TSD. Various species of reptiles and amphibians were documented in the Project area. Reptiles and amphibians were not selected as VECs for ecological health. This is because the ecotoxicological and exposure related information needed to assess amphibians and reptiles is not available. This is consistent with the information provided by the Ministry of the Environment (MOE 2011). The MOE indicates that amphibians and reptiles were not included in the development of the generic standards because there is currently not enough information to evaluate exposure and risk.

2.9 Temporal and Spatial Boundaries

Project activities and the potential changes that they may produce on the environment are subject to temporal and spatial boundaries. These boundaries are common to all environmental components but with some modifications. The temporal and spatial boundaries specific the human health and ecological risk assessment are described below.

2.9.1 Temporal Boundaries

The human health and ecological health temporal boundaries are directly related to the Project phases, namely:

- Construction phase: 30 months (i.e., 2.5 years).
- Operations phase: 11 years.
- Closure: 2 years.
- Post-closure: 10 years.

2.9.2 Spatial Boundaries

The spatial boundaries for the human health and ecological risk assessment were aligned with the spatial boundaries identified by the EA disciplines that will predict potential Project-related changes to environmental quality, or that provided information relevant to human activities, wildlife and aquatic life. These EA disciplines are as follows:

- Atmospheric environment.
- Water quality.

- Socio-economic environment and Aboriginal Interests.
- Aquatic environment.
- Terrestrial ecology.

This TSD has three study areas including the Regional Study Area (RSA), Local Study Area (LSA) and the Mine Study Area (MSA). These study areas are described in the following sub-sections.

2.9.2.1 Regional Study Area

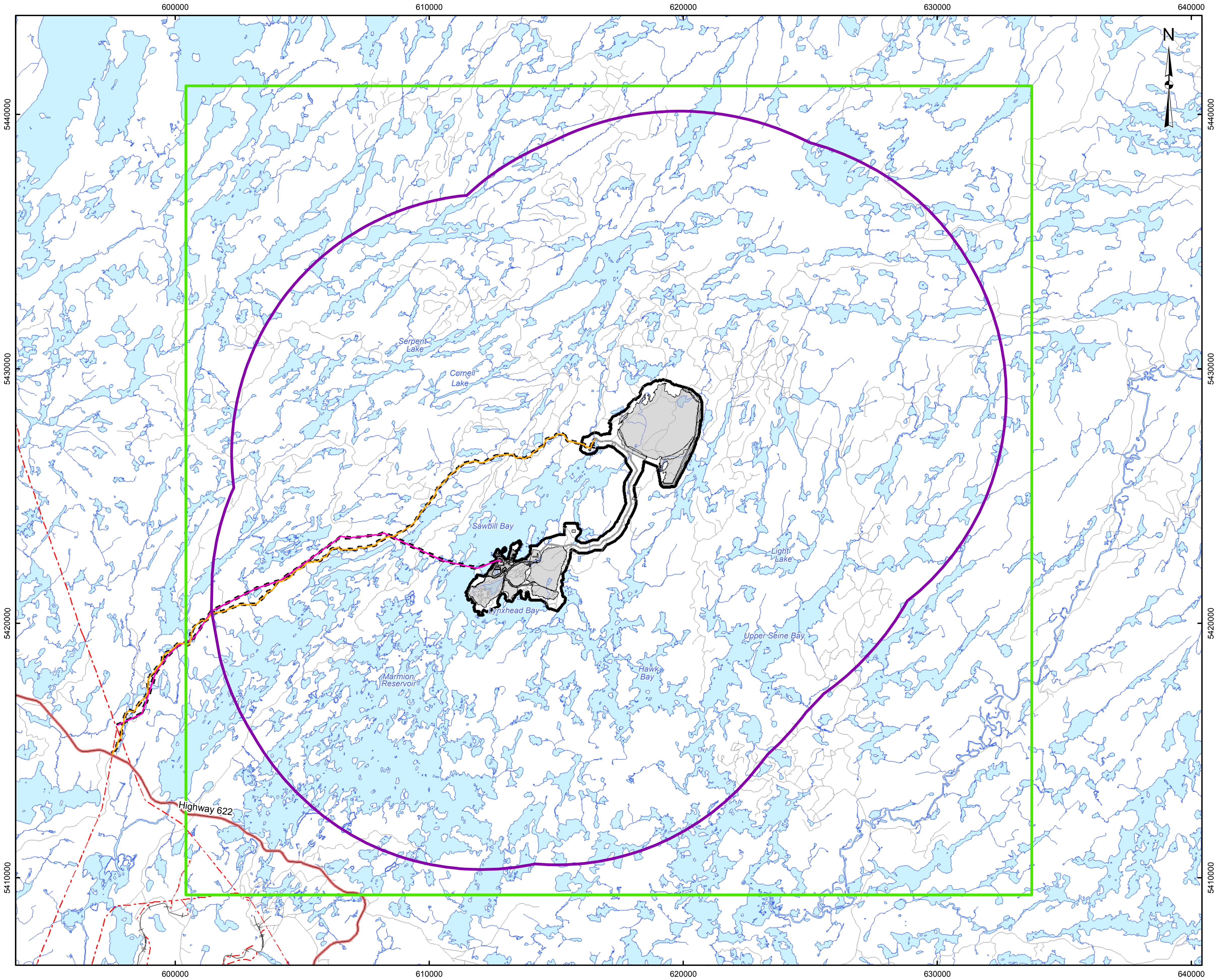
The Regional Study Area is consistent with the atmospheric environment discipline and is shown in Figure 2-5. The RSA for atmospheric environment encloses the domain of the model used to assess air quality for the Project. The RSA for atmospheric environment is defined by an area 35 km by 35 km in size (Atmospheric Environment TSD).

2.9.2.2 Local Study Area

The Local Study Area is consistent with the atmospheric environment discipline and is shown in Figure 2-5. The LSA for the atmospheric environment is defined as the area that will be most likely to experience changes due to the Project. Air emissions from operations are most likely to affect an area within several kilometres of the Project. Therefore, the air quality LSA was selected to extend approximately 10 km in all directions from the Mine Study Area (Atmospheric Environment TSD).

2.9.2.3 Mine Study Area

The Mine Study Area encompasses the footprints of the Mine, the Waste Rock Management Facility, the Ore Processing Facility, the Tailings Management Facility, and the Support and Ancillary Infrastructure as shown in Figure 2-5. Borrow Pits are not included in the assessment, as they are subject to a separate permitting process.



LEGEND

- Provincial Highway
- Road
- Existing Railway
- River/Stream
- Lake
- Mine Site Road
- Access Road (Hardtack / Sawbill)
- Project Transmission Line
- Project Facilities
- Linear Infrastructure Study Area
- Linear Infrastructure Study Area
- Air Regional Study Area
- Air Local Study Area

REFERENCE

Base Data - Provided by OSISKO Hammond Reef Gold Project Ltd
Base Data - MNR NRVIS, obtained 2004
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2008
Projection: Transverse Mercator   Datum: NAD 83   Coordinate System: UTM Zone 15N

2.5 1.25 0 2.5 5 7.5
KILOMETRES

PROJECT
HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE
AIR QUALITY REGIONAL AND LOCAL STUDY AREAS

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008	**FIGURE: 2-5**	
GIS	JO	8 Feb. 2013		
CHECK	GD	8 Feb. 2013		
REVIEW	TRS	8 Feb. 2013		

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3.0 EXISTING CONDITIONS

3.1 Methods

To determine the potential for incremental changes in the environment due to the Project, the existing (or baseline) conditions of the environment must first be understood. Several studies were carried out in support of the Project to characterize existing environmental conditions. The existing environmental information collected as part of the EA and used in support of the human and ecological health assessment is summarized below:

- Air quality data (Atmospheric Environment TSD).
- Water quality and sediment quality data (Water and Sediment Quality TSD).
- Vegetation and wildlife surveys (Terrestrial Ecology TSD).
- Land use information (Socio-economic Environment TSD).
- Traditional Land Use and Traditional Knowledge (Aboriginal Interests TSD).
- Fish community and fish tissue data (Aquatic Environment TSD).
- Soil quality data (Geochemistry, Geology and Soil TSD).
- Supplemental existing conditions vegetation, soil and sediment quality data collected in support of the human health assessment (Human Health and Ecological Risk Assessment TSD).

The information presented in the other TSDs was reviewed in order to understand existing environmental conditions, human activities in the area and existing wildlife and aquatic communities. Health information for the region was also collected and is summarized in Section 3.1.2.

3.1.1 Field Studies

The field studies were carried out by other disciplines and are presented in above noted TSDs. Supplemental field studies were carried out to support the human health and ecological risk assessment, including the collection of vegetation, soil and sediment quality data. Based on the land and resource interviews, diet surveys and trapline interviews (Aboriginal Interests TSD and Socio-economic Environment TSD) it is known that cranberries and blueberries are collected from the area and used for human consumption. The collection and use of teabush (e.g., Labrador tea) to make tea was also mentioned in the interviews. It was noted in the interviews that while wild rice is harvested in the larger region for human consumption, there is not enough wild rice in the RSA to harvest (Aboriginal Interests TSD and Socio-economic Environment TSD). Further discussion of the distribution of wild rice in the area is provided in the Terrestrial Ecology TSD. Due to the limited availability of wild rice in the RSA, it was not considered relevant for human health and was not sampled.

In order to understand existing conditions for relevant vegetation, blueberries, cranberries and Labrador tea were collected from within the RSA, along with co-located soil samples. Soil samples were collected in order to estimate site-specific soil-plant uptake factors. An uptake factor is the ratio of the chemical concentration in vegetation and soil. Uptake factors can be used to predict vegetation concentrations based on modelled soil concentrations. As uptake factors are variable depending on site-specific conditions, collecting site-specific uptake factors is important to reduce uncertainty in the evaluation of vegetation ingestion.

To support the ecological risk assessment, cattail (*Typha latifolia)* was sampled. Cattail was used in the ecological risk assessment as a surrogate for aquatic vegetation consumed by wildlife such as muskrat, a potential receptor for the ecological risk assessment. Sediment samples were collected at the same sample locations as the cattail to provide further existing characterization of sediment concentrations, supplementing the sediment concentrations presented in the Water and Sediment Quality TSD.

Further description of the vegetation sampled is provided below:

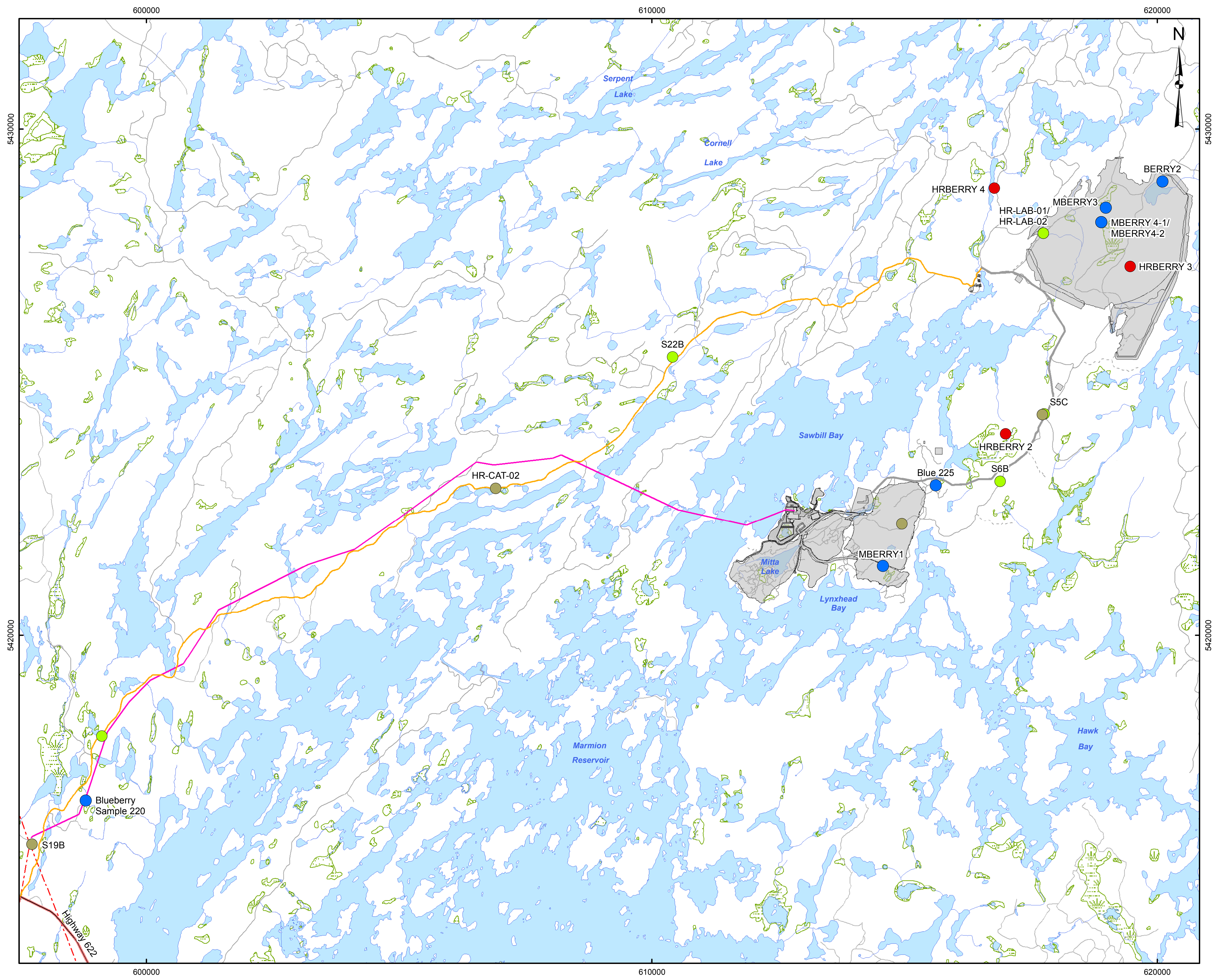
- Cattail (*Typha latifolia*) – a perennial plant with long, slender green stalks topped with brown flowering heads, found in or near water in marshes, ponds, lakes and depressions.
- Velvetleaf blueberries (*Vaccinium myrtilloides)* - a low spreading deciduous shrub with bright blue to dark blue berries, grows best in open coniferous woods.
- Cranberries *(Vaccinium oxycoccos*) – a trailing, vine-like shrub with delicate stems found in wetlands: bogs, swamps, and muskegs and along the marshy shores of ponds and lakes.
- Labrador tea (*Ledum groenlandicum*) – a low, evergreen shrub that is found in peatlands, tundra and moist coniferous woods. It is also found in swamps, muskegs and bogs.

Sample locations were selected to provide spatial variation within the constraints of accessibility and availability of vegetation. For cattail samples, the base of the stem and root were collected. For Labrador tea samples, leaves were collected primarily from the top of the plant to ensure samples were from the current season's growth. Only the berry was sampled for blueberries and cranberries. Approximately 200 grams (g) of plant material was collected from each sampling location, placed in a plastic bag inside a second plastic bag, and labelled with sample location, date and time. Field staff wore nitrile gloves to prevent contamination of the samples. All samples (vegetation and soil/sediment) were stored on ice until submission to the laboratory for analysis. Soil samples were collected following the method presented in the Geochemistry, Geology and Soil TSD. Sediment samples were collected following the method presented in the Water and Sediment Quality TSD.

Cattail, Labrador tea and associated sediment and soil samples were collected from June 26 to 28, 2012. Cranberries were collected from September 14 to 16, 2011. Blueberries and co-located soil samples were collected from August 5 to 7, 2012. All vegetation, soil and sediment samples were submitted to Maxxam Analytics Inc. under chain of custody. The analytical results are presented in Appendix 2.I, Tables 1 to 4. The sample locations are shown in Figure 3-1.

3.1.2 Secondary Data Review

It is important to understand the existing health conditions in the region before an assessment of the potential effects of the Project to human health can be completed. In addition to environmental condition, determinants of health including income, education, social status and access to health care and community services can provide information for predicting health disparities in a given population. Refer to the Cultural Heritage Resources TSD and the Socio-Economic Environment TSD for details on other determinants of health. This subsection describes health indicators as provided by Statistics Canada.



LEGEND

- 🔵 Blueberry and Paired Soil Sampling Location
- ● Cattail and Paired Sediment Sampling Location
- 🔴 Cranberry Sampling Location
- 🟢 Labrador Tea and Paired Soil Sampling Location
- - - - Trail
- —— Road
- —— River/Stream
- 🟦 Lake
- ▨ Wetland
- —— Mine Site Road
- —— Access Road (Hardtack / Sawbill)
- —— Project Transmission Line
- ⬜ Project Facilities

REFERENCE

Base Data - Provided by OSISKO Hammond Reef Gold Project Ltd.
Base Data - MNR NRVIS, obtained 2004
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2008
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15N

1,000 0 1,000 2,000 3,000 4,000
SCALE 1:75,000 METRES

PROJECT

HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE

VEGETATION SAMPLING LOCATIONS

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008	FIGURE: 3-1	
GIS	JO	8 Feb. 2013		
CHECK	GD	8 Feb. 2013		
REVIEW	TRS	8 Feb. 2013		

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Statistics Canada provides health indicators for defined health regions across Canada. Health indicators are standardized measures of various aspects of health and health care which can be used to monitor health status of the population and the performance and characteristics of the health system over time and across the country (Statistics Canada 2009). Health regions are administrative bodies, legislated by the provincial ministries of health (Statistics Canada 2009). Health regions are defined by geographical areas and are responsible for providing health services to their residents. The Project is located within the North West Local Health Integration Network (LHIN). This region has the largest land mass of all LHINs in Ontario at 458,010 square kilometres (km^2), equivalent to 47% of the province. The North West LHIN’s boundaries extend from White River in the east to the Manitoba border in the west, to Hudson Bay in the north and to the United States border in the south. Relative to the province of Ontario, the North West LHIN has a higher proportion of people who (North West LHIN 2011):

- Smoke daily.
- Are heavy drinkers.
- Are overweight or obese.
- Have a strong sense of community belonging.

Relative to the province of Ontario, the Northwest LHIN has a lower proportion of people who (North West LHIN 2011):

- Rate their health as excellent or very good.
- Have had contact with a medical doctor in the past year.
- Are physically inactive.

The prevalence of chronic conditions for the North West LHIN and Ontario are provided in Table 3-1 (North West LHIN 2011).

Table 3-1: Prevalence of Chronic Conditions for North West LHIN and Ontario

Indicator	Age	North West LHIN	Ontario
Canadian Community Health Survey, 2010: % report being diagnosed by health professional			
Arthritis	Age 14+	23.3%	17.1%
	Age 65+	51.5%	46.9%
Diabetes	Age 12+	7.5%	7.2%
	Age 65+	25.1%	19.8%
High blood pressure	Age 12+	20.8%	17.6%
	Age 65+	58.2%	50.6%
Hospitalizations, fiscal years 2008/09-2009/10; rate/100,000 population (average annual crude rate)			
Diabetes hospitalization rate		214.3	96.5
Chronic obstructive pulmonary disease, hospitalization rate	Age 45+	748.4	417.7
Ischaemic heart disease hospitalization rate	Age 40+	1245.8	791.4

Source: North West LHIN 2011.

A crude rate is the number of events per total population of interest. Crude rates (e.g., hospitalizations given in Table 3-1) should be viewed with caution because there is no adjustment for differences in age-sex distribution for the areas being compared. The North West LHIN has a higher prevalence of arthritis, diabetes and high blood pressure compared to the rest of Ontario. The North West LHIN has higher rates of hospitalizations in comparison to the rest of Ontario for diabetes, chronic obstructive pulmonary disease and ischaemic heart disease. The higher rates of hospital use for chronic conditions may be due to lack of alternative community-based services such as primary care through a family physician, nurse practitioner clinics, walk-in clinics or other community-based programs (North West LHIN 2011).

The age-standardized cancer incidence rates per 100,000 for 2009 to 2011 for the North West LHIN and the province are provided in Table 3-2 (North West LHIN 2011). Age-standardized rates are used to adjust for variations in the population age and sex structure; this allows comparisons between geographic areas (Northwestern Ontario and Ontario) and over time.

Table 3-2: Cancer Incidence Rates for North West LHIN and Ontario

Indicator	North West LHIN	Ontario
Estimated age-standardized cancer incidence rates per 100,000 population, 2009-2011		
Breast cancer	100.6	100.6
Prostate cancer	154.1	147.5
Colorectal cancer	55.3	48.0
Lung cancer	57.9	48.2
Cervical cancer	8.4	7.2

Source: North West LHIN 2011

The North West LHIN has age-standardized cancer incidence rates that are greater than the Province of Ontario for prostate cancer, colorectal cancer, lung cancer and cervical cancer. This assessment evaluates whether the Project will increase the risk of cancer and non-cancer health outcomes in workers and members of the public within the LSA and RSA.

4.0 HUMAN HEALTH EFFECTS ASSESSMENT

This section predicts and describes the changes to human health that are likely to result from the Project. These changes are then assessed to determine if an adverse effect is expected, whether an adverse effect can be mitigated, and for effects that cannot be fully mitigated (residual effects), a determination of the significance of the effect. Section 4.1 provides a description of effects assessment methods.

4.1 Effects Assessment Methods

The human health risk assessment (HHRA) was carried out consistent with the RA framework and methodology described in Section 2.5.

The HHRA was subdivided into four separate risk assessments: Inhalation Assessment (further divided into acute and chronic), Noise Assessment, Particulate Matter Risk Assessment, and Multi-Media Risk Assessment. As such, the HHRA is organized such that each of these assessments is addressed separately. These assessments are described in more detail below.

- The Inhalation Assessment focuses on exposure to substances that are emitted to air. The human health risks associated with changes in air quality for short-term or acute exposures are assessed in Section 4.3, and those for long-term or chronic exposures are assessed in Section 4.4.
- The Noise Assessment evaluates noise levels potentially generated by the Project and the potential impacts to identified receptors. The Noise Assessment is provided in Section 4.5.
- The Particulate Matter Risk Assessment focuses on exposure to particulate matter that is emitted to air (i.e., particulate matter less than 10 microns in diameter [PM_{10}], particulate matter less than 2.5 microns in diameter [$PM_{2.5}$], total suspended particulate [TSP] and diesel particulate matter [DPM]). The human health risks associated with changes in particulate matter concentrations are provided in Section 4.6.
- The Multi-Media Risk Assessment focuses on exposure to substances that are released to the environment, including soil and water. The human health risks associated with changes to chemical concentrations in soil and water are assessed in Section 4.7.

Note that the predicted emissions from the operations phase of the Project were used to represent the Project as assessed in the HHRA. The operations phase was identified as the bounding case for the other phases of the Project (i.e., construction, operations, closure, and post-closure) and the predictive air modelling (Atmospheric Environment TSD) and water quality modelling (Site Water Quality TSD and Lake Water Quality TSD) were carried out for the operations phase. The HHRA has used the predicted maximum concentrations of COPCs in air and water as inputs into the exposure calculations, which will result in a reasonable maximum exposure scenario. If the predicted risks are acceptable for the reasonable maximum scenario, then predicted risks can also be considered to be acceptable for other phases of the Project when anticipated emission and discharge rates are lower.

The effects of the Project on human health are assessed through the following six criteria:

- Direction: the direction of the effect as positive or negative.
- Magnitude: the size or degree of the effect for a given parameter.
- Geographic extent: the spatial area over which the effect may occur.
- Duration: the length of time over which the effect may occur.
- Frequency: the rate of recurrence of the effect (or conditions causing the effect).
- Reversibility: whether the effect may or may not be reversed.

In order to determine the significance of an effect, three levels are associated to each criterion: low, medium and high, as shown in Table 4-1. Effect levels for magnitude specific to human health are shown in Table 4-2. Significance levels are not assigned for direction, as the effect is either positive (i.e., health conditions improve compared to existing conditions) or negative (i.e., there is a decrease in health compared to existing conditions).

Table 4-1: Assessment Criteria and Levels for Determining Significance

Assessment Criteria	**Level**		
Geographic Extent (of effect)	**Low**	**Medium**	**High**
	Effect is within the MSA	Effect extends into the Local Study Area	Effect extends into the Regional Study Area
Duration (of conditions causing effect)	**Low**	**Medium**	**High**
	Conditions causing effect are evident during the construction phase or closure phase	Conditions causing effect are evident during the operations phase	Conditions causing effect extend beyond any one phase
Frequency (of effect)	**Low**	**Medium**	**High**
	Conditions causing the effect to occur infrequently (i.e., several times per year)	Conditions causing the effect to occur at regular, although infrequent intervals (i.e., several times per month)	Conditions causing the effect to occur at regular and frequent intervals (i.e., daily or continuously)
Degree of Reversibility (of effect)	**Low**	**Medium**	**High**
	Effect is readily (i.e., immediately) reversible	Effect is reversible with time	Effect is not reversible (i.e., permanent)

Table 4-2: Magnitude Levels for Human Health

	Magnitude			
	Negligible	**Low**	**Medium**	**High**
Non-Carcinogenic Compounds	No change from existing conditions, below applicable guidelines, or HQ ≤ 1	1 < HQ ≤ 10	10 < HQ ≤ 100	HQ > 100
Carcinogenic Compounds	No change from existing conditions, below applicable guidelines, or ILCR ≤ 1×10^{-6}	1×10^{-6} < ILCR ≤ 1×10^{-5}	1×10^{-5} < ILCR ≤ 1×10^{-4}	ILCR > 1×10^{-4}

Notes:

HQ = Hazard Quotient; represents the target ratio of the predicted chemical exposure relative to its health-based benchmarks.

ILCR = Incremental Lifetime Cancer Risks represents additional risk of developing cancer due to chemical exposure (from the Project) incurred over the lifetime of an individual.

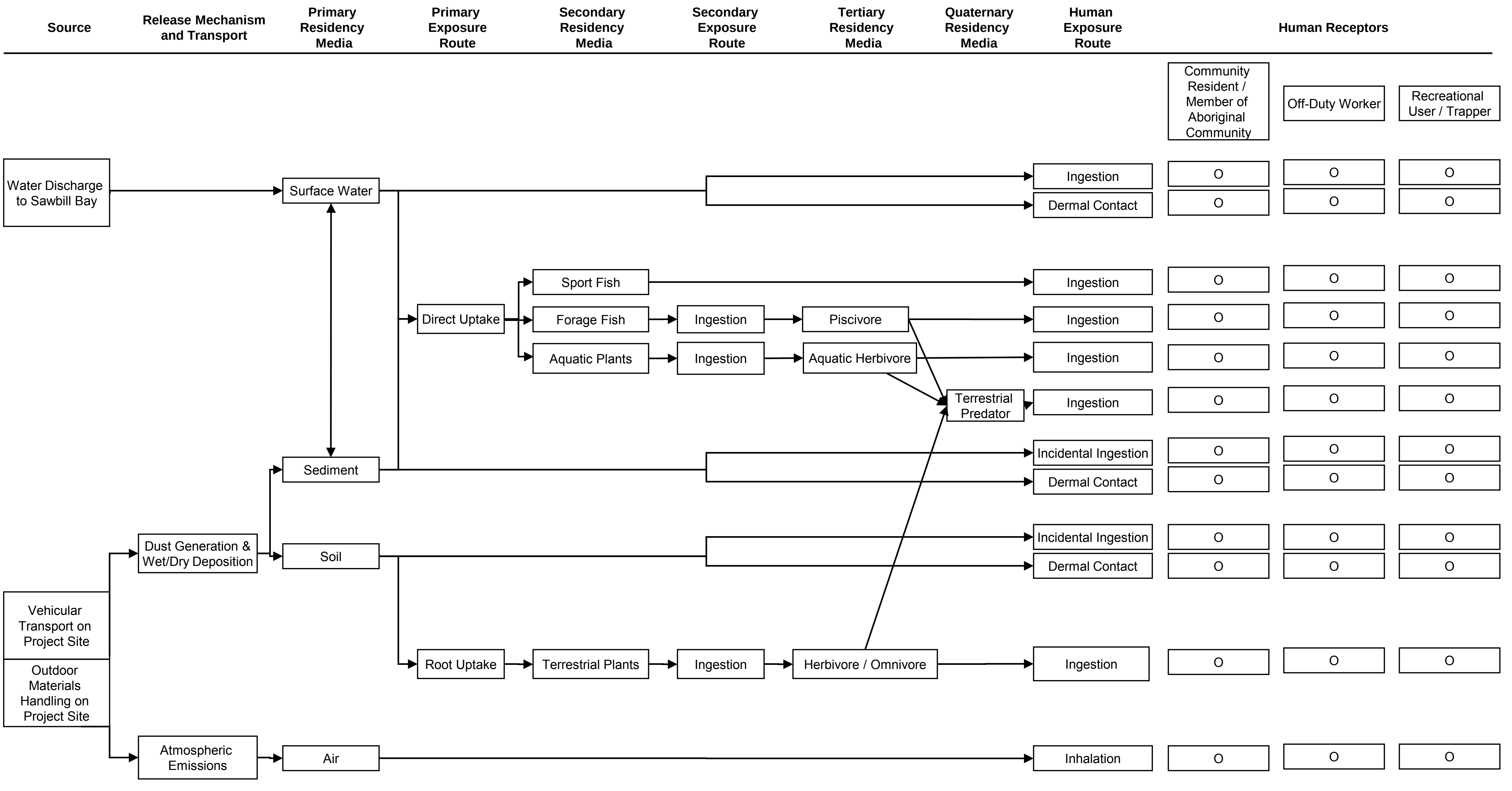
4.2 Problem Formulation

4.2.1 Conceptual Site Model

A CSM was developed for human health (Figure 4-1) using the approach outlined in Section 2.5.2. Five categories of human health receptors were identified in this HHRA, including a community resident, off-duty worker, trapper, recreational user and member of Aboriginal community. It was assumed that a community resident may live in Atikokan or Steep Rock and use the areas within the RSA for recreational purposes including fishing, hunting and harvesting plants. The off-duty worker would be living in the accommodation camp within the MSA. Exposure is considered for 365 days per year for the hours per day that they spend outside while they are not working (i.e., off duty) because exposure during working hours will be mitigated through best management practices in accordance with Ministry of Labour regulations. Trappers will be going to their traplines and trapper cabins on a regular basis from May until October (Socio-economic Environment TSD). They may consume the meat they have caught in the area in addition to occasionally fishing and collecting berries. There are several tourism establishments and designated camping sites within the LSA. It was assumed that a recreational user may use these facilities on a seasonal basis. Members of nearby Aboriginal communities may use areas within the RSA for fishing, hunting and harvesting plants (Aboriginal Interests TSD). Human health receptor locations were selected within the RSA based on identified land uses (e.g., designated camping sites, tourism establishments, trapper cabins, communities, accommodation camp) and proximity to the MSA. Further description of land uses are provided in the Socio-economic Environment TSD. Some receptor locations (i.e., 10, 11, 17, 19, 23, 36 and 37) that were initially identified will have access restricted once construction begins, therefore were not retained for further evaluation in the HHRA. Refer to the Atmospheric Environment TSD for further description of the access agreements. The selected human health receptor locations are shown in Figure 4-2 and listed in Table 4-3 below.

Conceptual Site Model for Hammond Reef Gold Project – Human Receptors

FIGURE 4-1



LEGEND

X Pathway incomplete and/or not evaluated

O Pathway complete and evaluated

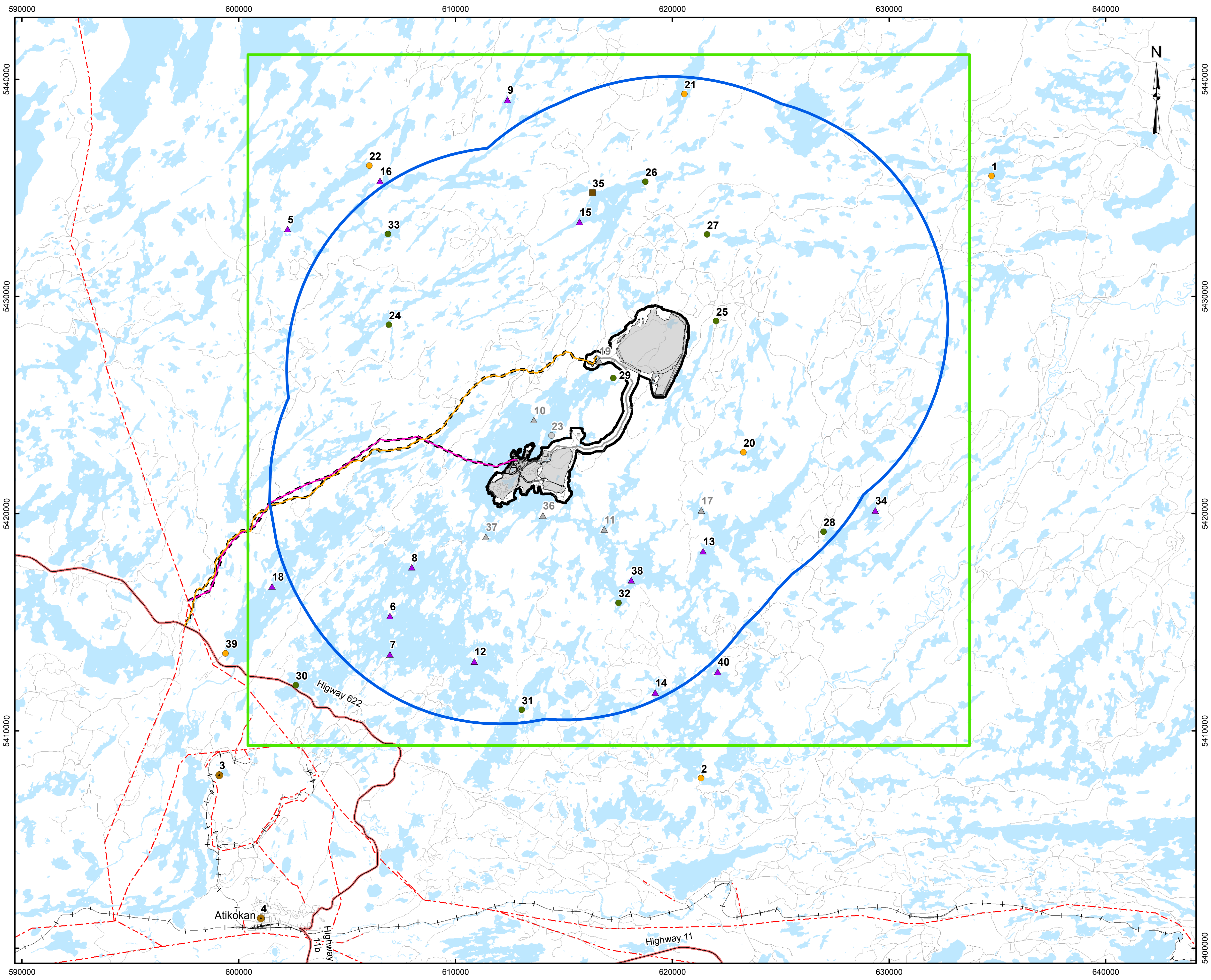
Date: February 2013

Project: 10-1118-0020

Golder Associates

CAD: GD

CKD: TRS



LEGEND

- ▬ Provincial Highway
- — Road
- ┼ Existing Railway
- — River/Stream
- 🟦 Lake

Human Risk Assessment Receptor

- ● Community
- ■ Cottage
- ▲ Designated Camping Site
- ● Tourism Establishment
- ● Trapper Cabin
- — Mine Site Road
- — Access Road (Hardtack / Sawbill)
- — Project Transmission Line
- ▨ Project Facilities
- ▭ Air Local Study Area
- ▭ Air Regional Study Area
- ▭ Linear Infrastructure Study Area
- ▭ Mine Facility Study Area

REFERENCE

Base Data - Provided by OSISKO Hammond Reef Gold Project Ltd
Base Data - MNR NRVIS, obtained 2004
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2008
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 15N

3 1.5 0 3 6 9
KILOMETRES

PROJECT

HAMMOND REEF GOLD PROJECT
ATIKOKAN, ONTARIO, CANADA

TITLE

HUMAN RISK ASSESSMENT RECEPTOR LOCATIONS

Golder Associates
Mississauga, Ontario

PROJECT NO. 10-1118-0020			SCALE AS SHOWN	VERSION 1
DESIGN	CGE	14 Nov. 2008	FIGURE: 4-2	
GIS	JO	8 Feb. 2013		
CHECK	GD	8 Feb. 2013		
REVIEW	TRS	8 Feb. 2013		

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Table 4-3: Human Health Receptor Locations

Number	Type	Description
1	Tourism Establishment	Eva Lake Resort
2	Tourism Establishment	Walleyes Forever
3	Community	Steep Rock Lake
4	Community	Atikokan
5	Designated Camping Site	Bow Lake
6	Designated Camping Site	Upper Marmion Reservoir
7	Designated Camping Site	Upper Marmion Reservoir
8	Designated Camping Site	Upper Marmion Reservoir
9	Designated Camping Site	No Name Lake
10	*Designated Camping Site*	*Sawbill Bay*
11	*Designated Camping Site*	*Flood Bay*
12	Designated Camping Site	Upper Marmion Reservoir
13	Designated Camping Site	Upper Seine Bay
14	Designated Camping Site	Bradshaw Bay
15	Designated Camping Site	—
16	Designated Camping Site	—
17	*Designated Camping Site*	—
18	Designated Camping Site	—
19	*Designated Camping Site*	—
20	Tourism Establishment	Eva Lake Resort Limited
21	Tourism Establishment	Pine Point Resort Limited
22	Tourism Establishment	Canoe Canada Outfitters
23	*Tourism Establishment*	*Canoe Canada Outfitters*
24	Trapper Cabin	—
25	Trapper Cabin	—
26	Trapper Cabin	—
27	Trapper Cabin	—
28	Trapper Cabin	—
29	Trapper Cabin	—
30	Trapper Cabin	—
31	Trapper Cabin	—
32	Trapper Cabin	—
33	Trapper Cabin	—
34	Designated Camping Site	—
35	Cottage	—
36	*Designated Camping Site*	—
37	*Designated Camping Site*	—
38	Designated Camping Site	—

Table 4-3: Human Health Receptor Locations (Continued)

Number	Type	Description
39	Tourism Establishment	Finlayson Resort
40	Designated Camping Site	Reserve Bay
41 to 51	—	Accommodation Camp

Notes:

— = No description provided.

Receptor locations in *italics* have not been retained for evaluation due to access restrictions.

4.3 Acute Inhalation Assessment

4.3.1 Problem Formulation

The objective of the acute inhalation assessment is to evaluate substances potentially emitted from the Project that may pose a health outcome following short-term or acute exposure duration (e.g., one hour) to human receptors.

4.3.1.1 Receptor Locations

Potential human health effects related to short-term inhalation exposure for the Project were evaluated for the following receptor locations (Figure 4-2):

- Communities (Atikokan and Steep Rock Lake).
- Designated Camping Sites (14 locations).
- Tourism Establishments (5 locations).
- Cottage (1 location).
- Trapper Cabins (10 locations).
- Accommodation Camp (11 locations).

4.3.1.2 Selection of Acute Air Thresholds

Substances that may change in concentration on a short-term basis as a result of the Project were identified based upon the Project activities that result in emissions to air as described in the Atmospheric Environment TSD. The following types of substances were assessed:

- Acid gases (e.g., sulphur dioxide [SO_2], nitrogen dioxide [NO_2]).
- Volatile organic compounds (VOCs, e.g., 1, 3-butadiene, acrolein).
- Metals (e.g., arsenic, lead).
- Petroleum hydrocarbons (e.g., C2-C6 aliphatic fraction, C8-C10 aromatic fraction).
- Polycyclic aromatic hydrocarbons (PAHs, e.g. anthracene, chrysene).

Maximum 1-hour concentrations for acid gases, VOCs, metals, petroleum hydrocarbons and PAHs were compared to the lowest, most conservative of the available 1-hour (i.e., acute) health-based thresholds from the following regulatory agencies:

- Ontario Ministry of the Environment (MOE 2012).
- Canadian Council of Ministers of the Environment (CCME 1999).
- Agency for Toxic Substances and Disease Registry (ATSDR 2012).
- California Office of Environmental Health Hazard Assessment (CalEPA 2008).
- World Health Organization (WHO 2000, WHO 2005).
- Texas Commission on Environmental Quality (TCEQ 2012a).

If no health-based jurisdictional standards were available, then an odour-based standard was used. Additionally, values from TCEQ were only used when thresholds from other jurisdictions were not available, given that detailed supporting documentation is not available.

Each of these agencies derived health-based air thresholds based upon a prescribed level of protection. Most often, these air thresholds are presented as air concentrations at and below which health effects are not expected to occur and may incorporate additional safety factors. Therefore, a predicted air concentration greater than the threshold indicates that a health effect is possible but not certain. Further assessment is required to determine the likelihood of that health effect occurring.

The Ontario Ambient Air Quality Criteria (AAQC) are defined as “a desirable concentration of a contaminant in air, based on protection against adverse effects on health or the environment” (MOE 2012). The effects considered include health, odour, vegetation, soiling visibility and corrosion. The AAQCs are updated based on new science; the criteria presented herein were released in April 2012. The endpoint on which the AAQC are based is listed for each chemical, but detailed supporting documentation is generally not available.

National Ambient Air Quality Objectives (NAAQOs) are defined as “national goals for outdoor air quality that protect public health, the environment, or aesthetic properties of the environment” (CCME 1999). The NAAQOs are presented for three levels defined as follows (from CCME 1999):

- The maximum **desirable** level is the long-term goal for air quality and provides a basis for an anti-degradation policy for unpolluted parts of the country and for the continuing development of pollution control technology.
- The maximum **acceptable** level is intended to provide adequate protection against effects on soil, water, vegetation, materials, animals, visibility and personal comfort and well-being.
- The maximum **tolerable** level denotes time-based concentrations of air contaminants beyond which, owing to a diminishing margin of safety, appropriate action is required without delay to protect the health of the general population.

For screening in the acute air quality assessment, the lowest screening level (i.e. desirable) was used.

The ATSDR derives Minimal Risk Levels (MRLs), which are defined as “an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure” (ATSDR 2012). The MRLs are derived when ATSDR determines that reliable and sufficient data exist to identify the target organ(s) of effect or the most sensitive health effect(s) for a specific duration for a given route of exposure to the substance. The ATSDR provides detailed toxicological profiles for each chemical that outline the derivation of the MRL. The ATSDR generally uses the No Observed Adverse Effect Level/Uncertainty Factor (NOAEL/UF) approach to derive MRLs. The MRLs are set below levels that may cause adverse health effects in the people most sensitive to such substance-induced effects. The MRLs derived for acute (1 to 14 days) exposure were used in the acute inhalation assessment herein. The MRLs are generally based on the most sensitive chemical-induced endpoint considered to be of relevance to humans. However, as MRLs are often based on animal studies (because of lack of relevant human studies), there is some degree of uncertainty associated with MRLs because of the lack of toxicological information on the people who might be most sensitive (e.g., infants, elderly and nutritionally or immunologically compromised) to effects of substances. The ATSDR assumes that humans are more sensitive than animals to the effects of substances and that certain people may be particularly sensitive, and uses a protective approach to address any uncertainties.

The CalEPA Acute Reference Exposure Levels (RELs) are levels at which exposure is not likely to cause adverse effects in a human population, including sensitive subgroups, exposed to that concentration for one hour on an intermittent basis (CalEPA 2008). The CalEPA provides detailed supporting documentation outlining the derivation of each REL. The CalEPA uses a NOAEL/UF approach, a benchmark approach and a categorical regression approach to derive the RELs.

The WHO has produced air quality guidelines to provide a basis for protecting public health from adverse effects of air pollution. The guidelines are intended to provide background information and guidance to governments in making risk management decisions, particularly in setting standards. Supporting documentation is provided for all WHO guidelines.

Texas has developed acute and chronic Effects Screening Levels (ESLs) that are used to evaluate the potential for effects to occur as a result of exposure to concentrations of substances in the air. The ESLs are based on data concerning health effects, the potential for odours to be a nuisance, effects on vegetation, and corrosive effects. It is considered that if predicted airborne levels of a chemical do not exceed the screening level, adverse effects are not expected. If predicted ambient levels of substances in air exceed the screening levels, it does not necessarily indicate a problem but rather triggers a review in more depth. Texas has developed a guidance document titled, *TCEQ Guidelines to Develop Toxicity Factors* (TCEQ 2012b), that outlines the approach and general methods used to derive the acute ESLs. However, Texas does not provide supporting documents for individual substances.

Some substances were modelled as a group, including aldehyde, ketone, thiophenes, trimethylbenzene and petroleum hydrocarbon fractions (Atmospheric Environment TSD). For these substances, screening standards for all chemicals within the group were reviewed and a surrogate chemical was selected with the lowest health-based screening value.

The available 1-hour thresholds from the agencies listed above are provided in Appendix 3.I, Table 1. Selected surrogate chemicals are noted within the table. The health endpoints and a summary of the supporting technical rationale for the thresholds (if available) are included within the table.

Screening thresholds for an 8-hour averaging time have been developed for carbon monoxide by the MOE (2012), CCME (1999) and WHO (2000). An 8-hour averaging time is considered an acute exposure time. The 8-hour screening thresholds for carbon monoxide have been added to Appendix 3.I, Table 1.

4.3.1.3 Comparison of Predicted Maximum Concentrations to Acute Thresholds

Chemical concentrations based on a 1-hour averaging period were predicted for all of the receptor locations during the operations phase of the Project. The predicted maximum 1-hour concentrations of substances in air were compared to the selected acute thresholds to determine whether further assessment was required. The maximum 1-hour concentration out of all receptor locations was selected for identification of COPCs. If the predicted maximum concentrations were greater than the selected acute thresholds, then the chemical was retained as a COPC and considered further in the acute inhalation assessment.

There were no 1-hour screening thresholds available for nitrogen oxides (NOx), calcium, lead, lithium or sodium. Nitrogen oxides are the sum of nitrogen dioxide and nitric oxide (NO). Emissions of NOx consist mainly of NO, with some NO_2. In ambient air, NO converts to NO_2 (MOE 2012). Nitrogen dioxide has adverse health effects at much lower concentrations than NO (MOE 2012). Therefore, evaluating health effects based on screening NO_2 is appropriate, and this is why ambient air criteria are generally defined for NO_2, not NOx. In this assessment, potential acute health effects are evaluated using the predicted maximum concentration of NO_2. Calcium and sodium are non-toxic substances and will not be evaluated further in the acute inhalation health assessment. While no 1-hour ambient screening thresholds are available for lead or lithium, 24-hour screening thresholds are available for lithium and 24-hour and annual screening thresholds are available for lead. These substances will be evaluated for these averaging periods, as there is not sufficient information to evaluate them for a 1-hour averaging period.

Predicted maximum 1-hour concentrations are compared to the selected screening thresholds in Appendix 3.I, Table 2. All substances had concentrations below the selected screening threshold. The predicted maximum 8-hour concentration for carbon monoxide was also below the selected 8-hour screening threshold. Therefore, no health effects are expected to occur and no further evaluation is required in the acute inhalation assessment.

4.3.2 Magnitude of Effects Assessment

There are no residual effects from the acute inhalation assessment based on comparison of chemical-specific predicted maximum 1-hour air concentrations from all receptor locations against the lowest available health-based screening thresholds. The use of the highest predicted air concentrations and the lowest health-based screening thresholds maintains a conservative approach. There are no health effects expected for acute inhalation given that no chemical concentrations exceeded the lowest health-based screening thresholds.

4.4 Chronic Inhalation Assessment

This section describes the methods applied to evaluate the potential effects on human health associated with chronic inhalation exposure to substances emitted from the Project as well as the results of the assessment.

4.4.1 Problem Formulation

The objective of the chronic inhalation assessment is to evaluate substances potentially emitted from the Project that may generate a health outcome following long-term or chronic exposure duration (e.g., many years to lifetime) by identified receptors. Air concentrations averaged over a 24-hour period and an annual period were used in this assessment.

4.4.1.1 Receptor Locations

Potential human health effects related to long-term inhalation exposure for the Project were evaluated for all of the receptor locations identified for the acute inhalation assessment (Section 4.3).

4.4.1.2 Selection of Chronic Air Thresholds

Substances that may change in concentration as a result of the Project were identified based on the Project activities that result in emissions to air as described in the Atmospheric Environment TSD. The substances assessed were the same as identified in the acute inhalation assessment (Section 4.3).

Predicted maximum 24-hour and annual concentrations for acid gases, VOCs, metals, petroleum hydrocarbons and PAHs were compared against the lowest, most conservative of the available chronic 24-hour and annual health-based thresholds from the following agencies:

- Ontario Ministry of the Environment (MOE 2012).
- Canadian Council of Ministers of the Environment (CCME 1999).
- Agency for Toxic Substances and Disease Registry (ATSDR 2012).
- California Office of Environmental Health Hazard Assessment (CalEPA 2008).
- World Health Organization (WHO 2000, WHO 2005); and
- Texas Commission on Environmental Quality (TCEQ 2012a).

If no jurisdictional health-based standards were available, then an odour-based standard was used. Additionally, the values from TCEQ were only used when thresholds from other jurisdictions were not available, given that detailed supporting documentation is not available from TCEQ.

A general description of the screening thresholds provided by each agency is included in Section 4.3. Relevant to chronic exposure, the MOE provides AAAQCs for 24-hour and annual averaging periods. The ATSDR has derived chronic MRLs (greater than or equal to 365 days) that were used to screen annual concentrations. The CalEPA has derived RELs for chronic exposure, which were compared to predicted concentrations for the annual averaging period. The WHO air quality guidelines are provided for 24-hour and annual averaging periods, and they were compared to predicted air concentrations of the same averaging period. The TCEQ provides chronic ESLs, which were used to screen the predicted annual average concentrations. The CalEPA and WHO also provide unit risks, which were used to derive screening thresholds for carcinogens for the annual averaging period.

The screening thresholds have been derived by each regulatory agency to achieve a target risk level that is considered to be protective of human health. The regulatory agency set their target risk level based on science policy decisions on what is an acceptable risk to human health. In setting target risk level, regulatory agencies consider both carcinogenic and non-carcinogenic health effects of substances, with target risk level for non-carcinogens being defined by a hazard quotient, and target risk level for carcinogens being defined by incremental lifetime cancer risks. Screening thresholds can be converted to a different target risk level by using a ratio of the threshold and the target risk and determining what threshold would generate the desired risk level. Screening thresholds for non-carcinogens were converted to a hazard quotient of 1.0 and thresholds for carcinogens were converted to a target cancer risk of 1 in 1 million (1×10^{-6}). These targets are based on MOE acceptable levels for risk assessment (MOE 2011).

Some substances were modelled as a group, including aldehyde, ketone, thiophenes, trimethylbenzene and petroleum hydrocarbon fractions (Atmospheric Environment TSD). For these substances, screening standards for all chemicals within the group were reviewed and a surrogate chemical was selected with the lowest health-based screening value.

The available jurisdictional 24-hour and annual health-based thresholds are provided in Appendix 3.I, Tables 3 and 4. Selected surrogate chemicals are noted within the table. The health endpoints and a summary of the supporting technical rationale for the thresholds (if available) are included within the table.

4.4.1.3 Comparison of Predicted Maximum Concentrations to Chronic Thresholds

Chemical concentrations for the year with the highest predicted emissions during the operations phase were modelled for all substances, at all identified receptor locations. To assess the chemical-specific health effects associated with potential long-term exposure, 24-hour and annual predictions were generated. From a chemical-specific toxicity perspective, health effects considered include non-carcinogenic and carcinogenic health effects which are evaluated on the basis of 24-hour and annual averaging periods, respectively. There were no 24-hour health-based screening thresholds available for NOx, ethylene, thiophenes, sodium hydroxide and several metals, PAHs and petroleum hydrocarbons. For all of these substances except for NOx, calcium and sodium, screening thresholds were available based on an annual averaging period. Therefore, potential chronic health effects for these substances were evaluated based on an annual averaging period. For NOx, as discussed in Section 4.3.1.3, the predicted concentration represents combined NO and NO_2. Known health effects are associated with NO_2 as ambient NO readily converts to NO_2 and as such, it is appropriate to evaluate NO_2, not NOx. Calcium and sodium are considered to be non-toxic and as such, they were not retained in the chronic inhalation assessment (see discussion in the acute inhalation assessment Section 4.3). There were no annual screening thresholds available for CO and lithium. Potential effects for CO and lithium will be evaluated based on comparison against an 8-hour screening threshold and a 24-hour screening threshold, respectively.

The predicted maximum 24-hour and annual concentrations of substances in air were compared to the selected chronic thresholds to determine whether further assessment was required. The maximum 24-hour concentration and annual concentrations were selected for identification of COPCs. If the predicted maximum concentrations were greater than the selected chronic thresholds, then the chemical was retained as a COPC and considered further in the chronic inhalation assessment.

Predicted maximum 24-hour and annual concentrations are compared to the selected screening thresholds in Appendix 3.I, Tables 5 through 7, inclusive, based on a 24-hour averaging period and annual averaging period for carcinogenic and non-carcinogenic health endpoints. The maximum concentrations for the following substances were above the screening threshold, and will be retained as COPCs for further evaluation in the chronic inhalation assessment:

- Acrolein (24-hour averaging period).
- Nitrogen dioxide (annual averaging period – non-carcinogenic endpoint).

No carcinogens were retained for evaluation. Acrolein and nitrogen dioxide are carried forward to the toxicity assessment and exposure assessment.

4.4.2 Toxicity Assessment

Toxicity assessment involves the classification of the harmful effects of substances and the estimation of the amounts of substances that can be received by an organism without adverse health effects. For each COPC identified in Section 4.4.1.3 (i.e., acrolein and nitrogen dioxide), an appropriate toxicity benchmark or TRV was determined based on reported mode of action (i.e., threshold vs. non-threshold mode of action). For threshold substances (i.e., generally not a carcinogen), adverse effects are expected to only occur above a certain dose rate. However, for non-threshold substances (i.e., most carcinogens) theoretically all doses can exert a toxic effect. The following sections classify the COPCs in order to determine whether they need to be evaluated as carcinogens.

4.4.2.1 Contaminant Classification

Environmental substances are quantitatively evaluated in a risk assessment based on their ability to cause cancer or non-cancer endpoints. Substances that are considered to cause health endpoints other than cancer (i.e., non-cancer endpoints) are considered to be threshold substances; that is, there is an acceptable health-based limit or threshold below which exposure to the substance does not cause an adverse effect. Substances that are considered to be cancer causing are considered non-threshold substances; that is, there is no acceptable health-based limit or threshold below which exposure to the substance does not cause an adverse effect. Therefore, different regulatory agencies will classify substances based on their mode of action (i.e., threshold vs. non-threshold substances). Classification systems have been developed based on the carcinogenic properties of substances, including those from Health Canada (2010a), U.S. EPA Integrated Risk Information System (IRIS; U.S. EPA 2012a, internet site), and the International Agency for Cancer Research (IARC 2012, internet site) (Table 4-4). Based on these agencies, the carcinogenicity classification of the identified COPCs was determined (Table 4-5).

Table 4-4: Classification Systems for Carcinogenic Substances

Health Canada[(a)]	IARC[(b)]	U.S. EPA IRIS[(c)]	Description
Group I	Group 1	Group A	Human carcinogen
Group II	Group 2A	Group B	Probable human carcinogen
—	—	Group B1	Limited human evidence available
—	—	Group B2	Inadequate human evidence, sufficient animal evidence
Group III	Group 2B	Group C	Possible human carcinogen

Table 4-4: Classification Systems for Carcinogenic Substances (Continued)

Health Canada[a]	IARC[b]	U.S. EPA IRIS[c]	Description
Group IV	—	—	Unlikely to be carcinogenic to humans
Group VI	Group 3	Group D	Unclassifiable as to human carcinogenicity
Group V	Group 4	Group E	Probably not carcinogenic to humans

Notes:

— = Classification not provided for this level.

[a] Health Canada 2010a.

[b] International Agency for Research on Cancer Monographs (IARC 2012, internet site).

[c] U.S. EPA IRIS (U.S. EPA 2012a, internet site).

Table 4-5: Carcinogenicity Classification of Chemicals of Potential Concern for Chronic Inhalation Assessment

Chemical	Health Canada[a]	IARC[b]	U.S. EPA IRIS[c]	Assessed as a Carcinogen?
Nitrogen dioxide	—	—	—	No
Acrolein	—	Group 3	—	No

Notes:

— = No classification provided.

[a] Health Canada 2010a.

[b] International Agency for Research on Cancer Monographs (IARC 2012, internet site).

[c] U.S. EPA IRIS (U.S. EPA 2012a, internet site).

Neither NO_2 nor acrolein are classified as cancer-causing substances and, therefore, they were not evaluated as carcinogens.

4.4.2.2 Dose-Response Assessment

For the chronic inhalation assessment, TRVs for non-carcinogenic substances are called Reference Concentrations (RfC), which are estimates of continuous inhalation exposure to a chemical by the human population (including sensitive subgroups) that is likely to be without an appreciable risk of harmful effects over a lifetime.

Available RfCs for identified COPCs were compiled from the following agencies:

- Health Canada (Health Canada 2010a).
- U.S. EPA's IRIS (U.S. EPA 2012a, internet site).
- CalEPA (CalEPA 2012, internet site).

There were no ATSDR chronic MRLs available for the COPCs. For NO_2, RfCs are not available, therefore, chronic screening thresholds derived by the following agencies were reviewed and used as a source of dose-response information:

- Canadian Council of Ministers of the Environment (CCME 1999).
- WHO (WHO 2000).

The most conservative (i.e., lowest RfC) of the RfCs were selected for use in the chronic inhalation assessment, except for acrolein. For acrolein, U.S. EPA IRIS published an RfC of 0.02 µg/m^3 in 2003 based on Feron et al. (1978) that identified a lowest-observed adverse effect level (LOAEL) of 0.4 ppm based on evidence of nasal histopathology in rats. The LOAEL was adjusted from the dosing regimen to a continuous exposure and adjusted to a human equivalent concentration. A total uncertainty factor of 1,000 was applied to account for extrapolation from animal to humans, intrahuman variability, sub-chronic to chronic duration and use of a minimal LOAEL. In 2008, CalEPA published a chronic reference level of 0.35 µg/m^3 for acrolein based on Dorman et al. (2008) that identified a no-observed adverse effect level (NOAEL) of 0.2 ppm based on lesions in the respiratory epithelium in rats. The NOAEL was adjusted for exposure time and human concentration equivalent and a cumulative uncertainty factor of 200 was applied to account for interspecies and intraspecies variation. The study by Dorman et al. (2008) was selected by CalEPA in preference to the Feron et al. (1978) study because it identified a NOAEL for the critical effect. On this basis, the CalEPA value was selected as the RfC for this assessment of acrolein for chronic inhalation assessment.

The RfCs from each agency along with supporting rationale are provided in Appendix 3.I Table 8, the selected values are shown in bold.

4.4.2.3 Chemical Mixtures

It is appropriate in a risk assessment to evaluate substances with similar modes of action and target organs by adding the estimated risks to determine the likelihood that an effect will occur on the same target organ/tissue (Health Canada 2010a). Target organ and effects for the COPCs are shown in Table 4-6. Identified COPCs, NO_2 and acrolein, do not have the same mode of action or target organ; therefore, estimated risks were not added together. For further details on the target organ and effects of each COPC see Appendix 3.I, Table 8.

Table 4-6: Potential Additive Interactions of Chemicals of Potential Concern for the Chronic Inhalation Assessment

Classification	Chemical	Target Organ	Effects
Non-Carcinogens	Nitrogen dioxide	Respiratory tract	Increased respiratory symptoms
	Acrolein	Nose	Changes in nasal histopathology

4.4.3 Exposure Assessment

4.4.3.1 Exposure Point Concentrations

The chronic assessment was carried out using the 24-hour and annual concentrations to represent concentrations for long-term exposure. The predicted concentrations for acrolein and nitrogen dioxide at all receptor locations are provided in Appendix 3.I, Table 9. Exposures and consequently, estimated risks, were evaluated for each COPC only at those receptor locations where concentrations exceeded screening thresholds. The locations with predicted concentrations above the selected screening thresholds are provided in Table 4-7 for each COPC. The predicted concentrations are used as exposure point concentrations.

Table 4-7: Predicted Air Concentrations at Receptor Locations with Concentrations Above Selected Screening Thresholds

Chemical of Potential Concern	Averaging Period	Selected Screening Threshold (µg/m^3)	Receptor Locations with Exceedances	Location type	Predicted Concentration (µg/m^3)
Nitrogen dioxide	Annual	40	44,45,47,48,50	Worker accommodation camp	Maximum 49
Acrolein	24-hour	0.40	38	Designated camping site	0.47
			32	Trapper cabin	0.41

The annual concentrations represent the highest annual emissions modelled during the operations phase and the highest concentrations predicted in 5 years of modelling based on meteorological conditions (Atmospheric Environment TSD). The 24-hour concentrations represent the highest daily emissions during the operations phase and the highest concentrations predicted in 5 years of modelling based on meteorological conditions. For acrolein, the 95th percentile of 24-hour concentrations at receptor locations 32 and 38 were 0.12 µg/m^3 and 0.14 µg/m^3, respectively. These concentrations are less than the selected screening threshold of 0.40 µg/m^3. Although 95% of the time, acrolein concentrations at these receptor locations will be less than the screening threshold, acrolein was still retained for further evaluation in the chronic inhalation assessment to maintain a conservative approach.

Where more than one receptor location of the same type (e.g., worker accommodation camp, designated camping site) had exceedances, the maximum predicted concentration at these locations was used as the exposure point concentration.

4.4.3.2 Receptor Characteristics

The VECs selected for the Project for human health included an off-duty worker, trapper, recreational user, member of Aboriginal community and community resident. The VECs that will be evaluated in the chronic inhalation assessment are based on the receptor locations where exceedances of chronic screening thresholds were identified (Table 3-6), specifically the worker accommodation camp, designated camping sites and trapper cabins. The VECs that are expected to be present at these receptor locations are the off-duty worker, trapper and recreational user. As the community receptor locations (i.e., Atikokan and Steep Rock Lake) were not identified as having concentrations above health-based screening thresholds, exposure for the community resident at these locations was not evaluated further in the chronic inhalation assessment. It is considered that the recreational user may be a local community resident or member of the Aboriginal community, but exposure will be evaluated only for the time period that they are expected to spend at the identified designated camp sites.

The worker is considered to be an adult who works full-time within the MSA and lives at the worker accommodation camp. Exposure is considered while they are not working (i.e., off duty) because exposure during working hours will be mitigated through best management practices in accordance with Ministry of Labour regulations. The worker is considered to be off-duty and potentially present at the accommodation camp for 12 hours a day. However, most of those hours will be spent sleeping and eating inside, where exposure to COPCs present in outdoor air would not occur. It is assumed that the worker receptor may spend 1.5 hours per day outdoors at the accommodation camp, consistent with Health Canada recommendations for time spent outdoors by the Canadian general population (Health Canada 2010a). As it is considered a residence, it was assumed that the worker would spend 365 days a year at the accommodation camp.

Interviews were carried out with trapline holders to identify typical usage patterns (Socio-Economic Environment TSD). The trapline holders indicated that trapping season started in October and ended in May and they went out to trap daily to weekly. Most of the time they noted returning to their homes in town after a day of trapping, with overnight stays at the trapper cabins limited to a few times a month. Based on this information, an exposure frequency of 105 days per year (i.e., every other day October – April inclusive) was used in the chronic inhalation assessment along with an exposure time of 8 hours per day. The exposure time was selected as 8 hours per day because at the end of the day the trapper returns to their home in town or if they stay at the trapper cabin they will be inside overnight, where exposure to substances present in outdoor air would not occur.

The recreational user is considered to be a child or an adult who may camp at one of the designated camp sites. The child receptor was evaluated along with the adult because the child receptor is more conservative than a teen receptor (i.e. predicted risks will be higher due to smaller body weight) and it was considered more likely for children to be present on camping trips than toddlers or infants. An interview with a local outdoor tourism operator (Socio-Economic Environment TSD) indicated that guests typically stay 4 to 7 days. The tourism operator offered cabins and campgrounds seasonally, open from May 1 to November 1. Considering that recreational users may stay at the campgrounds for an extended vacation (e.g. 7 days) as well as potentially several short-term weekend-length stays (e.g. 2 days) over the 6 months of the year with weather conducive to outdoor camping, a total exposure frequency of 30 days per year was considered appropriate for conservatively evaluating potential exposure. It is expected that recreational users will travel away from their campsites during the day and stay inside tents or cabins at night; therefore, an exposure time of 12 hours per day outside at each designated camping site was conservatively used for the exposure assessment.

Although predicted concentrations are based on one year in the operations phase where modelled Project emissions are at their maximum, it was assumed that receptors would be exposed to these maximum concentrations throughout the entire life of the Project (i.e., 15.5 years). Receptor characteristics are provided in Table 4-8 and Table 4-9.

Table 4-8: Receptor Characteristics for Off-duty Worker and Trapper

Parameter	Off-duty Worker	Reference	Trapper	Reference
Inhalation rate (m^3/h)	0.69	Health Canada 2010a	0.69	Health Canada 2010a
Exposure time (h/d)	1.5	Health Canada 2010a (time spent outdoors)	8	Interviews (Socio-economic Environment TSD)
Exposure frequency (d/y)	365	Health Canada 2010a (days per year residential land)	105	Interviews (Socio-economic Environment TSD)
Exposure duration (y)	15.5	Project description	15.5	Project description
Body weight (kg)	70.7	Health Canada 2010a	70.7	Health Canada 2010a

Table 4-9: Receptor Characteristics for Recreational User

Parameter	Adult Recreational User	Reference	Child Recreational User	Reference
Inhalation rate (m^3/h)	0.69	Health Canada 2010a	0.60	Health Canada 2010a
Exposure time (h/d)	12	Assumed	12	Assumed
Exposure frequency (d/y)	30	Assumed	30	Assumed
Exposure duration (y)	15.5	Project description	7	Health Canada 2010a (duration of child life stage)
Body weight (kg)	70.7	Health Canada 2010a	32.9	Health Canada 2010a

4.4.3.3 Exposure Estimates

Exposure doses for each receptor were estimated using the equation below:

$$Exp_{inh} = \frac{C_{air} \times RAF_{inh} \times IR \times ET \times EF \times ED}{BW \times AT \times CF_1}$$

Where:

Exp_{inh} = exposure dose due to inhalation of COPC in air (mg/kg/d)
C_{air} = 24-hour or annual average concentration of COPC in air (mg/m^3)
RAF_{inh} = inhalation relative absorption factor (unitless)
IR = inhalation rate (m^3/h)
ET = exposure time (h/d)
EF = exposure frequency (d/y)
ED = exposure duration (y)
BW = body weight (kg)
AT = averaging time (y)
CF_1 = unit correction factor (365 d/y)

Inhalation relative absorption factors are not available for the COPCs and were assumed to be 1, which is a conservative approach consistent with Health Canada recommendations (Health Canada 2010a). The averaging time is equal to the exposure duration for non-carcinogens (Health Canada 2010a). The exposure doses are provided in Table 4-10.

Table 4-10: Exposure Doses due to Chronic Inhalation

Chemical of Potential Concern	Exposure Doses (mg/kg/d)		
	Accommodation Camp	**Designated Camping Site**	**Trapper Cabin**
	Maximum Receptor Locations 44, 45, 47, 48, 50	*Receptor Location 38*	*Receptor Location 32*
	Off-duty Worker		
Nitrogen Dioxide (annual)	7.2×10^{-4}	—	—
	Trapper		

Table 4-10: Exposure Doses due to Chronic Inhalation (Continued)

Chemical of Potential Concern	Exposure Doses (mg/kg/d)		
	Accommodation Camp	**Designated Camping Site**	**Trapper Cabin**
Acrolein (24-hour)	—	—	9.2×10^{-6}
	Child Recreational User		
Acrolein (24-hour)	—	8.5×10^{-6}	—
	Adult Recreational User		
Acrolein (24-hour)	—	4.5×10^{-6}	—

Notes:

— = COPC not retained for this receptor or receptor location.

4.4.4 Risk Characterization

Long-term health effects were evaluated by calculating hazard quotients (HQs) for non-carcinogens. A HQ is the ratio between the exposure likely to be incurred by the person and the amount of exposure that is considered to be safe. No health risk is predicted if the HQ is less than 1.

When the HQ is greater than 1, the scenario poses a potential concern and requires further scrutiny. However, HQ values greater than 1 do not necessarily indicate that adverse health effects will occur; a large margin of safety has been included in their estimation.

In the risk characterization step, HQs were calculated for non-carcinogenic COPCs as the ratio of the exposure dose and the RfC (with appropriate unit conversion), according to the following equation:

$$HQ_{inh} = \frac{Exp_{inh}}{RfC \times IR \times CF_2 \div BW}$$

Where:

HQ_{inh} = hazard quotient due to inhalation of COPC in air (unitless)
Exp_{inh} = exposure dose due to inhalation of COPC in air (mg/kg/d)
RfC = reference concentration (mg/m^3)
IR = inhalation rate (m^3/h)
BW = body weight (kg)
CF_2 = unit correction factor (24 h/d)

An HQ less than or equal to 1 indicates that the estimated exposure is less than the RfC, signifying negligible health effects. The HQs are provided in Table 4-11.

Table 4-11: Hazard Quotients for Identified Receptor Locations of Concern

Chemical of Potential Concern	Hazard Quotient		
	Accommodation Camp	**Designated Camping Site**	**Trapper Cabin**
	Maximum Receptor Locations 44, 45, 47, 48, 50	*Receptor Location 38*	*Receptor Location 32*
	Off-duty Worker		
Nitrogen Dioxide (annual)	0.077	—	—
	Trapper		
Acrolein (24-hour)	—	—	0.11
	Child Recreational User		
Acrolein (24-hour)	—	0.055	—
	Adult Recreational User		
Acrolein (24-hour)	—	0.055	—

Notes:
— = COPC not retained for this receptor or receptor location.

All of the HQs are less than the target of 1, indicating negligible health effects.

4.4.5 Magnitude of Effects Assessment

Maximum 24-hour and annual concentrations for the one year in the operations phase where production and modelled Project emissions are at their maximum were screened against the lowest health-based screening thresholds in order to identify COPCs for the chronic inhalation assessment. These COPCs were retained for a more detailed evaluation of potential health effects for the specific receptor locations with exceedances of screening thresholds and for the HHRA VECs. The chronic inhalation assessment considered anticipated exposure times for each receptor as well as receptor-specific parameters such as inhalation rate and body weight. Risks in the form of HQs for non-carcinogens were calculated and compared to MOE target levels that represent safe levels of exposure (MOE 2011). All of the HQs were well below MOE target levels, indicating negligible health effects. Therefore, there are no residual effects from the Project related to chronic inhalation assessment.

4.5 Noise Assessment

The objective of the noise assessment is to evaluate noise levels potentially generated by the Project that may affect human health under a long-term or chronic exposure duration (e.g., many years to lifetime) by identified receptors. Specifically, the noise assessment will use the percent highly annoyed level (% HA) and the specific critical noise level (HCII) put forward by Health Canada (2005) to assess potential effects of noise on human health.

4.5.1 Noise Assessment Methods

Noise exposure levels have been selected as an indicator to assess potential health effects of the Project. The predicted noise levels at the identified receptor locations can be compared to the existing (or baseline) noise levels and provincial and international criteria adopted by Health Canada.

As described in the noise section of the Atmospheric Environment TSD, based on the remote nature of the Project, the existing noise conditions have been assumed to be 5 dB quieter than the MOE noise level limits for Class 3 (Rural) areas. Specifically, the existing noise levels have been assumed to be 40 dBA and 35 dBA during daytime and nighttime hours, respectively. The operations phase of the Project will produce the highest noise emissions (i.e., highest sound power levels). Therefore, the operations phase of the Project was identified as the bounding case for noise associated with Project activities (Atmospheric Environment TSD).

Health Canada has published a draft national guideline for evaluating health impacts of noise (Health Canada 2005). This guideline considers the following:

- Characteristics of the noise level.
- Construction noise impacts based on increased levels of annoyance in the population.
- Operational noise impacts based on increased levels of annoyance in the population.
- Impact on special land uses such as schools, hospitals and seniors' residences.
- Sleep disturbance impacts.

The Health Canada approach deals with increases in predicted noise levels over the existing conditions for the daytime (Ld) and nighttime (Ln) equivalent noise levels, as well as a whole day equivalent noise level descriptor (Leq24). In addition, impulsive and tonal characteristics of source noise are accounted for because they can increase potential effects. The following two measures are included in the draft guidance by Health Canada (2005) and were calculated for the identified receptor locations:

- The percentage of the exposed population that could be "highly annoyed" by increased noise levels caused by the Project (% HA), which is described by the following formula:

  $$HA = \frac{100}{1 + \exp[10.4 - 1.32 \times \log(10^{0.1 \times L_{eq24}} + 3.375 \times 10^{0.1 \times L_n})]}$$

  Where,

  L_{eq24} = the 24-hour equivalent noise level calculated according to ISO1996-1:05 (ISO 2003).

  L_n = the nighttime average sound level according to ISO1996-1:05 (ISO 2003).

- The specific impact, or impulse noise, indicator (HCII), which is defined as follows:

  $$HCII = 10 \times log(10^{0.1 \times L_{eq24}}) + 3.375 \times 10^{0.1 \times L_n}$$

  Where,

  L_{eq24} = the 24-hour equivalent noise level calculated according to ISO1996-1:05 (ISO 2003).

  L_n = the nighttime average sound level according to ISO1996-1:05 (ISO 2003).

The percentage of the population that could become highly annoyed (% HA) is a measure of health impact that Health Canada advises be used to evaluate long-term operational noise (Health Canada 2010b). There is a well-established dose-response relationship between day-night sound level and community noise annoyance, as measured by % HA (Michaud et al. 2008). The % HA approach as a measure of potential noise impact has been accepted by two US federal agencies, which are the Federal Transit Administration (U.S. FTA 1995) and the US Federal Railroad Administration (U.S. FRA 1998). It is also used in United States (ANSI 1996, as cited by Michaud et al. 2008) and ISO (ISO 2003) standards as a measure of noise impact. The World Health Organization (WHO) identifies noise annoyance as one of the health effects for which noise guideline levels have been set (WHO 1999).

Health Canada adopts the approach for guidance on construction noise from the Alberta Energy and Utilities Board (AEUB 2007). Under this guidance, the noise emitted from the Project is considered long-term because the duration is more than one year. Health Canada considers a change in % HA of 6.5% or an HCII value in excess of 75 dBA to have the potential for adverse effects on human health (Health Canada 2010b). The % HA and HCII predictions were compared to the Health Canada criteria of 6.5% and 75 dBA, respectively.

Noise predictions were carried out for human health receptor locations identified in the acute and chronic inhalation assessments and shown on Figure 4-2. Receptor locations that will have restricted access (i.e., receptor locations 10, 11, 17, 19, 23, 36 and 37) were not evaluated (Atmospheric Environment TSD). One maximum noise level was predicted for the 11 receptor locations at the accommodation camp.

4.5.2 Noise Assessment Results

The predicted noise levels in terms of the % HA measure for each receptor location are provided in Table 4-12. A value of 6.5% HA is considered by Health Canada to have the potential for adverse effects on human health.

Table 4-12: Noise Level Predictions at Human Health Locations (% HA)

Location	Predicted Ambient % HA	Existing % HA	Project-related Change Relative to Existing (%)
POR01	3.10	0.85	2.25
POR02	3.11	0.85	2.26
POR03	3.10	0.85	2.26
POR04	3.10	0.85	2.25
POR05	3.11	0.85	2.27
POR06	3.20	0.85	2.36
POR07	3.17	0.85	2.33
POR08	3.47	0.85	2.63
POR09	3.11	0.85	2.26
POR12	3.20	0.85	2.35
POR13	3.19	0.85	2.35
POR14	3.14	0.85	2.29
POR15	3.13	0.85	2.29
POR16	3.11	0.85	2.27
POR18	3.13	0.85	2.29
POR20	3.17	0.85	2.32
POR21	3.10	0.85	2.26

Table 4-12: Noise Level Predictions at Human Health Locations (% HA) (Continued)

Location	Predicted Ambient % HA	Existing % HA	Project-related Change Relative to Existing (%)
POR22	3.11	0.85	2.26
POR24	3.19	0.85	2.34
POR25	3.14	0.85	2.30
POR26	3.12	0.85	2.27
POR27	3.12	0.85	2.28
POR28	3.12	0.85	2.27
POR29	3.56	0.85	2.72
POR30	3.12	0.85	2.27
POR31	3.15	0.85	2.31
POR32	3.30	0.85	2.45
POR33	3.13	0.85	2.28
POR34	3.11	0.85	2.26
POR35	3.12	0.85	2.28
POR38	3.29	0.85	2.45
POR39	3.11	0.85	2.27
POR40	3.13	0.85	2.28
Accommodations Camp	3.39	0.85	2.54

All of receptor locations had change in % HA predictions below 6.5%, indicating that there is negligible potential for adverse health effects due to noise based on this measure.

Table 4-13 provides a summary of the predictions for human health receptor locations for the HCII measure. An exceedance of 75 dBA is considered by Health Canada to have the potential for adverse effects on human health.

Table 4-13: Noise Level Predictions at Human Health Locations (HCII)

Location	Existing HCII (dBA)	Predicted Ambient HCII (dBA)
POR01	43	53
POR02	43	53
POR03	43	53
POR04	43	53
POR05	43	53
POR06	43	53
POR07	43	53
POR08	43	54
POR09	43	53
POR12	43	53
POR13	43	53
POR14	43	53
POR15	43	53
POR16	43	53

Table 4-13: Noise Level Predictions at Human Health Locations (HCII) (Continued)

Location	Existing HCII (dBA)	Predicted Ambient HCII (dBA)
POR18	43	53
POR20	43	53
POR21	43	53
POR22	43	53
POR24	43	53
POR25	43	53
POR26	43	53
POR27	43	53
POR28	43	53
POR29	43	54
POR30	43	53
POR31	43	53
POR32	43	53
POR33	43	53
POR34	43	53
POR35	43	53
POR38	43	53
POR39	43	53
POR40	43	53
Accommodations Camp	43	53

The HCII values at all health receptor locations were less than 75 dBA. Health Canada suggests the threshold of 75 dBA as the sound level when the impact may be considered severe and mitigation should be proposed. This value is also used by the U.S. FRA (U.S. FRA 1998) and the U.S. FTA (U.S. FTA 1995). While 75 dBA is identified as a level of severe impact, a review of the literature has demonstrated that there is an increased risk for health effects at noise levels below 75 dBA:

- Sleep disturbance may occur following long-term exposure to road traffic, aircraft or railway noise levels of 40 dBA (L_{dn}) (WHO 2011; Health Council 1994, as cited by Passchier-Vermeer and Passchier 2000). In Europe, 40 dBA is considered a LOAEL of night noise above which health effects such as sleep disturbance may occur (WHO 2009).
- Hypertension may occur following long-term exposure to road traffic or aircraft noise levels of 40 to 70 dBA (L_{24h}) and 47-67 dBA (L_{dn}), respectively (WHO 2011; Health Council 1994, as cited by Passchier-Vermeer and Passchier 2000).
- An increased risk of cardiovascular disease may occur following long-term exposure to road traffic noise levels greater than 60 dBA (L_{16h}) (WHO 2011).
- Hearing impairment or ischemic heart disease may occur following long-term exposure to environmental noise levels of 70 dBA (L_{24h}) (Health Council 1994, as cited by Passchier-Vermeer and Passchier 2000).
- The U.S. EPA (1974) identifies 70 dBA (L_{eq24}) as the yearly average noise level identified as a requisite to protect the public health and welfare against hearing loss, with an adequate margin of safety.

The HCII values for the Project range from 53 to 54 dBA, which is within the range for which health effects such as sleep disturbance and hypertension may occur. Although the predicted HCII values meet the target of 75 dBA, an increased risk of health effects may occur at the levels predicted for the receptor locations. As a result, this measure was retained for further consideration with respect to magnitude of potential health effects

4.5.3 Magnitude of Effects Assessment

In the noise assessment, measures prescribed by Health Canada for assessing exposure to noise and potential human health effects were utilized. The % HA and HCII values for the Project are less than the targets prescribed by Health Canada. However, further literature review has shown that adverse effects such as sleep disturbance and hypertension may be associated with noise levels below the target levels. At receptor locations surrounding the Project, noise levels are within the ranges reported for increased risk of hypertension and sleep disturbance. The magnitude of effect for noise is considered to be low based on comparison to Health Canada targets and considering that predicted levels are in the lower end of ranges for hypertension effects.

4.6 Particulate Matter Risk Assessment

This section of the HHRA describes the assessment of particulate matter. Particulate matter includes Total Suspended Particulate (TSP), Diesel Particulate Matter (DPM), Particulate Matter of diameter <10 µm (PM_{10}) and Particulate Matter of diameter <2.5 µm ($PM_{2.5}$).

4.6.1 Approaches to Particulate Matter Risk Assessment

Many epidemiological studies have been conducted over the past 20 years to identify the relationship between health effects and particulate matter. Many of these studies have shown that there is a relationship between increases in ambient particulate matter concentrations and mortality and hospitalizations for respiratory and cardiac health effects (Health Canada and Environment Canada 1999). This relationship is stronger for $PM_{2.5}$ than PM_{10} (Health Canada and Environment Canada 1999). However, there has also been substantial controversy regarding what specifically the relationship is. Many epidemiological studies have been confounded by the presence of other air pollutants (e.g., sulphur dioxide), temperature and smoking habits. In addition, there is uncertainty regarding whether epidemiological studies have properly accounted for exposure by individuals if ambient concentrations are based on a fixed monitoring station and whether the particulate matter only advances health effects of people who already have advanced and serious illnesses (Health Canada and Environment Canada 1999). Therefore, there is no prescribed method for assessing health risks of particulate matter, nor does the assessment of particulate matter lend itself to RA methods in the same manner as other parameters. The method used in this assessment was to compare the predicted particulate matter concentrations to regulatory guidelines.

The effect of diesel particulate matter (DPM) on human health has also been the focus of toxicological studies. DPM is the particulate component of diesel exhaust. Long-term inhalation exposure to DPM is associated with non-carcinogenic and carcinogenic health effects (U.S. EPA 2002; CalEPA 1998). Non-carcinogenic health effects include increased incidence of cough, phlegm, chronic bronchitis, and reductions in pulmonary function (CalEPA 1998). DPM exposure has also been shown to induce immunological reactions, inflammatory responses, and to have a synergistic effect with pollen in humans (CalEPA 1998). Evidence of carcinogenic effects from exposure to DPM dates back to 1955 (U.S. EPA 2002). However, it was not until recently that the International Agency for Research on Cancer (IARC) classified DPM as a Group 1 carcinogen (IARC 2012, internet site), based on sufficient evidence of carcinogenicity in humans. The IARC evaluation is supported primarily by two studies, Attfield et al. (2012) and Silverman et al. (2012), which both conclude that exposure to DPM is associated with increased risk of lung cancer in humans. CalEPA has derived an inhalation unit risk for DPM based upon increased risk of lung cancer in occupationally-exposed individuals (OEHHA 2009). The method used to evaluate DPM in this assessment is first to screen against chronic screening thresholds for non-carcinogenic and carcinogenic effects and then retain for evaluation following the methods of the chronic inhalation assessment if concentrations are above screening thresholds.

4.6.2 Comparison of Predicted Particulate Concentrations to Regulatory Guidelines

Predicted concentrations of particulate matter for the Project were compared with available screening thresholds. Screening thresholds for particulate matter were reviewed and compiled from the following agencies:

- Ontario Ministry of the Environment (MOE 2012).
- Canadian Council of Ministers of the Environment (CCME 1999, 2000).
- California Office of Environmental Health Hazard Assessment (CalEPA 2008).
- World Health Organization (WHO 2005).

Screening thresholds for particulate matter are only available for a 24-hour or annual averaging period. Screening thresholds for TSP are only available for effects on visibility, which is not a human health concern. Therefore, TSP was not evaluated further in the particulate matter assessment. The inhalation unit risk provided by CalEPA for DPM was converted into a screening threshold based on a target cancer risk of 1 x 10^{-6}.

The screening thresholds that were available for particulate matter are provided in Table 4-14 and Table 4-15. Only agencies with available screening thresholds for each averaging time are shown in the tables.

Table 4-14: Screening Thresholds for Particulate Matter for the 24-hour Averaging Period

Chemical	MOE[a] (µg/m^3)	CCME[b] (µg/m^3)	WHO[c] (µg/m^3)	Derivation
DPM	—	—	—	—
$PM_{2.5}$	30	30	25	MOE – Based on the Canada-wide Standard; CCME – The Canada-Wide Standard represents a balance between achieving the best health and environmental protection possible and the feasibility and costs of reducing pollutant emissions; WHO - Based on relationship between 24-hour and annual PM levels and health effects from annual concentrations.
PM_{10}	50	25	137 (50)	MOE – An interim AAQC provided as a guide for decision making; CCME – A reference level above which there are demonstrated effects on human health and/or the environment; WHO – Based on the $PM_{2.5}$ standard and an assumed $PM_{10}/PM_{2.5}$ ratio of 2. It is recommended that a different value for this ratio, which better reflects local conditions, be employed when setting local standards. For the 24-hour averaging period the average $PM_{10}/PM_{2.5}$ ratio among the 51 receptor locations at the site is 5.5. The $PM_{2.5}$ standard has been adjusted by the site-specific ratio, and the original WHO standard is shown in brackets.

Notes:

— = Screening threshold not available.
(a) MOE (2012).
(b) CCME (2000).
(c) WHO (2005).

Table 4-15: Screening Thresholds for Particulate Matter for the Annual Averaging Period

Chemical	Endpoint	CalEPA[a] (µg/m^3)	WHO[b] (µg/m^3)	Derivation
DPM	Non-carcinogenic	5	-	CalEPA – Based on respiratory effects
	Carcinogenic	0.003	-	CalEPA – Based on lung cancer risk in occupationally exposed individuals. Derived from an inhalation unit risk using a target cancer risk of 1 x 10^{-6}.
$PM_{2.5}$	Non-carcinogenic	-	10	WHO – The lowest level at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to long-term exposure to $PM_{2.5}$
PM_{10}	Non-carcinogenic	-	47 (20)	WHO – Based on the $PM_{2.5}$ standard and an assumed $PM_{10}/PM_{2.5}$ ratio of 2. It is recommended that a different value for this ratio, which better reflects local conditions, be employed when setting local standards. For the annual averaging period the average $PM_{10}/PM_{2.5}$ ratio among the 51 receptor locations at the site is 4.7. The $PM_{2.5}$ standard has been adjusted by the site-specific ratio, and the original WHO standard is shown in brackets.

Notes:

— = Screening threshold not available.

(a) CalEPA (2008).

(b) WHO (2005).

The selected screening thresholds are shown in Tables 4-16 and 4-17 along with the maximum predicted concentrations for the Project.

Table 4-16: Screening of Maximum Predicted Particulate Concentrations against Selected Thresholds for the 24-hour Averaging Period

Chemical	Selected Screening Threshold (µg/m^3)	Maximum Concentration (µg/m^3)	Retain for Assessment?
$PM_{2.5}$	30	10*	No
PM_{10}	137	146	Yes

Notes:

* = 98th percentile concentration

Table 4-17: Screening of Maximum Predicted Particulate Matter Concentrations against Selected Thresholds for the Annual Averaging Period

Chemical		Selected Screening Threshold (µg/m^3)	Maximum Concentration (µg/m^3)	Retain for Assessment?
DPM	Non-carcinogenic	5	0.24	No
	Carcinogenic	0.003	0.24	Yes
$PM_{2.5}$	Non-carcinogenic	10	4.2	No
PM_{10}	Non-carcinogenic	47	9.95	No

The screening threshold selected for $PM_{2.5}$ for the 24-hour averaging period is the Canada-Wide Standard, because it has regulatory relevance for the Project and the WHO guideline is based on a ratio and not effects for the 24-hour averaging period. Achievement of the Canada-Wide Standard is based on 98th percentile concentrations. The maximum $PM_{2.5}$ 98th percentile concentration among all the identified human health receptor locations for the 24-hour averaging period was 10 µg/m^3. This concentration is less than the Canada-Wide Standard of 30 µg/m^3 for $PM_{2.5}$, therefore $PM_{2.5}$ was not retained for further evaluation for the 24-hour averaging period. The screening threshold selected for $PM_{2.5}$ for the annual averaging period was from the WHO (2005). The maximum concentration among all the human health receptor locations for the annual averaging period was 4.2 µg/m^3. This concentration is less than the WHO guideline of 10 µg/m^3 for $PM_{2.5}$, therefore $PM_{2.5}$ was not retained for further evaluation for the annual averaging period.

The screening threshold selected for PM_{10} for the 24-hour averaging period is the WHO standard adjusted with the site-specific PM_{10}/$PM_{2.5}$ ratio. This screening threshold was selected because it incorporates site-specific data and serves as a better comparison for the predicted PM_{10} concentrations at the receptor locations. The maximum predicted 24-hour PM_{10} concentration among all human health receptor locations was 146 µg/m^3. This concentration is above the selected screening threshold of 137 µg/m^3; therefore, 24-hour PM_{10} was retained for further evaluation in the magnitude of effects assessment. The maximum predicted annual PM_{10} concentration among all human health receptor locations was 9.95 µg/m^3, which is less than the original WHO annual standard and the standard once it is adjusted for the site-specific PM_{10}/$PM_{2.5}$ ratio. Therefore, PM_{10} was not retained for further evaluation for the annual averaging period.

The maximum annual DPM concentration at all receptor locations was 0.24 µg/m^3. This concentration is below the screening threshold for non-carcinogenic effects of 5 µg/m^3 from CalEPA, therefore DPM was not retained for further evaluation of non-carcinogenic effects. The predicted concentration is above the carcinogenic threshold of 0.003 µg/m^3; therefore, further evaluation of DPM for potential carcinogenic effects is required. The method for evaluating carcinogenic risks follows the same general approach as presented for the chronic inhalation assessment.

4.6.3 Toxicity Assessment

Toxicity assessment involves the classification of the harmful effects of substances and the estimation of the amounts of substances that can be received by an organism without adverse health effects. For DPM, an appropriate toxicity benchmark or TRV was determined based on the reported mode of action.

4.6.3.1 Contaminant Classification

The classification systems established by different regulatory agencies was presented in Section 3.4.2.1 of the chronic inhalation assessment. Health Canada has not classified DPM with regards to carcinogenicity. The U.S. EPA IRIS (U.S. EPA 2012a, internet site) states that diesel exhaust is “likely to be carcinogenic to humans by inhalation from environmental exposures.” The IARC has classified diesel engine exhaust as Group 1, human carcinogen. Based on the carcinogenicity classification, DPM was evaluated as a carcinogen.

4.6.3.2 Dose-Response Assessment

TRVs for carcinogenic substances are called inhalation unit risks (URs). A UR is the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to a chemical at a concentration of 1 µg/m^3 in air. A regulatory search for URs for DPM yielded only one UR available from CalEPA (2012, internet site). The CalEPA UR for DPM (0.0003 $[\mu g/m^3]^{-1}$) is based on occupational studies linking diesel exhaust exposure with lung cancer.

4.6.4 Exposure Assessment

4.6.4.1 Exposure Point Concentrations

The predicted concentrations of DPM range from 0.025 µg/m^3 to 0.24 µg/m^3 and are above the screening threshold of 0.003 µg/m^3 at all receptor locations. The maximum DPM concentrations at each receptor location type (i.e., communities, designated camping sites, tourism establishments, cottage, trapper cabins, accommodation camp) were used as exposure point concentrations (Table 4-18).

Table 4-18: Exposure Point Concentrations for Diesel Particulate Matter

	Annual DPM Concentration (µg/m^3)			
	Maximum Accommodation Camp	**Maximum Designated Camping Site, Tourism Establishment, Cottage**	**Maximum Community**	**Maximum Trapper Cabin**
Highest concentration	*Receptor Location 42*	*Receptor Location 38*	*Receptor Location 4*	*Receptor Location 32*
	0.19	0.24	0.034	0.22

The annual concentrations represent the highest annual emissions modelled during the operations phase and the highest concentrations predicted in 5 years of modelling based on meteorological conditions (Atmospheric Environment TSD).

Where more than one receptor location of the same type (e.g., worker accommodation camp, designated camping site) had exceedances, the maximum predicted concentration from these locations was used as the exposure point concentration.

4.6.4.2 Receptor Characteristics

Exposure for all receptor types was evaluated using the maximum concentration from the corresponding receptor location, specifically the off-duty worker was evaluated at the accommodation camp, the trapper was evaluated at the trapper cabins, the recreational user was evaluated at the designated camping sites, tourism establishments and cottage and the member of the Aboriginal community and community resident were evaluated at the communities. The receptor characteristics for the off-duty worker, recreational user and trapper were provided in Section 4.4.3.2. The receptor characteristics for the member of the Aboriginal community and the community resident are provided in Table 4-19. In relation to evaluating inhalation of particulate matter in communities, the member of the Aboriginal community and the community resident have the same receptor characteristics. Exposure for all life stages of the resident must be summed in order to determine lifetime cancer risk; this receptor is named the composite receptor. It is assumed that the resident may be living in Steep Rock or Atikokan and may be exposed to DPM generated by the Project during the 1.5 hours per day they spend outdoors (Health Canada 2010a).

Table 4-19: Receptor Characteristics for the Resident

Parameter	**Infant Resident**	**Toddler Resident**	**Child Resident**	**Teen Resident**	**Adult Resident**	**Reference**
Inhalation rate (m^3/h)	0.092	0.36	0.60	0.65	0.69	Health Canada 2010a
Exposure time (h/d)	1.5	1.5	1.5	1.5	1.5	Health Canada 2010a (time spent outdoors)
Exposure frequency (d/y)	365	365	365	365	365	Health Canada 2010a

Table 4-19: Receptor Characteristics for the Resident (Continued)

Parameter	Infant Resident	Toddler Resident	Child Resident	Teen Resident	Adult Resident	Reference
Exposure duration (y)	0.5	4.5	7	8	60	Health Canada 2010a (duration of life stages)
Body weight (kg)	8.2	16.5	32.9	59.7	70.7	Health Canada 2010a

4.6.4.3 *Exposure Estimates*

Exposure doses for DPM were estimated using the equation presented in Section 3.4.3.3. An averaging time of 80 years was used to evaluate carcinogenic effects for the composite resident and an averaging time of 60 years was used to evaluate carcinogenic effects for the adult trappers and off-duty workers (Health Canada 2010a). The exposure doses are provided in Table 4-20.

Table 4-20: Exposure Doses for Diesel Particulate Matter

Receptor		Incremental Lifetime Cancer Risk			
	Lifestage	Maximum Accommodation Camp	Maximum Designated Camping Site, Tourism Establishment, Cottage	Maximum Community	Maximum Trapper Cabin
		Receptor Location 42	*Receptor Location 38*	*Receptor Location 4*	*Receptor Location 32*
Off-duty Worker	Adult	7.2×10^{-7}	—	—	—
Trapper	Adult	—	—	—	1.3×10^{-6}
Recreational User	Child	—	3.8×10^{-7}	—	—
	Adult	—	2.5×10^{-7}	—	—
Composite Resident	Infant	—	—	2.0×10^{-10}	—
	Toddler	—	—	3.4×10^{-9}	—
	Child	—	—	5.4×10^{-8}	—
	Teen	—	—	3.0×10^{-9}	—
	Adult	—	—	2.5×10^{-7}	—

Notes:

— = Receptor not evaluated for this receptor location.

4.6.5 Risk Characterization

Risks for carcinogens are based on the Incremental Lifetime Cancer Risk (ILCR), which is the probability of developing cancer as a result of environmental exposure to a carcinogenic substance. Interpretation of these ILCRs was based on comparison of the calculated ILCR values with the "benchmark" of 1 in 1,000,000 (i.e., one extra cancer case in a population of 1,000,000 people). Ontario Ministry of the Environment (MOE 2011) considers cancer risks from chemical exposure to be essentially negligible if the ILCR is less than one in 1,000,000 (1×10^{-6}). For DPM, ILCRs were calculated as the product of the exposure dose and the UR (with appropriate unit conversion), according to the following equation:

$$ILCR_{inh} = \frac{Exp_{inh} \times UR \times BW}{IR \times CF_2}$$

Where:

$ILCR_{inh}$ = incremental lifetime cancer risk due to inhalation of COPC in air (unitless)
Exp_{inh} = exposure dose due to inhalation of COPC in air (mg/kg/d)
UR = inhalation unit risk $(mg/m^3)^{-1}$
IR = inhalation rate (m^3/h)
BW = body weight (kg)
CF_2 = unit correction factor (24 h/d)

The ILCR represents a lifetime cancer risk, and the ILCRs calculated for each lifestage are summed. The ILCRs for DPM are provided in Table 4-21.

Table 4-21: Incremental Lifetime Cancer Risks for Diesel Particulate Matter

Receptor	**Incremental Lifetime Cancer Risk**			
	Maximum Accommodation Camp	**Maximum Designated Camping Site, Tourism Establishment, Cottage**	**Maximum Community**	**Maximum Trapper Cabin**
	Receptor Location 42	*Receptor Location 38*	*Receptor Location 4*	*Receptor Location 32*
Off-duty Worker	9.2×10^{-7}	—	—	—
Trapper	—	—	—	**1.6×10^{-6}**
Recreational User	—	5.7×10^{-7}	—	—
Composite Resident	—	—	4.1×10^{-7}	—

Notes:
— = Receptor not evaluated for this receptor location.
ILCRs in bold font are greater than 1×10^{-6}.

All of the ILCRs are less than the target of 1×10^{-6} except for the trapper. In order to further evaluate risks for the trapper, the annual DPM concentrations from the receptor locations with the second highest concentration (0.21 µg/m^3 at receptor location 29) and third highest concentration (0.098 µg/m^3 at receptor location 31) for trapper cabins were used as an exposure point concentration. The ILCR for the trapper is 1.6×10^{-6} at receptor location 29 and 7.3×10^{-7} at receptor location 31. The ILCR for receptor location 31 is within an acceptable limit of carcinogenic risk. The carcinogenic risk at the trapper cabin locations 32 and 29 exceed the target cancer risk and as such, the magnitude of potential adverse effects was evaluated.

4.6.6 Magnitude of Effects Assessment

In the particulate matter assessment, concentrations of $PM_{2.5}$ were below guidelines, indicating negligible adverse health effects from $PM_{2.5}$. Annual concentrations of PM_{10} were also below guidelines and not expected to cause adverse health effects. At one receptor location only (receptor location #38, designated camping site), the 24-hour PM_{10} concentration was above the selected screening thresholds (predicted concentration of 146 µg/m^3 vs. screening threshold of 137 µg/m^3). The 95th and 75th percentile values for the 24-hour averaging period for this receptor location are 42 µg/m^3 and 14 µg/m^3. These concentrations are below the adjusted WHO standard as well as the interim MOE AAQC for PM_{10}. Therefore, 95% of the time, PM_{10} concentrations at this receptor location are within acceptable levels. In reality, this percentage will be even higher because the modelling relied on the maximum year of operations as a bounding case, and concentrations for other years within the Project lifetime will be lower. The magnitude of effect for PM_{10} inhalation is considered to be low.

Concentrations of DPM exceeded the screening threshold for carcinogenic effects, therefore DPM was evaluated following the chronic inhalation assessment method. The ILCRs calculated based on the maximum annual DPM concentrations were less than the target cancer risk of 1×10^{-6} for all receptors except for the trapper. The receptor locations with the highest concentrations for the trapper were #32 and #29 (Figure 4-2). These locations are in close proximity to the MSA. If the third highest receptor location concentration is used (receptor location #31), the ILCR for the trapper drops below the target cancer risk level. The ILCR calculations assume that the trapper spends 105 days per year, 8 hours a day for 15.5 years at the trapper cabin. It was also assumed that the maximum annual DPM concentration modelled for the Project exists for the entire life of the Project. These conservative assumptions contribute to potentially overestimating the ILCRs. Following the magnitude of effects assessment matrix presented in Table 4-2, the magnitude of effect for DPM inhalation is considered to be low because the ILCR is less than 1×10^{-5}.

4.7 Multi-Media Assessment

The objective of the multi-media assessment is to evaluate substances potentially emitted from the Project that may generate a health outcome following a long-term or chronic exposure duration (e.g., many years to lifetime) by identified receptors from all potentially impacted environmental media.

4.7.1 Problem Formulation

4.7.1.1 Identification of Receptors

Potential human health effects related to long-term multi-media exposure for the Project were evaluated for the following receptor locations (Figure 4-2):

- Communities (Atikokan and Steep Rock Lake).
- Designated Camping Sites (16 locations).
- Tourism Establishments (6 locations).
- Cottage (1 location).
- Trapper Cabins (9 locations).
- Accommodation Camp (11 locations).

4.7.1.2 Identification of Chemicals of Potential Concern

The multi-media assessment considered metals and PAHs that may be emitted by the Project and accumulate in soil and water within the RSA. The VOCs and acid gases were not evaluated in the multi-media assessment because they are considered to be primarily present in air. Acid gases and VOCs remain airborne due to their high vapour pressures, preventing any local deposition onto soils. If they do deposit, they tend not to persist in soil, rapidly biodegrading and volatilizing to the atmosphere. Consequently, VOCs and acid gases were evaluated in the chronic inhalation assessment but not in the multi-media assessment.

A comprehensive chemical screening process was used to determine the COPCs in water and soil, as discussed in the following subsections.

4.7.1.2.1 Chemical Screening Process for Substances in Water

The existing water quality for the Project is described in the Water and Sediment Quality TSD. The existing water quality monitoring program was developed based on consultation with regulatory agencies and included five sampling events from September 2010 to June 2011. Sample locations were chosen to characterize the existing environment at locations upstream and downstream of the Project. To characterize existing conditions for Upper Marmion Reservoir, water concentrations from Sawbill Bay and Lynxhead Bay (HRWQP-2 and HRWQP-7 in Water and Sediment Quality TSD were used. Water concentrations from samples collected in Lizard Lake (i.e., HRWQP-3 in Water and Sediment Quality TSD) were used to characterize existing conditions for Lizard Lake.

Predictive modelling was carried out to determine Project discharge water concentrations and resulting concentrations within receiving water bodies. The water quality predictions are provided in the Site Water Quality TSD and the Lake Water Quality TSD. For the operations phase, water quality was modelled for Upper Marmion Reservoir and Lizard Lake (Lake Water Quality TSD). The highest water concentrations for Upper Marmion Reservoir are predicted for Basin 6, which is located adjacent to the discharge point at the south end of Sawbill Bay. The predicted discharge includes the contribution of accommodation camp discharge (Site Water Quality TSD). Several scenarios were modelled in the Lake Water Quality TSD for Upper Marmion Reservoir, including scenarios based on steady state and maximum predicted reclaim water and average and maximum mixing conditions. The water quality predictions for the upper-bound scenario (maximum predicted reclaim tank water and maximum mixing) were used for screening for Upper Marmion Reservoir. The highest water concentrations for Lizard Lake are predicted for the central basin. Water quality predictions were carried out for Lizard Lake based on predicted Tailings Management Facility seepage at steady state and at maximum, along with either average or maximum mixing conditions for Lizard Lake (Lake Water Quality TSD). The water quality predictions for the upper-bound scenario (maximum seepage and maximum mixing) were used for screening for Lizard Lake. All of the water quality predictions incorporate aerial deposition of contaminants, which was modelled and presented in the Lake Water Quality TSD. The incremental change in predicted water quality concentrations as a result of aerial deposition was negligible.

Chemicals of potential concern in surface water were identified using a two-tiered approach. First, COPCs were identified by comparing the predicted concentrations of substances in surface water to relevant guidelines for human health including Guidelines for Canadian Drinking Water Quality (Health Canada 2012) and Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses (CCME 2012a, internet site). For substances with no guidelines available from Health Canada or CCME, screening levels from the U.S. EPA (2012c, internet site) for tap water ingestion were used. Then, maximum predicted concentrations in surface water were compared to the maximum measured existing concentrations plus 10%. Comparison to a threshold of 10% above existing concentrations was considered to represent a conservative evaluation of whether a measurable Project-related impact to surface water was likely to occur. Given spatial and temporal variability in surface water concentrations and variability in field sampling and laboratory analysis, any predicted increase of less than 10% above existing concentrations was considered unlikely to reflect a considerable change in environmental quality as a result of the Project. Substances were identified as COPCs and evaluated in the multi-media assessment if predicted concentrations were greater than guidelines and existing concentrations plus 10%. If a chemical only exceeds existing concentrations and not its respective health-based screening criterion, it is not considered to be present at levels that would affect human health. If a chemical exceeds its respective health-based screening criterion but is present in the environment at levels less than existing concentrations plus 10%, then it is not considered to be significantly different from existing and no health effect is predicted to occur. When the chemical is present at levels measurably greater than existing and greater than a health-based screening criterion, the Project may contribute to increases in concentration that could potentially affect human health. Where both conditions are fulfilled, further assessment is carried out.

The Guidelines for Canadian Drinking Water Quality are based on health effects, aesthetic effects and operational considerations for drinking water. Only the guidelines based on health effects were used for screening. Based on interviews with trappers and member of the Aboriginal community (Socio-economic Environment TSD), there are individuals who drink water from some of the surface water bodies within the RSA. Substances with concentrations above the drinking water guidelines and existing concentrations plus 10% were retained for further evaluation in the multi-media assessment. The Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses define safe concentrations for water that is to be used for irrigation or livestock watering. The lower of the guidelines for irrigation and livestock watering were used for screening. Although agricultural land uses have not been identified within the RSA, surface water concentrations were screened against the agricultural guidelines to identify COPCs in surface water that may be taken up by vegetation and animals and subsequently ingested by humans as a result of plant harvesting and hunting. Substances with surface water concentrations above the agricultural guidelines and existing concentrations plus 10% were retained for further evaluation in the multi-media assessment.

The existing concentrations, predicted concentrations and screening guidelines are presented in Appendix 3.II, Table 1 for Upper Marmion Reservoir and Appendix 3.II, Table 2 for Lizard Lake. No substances exceeded both guidelines and existing concentrations for Upper Marmion Reservoir or Lizard Lake. Maximum predicted concentrations for Upper Marmion Reservoir for ammonia and potassium were above maximum existing concentrations and there are no guidelines (drinking water or agricultural water) for these substances. Maximum predicted concentrations for Lizard Lake for ammonia, potassium and sodium were above maximum existing concentrations and there are no guidelines (drinking water or agricultural water) for these substances. A drinking water guideline for ammonia was not provided by Health Canada because "*it is produced in the body and efficiently metabolized in healthy people; no adverse effects at levels found in drinking water*" (Health Canada 2012). A drinking water guideline was also not provided by Health Canada for potassium because it is not considered to be a concern for the general population (Health Canada 2012). Similarly, sodium is considered to be naturally occurring and non-toxic and Health Canada (2012) has not developed a drinking water guideline for it. Given that ammonia, potassium and sodium only have human health effects at levels much higher than those predicted for the Project, they were not retained in the multi-media assessment. There were no COPCs identified in surface water for the multi-media assessment.

4.7.1.2.2 Chemical Screening Process for Substances in Soil

The existing soil quality for the Project is presented in the Geochemistry, Geology and Soils TSD. Existing soil metal data were collected during the April 2012 field program at 18 sample locations. Concentrations in soil can be predicted based on annual wet and dry deposition rates. Annual wet and dry deposition rates for metals and PAHs were predicted for the human health receptor locations identified in Figure 4-2. There are no regulatory guidelines or risk-based concentrations that can be directly compared to deposition rates. Thus, the deposition rates were used to predict mixed surface soil concentrations which were compared to soil quality guidelines. The maximum soil concentration predicted for all receptor locations was used for screening.

Incremental soil concentrations were calculated using protocols provided in the Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (U.S. EPA 2005). Specifically, the equations below were used to calculate the incremental soil concentrations of inorganic and organic substances, respectively.

$$ISC\ (Inorganic\ Chemicals)\frac{= (100 \times (D_{yd} + D_{yw}) \times tD)}{Z_s \times BD}$$

Where:

ISC = Incremental Soil Concentration (mg/kg)
Dyd = Dry Deposition Rate (g/m^2/y; Project and chemical specific)
Dyw = Wet Deposition Rate (g/m^2/y; Project and chemical specific)
tD = Deposition Time (15.5 y; Project specific)
Zs = Soil Mixing Depth (0.02 m untilled land [U.S. EPA 2005])
BD = Bulk Density (1.5 g/cm^3 [U.S. EPA 2005])

$$ISC\ (Organic\ Chemicals)\frac{= (100 \times (D_{yd} + D_{yw}) \times (1 - e^{-K_s \times tD})}{Z_s \times BD \times K_s}$$

Where:

ISC = Incremental Soil Concentration (mg/kg)
Dyd = Dry Deposition Rate (g/m^2/y; Project and chemical specific)
Dyw = Wet Deposition Rate (g/m^2/y; Project and chemical specific)
tD = Deposition Time (15.5 y; Project specific)
Zs = Soil Mixing Depth (0.02 m untilled land [U.S. EPA 2005])
BD = Bulk Density (1.5 g/cm^3 [U.S. EPA 2005])
Ks = Soil Loss Constant (y^{-1}; chemical specific [U.S. EPA 2005])

The modelled deposition rates represent a maximum scenario from any phase of the Project (i.e., construction, operations, closure, and post-closure). As the deposition rates used to predict incremental soil concentrations are a maximum scenario from any phase of the Project, a deposition time of 15.5 years was used. This includes 2.5 year of construction, 11 years of operation, and 2 years of closure. Atmospheric emissions are not expected during the post-closure phase. All substances deposited onto soil were assumed to mix within the top 0.02 m, as recommended for untilled soils (U.S. EPA 2005). Soil was assumed to have a bulk density of 1.5 grams per cubic centimetre (g/cm^3) (U.S. EPA 2005). Loss due to weathering and degradation was only assumed for PAHs because metals are not degraded by processes such as microbial degradation and photolysis (U.S. EPA 2005). Total soil loss constants for PAHs were adopted from the database provided in U.S. EPA 2005.

The incremental soil concentrations for inorganic substances were added to the maximum measured existing concentrations. Existing concentrations were collected for metals but not for PAHs. A typical laboratory method detection limit (DL) for PAHs is 0.05 mg/kg. Therefore, half of the laboratory DL (0.025 mg/kg) was used to represent existing concentrations for PAHs, and was added to the incremental soil concentrations.

Predicted soil concentrations were compared first to existing concentrations plus 10% (maximum measured existing concentrations for metals and assumed half-detection limits for PAHs). Comparison to a threshold of 10% above existing concentrations was considered to represent a conservative evaluation of whether a measurable Project-related impact to soil was likely to occur. Given spatial and temporal variability in soil concentrations, variability in field sampling and laboratory analysis and the conservatism applied in the predictive deposition modelling, any predicted increase of less than 10% above existing concentrations was considered unlikely to reflect a considerable change in environmental quality as a result of the Project. Next, predicted soil concentrations were compared to the Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health, agricultural land uses (CCME 2012b, internet site) and the Ontario Ministry of the Environment Table 1 Full Depth Background Soil Standards for agricultural land uses (MOE 2011). The CCME soil quality guidelines are derived to protect ecological receptors and human receptors. The MOE Table 1 standards are background values derived from the Ontario Typical Range values for identified land uses and are considered representative of upper limits of typical province-wide background concentrations in soils that are not contaminated by point sources. Overall, an exceedance of the CCME or MOE guideline/standard does not necessarily indicate an adverse human health effect; screening against these guidelines only indicates where further assessment of potential human health effects may be required. Although agricultural land uses have not been identified within the RSA, using the agricultural standards ensures that any substances that may exceed these screening guidelines/standards are identified in case of potential future land development for agricultural purposes. This is a conservative approach as the agricultural guidelines/standards are the lowest among all land uses. Where guidelines/standards from the CCME and MOE were not available, the U.S. EPA Regional Screening Levels (U.S. EPA 2012b) were used because these values are also risk-based and protective of human health. The U.S. EPA Regional Screening Levels are available for residential or industrial land uses; the screening levels for residential land uses were used. The substances in soil were retained as COPCs if the predicted soil concentrations exceeded existing concentrations plus 10% and exceeded a soil screening level.

The comparison of predicted metal soil concentrations to existing concentrations plus 10% and to the selected soil screening levels are provided in Appendix 3.II, Table 3. The predicted metal concentrations (incremental + existing) were less than the existing plus 10% concentrations for all substances. No further screening against soil screening levels was required. It is noted that maximum existing concentrations of copper, molybdenum and nickel are above soil screening levels, but addition of the incremental soil concentration represents only a 0.003%, 0.008% and 0.009% increase in concentrations, respectively. Therefore, no significant changes in metal soil quality are expected as a result of the Project and no metal COPCs were retained for the multi-media assessment.

The comparison of predicted PAH soil concentrations to existing concentrations plus 10% and to the selected soil screening levels are provided in Appendix 3.II, Table 4 (MOE standards) and Table 5 (CCME carcinogenic factors). The predicted PAH concentrations (incremental + existing) were less than the existing plus 10% concentrations for all substances. No further screening against soil screening levels was required. It is noted that existing concentrations plus incremental soil concentrations were less than all PAH screening levels. Therefore, no PAH COPCs were retained for the multi-media assessment for non-carcinogenic or carcinogenic effects.

Overall, no COPCs were retained in soil for the multi-media assessment.

4.7.1.2.3 Chemicals of Potential Concern in the Multi-Media Risk Assessment

Based on the screening, no COPCs were identified for exposure from the terrestrial or aquatic environment. No further evaluation of exposure is required in the multi-media assessment.

4.7.1.3 Identification of Potential Exposure Pathways

The objective of the exposure pathway screening process is to identify potential routes by which people could be exposed to substances and the relative significance of these pathways to total exposure. A substance represents a potential health risk only if it can reach receptors through an exposure pathway at a concentration that could potentially lead to adverse effects. If there is no pathway for a chemical to reach a receptor, then there cannot be a risk, regardless of the chemical concentration. The chemical screening process indicated that there were no COPCs present at concentrations that could potentially lead to adverse effects. Therefore, no further evaluation of potential exposure pathways is required.

4.7.2 Magnitude of Effects Assessment

The chemical screening process indicated that there were no COPCs present at concentrations that could potentially lead to adverse health effects. The chemical screening incorporated the following conservative assumptions:

- Predicted surface water concentrations from the surface water zone with highest concentrations were used for screening.
- The lowest daily mixing ratio was used to estimate mixed surface water concentrations from discharge concentrations.
- The maximum deposition rates among all phases of the Project was used to calculate incremental soil concentrations assuming those maximum deposition rates applied for the entire period of construction, operations and post-closure.
- The maximum soil concentration predicted among all human health receptor locations was used for screening.
- Predicted surface water concentrations were compared to guidelines based on potable use and use for irrigation and livestock watering, while exposure to water near the Project currently only occurs via incidental ingestion during swimming and boating, which, because of reduced exposure, would allow higher water concentrations considered to be safe.

No COPCs were identified following the conservative screening process. Therefore, no adverse health effects are expected as a result of changes in soil and water concentrations. No residual effects are predicted for the multi-media assessment.

4.8 Human Health Assessment for Post-closure Phase

The identified VECs for human health will continue to use the area within the RSA once the Project is closed, this period of time is called the post-closure phase. There will be no atmospheric emissions or noise generated in the post-closure phase. However, there will be pit flooding which will lead to a new water quality condition in the pit lake within the MSA. There will also be pit flood effluent and site runoff that will discharge into Upper Marmion Reservoir. In addition, it is assumed that there will be seepage from the Tailings Management Facility into Lizard Lake. The water quality modelling for the pit lake is presented in the Site Water Quality TSD and the water quality modelling for Upper Marmion Reservoir and Lizard Lake is presented in the Lake Water Quality TSD. For the pit lake, the results for the stratified lake condition were used because this is the expected steady-state condition of the pit lake. The results assuming diversion of water from the Tailings Management Facility to open pits and the results assuming no diversion of water are presented herein. It is possible that recreational users may incidentally ingest water from the pit lake, Upper Marmion Reservoir or Lizard Lake if they use the lake for swimming, boating or fishing. In order to evaluate potential ingestion of lake water, the water concentrations were screened against the Guidelines for Canadian Drinking Water Quality (Health Canada 2012). The guidelines are based on health effects, aesthetic effects and operational considerations for drinking water. Only the guidelines based on health effects were used for screening. Consistent with the screening approach for surface water for the operations phase identified in Section 4.7.1.2.1, predicted surface water conditions for post-closure were also compared to the Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses (CCME 2012a, internet site). This screening step was completed in order to evaluate uptake of substances in surface water by vegetation and animals and subsequent ingestion by humans as a result of plant harvesting or hunting. The WHO (2008) has developed health-based guidelines for drinking water and the U.S. EPA (2012c, internet site) has developed screening levels for tap water ingestion. Guidelines from these agencies were used where a guideline from Health Canada (2012) or CCME (2012a, internet site) was not available. Predicted concentrations were also compared to maximum existing concentrations plus 10%, refer to Section 4.7.1.2.1 for further description of this screening approach.

The predicted pit lake concentrations are compared to the relevant guidelines in Table 4-22. The ranges in pit lake water quality provided in Table 4-22 are a result of seasonal variability at steady state conditions. The predicted concentrations for Upper Marmion Reservoir as a result of pit flood effluent and site runoff, respectively, are presented in Table 4-23 along with the guidelines and maximum existing concentrations plus 10%. The maximum existing concentrations plus 10% and predicted concentrations for Lizard Lake, as well as the guidelines, are presented in Table 4-24.

Table 4-22: Screening of Steady State Open Pit Water Quality against Regulatory Guidelines

Parameter	Units	Health Canada[a]	CCME[b]	With Diversion of Water from Tailings Management Facility		No Diversion of Water from Tailings Management Facility	
				East Pit	West Pit	East Pit	West Pit
Ammonium	mg/L	—	—	0.02 to 0.03	0.11 to 0.12	0.05	0.12
Calcium	mg/L	—	1,000	7.9 to 9.5	11 to 13	5.4 to 7.6	7.5 to 11
Chlorine	mg/L	—	5[c]	3.0 to 3.6	3.2 to 3.9	1.7 to 2.5	1.8 to 2.7
Magnesium	mg/L	—	—	1.1 to 1.4	1.1 to 1.6	0.60 to 1.2	0.70 to 1.5
Nitrate (N)	mg/L	45,000	100,000	0.0003 to 0.0005	0.0003 to 0.0005	0.0003	0.0003 to 0.0005
Phosphorus	mg/L	—	—	0.004	0.02	0.006 to 0.007	0.02
Potassium	mg/L	—	—	0.36 to 0.65	0.60 to 0.87	0.34 to 0.55	0.60 to 0.80
Sodium	mg/L	—	—	0.68 to 0.90	0.68 to 1.0	0.38 to 0.81	0.37 to 1.0
Sulphate	mg/L	—	1,000	0.74 to 1.5	1.0 to 1.6	0.50 to 1.0	0.80 to 1.1

Table 4-22: Screening of Steady State Open Pit Water Quality Against Regulatory Guidelines (Continued)

Parameter	Units	Health Canada[a]	CCME[b]	With Diversion of Water from Tailings Management Facility		No Diversion of Water from Tailings Management Facility	
				East Pit	**West Pit**	**East Pit**	**West Pit**
Aluminum	mg/L	—	5	0.001	0.001	0.001	0.001
Antimony	mg/L	0.006	—	0.0001 to 0.001	0.0003 to 0.001	0.0001 to 0.0008	0.0003 to 0.0008
Arsenic	mg/L	0.01	0.025	0.000008 to 0.00002	0.0008 to 0.0009	0.00003 to 0.0001	0.0008 to 0.001
Boron	mg/L	5	0.5	0.002 to 0.01	0.002 to 0.01	0.001 to 0.009	0.001 to 0.008
Cadmium	mg/L	0.005	0.0051	0.00001 to 0.00003	0.00001 to 0.00003	0.000007 to 0.00002	0.000008 to 0.00002
Chromium	mg/L	0.05	0.0049	0.000009 to 0.00001	0.0005	0.000001 to 0.00005	0.0005
Cobalt	mg/L	—	0.05	0.0002 to 0.0003	0.0001 to 0.0003	0.00008 to 0.0002	0.00006 to 0.0001
Copper	mg/L	—	0.2	0.00008 to 0.0002	0.0006 to 0.0007	0.00009 to 0.0003	0.0006 to 0.0007
Iron	mg/L	—	5	0.0007 to 0.001	0.0004 to 0.0006	0.0004 to 0.0008	0.0003 to 0.0004
Lead	mg/L	0.01	0.1	0.0000005 to 0.000008	0.00003 to 0.00004	0.0000002 to 0.00002	0.00003 to 0.00005
Mercury	mg/L	0.001	0.003	0.00003 to 0.00005	0.0001	0.00005 to 0.00007	0.0001 to 0.0002
Molybdenum	mg/L	—	0.01	0.0002 to 0.0006	0.0002 to 0.0007	0.0002 to 0.0006	0.0002 to 0.001
Nickel	mg/L	—	0.2	0.0006 to 0.0008	0.0006 to 0.0008	0.0003 to 0.0005	0.0003 to 0.0005
Selenium	mg/L	0.01	0.02	0.0005 to 0.0007	0.001 to 0.002	0.0006 to 0.0008	0.001 to 0.002
Silver	mg/L	—	0.071(d)	0.00002 to 0.00007	0.00003 to 0.00008	0.00002 to 0.00005	0.00002 to 0.00005
Uranium	mg/L	0.02	0.01	0.0001 to 0.002	0.0005 to 0.002	0.0002 to 0.001	0.0006 to 0.001
Vanadium	mg/L	-	0.1	0.00008 to 0.0001	0.00004 to 0.0001	0.0001 to 0.0002	0.0003 to 0.0004
Zinc	mg/L	-	5	0.002	0.003	0.001 to 0.002	0.002

Notes:

— = Guideline not available.

n/a = Guideline not provided for U.S. EPA when available from Health Canada.

[a] Health Canada 2012. Guidelines for Canadian Drinking Water Quality Summary Table. August 2012. Only health-based guidelines are used for screening.

[b] Canadian Council of Ministers of the Environment 2012a. Water Quality Guidelines for the Protection of Agriculture Summary Table. The lowest of the livestock and irrigation guidelines were used for screening.

[c] WHO. 2008. Guidelines for Drinking Water Quality. Third edition incorporating the first and second addenda. Volume I Recommendations.

[d] U.S. EPA 2012c. Residential Tapwater Screening Levels. Mid-Atlantic Risk Assessment. Available at: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm. Accessed November 2012.

Table 4-23: Screening of Upper Marmion Reservoir Water Quality against Regulatory Guidelines and Existing Concentrations

Parameter	Units	Health Canada[a]	CCME[b]	Upper Marmion Reservoir		
				Existing Concentration	Predicted from Pit Flood Effluent	Predicted from Site Runoff
Un-ionized ammonia	mg/L	—	—	0.00019	0.0018	0.000067
Calcium	mg/L	—	1,000	7.4	6.5	7.0
Chloride	mg/L	—	100	2.0	1.1	1.1
Magnesium	mg/L	—	—	1.9	1.3	1.3
Nitrate (N)	mg/L	45,000	100,000	0.19	0.063	0.063
Phosphorus	mg/L	—	—	0.079	0.013	0.014
Potassium	mg/L	—	—	0.58	0.68	0.68
Sodium	mg/L	—	—	2.9	1.3	1.3
Sulphate	mg/L	—	1,000	2.0	1.6	1.7
Aluminum	mg/L	—	5	0.049	0.03	0.05
Antimony	mg/L	0.006	—	0.0055	0.00078	0.00089
Arsenic	mg/L	0.01	0.025	0.0005	0.00049	0.0005
Boron	mg/L	5	0.5	0.0044	0.014	0.014
Cadmium	mg/L	0.005	0.0051	0.000014	0.000036	0.000037
Chromium	mg/L	0.05	0.0049	0.0003	0.00049	0.00052
Cobalt	mg/L	—	0.05	0.0001	0.00017	0.0002
Copper	mg/L	—	0.2	0.0022	0.0011	0.0011
Iron	mg/L	—	5	0.45	0.24	0.33
Lead	mg/L	0.01	0.1	0.0001	0.00029	0.0003
Manganese	mg/L	—	0.2	0.11	0.024	0.024
Mercury	mg/L	0.001	0.003	0.00001	0.000005	0.000005
Molybdenum	mg/L	—	0.01	0.0011	0.00037	0.00038
Nickel	mg/L	—	0.2	0.0009	0.00099	0.00099
Selenium	mg/L	0.01	0.02	0.0004	0.0005	0.0012
Silver	mg/L	—	0.071[c]	0.0002	0.000087	0.000088
Uranium	mg/L	0.02	0.01	0.00003	0.0022	0.0022
Zinc	mg/L	—	5	0.012	0.0052	0.0052

Notes:

— = Guideline not available.

n/a = Guideline not provided for U.S. EPA when available from Health Canada.

[a] Health Canada 2012. Guidelines for Canadian Drinking Water Quality Summary Table. August 2012. Only health-based guidelines are used for screening.

[b] Canadian Council of Ministers of the Environment 2012a. Water Quality Guidelines for the Protection of Agriculture Summary Table. The lowest of the livestock and irrigation guidelines were used for screening.

[c] U.S. EPA 2012c. Residential Tapwater Screening Levels. Mid-Atlantic Risk Assessment. Available at: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm. Accessed November 2012.

Table 4-24: Screening of Lizard Lake Water Quality against Regulatory Guidelines and Existing Concentrations

Parameter	Units	Health Canada[(a)]	CCME[(b)]	Lizard Lake	
				Existing Concentration	Predicted from Tailings Management Seepage
Un-ionized ammonia	mg/L	—	—	0.00029	0.000047
Calcium	mg/L	—	1,000	13	10
Chloride	mg/L	—	100	0.48	0.3
Magnesium	mg/L	—	—	1.1	0.9
Nitrate (N)	mg/L	45,000	100,000	0.058	0.034
Phosphorus	mg/L	—	—	0.012	0.0082
Potassium	mg/L	—	—	0.38	0.7
Sodium	mg/L	—	—	0.77	0.7
Sulphate	mg/L	—	1,000	2.8	1.9
Aluminum	mg/L	—	5	0.031	0.018
Antimony	mg/L	0.006	—	0.0001	0.001
Arsenic	mg/L	0.01	0.025	0.0011	0.00043
Boron	mg/L	5	0.5	0.055	0.011
Cadmium	mg/L	0.005	0.0051	0.0001	0.00003
Chromium	mg/L	0.05	0.0049	0.0011	0.00049
Cobalt	mg/L	—	0.05	0.000055	0.00012
Copper	mg/L	—	0.2	0.0016	0.0009
Iron	mg/L	—	5	0.097	0.053
Lead	mg/L	0.01	0.1	0.0011	0.00024
Manganese	mg/L	—	0.2	0.028	0.009
Mercury	mg/L	0.001	0.003	0.00001	0.000005
Molybdenum	mg/L	—	0.01	0.0011	0.0003
Nickel	mg/L	—	0.2	0.0022	0.0008
Selenium	mg/L	0.01	0.02	0.00055	0.0005
Silver	mg/L	—	0.071[(c)]	0.000055	0.0001
Uranium	mg/L	0.02	0.01	0.0055	0.0025
Zinc	mg/L	—	5	0.0095	0.0055

Notes:

— = Guideline not available.

n/a = Guideline not provided for U.S. EPA when available from Health Canada.

(a) Health Canada 2012. Guidelines for Canadian Drinking Water Quality Summary Table. August 2012. Only health-based guidelines are used for screening.

(b) Canadian Council of Ministers of the Environment 2012a. Water Quality Guidelines for the Protection of Agriculture Summary Table. The lowest of the livestock and irrigation guidelines were used for screening.

(c) U.S. EPA 2012c. Residential Tapwater Screening Levels. Mid-Atlantic Risk Assessment. Available at: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm. Accessed November 2012.

All of the predicted lake concentrations are below the drinking water guidelines and agricultural use guidelines. This means that there are no expected adverse health effects for the pit lake, Upper Marmion Reservoir and Lizard Lake for direct ingestion of substances in water or secondary ingestion following chemical transfer from water to plants or animals. Predicted concentrations for Upper Marmion Reservoir and Lizard Lake are similar to existing concentrations. There were no guidelines available for ammonia, ammonium, magnesium, phosphorus, potassium and sodium. As discussed in WHO (1998) and Health Canada (2012), drinking water guidelines have not been developed for these substances because there is no evidence of adverse health effects from the presence of these substances in drinking water. There are no expected adverse health effects based on the incidental ingestion of these substances in the lakes post-closure.

4.9 Additional Mitigation for Human Health

As identified in the Atmospheric Environment TSD, at the onset of construction several receptor locations (i.e., 10, 11, 17, 19, 23, 36, 37) will have restricted access. Potential human health effects were not evaluated for these locations under the assumption that access will be restricted.

4.10 Residual Effects for Human Health

The residual effects identified for human health are summarized below for each evaluation completed as part of the HHRA:

- Acute inhalation assessment: No residual effects.
- Chronic inhalation assessment: No residual effects.
- Noise assessment: Residual effects of noise with the potential for increased risk of hypertension or sleep disturbance. In the noise assessment, measures prescribed by Health Canada for assessing exposure to noise and potential human health effects were utilized. The % HA and HCII values for the Project are less than the targets prescribed by Health Canada. However, further literature review has shown that adverse effects such as sleep disturbance and hypertension may be associated with noise levels below the target levels. At receptor locations surrounding the Project, noise levels are within the ranges reported for increased risk of hypertension and sleep disturbance. The magnitude of effect for noise is considered to be low based on comparison to Health Canada targets and considering that predicted levels are in the lower end of ranges for hypertension effects. It is recommended that best management practices be implemented to minimize activities that may generate noise (e.g., mine and materials handling, vehicle movement), in particular close to the property boundaries adjacent to identified receptor locations. It is also recommended that, to the extent possible, noise be minimized at night in these areas as well, to reduce the potential for sleep disturbance.
- Particulate assessment: Residual effect of increased risk of cardiopulmonary effects due to inhalation of PM_{10} at one designated camping site and increased cancer risk for trappers at two trapper cabins.
- Multi-media assessment: No residual effects.
- Post-closure assessment: No residual effects.

Residual effects were evaluated using the assessment criteria identified in Section 4.1. The direction of all the residual effects is negative (i.e., decrease in health from existing conditions).

Table 4-25: Human Health Residual Effects Evaluation by Assessment Criteria

Assessment Criteria	Noise Effects		DPM Effects		PM_{10} Effects	
	Level	Rationale	Level	Rationale	Level	Rationale
Geographic Extent (of effect)	Low	Noise levels do not exceed Health Canada guidelines anywhere. However, noise levels are above other literature-based health thresholds in the RSA.	Low	Cancer risks above target levels were only predicted at two trapper cabin within the LSA	Low	PM_{10} concentrations above screening thresholds were only predicted at one designated camping site within the LSA
Frequency (of effect)	High	Noise is expected to be generated daily	Medium	Cancer risk is a result of long-term exposure	Low	Concentrations are below the screening threshold 95% of the time
Duration (of conditions causing effect)	High	Noise is expected during constructions, operations and closure	High	Diesel emissions may occur on a daily basis due to vehicle traffic within the MSA	High	Emissions of PM_{10} may occur on a daily basis due to activities within the MSA
Degree of Reversibility (of effect)	Medium	Effect on sleep disturbance is reversible once the Project is finished, while effect on hypertension, if it occurred, may continue beyond the life of the Project.	High	Cancer effects are irreversible	Medium	Cardiopulmonary effects may decrease once the Project is finished

Table 4-26: Magnitude Levels for Human Health Residual Effects

Noise Effects		DPM Effects		PM_{10} Effects	
Level	**Rationale**	**Level**	**Rationale**	**Level**	**Rationale**
Low	■ Predicted health measures are below Health Canada guidelines ■ Additional literature search identified potential noise effects at levels below guidelines ■ Assumed the receptors are subject to the predicted noise concentrations on a long-term basis	Low	■ The ILCR for both locations is 1.6 x 10^{-6} ■ DPM concentration based on maximum emissions modelled during operation phase and assumed to apply for the entire constructions, operations and closure phases ■ The ILCR exceeded the target cancer risk level at one location only ■ Assumed that trapper is exposed to the maximum annual DPM concentration for 8 hours per day, 105 days per year for 15.5 years	Low	■ The maximum predicted 24-hour concentration was within 10 µg/m^3 of the screening threshold ■ The PM10 concentration was only above the screening threshold at one receptor location ■ 95% of the time the PM10 concentration would be below the screening threshold at that receptor location

5.0 ECOLOGICAL HEALTH EFFECTS ASSESSMENT

This section evaluates the potential for adverse effects to ecological (including wildlife and aquatic life) health associated with changes in environmental quality due to chemical releases from the Project. Any potential adverse effects are assessed to determine whether they can be mitigated, and for effects that cannot be fully mitigated (residual effects), a determination of the significance of the effect is made. All residual effects are assessed for significance. Section 5.1 provides a description of effects assessment methods.

5.1 Effects Assessment Methods

This section provides the detailed methods of the effects assessment. The effects assessment comprises the following steps:

- Completion of an ecological risk assessment (ERA).
    - Ecological risk assessment is the primary tool used to characterize potential adverse effects, if any, to ecological (wildlife and aquatic life) health associated with changes in environmental quality due to chemical releases from the Project. Ecological risk assessment is endorsed by federal and provincial regulatory agencies as a valid method to evaluate potential adverse health effects associated with changes in environmental quality. The ERA is completed based on guidance provided by the Canadian Council of Ministers of the Environment (CCME 1996; 1997), the United States Environmental Protection Agency (U.S. EPA 1993; 1998) and other applicable risk assessment guidance documents (e.g., Sample and Suter 1994), and includes the four steps of risk assessment, namely problem formulation, exposure assessment, toxicity assessment, and risk characterization, as first described in Section 2.5.
- Evaluation of any adverse effects identified in the ERA in terms of the assessment criteria established for ecological health.
- Identification of suitable mitigation measures to reduce or eliminate the identified adverse effects.
- Assessment of whether adverse effects remain after mitigation (i.e., residual effects).
- For adverse effects that remain, determination of the significance of the effects. If it is uncertain whether an effect remains, it is forwarded for determination of significance.

The effects of the Project on ecological health are assessed through the following six criteria:

- Direction: the direction of the effect as positive or negative.
- Magnitude: the size or degree of the effect for a given substance.
- Geographic extent: the spatial area over which the effect may occur.
- Duration: the length of time over which the effect may occur.
- Frequency: the rate of recurrence of the effect (or conditions causing the effect).
- Reversibility: whether the effect may or may not be reversed.

In order to determine the significance of an effect, three levels are associated to each criterion: low, medium and high, as shown in Table 5-1. Significance levels are not assigned for direction, as the effect is either positive (i.e., health conditions improve compared to existing conditions) or negative (i.e., there is a decrease in health compared to existing conditions).

Table 5-1: Assessment Criteria and Levels for Determining Significance for Ecological Health

Assessment Criteria	**Level**		
Geographic Extent (of effect)	**Low**	**Medium**	**High**
	Effect is within the MSA	Effect extends into the Local Study Area	Effect extends into the Regional Study Area
Duration (of conditions causing effect)	**Low**	**Medium**	**High**
	Conditions causing effect are evident during the construction phase or closure phase	Conditions causing effect are evident during the operations phase	Conditions causing effect extend beyond any one phase
Frequency (of effect)	**Low**	**Medium**	**High**
	Conditions causing the effect to occur infrequently (i.e., several times per year)	Conditions causing the effect to occur at regular, although infrequent intervals (i.e., several times per month)	Conditions causing the effect to occur at regular and frequent intervals (i.e., daily or continuously)
Degree of Reversibility (of effect)	**Low**	**Medium**	**High**
	Effect is readily (i.e., immediately) reversible	Effect is reversible with time	Effect is not reversible (i.e., permanent)

Effect levels for magnitude specific to ecological health are shown in Table 5-2.

Table 5-2: Magnitude Levels for Ecological Health

Magnitude		
Low	**Medium**	**High**
1 < HQ ≤ 10	10 < HQ ≤ 100	HQ > 100

Notes:
HQ = Hazard quotient; represents the ratio of the predicted chemical exposure relative to its health-based benchmark.

5.2 Ecological Risk Assessment

5.2.1 Problem Formulation

The problem formulation identifies the substances released by the Project that may be harmful to wildlife and aquatic life (i.e., COPCs), the wildlife and aquatic life expected to occur within the RSA (i.e., receptors), and the plausible exposure pathways between wildlife and aquatic life and substances emitted by the Project. The potential for ecological health effects from substances emitted by the Project is predicated on the coexistence of these 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 emitted by the Project. The problem formulation focuses the ERA on the substances, receptors, and exposure pathways of greatest concern (i.e., substances with the greatest toxic potential, receptors with the greatest likelihood of being exposed and the greatest susceptibilities, and exposure pathways that account for the majority of exposure to the substances emitted by the Project). If no potential health effects are predicted for these substances, receptors, and exposure pathways, it is unlikely that there would be potential health effects for other substances, receptors, and exposure pathways. The information from the problem formulation is summarized in a CSM, which illustrates the sources of COPCs, the pathways of exposure, and the receptors that are evaluated in the ERA.

Potential adverse effects on ecological health can only occur where there is a direct link between a Project activity and chemical releases to the environment. Therefore, the ERA focused on those activities of the Project that could result in Project-related substance releases to the environment. These activities are described below:

- Particulate deposition to land (i.e., onto soil and vegetation) from air emissions and dust generation during operations. Wildlife could be exposed to substances by direct contact pathways with soil and indirectly through food consumption.
- Particulate deposition to surface water from air emissions and dust generation during operations. Wildlife and aquatic life could be exposed to substances by direct contact pathways with surface water. Wildlife could be exposed to substances indirectly through food consumption.
- Discharge of treated water from the Effluent Treatment Plant (ETP) to Upper Marmion Reservoir during operations. Wildlife and aquatic life could be exposed to substances by direct contact pathways with surface water and indirectly through food ingestion.
- Wildlife could be exposed to substances in water in the Tailings Management Facility (TMF) Reclaim Pond, where seepage and contact runoff will be collected during operations.
- Seepage of water from the Tailings Management Facility (TMF) to Lizard Lake during operations and post-closure. Wildlife and aquatic life could be exposed to substances by direct contact pathways with surface water and indirectly through food ingestion.
- Discharge of water from the former east and west pits upon flooding during post-closure to Upper Marmion Reservoir. Wildlife and aquatic life could be exposed to substances by direct contact pathways with surface water and indirectly through food ingestion.
- Runoff of water from the Site to Upper Marmion Reservoir during post-closure. Wildlife and aquatic life could be exposed to substances by direct contact pathways with surface water and indirectly through food ingestion.
- Wildlife and aquatic life could be exposed to substances in water in the pit lakes by direct contact pathways (ingestion) and via ingestion of contaminated food during post-closure.

5.2.1.1 Chemicals of Potential Concern (COPCs)

Substances may be emitted from the Project via airborne emissions and subsequent particulate (dust) deposition to soil, as well as via discharges to the aquatic environment. Airborne emissions include acid gases, VOCs, Polycyclic Aromatic Hydrocarbons (PAHs), and metals. Particulate deposition to soil includes PAHs and metals. Acid gases and VOCs remain airborne due to their high vapour pressures, preventing any local deposition onto soils. If they do deposit, they tend not to persist in soil, rapidly biodegrading and volatilizing to the atmosphere. Therefore, acid gases and VOCs were not assessed further in the ERA but rather the assessment focussed on those substances that may potentially deposit, including metals and PAHs. Discharges to the aquatic environment include metals only.

The following sections provide the detailed screening approaches used for the identification of COPCs in soil, surface water and pit lake water respectively, as well as the results of the chemical screening.

5.2.1.1.1 Soil

The existing soil quality for the Project is presented in the Geochemistry, Geology and Soils TSD. Existing soil metal data were collected during the April 2012 field program at 18 sample locations. The predicted concentrations of substances in soil were calculated as the sum of the incremental soil concentrations (ISCs) and the existing concentrations. Incremental soil concentrations were calculated using the modelling methods developed by the U.S. EPA (2005). Specifically, Equations 1 and 2 were used to calculate the ISCs of inorganic and organic substances, respectively.

$$ISC_{Inorganic\ Chemicals} = \frac{100 \times (Dyd + Dyw) \times tD}{Z_S \times BD} \qquad \mathbf{(1)}$$

Where:

ISC = Incremental Soil Concentration (mg/kg dw)
100 = Units Conversion Factor (mg-m^2/kg-cm^2)
Dyd = Dry Deposition Rate (g/m^2/y)
Dyw = Wet Deposition Rate (g/m^2/y)
tD = Deposition Time (y)
Z_s = Soil Mixing Depth (cm)
BD = Soil Bulk Density (g/cm^3)

$$ISC_{Organic\ Chemicals} = \frac{100 \times (Dyd + Dyw) \times [1 - exp(-ks \times tD)]}{Z_s \times BD \times ks} \qquad \mathbf{(2)}$$

Where:

ISC = Incremental Soil Concentration (mg/kg)
100 = Units Conversion Factor (mg-m^2/kg-cm^2)
Dyd = Dry Deposition Rate (g/m^2/y)
Dyw = Wet Deposition Rate (g/m^2/y)
tD = Deposition Time (y)
Z_s = Soil Mixing Depth (cm)
BD = Soil Bulk Density (g/cm^3)
ks = Soil Loss Constant (y^{-1})

A detailed description of the particulate deposition modelling used to determine the dry and wet deposition rates is provided in the Atmospheric Environment TSD. In brief, the modelled deposition rates represent a maximum scenario from any phase of the Project (i.e., construction, operations, closure and post-closure). The wet and dry deposition rates were modelled for a 1 km × 1 km grid for the LSA and a 5 km × 5 km grid for the RSA.

Deposition onto soil was assumed to occur throughout the construction, operations and closure phases of the Project (i.e., a maximum of 15.5 years was assumed). Atmospheric emissions are not expected during the post-closure phase. All substances deposited onto soil were assumed to mix within the top 2 cm of soil. Soil was assumed to have a bulk density of 1.5 g/cm^3. The soil loss constant (for calculation of the ISCs for PAHs) represents the loss constant due to all processes, including soil erosion, surface runoff, leaching, volatilization, and biotic and abiotic degradation. The processes of soil erosion, surface runoff and leaching can transfer substances both onto and off the MSA; thus, loss constants for these processes were set at zero. Only non-volatile substances were assumed to deposit to soil; as such, the loss constant due to volatilization was also set to zero. Loss constants for biotic and abiotic degradation have been measured in field studies, and the loss constants recommended by the U.S. EPA (2005) were applied in this calculation. The soil loss constants for degradation for each of the modelled PAHs are shown in Appendix 4.I, Table 1. Because all other loss constants have been set to zero, the soil loss constant is equal to the degradation loss constant.

An ISC was calculated at the location of the maximum dry/wet deposition rate of all modelled locations. The calculated ISCs were added to the maximum measured existing soil concentrations (all measured existing concentrations can be found in the Geochemistry, Geology and Soils TSD) to obtain the predicted soil concentrations for each chemical (Appendix 4.I, Table 2). There are no measured existing soil concentrations for PAHs; however, deposition rates were obtained for these chemicals. The predicted soil concentrations of these substances were calculated as the sums of one-half the typical method detection limit (the typical method detection limit is 0.05 mg/kg) and the ISCs.

Chemicals of potential concern in soil were identified using a three-tiered screening approach. In the first tier of screening, the predicted concentrations in soil were compared to soil quality standards. Concentrations were compared to the Ontario Ministry of the Environment (MOE) Table 1 Full Depth Background Site Condition Standards for Soil for Agricultural or Other Property Use (MOE 2011). If a Table 1 Standard was not available for a chemical, the Ontario Typical Range (OTR_{98}) of Chemical Parameters in Soil (MOE 2011) was used as the standard. The OTR_{98} values are the 97.5th percentile concentrations of substances from a database of surface soils in Ontario that are not contaminated by point sources, and are the basis for the Table 1 Standards. The Table 1 Site Condition Standards (SCS) and the OTR_{98} values represent background concentrations across the Province of Ontario. Comparison to standards was considered to represent a conservative evaluation of the potential for the predicted concentrations to elicit adverse effects. Therefore, substances with predicted concentrations that were below standards were considered to pose no risk to wildlife (mammal and bird) health and were not identified as COPCs. If the predicted concentration was greater than standards, the chemical was carried forward to the next tier of the screening process. Likewise, substances that lacked standards were carried forward to the next tier of the screening process.

A second tier screening was conducted by comparing the predicted concentrations in soil to the maximum measured existing concentrations plus 10% (Appendix 4.I, Table 3). The second tier screening included only those substances that were above standards, or for which standards are not available, as determined through the first tier of screening. Comparison to maximum measured existing concentrations plus 10% was considered to represent a conservative evaluation of whether a measurable Project-related impact on soil quality will occur. Given spatial and temporal variability, field sampling variability, variability in laboratory methods, and the conservatism applied in the deposition modelling, any predicted increase of less than 10% above existing concentrations was considered unlikely to reflect a considerable change in environmental quality as a result of the Project.

During the third tier of screening, substances with predicted concentrations higher than the MOE Table 1 Standards and OTR_{98} values (for substances without Table 1 Standards) and maximum measured existing concentrations plus 10% were compared to the CCME Canadian Soil Quality Guidelines for the Protection of Environmental Health (SQG_Es) for agricultural land use (CCME 2012b, internet site) (Appendix 4.I, Table 3). Comparison to the CCME SQG_Es was considered appropriate because the Table 1 Standards and OTR_{98} values represent background concentrations and are not related to ecological health, whereas the CCME SQG_Es are based on ecological health effects. If the predicted concentration was greater than the guideline, the chemical was identified as a COPC and carried forward in the ERA.

Predicted concentrations of copper, molybdenum, nickel and silver are greater than the Table 1 Standards, however, predicted concentrations are lower than the maximum measured existing concentrations plus 10% (Appendix 4.I, Table 3). The predicted concentration of naphthalene is greater than the Table 1 Standard and the maximum measured existing concentration plus 10%, however the concentration is lower than the SQG_E. There are no Table 1 Standards for bismuth, lithium, tin, yttrium and thiophene; however, predicted concentrations are lower than the maximum measured existing concentrations plus 10%. There is no Table 1 Standard for sodium and the predicted concentration is higher than the maximum measured existing concentration. Sodium is ubiquitous in soil, essential and non-toxic. Furthermore, the predicted concentration (1525 mg/kg) is within the range of background soil concentrations measured in Ontario (approximately 25 to 1600 mg/kg) (MOEE 1994a). As a result, no COPCs were identified in soil for further assessment in the ERA.

5.2.1.1.2 Surface Water

The existing water quality for the Project is presented in the Water and Sediment Quality TSD. The existing water quality monitoring program included five sampling events from September 2010 to June 2011. Sample locations were chosen to characterize the existing environment at locations upstream and downstream of the Project.

Chemicals of potential concern in surface water were identified using a three-tiered approach. In the first tier of screening, the maximum predicted concentrations in surface water were compared to water quality objectives (Appendix 4.I, Tables 4, 5, 6 and 7). For both wildlife and aquatic life, concentrations were compared to Provincial Water Quality Objectives (PWQOs) (MOEE 1994b). While these objectives are intended to be protective of aquatic life, it is considered that they are also protective of wildlife. Objectives for protection of aquatic life are typically much lower than guidelines for wildlife ingestion/livestock watering. Comparison to objectives was considered to represent a conservative evaluation of the potential for the predicted concentrations to elicit adverse effects. Therefore, substances with predicted concentrations that were below objectives were considered to pose no risk to wildlife and aquatic health and were not identified as COPCs. If the predicted concentration was greater than the objective, the chemical was carried forward to the next tier of the screening process. Likewise, substances that lacked objectives were carried forward to the next tier of the screening process.

A second tier screening was conducted by comparing the maximum predicted concentrations in surface water to the maximum measured existing concentrations plus 10% (Appendix 4.I, Tables 4, 5, 6 and 7). This tier of screening was completed for all predictions with the exceptions of those for the TMF Reclaim Pond and the pit lake, for which existing water quality data are not available. If the predicted concentration was greater than the maximum measured existing concentration plus 10%, the chemical was carried forward to the next tier of the screening process. Water quality samples from Sawbill Bay and Lynxhead Bay (HRWQP-2 and HRWQP-7) were used to characterize existing conditions in Upper Marmion Reservoir (the Water and Sediment Quality TSD provides the sampling locations). Water quality samples from HRWQP-3 were used to characterize existing conditions for Lizard Lake (the Water and Sediment Quality TSD provides the sampling locations). The second tier screening included only those substances that were above objectives, or for which objectives are not available, as determined through the first tier of screening.

During the third tier of screening, the maximum predicted concentrations in surface water were compared to guidelines available from other jurisdictions (e.g., British Columbia Ministry of Environment [BCMOE]) or to site-specific water quality objectives (SSWQOs), if required.

Upper Marmion Reservoir – Effluent Discharge during Operations

To address discharge of treated water from the ETP to Upper Marmion Reservoir during operations, predictive modelling was carried out for Upper Marmion Reservoir (Lake Water Quality TSD). The predicted discharge also includes the contribution of accommodation camp discharge (Site Water Quality TSD). All of the water quality predictions (see below) incorporate aerial deposition of chemicals, which was modelled and presented in the Lake Water Quality TSD. The incremental change in predicted water quality concentrations as a result of aerial deposition was negligible.

The highest water concentrations are predicted for Basin 6, which is located adjacent to the discharge point at the south end of Sawbill Bay. Several scenarios were modelled, including scenarios based on steady state and maximum predicted reclaim water and average and maximum mixing conditions. The water quality predictions for the upper-bound scenario (maximum predicted reclaim tank water and maximum mixing) were used to determine COPCs in Upper Marmion Reservoir from effluent discharge during operations.

There are no PWQOs for nitrate, calcium, chloride, chromium, magnesium, manganese, sodium, hardness and tin; however, predicted concentrations are lower than or equivalent to the maximum measured existing concentrations plus 10% (Appendix 4.I, Table 4). There are no PWQOs for potassium, sulphate, total cyanide, ammonia, barium and strontium and predicted concentrations are greater than the maximum measured existing concentrations. The screening of substances included elimination of essential elements that are fundamentally non-toxic substances, such as potassium. Furthermore, major ions such as potassium can effectively reduce metal toxicity in aquatic biota through competitive interactions at uptake sites. As such, an increase in the concentration of this parameter above existing would not necessarily constitute a potential adverse effect but would serve to ameliorate metal toxicity to aquatic biota. In addition, the British Columbia Ministry of Environment (BCMOE) provides a working water quality guideline for potassium of 373 to 432 mg/L (as potassium chloride) (BCMOE 2012a, internet site). This equates to a guideline of 194 to 225 mg/L as potassium. The guideline is based on a threshold for immobilization of *Daphnia magna*. The predicted concentration of potassium (551 µg/L or 0.551 mg/L) is well below the BCMOE guideline of 194 to 225 mg/L. As such, potassium was not retained as a COPC in the ERA.

The BCMOE derived a chronic water quality guideline for sulphate for the protection of freshwater aquatic life of 100 mg/L for dissolved sulphate (as SO_4), which represents a maximum concentration that should not be exceeded at any time (BCMOE 2012b, internet site). A guideline value of 50 mg/L for dissolved sulphate (as SO_4) is also provided as an “alert” level because some aquatic mosses appear to be particularly sensitive to the toxic effects of dissolved sulphate. A concentration of 100 mg/L was toxic to the aquatic moss, *Fontinalis antipyretica*. Toxicity ranged from 100 to >250 mg/L for four other species of aquatic moss. The BCMOE recommends that when dissolved sulphate concentrations exceed 50 mg/L, the health of aquatic mosses should be monitored. The predicted concentration of sulphate (3261 ug/L or 3.261 mg/L) is well below the BCMOE guideline of 50 mg/L. The predicted concentration of sulphate is also well below the Minnesota water quality standard of 10 mg/L for the protection of wild rice (Minnesota Pollution Control Agency 2012, internet site). As such, sulphate was not retained as a COPC in the ERA.

Free cyanide is the most toxicologically relevant to aquatic life so cyanide has been considered further with respect to the free cyanide concentration, and not the total cyanide concentration (see below).

The predicted concentration of ammonia is less than the most conservative CCME guideline for the protection of aquatic life for total ammonia-N for the existing pH and temperature measurements available for Upper Marmion Reservoir of 1.27 mg/L as N (CCME 2012c, internet site). As such, ammonia was not retained as a COPC in the ERA.

The BCMOE (2012a, internet site) provides a working water quality guideline for barium for freshwater aquatic life of 1000 µg/L. The predicted concentration of barium of 7.2 µg/L is well below the BCMOE guideline and this parameter was not retained as a COPC in the ERA.

The Quebec Ministry of Environment adopted a chronic benchmark for strontium of 21,000 µg/L (MDDEP 2012, internet site). This benchmark is the same as that adopted by the US states of Michigan and Ohio. The predicted concentration of strontium of 18 µg/L is below the benchmark of 21,000 µg/L.

The predicted concentration of free cyanide is greater than the PWQO and maximum existing concentration plus 10%. The PWQO is consistent with the current CCME Canadian Water Quality Guideline for the Protection of Aquatic Life (developed in 1987; CCME 2012c, internet site) and the current BCMOE guideline (developed in 1986; BCMOE 2012c, internet site). The PWQO is also consistent with the current United States Environmental Protection Agency (U.S. EPA) ambient water quality criterion (developed in 1984; U.S. EPA 2012d, internet site). In 2007, the Water Environment Research Foundation (WERF) completed a scientific review and evaluation of the current U.S. EPA criterion (WERF 2007). Two criteria were generated: one that considers all aquatic species for which there are data; and a second that excludes salmonids, which are the most sensitive group of aquatic organisms to free cyanide. The criteria calculated were 4.8 µg/L (considering all species) and 9.8 µg/L (excluding salmonids). Salmonids have not been captured in the LSA (Aquatic Environment TSD). The species included in the dataset used to calculate the criterion excluding salmonids included yellow perch, bluegill, black crappie and stickleback. Yellow perch and stickleback have been identified in the Project area (Aquatic Environment TSD). Bluegill and black crappie have not been identified in the Project area but other cyprinids (e.g., fathead minnow) and centrarchids (smallmouth bass and pumpkinseed) have been identified in the Project area. Following salmonids, yellow perch is the most sensitive species to free cyanide. The maximum predicted surface water concentration was compared to the criterion of 9.8 µg/L. This was considered appropriate given the fish species identified in the Project area and that the criterion is based on more complete and recent datasets than the PWQO. Furthermore, the criterion was developed using a species sensitivity distribution (SSD)-type approach. The CCME has used an SSD approach to develop the CWQGs for the protection of aquatic life for some substances, including boron, chloride and uranium (CCME 2009; CCME 2011a; CCME 2011b). The CCME (2007) recommends using this approach to develop other CWQGs and to develop SSWQOs. The predicted concentration of free cyanide is above the SSWQO under upper-bound conditions but the predicted concentration is below the SSWQO under average conditions (Appendix 4.I, Table 4). Under average conditions no adverse effects are expected on any of the species present in Upper Marion Reservoir. Potential adverse effects may occur for some species during predicted upper-bound conditions in Sawbill Bay when the SSWQO is exceeded (predicted concentrations ranged up to 0.016 mg/L at the south end of

Sawbill Bay an up to 0.012 mg/L at the Raft Lake Dam). A review of cyanide toxicity data (recent data have been summarized in WERF 2007) provides chronic thresholds for warm water fish species and invertebrates. No effect concentrations (NOECs) for fathead minnow and bluegill were reported as 0.016 mg/L and 0.009 mg/L, while lowest effect levels (LOECs) for these same species were reported as 0.02 mg/L. Invertebrates appeared to be less sensitive, with reported NOECs and LOECs for amphipods of 0.016 and 0.021 mg/L, respectively. Reported NOECs and LOECs for isopods (*Asellus* sp.) were 0.029 and 0.04 mg/L, respectively. As a result, predicted worst case concentrations of free cyanide are not expected to have adverse effects on aquatic life. Furthermore, as noted in Chapter 5, there is no predicted discharge during dry years, which represents the modelled upper-bound conditions (i.e., highest concentrations during lowest water levels). Since lowest water levels would occur only during dry years, it is unlikely that the predicted worst case condition would actually occur, since during dry years all excess water would be re-used and there would be no discharge. As such, free cyanide was not identified as a COPC for further assessment in the ERA.

The predicted concentration of copper is above the PWQO. Since the development of the PWQO for copper in 1994, there have been a number of advances in the understanding of copper toxicity and the factors that influence toxicity in surface waters. While hardness, and specifically calcium and magnesium ions, plays an important role in mitigating the toxicity of copper to aquatic organisms, other water quality parameters also influence toxicity [e.g., dissolved organic carbon (DOC)]. In recognition of this, the U.S. EPA recently revised the aquatic life ambient freshwater criteria for copper (U.S. EPA 2007). In the revision, a Biotic Ligand Model (BLM)-based approach was used in place of the formerly applied hardness-based approach to calculate the water quality criteria for copper. The BLM approach offers a vast improvement over the hardness-based approach because in addition to water hardness, it incorporates the protective effects of other water chemistry 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). The BLM generates acute and chronic criteria (criterion maximum concentration [CMC] and criterion continuous concentration [CCC], respectively); the chronic criterion is calculated from the acute criterion using an acute-to-chronic ratio (ACR).

The BLM was used to derive an SSWQO for copper in Upper Marmion Reservoir. In brief, measured existing water quality data for Lynxhead Bay and Sawbill Bay were used in the model (Appendix 4.II, Table 1). Existing data were used because water quality predictions are not available for all parameters required to run the BLM. This is considered to be a conservative approach because the concentrations of most water quality parameters are predicted to increase with the Project, resulting in lower copper toxicity.

The fifth percentile of the BLM-derived chronic criteria were calculated for Upper Marmion Reservoir (Appendix 4.II, Table 2), and this value (7.9 µg/L) was used as the SSWQO in the assessment. The predicted concentration of copper was below the SSWQO (Appendix 4.I, Table 4). As such, copper was not identified as a COPC for further assessment in the ERA.

Predicted concentrations of all other parameters were lower than the PWQOs. As a result, no COPCs were identified in Upper Marmion Reservoir for further assessment for effluent discharge during operations.

Tailings Management Facility Reclaim Pond

For the TMF Reclaim Pond, there are no PWQOs for nitrate, ammonia, barium, calcium, chloride, potassium, magnesium, manganese, sodium, sulphate, strontium, tin and cyanide (Appendix 4.I, Table 5). Predicted concentrations of nitrate, barium, manganese, strontium, tin and cyanide are below guidelines or toxicological benchmarks that are considered protective of wildlife health (Sample et al. 1996; BCMOE 2012d, internet site). Alkalinity, calcium, magnesium, potassium and sodium were eliminated as COPCs for the same reasons described above for Upper Marmion Reservoir (no direct impact on wildlife health, essential nutrients, ameliorate metal toxicity). The predicted concentration of chloride is less than the CCME CWQG for freshwater aquatic life. The BCMOE derived a chronic water quality guideline for sulphate for the protection of freshwater aquatic life of 100 mg/L for dissolved sulphate (as SO_4), which represents a maximum concentration that should not be exceeded at any time (BCMOE 2012b, internet site). A guideline value of 50 mg/L for dissolved sulphate (as SO_4) is also provided as an “alert” level. The guidelines are based on a study by Frahm (1975; as cited in BCMOE 2012b, internet site) that investigated the effect of sulphate concentrations on the aquatic moss, *Fontinalis antipyretica*. A concentration of 100 mg/L SO_4 was toxic to the aquatic moss *F. antipyretica*. Davies (2007) demonstrated that *F. antipyretica* is much more tolerant to sulphate than indicated in the current BCMOE water quality guideline. Depending on water hardness, no effect concentrations for growth ranged upwards from 200 mg/L SO_4 (added as sodium sulphate (Na_2SO_4)). Davies (2007) indicated that the toxicity reported by Frahm (1975; as cited in BCMOE 2012b, internet site) was likely to be from the associated potassium ion (sulphate was added as potassium sulphate (K_2SO_4) in the Frahm (1975) study) rather than the sulphate ion. Based on the work of Davies (2007), a toxicity benchmark of 200 mg/L for sulphate is considered appropriate for the current assessment. The predicted concentration of sulphate is below this benchmark. No toxicity data for ammonia is available for wildlife, although some short-term toxicity data is available for laboratory animals. No effect or less serious low effect dose levels range from about 20 to 3000 mg/kg/d. These dose levels would be associated with a drinking water concentration orders of magnitude greater than the predicted concentration. Wildlife would have to consume upwards of thousands of litres of water per day to be potentially toxic. Therefore, ammonia was eliminated as a COPC.

Predicted concentrations of cobalt, copper, molybdenum and uranium are above the PWQOs but are below guidelines or toxicological benchmarks that are considered protective of wildlife health (Sample et al. 1996; BCMOE 2012d, internet site).

Predicted concentrations of all other parameters were lower than the PWQOs. As a result, no COPCs were identified in the TMF Reclaim Pond for further assessment for wildlife.

Lizard Lake - Seepage from TMF during Operations and Post-closure

Water quality predictions were carried out for Lizard Lake based on predicted TMF seepage at steady state and at maximum, along with either average or maximum mixing conditions for Lizard Lake during operations (Lake Water Quality TSD). The water quality predictions for the upper-bound scenario (maximum seepage and maximum mixing) were used to determine COPCs in Lizard Lake from seepage during operations.

There are no PWQOs for calcium, chloride, magnesium, potassium, sodium, sulphate, hardness, total cyanide, nitrate and ammonia. Predicted concentrations of calcium, magnesium, hardness and nitrate are lower than the maximum measured existing concentrations plus 10% (Appendix 4.I, Table 6). The predicted concentrations of chloride and ammonia are less than the CCME guidelines for aquatic life (CCME 2012c, internet site). Free cyanide is the most toxicologically relevant to aquatic life so cyanide has been considered further with respect to the free cyanide concentration, and not the total cyanide concentration. The predicted concentration of free cyanide is below the PWQO. The predicted concentration of sulphate is less than the BCMOE guideline of 50 mg/L (BCMOE 2012b, internet site). Potassium and cyanide are essential nutrients and ameliorate metal toxicity. Predicted concentrations for all other parameters were lower than the PWQOs. As a result, no COPCs were identified for further assessment in Lizard Lake for seepage from the TMF during operations.

Water quality predictions were also carried out for Lizard Lake based on predicted TMF seepage for Lizard Lake during post-closure (Lake Water Quality TSD). There are no PWQOs for calcium, chloride, magnesium, potassium, sodium, sulphate, hardness, nitrate and manganese; however, predicted concentrations are lower than the maximum measured existing concentrations plus 10% (Appendix 4.I, Table 7). Predicted concentrations for all other parameters were lower than the PWQOs. As a result, no COPCs were identified for further assessment in Lizard Lake for seepage from the TMF during post-closure.

Upper Marmion Reservoir – Pit Lake Discharge during Post-closure

To address the discharge of water from the former east and west pits upon flooding to Upper Marmion Reservoir during post-closure, predictive modelling was carried out for Upper Marmion Reservoir as detailed in the Lake Water Quality TSD.

There are no PWQOs for calcium, chloride, magnesium, potassium, sodium, sulphate, hardness, nitrate and manganese; however, predicted concentrations are lower than maximum measured existing concentrations plus 10% (Appendix 4.I, Table 8). Predicted concentrations for all other parameters were lower than the PWQOs. As a result, no COPCs were identified for further assessment in Upper Marmion Reservoir for the pit lake discharge during post-closure.

Upper Marmion Reservoir – Site Runoff during Post-closure

To address runoff of water from the Site to Upper Marmion Reservoir during post-closure, predictive modelling was carried out for Upper Marmion Reservoir as detailed in the Lake Water Quality TSD.

There are no PWQOs for calcium, chloride, magnesium, potassium, sodium, sulphate, hardness, nitrate and manganese; however, predicted concentrations are lower than the average measured existing concentrations (Appendix 4.I, Table 9). The predicted concentration of iron is above the PWQO but below the maximum existing concentration plus 10%. As a result, no COPCs were identified for further assessment in Marmion Reservoir for site runoff during post-closure.

Pit Lake Water

Predictive modelling was carried out to determine the water quality of the pit lakes. The water quality modelling for the pit lakes is presented in the Site Water Quality TSD. In brief, two scenarios were modelled for the East Pit and West Pit: (1) assuming no diversion of water from the Tailings Management Facility to the pit lake and (2) assuming diversion of water from the Tailings Management Facility to the pit lake. Results for both a stratified (top of pit) and mixed condition are presented.

Chemicals of potential concern in pit lake water were identified using a two-tiered approach. In the first tier of screening, the highest predicted concentrations of the two modelled scenarios for the stratified condition were compared to PWQOs (Appendix 4.I, Table 10). The results for the stratified condition were used because this is the expected steady state condition of the pit lake. Comparison to objectives was considered to represent a conservative evaluation of the potential for the predicted concentrations to elicit adverse effects. Therefore, substances with predicted concentrations that were below objectives were considered to pose no risk to wildlife and aquatic health and were not identified as COPCs. If the predicted concentration was greater than the objective, the substance was carried forward to the next tier of the screening process. Likewise substances that lacked objectives were carried forward to the next tier of the screening process.

A second tier of screening was conducted by comparing predicted concentrations to guidelines available from other jurisdictions (e.g., CCME and BCMOE) and considering other factors including the general toxicity of substances (Appendix 4.I, Table 10).

Predicted concentrations are below PWQOs for all substances with objectives. There are no PWQOs for nitrate, ammonium, calcium, chloride, potassium, magnesium, sodium and sulphate. Predicted concentrations of nitrate and chloride are below the CCME guidelines of 3 mg NO_3-N/L and 120,000 µg/L, respectively (CCME 2012c, internet site). The predicted concentration of ammonium is less than the most conservative CCME guideline for total ammonia-N for the predicted pH range for pit lake water quality of 1.9 mg/L. In the predicted pH range for pit lake water quality, most of the total ammonia present will be in the form of the ammonium ion (U.S. EPA 1999). Calcium, potassium, magnesium and sodium are essential substances and non-toxic. Predicted concentrations of sulphate are below the BCMOE guideline of 50,000 µg/L and the Minnesota guideline of 10,000 µg/L (see discussion related to the BCMOE and Minnesota guidelines in Section 5.2.1.2). As such, nitrate, ammonium, calcium, chloride, potassium, magnesium, sodium and sulphate have not been identified as COPCs in the ERA. As a result, no COPCs were identified for further assessment in pit lake water.

As discussed previously, three conditions must be present for there to be a potential for adverse ecological health effects from substances released from the Project: 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 released by the Project. There were no COPCs identified in soil, surface water (Upper Marmion Reservoir, Lizard Lake, or pit lake water) for further evaluation in the ERA. As such, the ERA did not proceed beyond the chemical screening stage of the problem formulation. This indicates that adverse ecological health effects as a result of the Project are not expected.

5.3 Assessment of Ecological Effects

There were no COPCs identified in soil or surface water for further evaluation in the ERA. As such, the ERA did not proceed beyond the chemical screening stage of the problem formulation. This indicates that adverse effects to ecological health as a result of the Project are not expected. For this reason, evaluation of the identified effects in terms of the assessment criteria established for ecological health (Tables 4.1-1 and 4.1-2) is not required.

5.4 Additional Mitigation for Ecological Health

Adverse effects to ecological health as a result of the Project are not expected, therefore, no additional mitigation measures are required for ecological health.

5.5 Residual Effects for Ecological Health

Adverse effects to ecological health as a result of the Project are not expected, therefore, an assessment of residual effects for ecological health was not completed.

5.6 Significance of Residual Effects for Ecological Health

Adverse effects to ecological health as a result of the Project are not expected, therefore, an assessment of residual effects and the significance of residual effects for ecological health was not completed.

6.0 REQUIREMENTS OF THE MONITORING PROGRAM

There is no monitoring recommended for directly evaluating human and ecological health. Any monitoring requirements for the atmospheric environment and water quality disciplines will support the continuing assessment of health. The SSWQO for copper was derived using the BLM and existing water quality in the Project area. The SSWQO should be verified and updated as necessary by continued monitoring of water quality over the life of the Project. The water quality parameters required to run the BLM, and that should be included in the water quality monitoring effort, include: temperature, pH, DOC, major cations (calcium, magnesium, sodium and potassium), major anions (sulfate and chloride), and alkalinity.

7.0 SUMMARY OF FINDINGS

Human health and ecological assessments were carried out for the Project following a risk assessment approach. The human health assessment included an evaluation of acute inhalation, chronic inhalation, noise, particulate matter and multi-media exposure. Selected VECs for human health were an off-duty worker, trapper, recreational user, member of Aboriginal community and community resident. There were no residual health effects identified for acute inhalation, chronic inhalation or multi-media exposure. Residual effects of low magnitude were identified as follows:

- Noise assessment: Residual effects of noise with the potential for increased risk of hypertension or sleep disturbance. In the noise assessment, measures prescribed by Health Canada for assessing exposure to noise and potential human health effects were utilized. The % HA and HCII values for the Project are less than the targets prescribed by Health Canada. However, further literature review has shown that adverse effects such as sleep disturbance and hypertension may be associated with noise levels below the target levels. At receptor locations surrounding the Project, noise levels are within the ranges reported for increased risk of hypertension and sleep disturbance. The magnitude of effect for noise is considered to be low based on comparison to Health Canada targets and considering that predicted levels are in the lower end of ranges for hypertension effects. It is recommended that best management practices be implemented to minimize activities that may generate noise (e.g., mine and materials handling, vehicle movement) in particular close to the property boundaries adjacent to identified receptor locations. It is also recommended that, to the extent possible, noise be minimized at night in these areas as well, to reduce the potential for sleep disturbance.
- Particulate assessment: Residual effect of increased risk of cardiopulmonary effects due to inhalation of PM_{10} at one designated camping site and increased cancer risk for trappers at one receptor location.

The ecological assessment included an evaluation of multi-media exposure for selected VECs. The chemical screening process, including predictions of soil and water quality and comparison to existing conditions and ecological screening guidelines, did not identify any chemicals of concern that would be relevant for ecological exposure. Therefore, no residual effects on ecological VECs were identified.

No monitoring specifically for human and ecological health is recommended, however any monitoring required as part of the atmospheric and water quality evaluations could be used for on-going evaluations of health. The mitigation measures as outlined in the Atmospheric Environment TSD with regards to restricted access at selected receptor locations are required to remain in place for the protection of human health at these receptor locations.

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9.0 GLOSSARY OF TERMS

Table 9-1: Glossary of Terms

Definition	Term
HQ	Hazard Quotient; represents the target ratio of the predicted chemical exposure relative to its health-based benchmarks.
ILCR	Incremental Lifetime Cancer Risk represents additional or extra risk of developing cancer due to exposure to a chemical incurred over the lifetime of an individual.
NOx	Nitrogen oxides, the sum of nitrogen dioxide and nitric oxide
PM_{10}	Particulate matter less than 10 microns in diameter
$PM_{2.5}$	Particulate matter less than 2.5 microns in diameter

10.0 LIST OF ABBREVIATIONS, ACRONYMS AND INITIALISMS

Table 10-1: List of Abbreviations, Acronyms and Initialisms

Acronym	Definition
% HA	% highly annoyed by increased noise levels caused by projects
AAQC	Ambient Air Quality Criteria
ACR	Acute-to-chronic ratio
AEUB	Alberta Energy and Utilities Board
ANSI	American National Standards Institute
AT	Averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
BCMOE	British Columbia Ministry of Environment
BD	Bulk density
BLM	Biotic Ligand Model
BW	Body weight
CalEPA	California Environmental Protection Agency
CCC	Criterion Continuous Concentration
CCME	Canadian Council of Ministers of the Environment
CEA Agency	Canadian Environmental Assessment Agency
CMC	Criterion Maximum Concentration
CO	Carbon monoxide
COPC	Chemicals of potential concern
CSM	Conceptual Site Model
CWQGs	Canadian Water Quality Guidelines
DL	Detection limit
DPM	Diesel Particulate Matter
DOC	Dissolved organic carbon
Dyd	Dry deposition rate
Dyw	Wet deposition rate
EIS/EA Report	Hammond Reef Gold Project Environmental Impact Statement/Environmental Assessment Report
ED	Exposure duration
EDI	Estimated daily intake
EF	Exposure frequency
EIS Guidelines	Environmental Impact Statement Guidelines
ERA	Ecological risk assessment
ESL	Effects Screening Level
ET	Exposure time
ETP	Effluent treatment plant
FRA	United States Federal Railroad Administration

Table 10-1: List of Abbreviations, Acronyms and Initialisms (Continued)

Acronym	Definition
FTA	United States Federal Transit Administration
HCII	Impulse noise indicator
HHRA	Human health risk assessment
HQ	Hazard quotient
IARC	International Agency for Cancer Research
ILCR	Incremental lifetime cancer risks
IR	Inhalation rate
ISC	Incremental Soil Concentration
ISO	International Organization for Standardization
K_2SO_4	Potassium sulphate
Ks	Soil loss constant
Ld	Daytime average sound level
Leq24	Whole day equivalent noise level
LHIN	Local Health Integration Network
Ln	Nighttime average sound level
LOAEL	Lowest Observed Adverse Effect Levels
LOEC	Lowest Observed Effect Concentration
LSA	Local study area
MOE	Ontario Ministry of the Environment
MRL	Minimal Risk Level
MSA	Mine Study Area
NAAQOs	National Ambient Air Quality Objectives
Na_2SO_4	Sodium sulphate
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_3	Nitrate
NOAEL	No Observed Adverse Effect Levels
NOEC	No Observed Effect Concentration
OEHHA	California Office of Environmental Health Hazard Assessment
OHRG	Osisko Hammond Reef Gold Ltd.
OTR_{98}	Ontario Typical Range
PAHs	Polycyclic Aromatic Hydrocarbons
PM	Particulate Matter
PWQO	Provincial Water Quality Objectives
RA	Risk assessment
REL	Reference Exposure Level
RfC	Reference concentration
RSA	Regional study area
SCS	Site Condition Standards

Table 10-1: List of Abbreviations, Acronyms and Initialisms (Continued)

Acronym	Definition
SO_2	Sulphur dioxide
SO_4	Sulphate
SQG_E	CCME Canadian Soil Quality Guideline for the Protection of Environmental Health
SSD	Species sensitivity distribution
SSWQO	Site-specific water quality objective
TCEQ	Texas Commission on Environmental Quality
tD	Deposition time
TMF	Tailings Management Facility
ToR	Terms of Reference
TRV	Toxicity Reference Values
TSD	Technical support document
TSP	Total Suspended Particulate Matter
UF	Uncertainty Factor
UR	Unit Risk
U.S. EPA	United States Environmental Protection Agency
U.S. EPA IRIS	United States Environmental Protection Agency Integrated Risk Information System
VEC	Valued ecosystem component
VOCs	Volatile organic compounds
WERF	Water Environment Research Foundation
WHO	World Health Organization
Zs	Soil mixing depth

11.0 LIST OF UNITS

Table 11-1: List of Units

Abbreviation	Unit
cm	centimetre
m^3/h	cubic metres per hour
d/y	days per year
dB	decibels
°C	degrees Celsius
g	grams
g/cm^3	grams per cubic centimetre
g/m^3	grams per cubic metre
g/m^2/y	grams per square metre per year
h/d	hours per day
kg	kilogram
kg/m^3	kilograms per cubic metre
km	kilometre
m	metre
µg/m^3	micrograms per cubic metre
µg/L	micrograms per litre
m^3/h	Cubic metres per hour
mg	milligrams
mg/L	Milligrams per litre
mg/m^3	milligrams per cubic metre
mg/kg	milligrams per kilogram
mg/kg/d	milligrams per kilogram per day
mm	millimetre
%	percent
km^2	square kilometres
y	year

APPENDIX 2.I

Supplemental Baseline Vegetation, Soil and Sediment Quality Results

TABLE 1
Cattail and Sediment Quality Results

	Sample Location	HR–CAT–01		HR–CAT–02		HR–CAT–02 Field Duplicate	S5B		S9B		S19B	
	Sample Date	26/06/2012	26/06/2012	27/06/2012	27/06/2012	27-Jun-12	26/06/2012	26/06/2012	26/06/2012	26/06/2012	28/06/2012	28/06/2012
	Media	Sediment	Vegetation	Sediment	Vegetation	Vegetation	Sediment	Vegetation	Sediment	Vegetation	Sediment	Vegetation
	Species	—	Cattail (*Typha latifolia*)	—	Cattail (*Typha latifolia*)	Cattail (*Typha latifolia*)	—	Cattail (*Typha latifolia*)	—	Cattail (*Typha latifolia*)	—	Cattail (*Typha latifolia*)
Parameter	**Units**											
Free Cyanide	µg/g	0.04	—	0.02	—	—	0.48	—	0.09	—	0.62	—
Moisture	%	76	—	58	—	—	94	—	89	—	94	—
Metals												
Acid Extractable Aluminum (Al)	µg/g	3900	47.3	6100	130	29.4	2800	127	6900	451	1100	40.2
Acid Extractable Antimony (Sb)	µg/g	<0.20	<0.05	<0.20	<0.05	<0.05	<0.20	<0.05	<0.20	<0.05	<0.20	<0.05
Acid Extractable Arsenic (As)	µg/g	1.8	<0.1	1.4	<0.1	<0.1	2.0	<0.1	2.6	0.2	1.8	<0.1
Acid Extractable Barium (Ba)	µg/g	37	1.3	38	1.8	1.3	65	4.3	83	5.4	62	4.2
Acid Extractable Beryllium (Be)	µg/g	<0.20	<0.05	<0.20	<0.05	<0.05	<0.20	<0.05	0.30	<0.05	<0.20	<0.05
Bismuth (Bi)	µg/g	—	<0.05	—	<0.05	<0.05	—	<0.05	—	<0.05	—	<0.05
Boron (B)	µg/g	—	0.9	—	1.1	0.9	—	0.8	—	0.7	—	0.6
Acid Extractable Cadmium (Cd)	µg/g	0.22	<0.01	0.14	<0.01	<0.01	0.59	0.02	0.38	0.03	0.18	<0.01
Acid Extractable Calcium (Ca)	µg/g	8100	1580	5300	2090	1980	11000	926	25000	1600	7400	644
Acid Extractable Chromium (Cr)	µg/g	8.0	<0.3	18	<0.3	<0.3	1.8	<0.3	5.9	0.5	1.3	<0.3
Acid Extractable Cobalt (Co)	µg/g	1.9	0.034	5.3	0.064	0.020	2.6	0.306	1.6	0.189	1.4	0.143
Acid Extractable Copper (Cu)	µg/g	13	<0.5	17	1.0	0.9	16	0.6	22	1.4	8.4	<0.5
Acid Extractable Iron (Fe)	µg/g	5100	54	11000	123	75	3600	355	5200	868	4600	382
Acid Extractable Lead (Pb)	µg/g	9.5	0.07	8.2	0.05	0.03	13	0.35	6.3	0.54	6.0	0.17
Acid Extractable Magnesium (Mg)	µg/g	910	246	3600	246	167	1200	245	840	165	1200	216
Acid Extractable Manganese (Mn)	µg/g	180	37.5	120	18.3	15.4	40	11.4	93	17.5	85	9.8
Acid Extractable Molybdenum (Mo)	µg/g	<0.50	<0.05	<0.50	<0.05	<0.05	<0.50	<0.05	0.77	0.08	<0.50	<0.05
Acid Extractable Nickel (Ni)	µg/g	5.4	0.05	14	0.15	0.06	3.9	0.24	6.5	0.40	3.0	0.12
Acid Extractable Phosphorus (P)	µg/g	370	184	470	312	207	610	146	920	170	650	110
Acid Extractable Potassium (K)	µg/g	<200	2540	530	4590	3650	330	1010	<200	1270	480	1210
Acid Extractable Selenium (Se)	µg/g	0.56	<0.2	<0.50	<0.2	<0.2	0.59	<0.2	1.2	<0.2	<0.50	<0.2
Acid Extractable Silver (Ag)	µg/g	<0.20	<0.05	<0.20	<0.05	<0.05	<0.20	<0.05	<0.20	<0.05	<0.20	<0.05
Acid Extractable Sodium (Na)	µg/g	<100	712	200	191	231	120	189	110	187	120	166
Acid Extractable Strontium (Sr)	µg/g	19	2.6	9.7	2.4	2.0	50	4.7	95	6.5	38	3.5
Acid Extractable Thallium (Tl)	µg/g	<0.050	0.013	0.055	<0.003	<0.003	0.053	0.003	<0.050	0.015	<0.050	<0.003
Tin (Sn)	µg/g	—	<0.3	—	<0.3	<0.3	—	<0.3	—	<0.3	—	<0.3
Titanium (Ti)	µg/g	—	3.6	—	8.2	1.8	—	2.2	—	8.6	—	0.7
Uranium (U)	µg/g	—	0.020	—	0.015	0.014	—	0.025	—	0.167	—	0.020
Acid Extractable Vanadium (V)	µg/g	14	0.10	25	0.30	0.08	8.6	0.30	11	0.70	<5.0	0.06
Acid Extractable Zinc (Zn)	µg/g	20	4	34	6	7	37	5	16	2	23	3
Acid Extractable Mercury (Hg)	µg/g	0.070	<0.01	<0.050	<0.01	<0.01	0.11	<0.01	0.19	0.01	0.082	<0.01

Notes:

<0.5	Parameter not detected above the method detection limit.
— =	Parameter not analyzed.
	Concentrations are reported on a dry weight basis

TABLE 2
Labrador Tea and Soil Quality Results

Sample Location		S5C		S22B		S6B		HR–LAB–01	HR–LAB–01 Field Duplicate	HR–LAB–03
Sample Date		28/06/2012	28/06/2012	28/06/2012	28/06/2012	26/06/2012	26/06/2012	26/06/2012	26/06/2012	27/06/2012
Media		Soil	Vegetation	Soil	Vegetation	Soil	Vegetation	Vegetation	Vegetation	Vegetation
Species			Labrador Tea (*Ledum groenlandicum*)		Labrador Tea *(Ledum groenlandicum)*		Labrador Tea *(Ledum groenlandicum)*	Labrador Tea *(Ledum groenlandicum)*	Labrador Tea *(Ledum groenlandicum)*	Labrador Tea *(Ledum groenlandicum*)
Parameter	**Units**									
Moisture	%	83	—	52	—	69	—	—	—	—
Metals										
Acid Extractable Aluminum (Al)	µg/g	480	18.6	6300	24.5	2600	63.8	11.0	8.4	17.9
Acid Extractable Antimony (Sb)	µg/g	0.34	<0.05	0.40	<0.05	0.32	<0.05	<0.05	<0.05	<0.05
Acid Extractable Arsenic (As)	µg/g	2.2	<0.1	6.3	<0.1	4.4	<0.1	<0.1	<0.1	<0.1
Acid Extractable Barium (Ba)	µg/g	28	22.0	63	34.3	48	29.3	22.7	17.5	18.2
Acid Extractable Beryllium (Be)	µg/g	<0.20	<0.05	<0.20	<0.05	<0.20	<0.05	<0.05	<0.05	<0.05
Bismuth (Bi)	µg/g	—	<0.05	—	<0.05	—	<0.05	<0.05	0.08	<0.05
Boron (B)	µg/g	—	5.5	—	7.3	—	6.5	5.1	4.4	5.5
Acid Extractable Cadmium (Cd)	µg/g	0.22	<0.01	0.30	<0.01	0.34	<0.01	<0.01	<0.01	<0.01
Acid Extractable Calcium (Ca)	µg/g	4100	1710	1700	2260	2300	1800	1570	1580	1750
Acid Extractable Chromium (Cr)	µg/g	<1.0	<0.3	8.8	<0.3	4.0	0.3	<0.3	<0.3	<0.3
Acid Extractable Cobalt (Co)	µg/g	0.50	0.011	1.9	0.013	1.3	0.054	<0.005	0.005	0.017
Acid Extractable Copper (Cu)	µg/g	10	1.8	7.3	2.4	6.6	2.3	2.2	2.2	2.2
Acid Extractable Iron (Fe)	µg/g	1200	27	9400	29	4000	88	16	16	26
Acid Extractable Lead (Pb)	µg/g	3.5	<0.03	27	<0.03	27	0.04	<0.03	0.07	<0.03
Acid Extractable Magnesium (Mg)	µg/g	890	492	1000	602	730	558	501	418	447
Acid Extractable Manganese (Mn)	µg/g	31	139	74	187	73	126	171	171	172
Acid Extractable Molybdenum (Mo)	µg/g	<0.50	<0.05	—	<0.05	<0.50	<0.05	<0.05	<0.05	<0.05
Acid Extractable Nickel (Ni)	µg/g	1.1	0.20	4.8	0.44	3.1	0.28	0.13	0.20	0.33
Acid Extractable Phosphorus (P)	µg/g	330	485	490	599	550	479	584	543	496
Acid Extractable Potassium (K)	µg/g	640	3210	460	3560	470	3110	3200	3300	3030
Acid Extractable Selenium (Se)	µg/g	<0.50	<0.2	0.63	<0.2	<0.50	<0.2	<0.2	<0.2	<0.2
Acid Extractable Silver (Ag)	µg/g	<0.20	<0.05	<0.20	<0.05	<0.20	<0.05	<0.05	<0.05	<0.05
Acid Extractable Sodium (Na)	µg/g	<100	<50	<100	<50	<100	<50	<50	<50	<50
Acid Extractable Strontium (Sr)	µg/g	17	2.5	11	5.3	15	4.0	2.0	2.0	3.0
Acid Extractable Thallium (Tl)	µg/g	<0.050	<0.003	<0.050	<0.003	<0.050	<0.003	<0.003	<0.003	<0.003
Tin (Sn)	µg/g	—	<0.3	—	<0.3	—	<0.3	<0.3	<0.3	<0.3
Titanium (Ti)	µg/g	—	1.5	—	0.7	—	5.0	<0.5	<0.5	0.9
Uranium (U)	µg/g	—	<0.005	—	<0.005	—	<0.005	<0.005	<0.005	<0.005
Acid Extractable Vanadium (V)	µg/g	<5.0	<0.05	23	<0.05	9.7	0.18	<0.05	<0.05	<0.05
Acid Extractable Zinc (Zn)	µg/g	29	10	32	13	22	8	7	8	8
Acid Extractable Mercury (Hg)	µg/g	0.077	<0.01	0.29	0.01	0.19	<0.01	<0.01	<0.01	<0.01

Notes:

<0.5 Parameter not detected above the method detection limit.
— = Parameter not analyzed.
Concentrations are reported on a dry weight basis

TABLE 3
Cranberry Quality Results

Sample Location		**HRBERRY 2**	**HRBERRY 2**	**HRBERRY 2**	**HRBERRY 3**	**HRBERRY 3**	**HRBERRY 3**	**HRBERRY 4**	**HRBERRY 4**	**HRBERRY 4**
Sample ID		**HRBERRY 2 REP 1**	**HRBERRY 2 REP 2**	**HRBERRY 2 REP 3**	**HRBERRY 3 REP 1**	**HRBERRY 3 REP 2**	**HRBERRY 3 REP 3**	**HRBERRY 4 REP 1**	**HRBERRY 4 REP 2**	**HRBERRY 4 REP 3**
Sample Date		**14/09/2011**	**14/09/2011**	**14/09/2011**	**15/09/2011**	**15/09/2011**	**15/09/2011**	**16/09/2011**	**16/09/2011**	**16/09/2011**
Species		**Cranberry *(Vaccinium oxycoccos)***	**Cranberry *(Vaccinium oxycoccos)***	**Cranberry *(Vaccinium oxycoccos)***	**Cranberry *(Vaccinium oxycoccos)***	**Cranberry *(Vaccinium oxycoccos)***	**Cranberry *(Vaccinium oxycoccos)***	**Cranberry *(Vaccinium oxycoccos)***	**Cranberry *(Vaccinium oxycoccos)***	**Cranberry *(Vaccinium oxycoccos)***
Parameter	**Units**									
Metals										
Aluminum (Al)	µg/g	0.6	0.6	0.7	0.4	0.5	0.4	1.3	0.6	0.8
Antimony (Sb)	µg/g	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Arsenic (As)	µg/g	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Barium (Ba)	µg/g	1.9	1.8	1.6	1.3	1.7	1.7	1.5	1.0	1.4
Beryllium (Be)	µg/g	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Bismuth (Bi)	µg/g	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Boron (B)	µg/g	1.0	0.9	1.0	0.7	0.8	0.6	0.9	0.8	0.9
Cadmium (Cd)	µg/g	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Calcium (Ca)	µg/g	179	164	136	124	158	153	143	106	134
Chromium (Cr)	µg/g	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Cobalt (Co)	µg/g	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Copper (Cu)	µg/g	1.0	0.7	1.0	1.1	0.8	1.2	1.4	1.0	1.0
Iron (Fe)	µg/g	<3	<3	<3	3	<3	<3	4	4	<3
Lead (Pb)	µg/g	<0.03	<0.03	0.04	<0.03	<0.03	<0.03	0.05	<0.03	<0.03
Magnesium (Mg)	µg/g	<100	<100	<100	<100	<100	<100	105	<100	<100
Manganese (Mn)	µg/g	30.8	28.5	25.5	27.2	31.7	28.3	18.7	13.1	16.0
Molybdenum (Mo)	µg/g	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nickel (Ni)	µg/g	0.06	0.05	0.06	<0.05	<0.05	<0.05	0.12	0.18	0.09
Phosphorus (P)	µg/g	141	124	131	103	107	65	148	130	102
Potassium (K)	µg/g	965	963	974	786	797	760	1040	884	906
Selenium (Se)	µg/g	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Silver (Ag)	µg/g	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Sodium (Na)	µg/g	<50	<50	<50	<50	<50	<50	<50	<50	<50
Strontium (Sr)	µg/g	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Thallium (Tl)	µg/g	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Tin (Sn)	µg/g	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Titanium (Ti)	µg/g	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Uranium (U)	µg/g	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Vanadium (V)	µg/g	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Zinc (Zn)	µg/g	3	<2	<2	4	2	3	3	2	<2
Mercury (Hg)	µg/g	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

TABLE 3
Cranberry Quality Results

Sample Location		HRBERRY 2	HRBERRY 2	HRBERRY 2	HRBERRY 3	HRBERRY 3	HRBERRY 3	HRBERRY 4	HRBERRY 4	HRBERRY 4
Sample ID		**HRBERRY 2 REP 1**	**HRBERRY 2 REP 2**	**HRBERRY 2 REP 3**	**HRBERRY 3 REP 1**	**HRBERRY 3 REP 2**	**HRBERRY 3 REP 3**	**HRBERRY 4 REP 1**	**HRBERRY 4 REP 2**	**HRBERRY 4 REP 3**
Sample Date		**14/09/2011**	**14/09/2011**	**14/09/2011**	**15/09/2011**	**15/09/2011**	**15/09/2011**	**16/09/2011**	**16/09/2011**	**16/09/2011**
Species		**Cranberry *(Vaccinium oxycoccos)***	**Cranberry *(Vaccinium oxycoccos)***	**Cranberry *(Vaccinium oxycoccos)***	**Cranberry *(Vaccinium oxycoccos)***	**Cranberry *(Vaccinium oxycoccos)***	**Cranberry *(Vaccinium oxycoccos)***	**Cranberry *(Vaccinium oxycoccos)***	**Cranberry *(Vaccinium oxycoccos)***	**Cranberry *(Vaccinium oxycoccos)***
Parameter	**Units**									
Polyaromatic Hydrocarbons										
Acenaphthene	µg/g	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Acenaphthylene	µg/g	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Anthracene	µg/g	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Benzo(a)anthracene	µg/g	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Benzo(a)pyrene	µg/g	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Benzo(b/j)fluoranthene	µg/g	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Benzo(g,h,i)perylene	µg/g	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzo(k)fluoranthene	µg/g	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chrysene	µg/g	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dibenz(a,h)anthracene	µg/g	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.3	<0.2
Fluoranthene	µg/g	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fluorene	µg/g	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Indeno(1,2,3-cd)pyrene	µg/g	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
1-Methylnaphthalene	µg/g	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
2-Methylnaphthalene	µg/g	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Naphthalene	µg/g	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phenanthrene	µg/g	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Pyrene	µg/g	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Notes:

<0.5	Parameter not detected above the method detection limit.
	Concentrations are reported on a dry weight basis.

TABLE 4
Blueberry and Sediment Quality Results

Sample Location		**MBERRY1**		**BERRY2**		**MBERRY3**		**MBERRY4–1**		**MBERRY4–1 Field Duplicate**		**220**		**BLUE 225**	
Sample ID		**MBERRY1**	**MBERRY1**	**BERRY2**	**BERRY2**	**MBERRY3**	**MBERRY3**	**MBERRY4–1**	**MBERRY 4–1**	**MBERRY 4–2**	**MBERRY 4–2**	**220**	**BLUEBERRY SAMPLE 220**	**BLUE 225**	**BLUE 225**
Media		**Soil**	**Vegetation**	**Soil**	**Vegetation**	**Soil**	**Vegetation**	**Soil**	**Vegetation**	**Soil**	**Vegetation**	**Soil**	**Vegetation**	**Soil**	**Vegetation**
Date Sampled		**05/08/2012**		**06/08/2012**		**07/08/2012**		**07/08/2012**		**07/08/2012**		**07/08/2012**		**07/08/2012**	
Species		**–**	**Blueberry *(Vaccinium myrtilloides)***	**–**	**Blueberry *(Vaccinium myrtilloides)***	**–**	**Blueberry *(Vaccinium myrtilloides)***	**–**	**Blueberry *(Vaccinium myrtilloides)***	**–**	**Blueberry *(Vaccinium myrtilloides)***	**–**	**Blueberry *(Vaccinium myrtilloides)***	**–**	**Blueberry *(Vaccinium myrtilloides)***
Parameters	**Units**														
% Moisture	%	26	82.1	74	81.8	30	83.1	23	80.6	22	80.8	11	81.7	24	79.0
Metals															
Aluminum (Al)	µg/g	—	1.9	—	3.3	—	2.9	—	2.4	—	2.2	—	3.5	—	5.4
Antimony (Sb)	µg/g	<0.20	<0.05	0.28	<0.05	<0.20	<0.05	<0.20	<0.05	<0.20	<0.05	<0.20	<0.05	<0.20	<0.05
Arsenic (As)	µg/g	<1.0	<0.1	4.3	<0.1	<1.0	<0.1	1.5	<0.1	<1.0	<0.1	2.4	<0.1	2.6	<0.1
Barium (Ba)	µg/g	26	2.4	78	3.8	24	4.0	21	4.2	12	3.9	30	4.2	47	7.0
Beryllium (Be)	µg/g	<0.20	<0.05	<0.20	<0.05	<0.20	<0.05	<0.20	<0.05	<0.20	<0.05	<0.20	<0.05	<0.20	<0.05
Bismuth (Bi)	µg/g	—	<0.05	—	<0.05	—	<0.05	—	<0.05	—	<0.05	—	<0.05	—	<0.05
Boron (B)	µg/g	<5.0	1.0	<5.0	1.5	<5.0	1.8	<5.0	1.4	<5.0	1.3	<5.0	1.8	<5.0	1.9
Cadmium (Cd)	µg/g	0.17	<0.01	0.9	<0.01	0.15	<0.01	<0.10	<0.01	<0.10	<0.01	<0.10	<0.01	0.18	<0.01
Calcium (Ca)	µg/g	—	208	—	351	—	348	—	354	—	376	—	332	—	602
Chromium (Cr)	µg/g	4	<0.3	1.5	<0.3	8.3	<0.3	8.5	<0.3	16	<0.3	9.1	<0.3	4.9	<0.3
Cobalt (Co)	µg/g	0.61	<0.005	1	<0.005	0.67	<0.005	0.92	<0.005	1.7	0.007	1.4	<0.005	4.9	0.015
Copper (Cu)	µg/g	3.5	0.9	16	1.0	6.1	1.2	4.6	1.0	4.2	1.0	5.2	0.9	79	1.2
Iron (Fe)	µg/g	—	4	—	4	—	4	—	3	—	5	—	4	—	6
Lead (Pb)	µg/g	6.3	<0.03	24	<0.03	9.5	<0.03	9.2	<0.03	5.7	<0.03	7.7	<0.03	13	<0.03
Magnesium (Mg)	µg/g	—	<100	—	151	—	152	—	154	—	147	—	128	—	191
Manganese (Mn)	µg/g	—	66.0	—	54.2	—	80.5	—	62.2	—	63.3	—	106	—	125
Mercury (Hg)	µg/g	<0.050	<0.01	0.25	<0.01	<0.050	<0.01	<0.050	<0.01	<0.050	<0.01	<0.050	<0.01	0.061	<0.01
Molybdenum (Mo)	µg/g	<0.50	<0.05	0.5	<0.05	0.57	<0.05	1.5	<0.05	<0.50	<0.05	0.88	<0.05	2.2	<0.05
Nickel (Ni)	µg/g	1.3	0.12	3.3	0.16	2.4	0.23	2.2	0.21	8.1	0.20	3.7	0.18	4.7	0.25
Phosphorus	µg/g	—	134	—	187	—	171	—	186	—	172	—	173	—	362
Potassium (K)	µg/g	—	991	—	1080	—	1120	—	945	—	919	—	941	—	1300
Selenium (Se)	µg/g	<0.50	<0.2	0.74	<0.2	<0.50	<0.2	<0.50	<0.2	<0.50	<0.2	<0.50	<0.2	<0.50	<0.2
Silver (Ag)	µg/g	<0.20	<0.05	<0.20	<0.05	<0.20	<0.05	<0.20	<0.05	<0.20	<0.05	<0.20	<0.05	0.24	<0.05
Sodium (Na)	µg/g	—	<50	—	<50	—	<50	—	<50	—	<50	—	<50	—	<50
Strontium (Sr)	µg/g	—	<0.5	—	<0.5	—	<0.5	—	0.5	—	0.5	—	0.6	—	0.9
Thallium (Tl)	µg/g	<0.050	<0.003	<0.050	<0.003	<0.050	<0.003	<0.050	<0.003	<0.050	<0.003	<0.050	0.003	0.059	<0.003
Tin (Sn)	µg/g	—	<0.3	—	<0.3	—	<0.3	—	<0.3	—	<0.3	—	<0.3	—	<0.3
Titanium (Ti)	µg/g	—	<0.5	—	<0.5	—	<0.5	—	<0.5	—	<0.5	—	<0.5	—	<0.5
Uranium (U)	µg/g	0.12	<0.005	0.18	<0.005	0.3	<0.005	0.21	<0.005	0.29	<0.005	0.3	<0.005	0.28	<0.005
Vanadium (V)	µg/g	17	<0.05	<5.0	<0.05	29	<0.05	46	<0.05	26	<0.05	31	<0.05	18	<0.05
Zinc (Zn)	µg/g	7.4	<2	35	2	12	2	8.2	<2	8.2	<2	8.2	<2	26	2

Notes:

<0.5	Parameter not detected above the method detection limit.
— =	Parameter not analyzed.
	Concentrations are reported on a dry weight basis

APPENDIX 3.I

Supporting Tables for Human Health Inhalation Assessment

TABLE 1
Acute Inhalation 1-Hour Thresholds

Parameter	MOE(a)	CCME NAAQO[b]		ATSDR[c]	California EPA[d]	WHO[e][f]	TCEQ[g]	Toxicological Endpoints and Derivations
		Desirable	Acceptable					
Acid Gases								
Sulfur dioxide (SO_2)	690	450	900	**26**	660	500[a]	—	MOE - health and vegetation; CCME - health and environment; ATSDR - A minimal LOAEL of 0.1 ppm for bronchoconstriction in excercising asthmatics. An uncertainty factor of 9 was applied. CalEPA - A consensus value from several studies; WHO - Changes in pulmonary function and respiratory symptoms.
Carbon monoxide (CO) - 1 hour	36,200	**15,000**	35,000	—	23,000	30,000	—	MOE - health; CCME - health and environment; CalEPA - Effects of angina in individuals with known cardiovascular disease that are exercising heavily; WHO - Considering physiological variables affecting carbon monoxide uptake, threshold determined so that carboxyhaemoglobin level of 2.5% is not exceeded even during light or moderate exercise.
CO - 8 hour	15,700	**6000**	15000	—	—	10,000	—	MOE - health; CCME - health and environment; WHO - Based on COHb levels. To protect non-smoking, middle-aged and elderly populations with documented or latent heart diseases, and fetuses of non-smoking pregnant women from untoward hypoxic effects, a COHb level of 2.5% should not be exceeded.
Nitrogen oxides (NO_x)	—	—	—	—	—	—	—	—
Nitrogen dioxide	400	—	400	—	470	**200**	—	MOE - Health; CCME - health and environment; CalEPA - Increased airway reactivity in asthmatics; WHO - Based on an increase in bronchial responsiveness in asthmatics.
Volatile Organic Compounds								
1,3-butadiene	—	—	—	**220**	—	—	—	ATSDR - Based on a LOAEL of 40 ppm for reduced male fetal body weight gain from exposed pregnant mice. The LOAEL was adjusted for intermittent exposure (6 h/day), resulting in adjusted LOAEL of 10 ppm. An uncertainty factor of 90 was applied.
acetaldehyde	500[i]	—	—	—	**470**	—	—	MOE - health; CalEPA - Based on a LOAEL from a human study. The critical effects of the study were sensory irritation in bronchi, eyes, nose and throat.
acetone	—	—	—	—	—	—	**5,900**	TCEQ - health
acrolein	**4.5**	—	—	—	—	—	—	MOE: health
aldehyde (surrogate acetaldehyde)	500[i]	—	—	—	**470**	—	—	MOE - health; CalEPA - Based on a LOAEL from a human study. The critical effects of the study were sensory irritation in bronchi, eyes, nose and throat.
benzene	—	—	—	**29**	—	—	—	ATSDR - Based on a LOAEL of 10.2 ppm for reduced lymphocyte proliferation following mitogen stimulation in mice. The concentration was adjusted for intermittent exposure to derive a LOAEL of 2.55 ppm, and then was converted to a human equivalent concentration according to the EPA method. An uncertainty factor of 300 was applied (10 for using a LOAEL, 3 for extrapolation from animals to humans, and 10 for human variability).
ethylbenzene	1,900	—	—	**27680**	—	—	—	MOE - odour, not selected in favour of the ATSDR health-based value; ATSDR - Based on damage to auditory capacity of rats. A human equivalency concentration of 154 ppm was selected and an uncertainty factor of 30 was applied.
ethylene	—	—	—	—	—	—	**170,000**	TCEQ - health
formaldehyde	—	—	—	**49**	—	100[b]	—	ATSDR - Based on a LOAEL of 0.4 ppm for nasal and eye irritation, an uncertainty factor of 9 was applied. WHO - Based on the lowest concentration that has been associated with nose and throat irritation in humans. This concentration would also be associated with negligible risk of upper respiratory tract cancer in humans.
ketone (surrogate methyl ethyl ketone)	—	—	—	—	**13,000**	—	—	CalEPA - Based on the LOAEL for eye, nose and throat irritation in humans. An uncertainty factor of 60 was applied; 6 for use of a LOAEL and 10 for sensitive individuals.
thiophenes (surrogate dibenzothiophene)	—	—	—	—	—	—	**25**	TCEQ - health
toluene	—	—	—	**3770**	37,000	1,000	—	ATSDR - Based on a NOAEL of 40 ppm for neurological effects. The 40 ppm NOAEL was adjusted for a duration of 5 days per week and 8 hours per day and an uncertainty factor of 10 was applied, resulting in a threshold of 1 ppm (3800 $\mu g/m^3$). CalEPA - Based on a LOAEL for headaches, dizziness and slight eye and nose irritation in humans exposed for 6 hours. The LOAEL was extrapolated to represent 1 hour exposure and an uncertainty factor of 10 was applied for intraspecies differences. WHO - Based on an odour detection threshold, not selected in favour of the health-based values.
trimethylbenzene (surrogate 1,2,3-trimethylbenzene)	—	—	—	—	—	—	**1,250**	TCEQ - health
xylenes	3,000[h]	—	—	**8670**	22,000	—	—	MOE - Odour, not selected in favour of health-based values; ATSDR - Based on a minimal LOAEL for neurological and respiratory effects in humans exposed to m-xylene. An uncertainty factor of 30 was applied. The threshold is considered to be protective of exposure to mixed xylenes or individual isomers. CalEPA - Based on a LOAEL for eye, nose and throat irritation in humans exposed for 30 minutes. The LOAEL was extrapolated to 1 hour and an uncertainty factor of 10 was applied for intraspecies differences.

TABLE 1

Acute Inhalation 1-Hour Thresholds

Parameter	MOE(a)	CCME NAAQO(b)		ATSDR(c)	California EPA(d)	WHO(e)(f)	TCEQ(g)	Toxicological Endpoints and Derivations
		Desirable	Acceptable					
Metals								
Aluminum	—	—	—	—	—	—	**50**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Antimony	—	—	—	—	—	—	**5**	TCEQ - health
Arsenic	—	—	—	—	**0.2**	—	—	Cal OEHHA: Threshold based on development (teratogenicity), cardiovascular system, and nervous system effects in mice.
Barium	—	—	—	—	—	—	**5**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Beryllium	—	—	—	—	—	—	**0.02**	TCEQ - Threshold based on health for the particulate form of beryllium
Bismuth	—	—	—	—	—	—	**50**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Cadmium	—	—	—	**0.03**	—	—	—	ATSDR - Acute inhalation MRL was derived based on a LOAEL of 0.088 mg Cd/m^3 for inflammation and minimal fibrosis in alveolar septa in rats. The LOAEL was converted to a human equivalent concentration, and adjusted for duration of exposure. An uncertainty factor of 300 was applied (10 for using a LOAEL, 3 for extrapolation from animals to humans, and 10 for human variability).
Calcium	—	—	—	—	—	—	—	—
Chromium	—	—	—	—	—	—	**3.6**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction, for chromium metal
Cobalt	—	—	—	—	—	—	**0.2**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Copper	—	—	—	—	**100**	—	—	Cal EPA - Threshold based on respiratory system effects in humans
Iron	—	—	—	—	—	—	**10**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Lead	—	—	—	—	—	—	—	—
Lithium	—	—	—	—	—	—	—	—
Magnesium	—	—	—	—	—	—	**50**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Manganese	—	—	—	—	—	—	**2**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Molybdenum	—	—	—	—	—	—	**30**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Nickel	—	—	—	—	**0.2**	—	—	Cal EPA -Threshold based on immune system effects in mice;
Potassium	—	—	—	—	—	—	**20**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Selenium	—	—	—	—	—	—	**2**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Silver	—	—	—	—	—	—	**0.1**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Sodium	—	—	—	—	—	—	—	—
Strontium	—	—	—	—	—	—	**20**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Thallium	—	—	—	—	—	—	**1**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Tin	—	—	—	—	—	—	**20**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Titanium	—	—	—	—	—	—	**50**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Uranium	—	—	—	—	—	—	**0.5**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Vanadium	—	—	—	**0.8**	—	—	—	ATSDR -Acute inhalation MRL was derived based on a LOAEL of 0.56 mg V/m^3 for lung inflammation in rats. The LOAEL was converted to a human equivalent concentration of 0.073 mg V/m^3. An uncertainty factor of 90 was applied (3 for using a minimal LOAEL, 3 for extrapolation from animals to humans, and 10 for human variability).
Yttrium	—	—	—	—	—	—	**10**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Zinc	—	—	—	—	—	—	**20**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Petroleum Hydrocarbons								
C2-C6 aliphatic (surrogate n-butanol)	**2,100(h)**	—	—	—	—	—	—	MOE - odour
C6-C8 aliphatic (surrogate octane)	**61,800(h)**	—	—	—	—	—	—	MOE - odour
C8-C10 aliphatic (surrogate decane)	**60,000**	—	—	—	—	—	—	MOE - health
C8-C10 aromatic (surrogate propylbenzene)	—	—	—	—	—	—	**1,250**	TCEQ - health
C10-C12 aliphatic (surrogate dodecane)	—	—	—	—	—	—	**3,500**	TCEQ - health
C12-C16 aliphatic (surrogate tridecane)	—	—	—	—	—	—	**3,500**	TCEQ - health
C12-C16 aromatic (surrogate n-octyl benzene)	—	—	—	—	—	—	**1,250**	TCEQ - health
C16-C21 aliphatic (surrogate n-heptadecane)	—	—	—	—	—	—	**100**	TCEQ - health

TABLE 1

Acute Inhalation 1-Hour Thresholds

Parameter	MOE(a)	CCME NAAQO[b]		ATSDR[c]	California EPA[d]	WHO[e][f]	TCEQ[g]	Toxicological Endpoints and Derivations
		Desirable	Acceptable					
Polycyclic Aromatic Hydrocarbons								
acenaphthene	—	—	—	—	—	—	**1**	TCEQ - health
acenaphthylene	—	—	—	—	—	—	**1**	TCEQ - health
anthracene	—	—	—	—	—	—	**0.5**	TCEQ -health
benz(a)anthracene	—	—	—	—	—	—	**0.5**	TCEQ - health
benzo(a)pyrene	—	—	—	—	—	—	**0.03**	TCEQ - health
benzo(b)fluoranthene	—	—	—	—	—	—	**0.5**	TCEQ - health
benzo(g,h,i)perylene	—	—	—	—	—	—	**0.5**	TCEQ - health
benzo(k)fluoranthene	—	—	—	—	—	—	**0.5**	TCEQ - health
chrysene	—	—	—	—	—	—	**0.5**	TCEQ - health
dibenzo(a,h)anthracene	—	—	—	—	—	—	**0.5**	TCEQ - health
fluoranthene	—	—	—	—	—	—	**0.5**	TCEQ - health
fluorene	—	—	—	—	—	—	**10**	TCEQ - health
indeno(1,2,3-cd)pyrene	—	—	—	—	—	—	**0.5**	TCEQ - health
naphthalene	**50[h]**	—	—	—	—	—	—	MOE - odour
phenanthrene	—	—	—	—	—	—	**0.5**	TCEQ - health
pyrene	—	—	—	—	—	—	**0.5**	TCEQ - health
Other								
ammonia	—	—	—	**1,180**	3200	—	—	ATSDR - Based on a LOAEL of 50 ppm for mild irritation to the eyes, nose and throat in humans exposed to ammonia as a gas for 2 hours; CalEPA - Based on eye and respiratory irritation in a human study with an uncertainty factor of 3.
hydrogen cyanide	—	—	—	—	—	—	**20**	TCEQ - health
hydrogen chloride	—	—	—	—	—	—	**190**	TCEQ - health
sodium hydroxide	—	—	—	—	—	—	**20**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction

Notes:
All values are in µg/m^3.
LOAEL = Lowest Observed Adverse Effect Level.
NOAEL = No Observed Adverse Effect Level.
— = Value not available.
Shaded + Bold = Screening threshold selected for use in the assessment.

[a] Ontario Ministry of the Environment (MOE), Ontario's Ambient Air Quality Criteria. Standards Development Branch, MOE. (April 2012)

[b] Canadian Council of Ministers of the Environment (CCME), Canadian national ambient air quality objectives: Process and status. In: Canadian environmental quality guidelines (199

[c] Agency of Toxic Substances and Disease Registry (ATSDR), Minimum Risk Levels (MRLs), February 2012 and supporting toxicological profiles

[d] California Office of Environmental Health Hazard Assessment (CalEPA), Air Toxicology and Epidemiology. Acute, 8-hour and Chronic Reference Exposure Levels (Dec. 18, 2008

[e] World Health Organization (WHO), WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Global update 2005. Summary of risk assessment (2005

[f] World Health Organization (WHO), Air Quality Guidelines for Europe. Second Edition. WHO Regional Publications, European Series, No. 91 (2000

[g] Texas Commission on Environmental Quality (TCEQ) Effects Screening Levels (March 2012). Guideline was provided from TCEQ if values were not available from any of the other jurisdictions.

[h] 10 minutes.

[i] 30 minutes.

TABLE 2

Screening of Maximum Predicted Concentrations Against Selected Acute Inhalation 1-Hour Thresholds

Parameter	Selected 1-hour Screening Threshold (µg/m^3)	Maximum Predicted 1-hour Concentration (µg/m^3)	Retain for Acute Inhalation Assessment?
Acid Gases			
Sulfur dioxide (SO_2)	26	14	No
Carbon monoxide (CO) - 1-hour	15,000	899	No
CO - 8 hour	6000	502	No
Nitrogen oxides (NO_x)	—	1,015	No(a)
Nitrogen dioxide	200	180	No
Volatile Organic Compounds			
1,3-butadiene	220	0.09	No
acetaldehyde	470	13	No
acetone	5,900	6.7	No
acrolein	4.5	2.2	No
aldehyde (surrogate acetaldehyde)	470	17	No
benzene	29	0.8	No
ethylbenzene	27,680	0.14	No
ethylene	170,000	2.6	No
formaldehyde	49	6.7	No
ketone (surrogate methyl ethyl ketone)	13,000	3.8	No
thiophenes (surrogate dibenzothiophene)	25	0.0000037	No
toluene	3,770	1.2	No
trimethylbenzene (surrogate 1,2,3-trimethylbenzene)	1,250	0.34	No
xylenes	8,670	1.0	No

TABLE 2

Screening of Maximum Predicted Concentrations Against Selected Acute Inhalation 1-Hour Thresholds

Parameter	Selected 1-hour Screening Threshold (μg/m^3)	Maximum Predicted 1-hour Concentration (μg/m^3)	Retain for Acute Inhalation Assessment?
Metals			
Aluminum	50	15	No
Antimony	5	0.00005	No
Arsenic	0.2	0.0006	No
Barium	5	0.10	No
Beryllium	0.02	0.0002	No
Bismuth	50	0.00005	No
Cadmium	0.03	0.010	No
Calcium	—	5.5	No
Chromium	3.6	0.010	No
Cobalt	0.2	0.0021	No
Copper	100	0.0047	No
Iron	10	5.6	No
Lead	—	0.0063	No
Lithium	—	0.0016	No
Magnesium	50	1.5	No
Manganese	2	0.10	No
Molybdenum	30	0.0010	No
Nickel	0.2	0.0058	No
Potassium	20	5.1	No
Selenium	2	0.0003	No
Silver	0.1	0.0001	No
Sodium	—	4.6	No
Strontium	20	0.031	No
Thallium	1	0.0001	No
Tin	20	0.0003	No
Titanium	50	0.35	No
Uranium	0.5	0.0003	No
Vanadium	0.8	0.009	No
Yttrium	10	0.0014	No
Zinc	20	0.024	No

TABLE 2
Screening of Maximum Predicted Concentrations Against Selected Acute Inhalation 1-Hour Thresholds

Parameter	Selected 1-hour Screening Threshold (µg/m^3)	Maximum Predicted 1-hour Concentration (µg/m^3)	Retain for Acute Inhalation Assessment?
Petroleum Hydrocarbons			
C2-C6 aliphatic (surrogate n-butanol)	2,100$^{(b)}$	5.0	No
C6-C8 aliphatic (surrogate octane)	61,800$^{(b)}$	3.4	No
C8-C10 aliphatic (surrogate decane)	60,000	0.048	No
C8-C10 aromatic (surrogate propylbenzene)	1,250	0.27	No
C10-C12 aliphatic (surrogate dodecane)	3,500	0.18	No
C12-C16 aliphatic (surrogate tridecane)	3,500	1.1	No
C12-C16 aromatic (surrogate n-octyl benzene)	1,250	0.014	No
C16-C21 aliphatic (surrogate n-heptadecane)	100	1.1	No
Polycyclic Aromatic Hydrocarbons			
acenaphthene	1	0.00006	No
acenaphthylene	1	0.0002	No
anthracene	0.5	0.00007	No
benz(a)anthracene	0.5	0.00001	No
benzo(a)pyrene	0.03	0.00002	No
benzo(b)fluoranthene	0.5	0.00004	No
benzo(g,h,i)perylene	0.5	0.0000008	No
benzo(k)fluoranthene	0.5	0.000005	No
chrysene	0.5	0.00001	No
dibenzo(a,h)anthracene	0.5	0.00001	No
fluoranthene	0.5	0.0002	No
fluorene	10	0.0003	No
indeno(1,2,3-cd)pyrene	0.5	0.000008	No
naphthalene	50$^{(b)}$	0.0071	No
phenanthrene	0.5	0.0006	No
pyrene	0.5	0.0002	No

TABLE 2
Screening of Maximum Predicted Concentrations Against Selected Acute Inhalation 1-Hour Thresholds

Parameter	Selected 1-hour Screening Threshold (µg/m^3)	Maximum Predicted 1-hour Concentration (µg/m^3)	Retain for Acute Inhalation Assessment?
Other			
ammonia	1,180	16	No
hydrogen cyanide	20	7	No
hydrogen chloride	190	30	No
sodium hydroxide	20	7	No

Notes:
— = Value not available.

[a] Potential health effects for nitrogen oxides were evaluated based on nitrogen dioxide because in ambient air NO converts to NO_2 and NO_2 has adverse health effects at much lower concentrations than NO.

[b] 10 minutes.

TABLE 3
Chronic Inhalation 24-Hour Thresholds

Parameter	MOE(a)	CCME NAAQO(b)(c)		ATSDR[4]	WHO(d)(e)	Toxicological Endpoints and Derivations
		Desirable	Acceptable			
Acid Gases						
Sulfur dioxide (SO_2)	275	150	300	—	**125**	MOE - health and vegetation ; CCME - health and environment; WHO - lung function
Carbon monoxide (CO)	—	—	—	—	—	—
Nitrogen oxides (NO_x)	—	—	—	—	—	—
Nitrogen Dioxide	**200**	—	200	—	—	MOE - health; CCME - health and environment
Volatile Organic Compounds						
1,3-butadiene	**10**	—	—	—	—	MOE - health
acetaldehyde	**500**	—	—	—	—	MOE - health
acetone	**11,880**	—	—	—	—	MOE - health
acrolein	**0.40**	—	—	—	—	MOE - health
aldehyde (surrogate acetaldehyde)	**500**	—	—	—	—	MOE - health
benzene	**2.30**	—	—	—	—	MOE - health
ethylbenzene	**1,000**	—	—	—	—	MOE - health
ethylene	—	—	—	—	—	—
formaldehyde	**65**	—	—	—	—	MOE - health
ketone (surrogate methyl ethyl ketone)	**1,000**	—	—	—	—	MOE - health
thiophenes	—	—	—	—	—	—
toluene	**2,000**	—	—	—	—	MOE - odour
trimethylbenzene	**220**	—	—	—	—	MOE - health
xylenes	**730**	—	—	—	—	MOE - health

TABLE 3

Chronic Inhalation 24-Hour Thresholds

Parameter	MOE(a)	CCME NAAQO(b)(c)		ATSDR[4]	WHO(d)(e)	Toxicological Endpoints and Derivations
		Desirable	Acceptable			
Metals & Inorganics						
Aluminum	—	—	—	—	—	—
Antimony	**25**	—	—	—	—	MOE - health
Arsenic	**0.3**	—	—	—	—	MOE - health
Barium	**10**	—	—	—	—	MOE - health; total water soluble
Beryllium	**0.01**	—	—	—	—	MOE - health
Bismuth	—	—	—	—	—	—
Cadmium	**0.025**	—	—	—	—	MOE - health
Calcium	—	—	—	—	—	—
Chromium	**0.5**	—	—	—	—	MOE: health for metallic, divalent and trivalent chromium compounds
Cobalt	**0.1**	—	—	—	—	MOE - health
Copper	**50**	—	—	—	—	MOE - health
Iron	**4**	—	—	—	—	MOE - health
Lead	**0.5**	—	—	—	—	MOE - health
Lithium	**20**	—	—	—	—	MOE - health
Magnesium	—	—	—	—	—	—
Manganese	**0.1**	—	—	—	—	MOE - health effects for chemical present as particulate matter, PM2.5 fraction
Molybdenum	**120**	—	—	—	—	MOE - particulate
Nickel	**0.1**	—	—	—	—	MOE - health effects for chemical present as particulate matter, PM10 fraction
Potassium	—	—	—	—	—	—
Selenium	**10**	—	—	—	—	MOE - health
Silver	**1**	—	—	—	—	MOE - health
Sodium	—	—	—	—	—	—
Strontium	**120**	—	—	—	—	MOE - particulate
Thallium	—	—	—	—	—	—
Tin	**10**	—	—	—	—	MOE - health
Titanium	**120**	—	—	—	—	MOE - particulate
Uranium	**0.15**	—	—	—	—	MOE - health effects for chemical present as particulate matter, PM10 fraction
Vanadium	2	—	—	—	**1**	MOE - health; WHO - Based on a LOAEL of 20 µg/m3 for chronic upper respiratory tract symptoms. A protection factor of 20 was applied based on minimal upper respiratory tract effects and susceptible sub-populations.
Yttrium	—	—	—	—	—	—
Zinc	**120**	—	—	—	—	MOE - particulate

TABLE 3

Chronic Inhalation 24-Hour Thresholds

Parameter	MOE(a)	CCME NAAQO(b)(c)		ATSDR[4]	WHO(d)(e)	Toxicological Endpoints and Derivations
		Desirable	Acceptable			
Petroleum Hydrocarbons						
C2-C6 aliphatic (surrogate n-butanol)	**920**	—	—	—	—	MOE - health
C6-C8 aliphatic (surrogate cyclohexane)	**6,100**	—	—	—	—	MOE - health
C8-C10 aliphatic (surrogate 1-decene)	**60,000**	—	—	—	—	MOE - health
C8-C10 aromatic (surrogate	**400**	—	—	—	—	MOE - health
C10-C12 aliphatic	—	—	—	—	—	—
C12-C16 aliphatic	—	—	—	—	—	—
C12-C16 aromatic	—	—	—	—	—	—
C16-C21 aliphatic	—	—	—	—	—	—
Polycyclic Aromatic Hydrocarbons						
acenaphthene	—	—	—	—	—	—
acenaphthylene	—	—	—	—	—	—
anthracene	—	—	—	—	—	—
benz(a)anthracene	—	—	—	—	—	—
benzo(a)pyrene	**0.00005**	—	—	—	—	MOE - health
benzo(b)fluoranthene	—	—	—	—	—	—
benzo(g,h,i)perylene	—	—	—	—	—	—
benzo(k)fluoranthene	—	—	—	—	—	—
chrysene	—	—	—	—	—	—
dibenzo(a,h)anthracene	—	—	—	—	—	—
fluoranthene	—	—	—	—	—	—
fluorene	—	—	—	—	—	—
indeno(1,2,3-cd)pyrene	—	—	—	—	—	—
naphthalene	**22.5**	—	—	—	—	MOE - health
phenanthrene	—	—	—	—	—	—
pyrene	—	—	—	—	—	—
Other						
ammonia	**100**	—	—	—	—	MOE - health
hydrogen cyanide	**8**	—	—	—	—	MOE - health
hydrogen chloride	**20**	—	—	—	—	MOE - health
sodium hydroxide	—	—	—	—	—	—

Notes:

All values are in µg/m^3, unless otherwise noted.
LOAEL = Lowest Observed Adverse Effect Level.
— = Value not available.
Shaded + Bold = Screening threshold selected for use in the assessment.
(a) Ontario Ministry of the Environment (MOE), Ontario's Ambient Air Quality Criteria. Standards Development Branch, MOE. (April, 2012).
(b) Canadian Council of Ministers of the Environment (CCME), Canadian national ambient air quality objectives: Process and status. In: Canadian environmental quality guidelines (1999).
(c) Guidelines from the Canadian Council of Ministers of the Environment (CCME), Canada-Wide Standards for Particulate Matter and Ozone. 2000.
(d) World Health Organization (WHO), WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Global update 2005. Summary of risk assessment (2005).
(e) World Health Organization (WHO), Air Quality Guidelines for Europe. Second Edition. WHO Regional Publications, European Series, No. 91 (2000).

TABLE 4
Chronic Inhalation Annual Thresholds

Parameter		MOE(a)	CCME NAAQO[b]		ATSDR[c]	California EPA[d][e]	WHO[f][g]	TCEQ[h]	Toxicological Endpoints and Derivations
			Desirable	Acceptable					
Acid Gases									
Sulfur dioxide (SO_2)		55	**30**	60	—	—	50	—	MOE - health and vegetation; CCME - health and environment; WHO - Based on a LOAEL of 100 µg/m3 for respiratory symptoms and illnesses or differences in lung function values
Carbon monoxide (CO)		—	—	—	—	—	—	—	—
Nitrogen oxides (NO_x)		—	—	—	—	—	—	—	—
Nitrogen dioxide		—	60	100	—	—	**40**	—	CCME - health and environment; WHO - Based on outdoor epidemiological studies that found exposures to NO_2 in ambient air associated with increased respiratory symptoms and lung function decreases in children.
Volatile Organic Compounds									
1,3-butadiene	Non-carcinogenic	**2**	—	—	—	20	—	—	MOE - health; CalEPA - Based on a LOAEL of 6.25 ppm for increased incidence of ovarian atrophy in mice. Adjusted for duration and an uncertainty factor of 30 was applied.
	Carcinogenic	—	—	—	—	**0.006**	—	—	CalEPA - Based on lung alveolar and bronchiolar neoplasms in female mice
acetaldehyde	Non-carcinogenic	—	—	—	—	**140**	—	—	CalEPA - Based on degenerative, inflammatory and hyperplastic changes of the nasal mucosa in animals. Adjusted for duration and an uncertainty factor of 300 was applied.
	Carcinogenic	—	—	—	—	**0.37**	—	—	CalEPA - Based on nasal tumours in rats and laryngeal tumours in hamsters
acetone		—	—	—	**30890**	-	—	—	ATSDR - Based on a LOAEL of 1250 ppm for neurological effects in humans during a 6 week study. An uncertainty factor of 100 was applied.
acrolein		—	—	—	—	**0.35**	—	—	CalEPA - Based on a NOAEL of 0.2 ppm for lesions in the respiratory epithelium. The NOAEL was adjusted for duration and an uncertainty factor of 200 was applied.
aldehyde (surrogate crotonaldehyde)		—	—	—	—	—	—	**3 (0.9)**	TCEQ - health
benzene	Non-carcinogenic	—	—	—	**9.6**	60	—	—	ATSDR - Based on significantly decreased counts of B-lymphocytes in workers. Adjusted for exposure duration and an uncertainty factor of 10 was applied. CalEPA - Based on a NOAEL of 0.53 ppm for hematological effects. The NOAEL was adjusted for duration and an uncertainty factor of 10 was applied
	Carcinogenic	0.45	—	—	—	**0.034**	0.17	—	MOE - health, assumed to be based on a carcinogenic endpoint; CalEPA - Based on leukemia incidence in occupationally-exposed workers
ethylbenzene	Non-carcinogenic	—	—	—	**260**	2000	—	—	ATSDR - Based on a LOAEL of 75 ppm for increased severity of chronic progressive nephropathy in female rats. A human equivalent concentration of 17.45 ppm was selected as the point of departure and an uncertainty factor of 30 was applied. CalEPA - Based on a NOAEL of 75 ppm for nephrotoxicity and body weight reduction in rats and hyperplasia of the pituitary gland, liver cellular alterations and necrosis in mice. The NOAEL was adjusted for duration and an uncertainty factor of 30 was applied.
	Carcinogenic	—	—	—	—	**0.4**	—	—	CalEPA - Based on male rat renal tumours
ethylene		—	—	—	—	—	—	**6000 (1800)**	TCEQ - health
formaldehyde	Non-carcinogenic	—	—	—	9.8	**9**	—	—	ATSDR - Based on a LOAEL of 0.24 ppm for mild eye and upper respiratory tract irritation and mild damage to the nasal epithelium. An uncertainty factor of 30 was applied. CalEPA - Based on a NOAEL of 0.09 mg/m^3 for nasal obstruction and discomfort and lower airway discomfort in occupationally-exposed workers. The NOAEL was adjusted for an uncertainty factor of 10
	Carcinogenic	—	—	—	—	**0.17**	—	—	CalEPA - Based on rat nasal squamous carcinoma incidence
ketone (surrogate 3-Buten-2-one)		—	—	—	—	—	—	**2 (0.6)**	TCEQ - health
thiophenes (surrogate dibenzothiophene)		—	—	—	—	—	—	**8.3 (2.5)**	TCEQ - health

TABLE 4
Chronic Inhalation Annual Thresholds

Parameter		MOE(a)	CCME NAAQO[b]		ATSDR[c]	California EPA[d][e]	WHO[f][g]	TCEQ[h]	Toxicological Endpoints and Derivations
			Desirable	Acceptable					
toluene		—	—	—	300	—	**260[a]**	—	ATSDR - Based on a LOAEL of 35 ppm for alcohol and age-adjusted colour vision impairment. The LOAEL was adjusted for duration and an uncertainty factor of 100 was applied. CalEPA - Based on a NOAEL of 40 ppm for decreased brain weight an altered dopamine receptor binding in male rats. The NOAEL was adjusted for exposure duration and an uncertainty factor of 100 was applied. WHO - A LOAEL of 332 mg/m^3 for CNS effects was used to derive the WHO threshold. The LOAEL was adjusted for continuous exposure by a factor of 4.2 and an uncertainty facotr of 300 was applied.
trimethylbenzene (surrogate 1,2,3-trimethylbenzene)		—	—	—	—	—	—	**417 (125)**	TCEQ - health
xylenes		—	—	—	**220**	700	—	—	ATSDR - Based on a LOAEL of 14 ppm for neurotoxicity, respiratory toxicity and eye irritation in humans. An uncertainty factor of 100 and a modifying factor of 3 were applied. The threshold is considered to be appropriate for mixed xylenes and all of the individual isomers. CalEPA - Based on a LOAEL of 14.2 ppm for dose-related increases in the prevalence of eye irritation, sore throat, floating sensation and poor appetite in factory workers. The LOAEL was adjusted for exposure duration and an uncertainty factor of 30 was applied.
Metals & Inorganics									
Aluminum	—	—	—	—	—	—	—	**17 (5)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction, for metal and insoluble aluminum
Antimony		—	—	—	—	—	—	**1.7 (0.5)**	TCEQ - health effects for chemical present as particulate matter, PM10 fractio
Arsenic	Non-carcinogenic	—	—	—	—	**0.015**	—	—	CalEPA - Based on a LOAEL of 0.23 $\mu g/m^3$ for decrease in intellectual function and adverse effects on neurobehavioural development in children. An uncertainty factor o 30 was applied.
	Carcinogenic	—	—	—	—	**0.0003**	0.00067	—	CalEPA - Based on the 95% upper confidence limit of cancer incidence predicted from fitting a linear model to human data, adjusted for interaction with smoking. WHO - Derived from lung cancer in human studies.
Barium		—	—	—	—	—	—	**2 (0.5)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Beryllium	Non-carcinogenic	—	—	—	—	**0.007**	—	—	CalEPA - Based on beryllium sensitization and chronic beryllium disease i occupationally exposed humans. A LOAEL of 0.55 $\mu g/m^3$ for the above effects was selected. The LOAEL was adjusted for duration and an uncertainty factor of 30 was applied.
	Carcinogenic	—	—	—	—	**0.00042**	—	—	CalEPA - Based on lung cancer in occupationally exposed males
Bismuth		—	—	—	—	—	—	**17 (5)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Cadmium	Non-carcinogenic	**0.005**	—	—	0.01	0.02	0.005	—	MOE - health; ATSDR - Based on creatinine in the urine; CalEPA - Based on a NOAEL of 1.4 µg/m3 for kidney and respiratory effects. The NOAEL was adjusted for duration and an uncertainty factor of 30 was applied. WHO - Based on renal effects
	Carcinogenic	—	—	—	—	**0.00024**	—	—	CalEPA - Based on human occupational exposures and lung cancer
Calcium		—	—	—	—	—	—	—	—
Chromium		—	—	—	—	—	—	**0.041 (0.14)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction, for chromium metal

TABLE 4

Chronic Inhalation Annual Thresholds

Parameter		**MOE(a)**	**CCME NAAQO[b]**		**ATSDR[c]**	**California EPA[d][e]**	**WHO[f][g]**	**TCEQ[h]**	**Toxicological Endpoints and Derivations**
			Desirable	**Acceptable**					
Cobalt		—	—	—	**0.1**	—	—	—	ATSDR - Based on a NOAEL of 0.0053 mg/m^3 for pulmonary function effects. The NOAEL was adjusted for duration and an uncertainty factor of 10 was applied
Copper		—	—	—	—	—	—	**3 (1)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Iron		—	—	—	—	—	—	**3 (1)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Lead	Non-carcinogenic	**0.2[i]**	—	—	—	—	0.5	—	MOE - health; WHO - Based on the concentration of lead in blood. Critical effects occur in adults at 150 - 300 µg/L and include erythrocyte protoporphyrin elevation. Critical effects in children include cognitive deficit, hearing impairment and disturbed vitamin D metabolism occurs at 100-150 µg/L
	Carcinogenic	—	—	—	—	**0.083**	—	—	CalEPA - Based on kidney tumours in rats exposed to lead via the oral route
Lithium		—	—	—	—	—	—	—	—
Magnesium		—	—	—	—	—	—	**17 (5)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Manganese		—	—	—	0.3	**0.09**	0.15	—	ATSDR - Based on abnormal eye-hand coordination scores in workers. Adjusted for duration and an uncertainty factor of 100 was applied. CalEPA - Based on a benchmark concentration of 72 µg/m^3 for impaired neurobehaviour (visual reaction time, eye-hand coordination and hand steadiness). The benchmark concentration was adjusted for duration and an uncertainty factor of 300 was applied. WHO - A NOAEL of 30 µg/m^3 for neurotoxic effects was selected as the basis of the WHO threshold. The NOAEL was divided by adjusted for exposure duration and an uncertainty factor of 50 was applied.
Molybdenum		—	—	—	—	—	—	**10 (3)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Nickel	Non-carcinogenic	0.02	—	—	0.09	**0.014**	—	—	MOE - health effects for chemical present as particulate matter, PM10 fraction; ATSDR - Based on a NOAEL of 0.03 mg/m3 for chronic active inflammation and lung fibrosis in rats. The LOAEL was adjusted for exposure duration and an uncertainty factor of 30 was applied. CalEPA - Based on pathological changes in lung, lymph nodes and nasal epithelium, adjusted for exposure duration and an uncertainty factor of 100 was applied
	Carcinogenic	—	—	—	—	0.0038	**0.0025**	—	CalEPA - Based on a study that demonstrated an increased risk of lung cancer associated with occupationally-exposed humans. WHO - Based on lung cancer in human studies.
Potassium		—	—	—	—	—	—	**7 (2)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Selenium		—	—	—	—	**20**	—	—	CalEPA - Based on a NOAEL of 0.015 mg/kg/day. The NOAEL was adjusted with an uncertainty factor of 3 and extrapolated to an inhalation threshold
Silver		—	—	—	—	—	—	**0.03 (0.01)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Sodium		—	—	—	—	—	—	—	—
Strontium		—	—	—	—	—	—	**7 (2)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Thallium		—	—	—	—	—	—	**0.3 (0.1)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Tin		—	—	—	—	—	—	**7 (2)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Titanium		—	—	—	—	—	—	**17 (5)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Uranium		**0.03**	—	—	—	—	—	—	MOE - health effects for chemical present as particulate matter, PM10 fraction; ATSDR - For soluble uranium salts based on renal toxicity in dogs, adjusted for exposure duration and an uncertainty factor of 100 was applied.
Vanadium		—	—	—	**0.1**	—	—	—	ATSDR - Based on degeneration of respiratory epithelium of the epiglottis in rats. Adjusted for intermittent exposure and an uncertainty factor of 30 was applied
Yttrium		—	—	—	—	—	—	**3 (1)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
Zinc		—	—	—	—	—	—	**7 (2)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction

TABLE 4
Chronic Inhalation Annual Thresholds

Parameter		MOE(a)	CCME NAAQO(b)		ATSDR(c)	California EPA(d)(e)	WHO(f)(g)	TCEQ(h)	Toxicological Endpoints and Derivations
			Desirable	Acceptable					
Petroleum Hydrocarbons									
C2-C6 aliphatic (surrogate methyl-tert-butyl ether)	Non-carcinogenic	—	—	—	**2530**	8000	—	—	ATSDR - Based on a NOAEL of 400 ppm for no increased incidence and severity of chronic progressive nephropathy. The NOAEL was adjusted for duration and an uncertainty factor of 100 was applied. CalEPA - Based on a NOAEL of 403 ppm for nephrotoxicity, increased liver and kidney wieght and prostration and periocular swelling. The NOAEL was adjusted for exposure duration and an uncertainty factor o 30 was applied.
	Carcinogenic	—	—	—	—	**3.85**	—	—	CalEPA - Based on male rat kidney adenomas and carcinomas, male rat cell tumours and female rat leukemia and lymphomas
C6-C8 aliphatic (surrogate 2-methyl-1-pentene)		—	—	—	—	—	—	**333 (100)**	TCEQ - health
C8-C10 aliphatic (surrogate 1-decene)		—	—	—	—	—	—	**333 (100)**	TCEQ - health
C8-C10 aromatic (propylbenzene)		—	—	—	—	—	—	**417 (125)**	TCEQ - health
C10-C12 aliphatic (surrogate dodecane)		—	—	—	—	—	—	**1167 (350)**	TCEQ - health
C12-C16 aliphatic (surrogate tridecane)		—	—	—	—	—	—	**1167 (350)**	TCEQ - health
C12-C16 aromatic (surrogate n-octylbenzene)		—	—	—	—	—	—	**417 (125)**	TCEQ - health
C16-C21 aliphatic (n-heptadecane)		—	—	—	—	—	—	**33 (10)**	TCEQ - health
Polycyclic Aromatic Hydrocarbons									
acenaphthene		—	—	—	—	—	—	**0.3 (0.1)**	TCEQ - health
acenaphthylene		—	—	—	—	—	—	**0.3 (0.1)**	TCEQ - health
anthracene		—	—	—	—	—	—	**0.2 (0.05)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
benz(a)anthracene	Carcinogenic	—	—	—	—	**0.0091**	—	—	CalEPA - Based on lung adenomas in newborn mice
benzo(a)pyrene	Carcinogenic	**0.00001**	—	—	—	0.00091	0.000011	—	MOE - health, as a surrogate of total PAHs; CalEPA - Based on male hamster respiratory tract tumour incidence; WHO - Based on lung cancer in human studies
benzo(b)fluoranthene	Carcinogenic	—	—	—	—	**0.0091**	—	—	CalEPA - Based on mouse carcinogenesis
benzo(g,h,i)perylene		—	—	—	—	—	—	**0.2 (0.05)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
benzo(k)fluoranthene	Carcinogenic	—	—	—	—	**0.0091**	—	—	CalEPA - Based on mouse skin carcinogenesis
chrysene	Carcinogenic	—	—	—	—	**0.091**	—	—	CalEPA - Based on mouse skin carcinogenesis
dibenzo(a,h)anthracene	Carcinogenic	—	—	—	—	**0.00083**	—	—	CalEPA - Based on alveolar carcinomas of the lung in a drinking water study. The 4.1 (mg/kg/day)-1 cancer potency factor was converted to a unit risk.
fluoranthene		—	—	—	—	—	—	**0.2 (0.05)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
fluorene		—	—	—	—	—	—	**3 (1)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction
indeno(1,2,3-cd)pyrene	Carcinogenic	—	—	—	—	**0.0091**	—	—	CalEPA - Based on skin carcinogenesis and lung tumours
naphthalene	Non-carcinogeni	—	—	—	**3.7**	9	—	—	ATSDR - Based on a LOAEL of 10 ppm for nonneoplastic lesions in nasal olfactory epithelium and respiratory epithelium in rats. The LOAEL was adjusted for exposure duration and an uncertainty factor of 300 was applied. CalEPA - Based on a LOAEL of 10 ppm for nasal inflammation, olfactory epithelial metaplasia and respiratory epithelial hyperplasia in mice. The LOAEL was adjusted for exposure duration and an uncertainty factor of 1000 was applied.
	Carcinogenic	—	—	—	—	**0.029**	—	—	CalEPA - Based on male rat respiratory epithelial adenoma and nasal olfactory epithelial neuroblastoma incidence
phenanthrene		—	—	—	—	—	—	**0.2 (0.05)**	TCEQ - health
pyrene		—	—	—	—	—	—	**0.2 (0.05)**	TCEQ - health

TABLE 4
Chronic Inhalation Annual Thresholds

Parameter	MOE(a)	CCME NAAQO(b)		ATSDR(c)	California EPA(d)(e)	WHO(f)(g)	TCEQ(h)	Toxicological Endpoints and Derivations
		Desirable	Acceptable					
Other								
ammonia	—	—	—	70	200	—	—	ATSDR - Based on a NOAEL of 9.2 ppm for sense of smell, prevalence of respiratory symptoms, eye and throat irritation and lung function parameters in humans exposed for an average of 12.2 years in a soda ash plant; CalEPA - Based on pulmonary function, eye, skin and respiratory irritation in an occupational study with an uncertainty factor of 10
hydrogen cyanide	—	—	—	—	—	—	**6.7 (2)**	TCEQ - health
hydrogen chloride	—	—	—	—	—	—	**28 (8.4)**	TCEQ - health
sodium hydroxide	—	—	—	—	—	—	**6.7 (2)**	TCEQ - health effects for chemical present as particulate matter, PM10 fraction

Notes:

All values are in $\mu g/m^3$, unless otherwise noted.

All guideline values are for non-carcinogens, unless otherwise noted.

The screening levels derived by MOE, ATSDR, CalEPA, and WHO are based on an HQ=1.0 for non-carcinogens.

The screening levels derived by TCEQ are based on an HQ=0.3 for non-carcinogens. These guidelines have been adjusted to a HQ=1 for comparison to other guidelines. The original values are provided in brackets.

Chemical-specific inhalation unit risks were used to derive carcinogenic thresholds. An ILCR of 10^{-6} was assumed in calculating thresholds from Inhalation Unit Risk factors.

LOAEL = Lowest Observed Adverse Effect Level.

NOAEL = No Observed Adverse Effect Level.

— = Value not available.

Shaded + Bold = Screening threshold selected for use in the assessment.

(a) Ontario Ministry of the Environment (MOE), Ontario's Ambient Air Quality Criteria. Standards Development Branch, MOE. (April, 2012).

(b) Canadian Council of Ministers of the Environment (CCME), Canadian national ambient air quality objectives - Process and status. In - Canadian environmental quality guidelines (1999).

(c) Agency of Toxic Substances and Disease Registry (ATSDR), Minimum Risk Levels (MRLs), February 2012 and supporting toxicological profiles.

(d) California Office of Environmental Health Hazard Assessment (CalEPA), Air Toxicology and Epidemiology. Acute, 8-hour and Chronic Reference Exposure Levels (Dec. 18, 2008).

(e) California Office of Environmental Health Hazard Assessment (CalEPA), 2012, Toxicity Criteria Database.

(f) World Health Organization (WHO), WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Global update 2005. Summary of risk assessment (2005).

(g) World Health Organization (WHO), Air Quality Guidelines for Europe. Second Edition. WHO Regional Publications, European Series, No. 91 (2000).

(h) Texas Commission on Environmental Quality (TCEQ), Interoffice memorandum, Effects Screening Levels (March 2012). Guideline was provided from TCEQ if values were not available from any of the other jurisdictions.

(i) 7 days.

TABLE 5
Screening of Maximum Predicted Concentrations Against Selected Chronic Inhalation 24-Hour Thresholds

Parameter	Selected Screening Standard (µg/m^3)	Maximum Concentration (µg/m^3)	Retain for Chronic Inhalation Assessment?
Acid Gases			
Sulfur dioxide (SO_2)	125	14	No
Carbon monoxide (CO)	—	147	No
Nitrogen oxides (NO_x)	—	251	No
Nitrogen Dioxide	200	104	No
Volatile Organic Compounds			
1,3-butadiene	10	0.020	No
acetaldehyde	500	2.7	No
acetone	11,880	1.4	No
acrolein	0.40	**0.47**	**Yes**
aldehyde (surrogate acetaldehyde)	500	3.5	No
benzene	2.3	0.17	No
ethylbenzene	1,000	0.030	No
ethylene	—	0.54	No
formaldehyde	65	1.4	No
ketone (surrogate methyl ethyl ketone)	1,000	0.8	No
thiophenes	—	0.000001	No
toluene	2,000	0.25	No
trimethylbenzene	220	0.07	No
xylenes	730	0.20	No

TABLE 5

Screening of Maximum Predicted Concentrations Against Selected Chronic Inhalation 24-Hour Thresholds

Parameter	Selected Screening Standard (µg/m^3)	Maximum Concentration (µg/m^3)	Retain for Chronic Inhalation Assessment?
Metals & Inorganics			
Aluminum	—	3.45	No
Antimony	25	0.00001	No
Arsenic	0.3	0.00013	No
Barium	10	0.023	No
Beryllium	0.01	0.00005	No
Bismuth	—	0.00001	No
Cadmium	0.025	0.0021	No
Calcium	—	1.3	No
Chromium	0.5	0.0023	No
Cobalt	0.1	0.0005	No
Copper	50	0.0011	No
Iron	4	1.3	No
Lead	0.5	0.0014	No
Lithium	20	0.0004	No
Magnesium	—	0.35	No
Manganese	0.1	0.022	No
Molybdenum	120	0.0002	No
Nickel	0.1	0.0013	No
Potassium	—	1.2	No
Selenium	10	0.0001	No
Silver	1	0.00003	No
Sodium	—	1.1	No
Strontium	120	0.007	No
Thallium	—	0.00002	No
Tin	10	0.0001	No
Titanium	120	0.08	No
Uranium	0.15	0.00006	No
Vanadium	1	0.0021	No
Yttrium	—	0.0003	No
Zinc	120	0.0052	No

TABLE 5
Screening of Maximum Predicted Concentrations Against Selected Chronic Inhalation 24-Hour Thresholds

Parameter	Selected Screening Standard (µg/m^3)	Maximum Concentration (µg/m^3)	Retain for Chronic Inhalation Assessment?
Petroleum Hydrocarbons			
C2-C6 aliphatic (surrogate n-butanol)	920	1.1	No
C6-C8 aliphatic (surrogate cyclohexane)	6,100	0.7	No
C8-C10 aliphatic (surrogate 1-decene)	60,000	0.010	No
C8-C10 aromatic (surrogate	400	0.057	No
C10-C12 aliphatic	—	0.038	No
C12-C16 aliphatic	—	0.22	No
C12-C16 aromatic	—	0.0030	No
C16-C21 aliphatic	—	0.22	No
Polycyclic Aromatic Hydrocarbons			
acenaphthene	—	0.00001	No
acenaphthylene	—	0.00004	No
anthracene	—	0.00001	No
benz(a)anthracene	—	0.000002	No
benzo(a)pyrene	0.00005	0.000004	No
benzo(b)fluoranthene	—	0.00001	No
benzo(g,h,i)perylene	—	0.0000002	No
benzo(k)fluoranthene	—	0.000001	No
chrysene	—	0.000002	No
dibenzo(a,h)anthracene	—	0.000003	No
fluoranthene	—	0.00004	No
fluorene	—	0.00006	No
indeno(1,2,3-cd)pyrene	—	0.000002	No
naphthalene	22.5	0.0015	No
phenanthrene	—	0.0001	No
pyrene	—	0.00005	No

TABLE 5

Screening of Maximum Predicted Concentrations Against Selected Chronic Inhalation 24-Hour Thresholds

Parameter	Selected Screening Standard (μg/m^3)	Maximum Concentration (μg/m^3)	Retain for Chronic Inhalation Assessment?
Other			
ammonia	100	3.8	No
hydrogen cyanide	8	1.7	No
hydrogen chloride	20	6.5	No
sodium hydroxide	—	1.7	No

Notes:

— = Value not available.

Shaded + Bold = Chemical retained for further assessment.

(a) 8-hour.

TABLE 6
Screening of Maximum Predicted Concentrations Against Selected Chronic Inhalation Annual Thresholds
Non-Carcinogenic

Parameter	Selected Non-Carcinogenic Screening Standard (μg/m^3)	Maximum Concentration (μg/m^3)	Retain for Chronic Inhalation Assessment - Non-Carcinogenic Endpoint?
Acid Gases			
Sulfur dioxide (SO_2)	30	0.58	No
Carbon monoxide (CO)	—	29	No
Nitrogen oxides (NO_x)	—	49	No
Nitrogen dioxide	40	**49**	**Yes**
Volatile Organic Compounds			
1,3-butadiene	2	0.0014	No
acetaldehyde	140	0.19	No
acetone	30,890	0.10	No
acrolein	0.35	0.033	No
aldehyde (surrogate crotonaldehyde)	3	0.25	No
benzene	9.6	0.012	No
ethylbenzene	260	0.002	No
ethylene	6,000	0.039	No
formaldehyde	9.00	0.10	No
ketone (surrogate 3-Buten-2-one)	2	0.06	No
thiophenes (surrogate dibenzothiophene)	8.3	0.0000001	No
toluene	260[(a)]	0.018	No
trimethylbenzene (surrogate 1,2,3-	417	0.005	No
xylenes	220	0.014	No

TABLE 6
Screening of Maximum Predicted Concentrations Against Selected Chronic Inhalation Annual Thresholds Non-Carcinogenic

Parameter	Selected Non-Carcinogenic Screening Standard (µg/m^3)	Maximum Concentration (µg/m^3)	Retain for Chronic Inhalation Assessment - Non-Carcinogenic Endpoint?
Metals & Inorganics			
Aluminum	17	0.23	No
Antimony	1.7	0.000001	No
Arsenic	0.015	0.00001	No
Barium	2	0.002	No
Beryllium	0.007	0.00000	No
Bismuth	17	0.000001	No
Cadmium	0.005	0.0001	No
Calcium	—	0.08	No
Chromium	0.041	0.0002	No
Cobalt	0.1	0.00003	No
Copper	3.000	0.0001	No
Iron	3.000	0.09	No
Lead	0.5	0.0001	No
Lithium	—	0.0000	No
Magnesium	17	0.023	No
Manganese	0.09	0.001	No
Molybdenum	10	0.00002	No
Nickel	0.014	0.0001	No
Potassium	7	0.08	No
Selenium	20	0.00000	No
Silver	0.03	0.000002	No
Sodium	—	0.07	No
Strontium	7	0.000	No
Thallium	0.3	0.000001	No
Tin	7	0.000004	No
Titanium	17	0.005	No
Uranium	0.03	0.00000	No
Vanadium	0.1	0.0001	No
Yttrium	3	0.00002	No
Zinc	7	0.0004	No

TABLE 6
Screening of Maximum Predicted Concentrations Against Selected Chronic Inhalation Annual Thresholds
Non-Carcinogenic

Parameter	Selected Non-Carcinogenic Screening Standard (µg/m^3)	Maximum Concentration (µg/m^3)	Retain for Chronic Inhalation Assessment - Non-Carcinogenic Endpoint?
Petroleum Hydrocarbons			
C2-C6 aliphatic (surrogate methyl-tert-butyl	2,530	0.07	No
C6-C8 aliphatic (surrogate 2-methyl-1-	333	0.05	No
C8-C10 aliphatic (surrogate 1-decene)	333	0.001	No
C8-C10 aromatic (propylbenzene)	417	0.004	No
C10-C12 aliphatic (surrogate dodecane)	1,167	0.003	No
C12-C16 aliphatic (surrogate tridecane)	1,167	0.016	No
C12-C16 aromatic (surrogate n-octylbenzene)	417	0.0002	No
C16-C21 aliphatic (n-heptadecane)	33	0.016	No
Polycyclic Aromatic Hydrocarbons			
acenaphthene	0.3	0.000001	No
acenaphthylene	0.3	0.00000	No
anthracene	0.2	0.000001	No
benzo(g,h,i)perylene	0.2	0.00000001	No
fluoranthene	0.2	0.000003	No
fluorene	3	0.000004	No
naphthalene	3.7	0.0001	No
phenanthrene	0.2	0.00001	No
pyrene	0.2	0.000003	No
Other			
ammonia	70	0.16	No
hydrogen cyanide	6.7	0.07	No
hydrogen chloride	28	0.29	No
sodium hydroxide	6.7	0.07	No

Notes:
— = Value not available.
Shaded + Bold = Chemical retained for further assessment.
(a) 7 days.

TABLE 7
Screening of Maximum Predicted Concentrations Against Selected Chronic Inhalation Annual Thresholds Carcinogenic

Parameter	Selected Carcinogenic Screening Standard (µg/m^3)	Maximum Concentration (µg/m^3)	Retain for Chronic Inhalation Assessment - Carcinogenic Endpoint?
Volatile Organic Compounds			
1,3-butadiene	0.006	0.001	No
acetaldehyde	0.37	0.19	No
benzene	0.034	0.012	No
ethylbenzene	0.4	0.002	No
formaldehyde	0.17	0.10	No
Metals & Inorganics			
Arsenic	0.0003	0.00001	No
Beryllium	0.00042	0.00000	No
Cadmium	0.00024	0.0001	No
Lead	0.083	0.0001	No
Nickel	0.0025	0.0001	No
Petroleum Hydrocarbons			
C2-C6 aliphatic (surrogate methyl-tert-butyl ether)	3.85	0.07	No
Polycyclic Aromatic Hydrocarbons			
benz(a)anthracene	0.0091	0.0000001	No
benzo(a)pyrene	0.00001	0.0000003	No
benzo(b)fluoranthene	0.0091	0.000001	No
benzo(k)fluoranthene	0.0091	0.0000001	No
chrysene	0.091	0.0000001	No
dibenzo(a,h)anthracene	0.00083	0.0000002	No
indeno(1,2,3-cd)pyrene	0.0091	0.0000001	No
naphthalene	0.029	0.00011	No

TABLE 8
Toxicity Reference Values

Parameter	Health Canada[a]	CCME NAAQO[b]		U.S. EPA IRIS[c]	California EPA[d]	WHO[e][f]	Toxicological Endpoints and Derivations
		Desirable	Acceptable				
	Reference Concentrations (µg/m^3)						
Nitrogen dioxide	—	60	100	—	—	**40**	CCME - health and environment; WHO - Based on outdoor epidemiological studies that found exposures to NO_2 in ambient air associated with increased respiratory symptoms and lung function decreases in children.
acrolein	—	—	—	0.02	**0.35**	—	U.S. EPA IRIS - Based on a LOAEL for nasal histopathology in rats. Report dated 2003 based on critical studies from 1978 and 1985; CalEPA - Based on a NOAEL for lesions in the respiratory epithelium of rats. Report dated 2008 based on critical study from 2008. The 2008 study was selected by CalEPA in preference to the earlier studies used by U.S. EPA because it identified a NOAEL for the critical effect. For this reason, the CalEPA RfC was selected in preference to the U.S. EPA IRIS RfC for the chronic inhalataion assessment.

Notes:

— = Value not available.

Shaded + Bold = Toxicity reference value selected for use in assessment.

[a] Health Canada 2010. Health Canada Toxicological Reference Values and Chemical-Specific Factors. Federal Contaminated Site Risk Assessment in Canada. Version 2.0

[b] Canadian Council of Ministers of the Environment (CCME), Canadian national ambient air quality objectives - Process and status. In - Canadian environmental quality guidelines (1999).

[c] U.S. EPA IRIS. 2012. Integrated Risk Information System Online Database. http://www.epa.gov/iris/index.html Accessed October 2012.

[d] California Office of Environmental Health Hazard Assessment (CalEPA), Air Toxicology and Epidemiology. Acute, 8-hour and Chronic Reference Exposure Levels (Dec. 18, 2008).

[e] World Health Organization (WHO), WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Global update 2005. Summary of risk assessment (2005).

[f] World Health Organization (WHO), Air Quality Guidelines for Europe. Second Edition. WHO Regional Publications, European Series, No. 91 (2000).

TABLE 9
Predicted Concentrations for Chronic Inhalation COPCs at each Receptor Location

Receptor Location	Predicted 24-hour acrolein concentration (µg/m^3)	Predicted annual NO_2 concentration (µg/m^3)
Selected Screening Threshold	**0.4**	**40**
Receptor 1	0.11	0.83
Receptor 2	0.13	1.91
Receptor 3	0.06	0.97
Receptor 4	0.11	1.00
Receptor 5	0.10	1.04
Receptor 6	0.18	3.79
Receptor 7	0.23	3.74
Receptor 8	0.31	6.83
Receptor 9	0.08	0.96
Receptor 12	0.35	4.08
Receptor 13	0.32	5.61
Receptor 14	0.20	3.10
Receptor 15	0.11	1.83
Receptor 16	0.10	1.02
Receptor 18	0.12	2.13
Receptor 20	0.22	3.56
Receptor 21	0.07	0.76
Receptor 22	0.09	0.99
Receptor 24	0.21	1.91
Receptor 25	0.20	2.48
Receptor 26	0.07	1.34
Receptor 27	0.15	1.49
Receptor 28	0.19	2.84
Receptor 29	0.33	6.75
Receptor 30	0.10	1.93
Receptor 31	0.28	2.88
Receptor 32	**0.41**	6.43
Receptor 33	0.11	1.31
Receptor 34	0.15	2.04
Receptor 35	0.09	1.57
Receptor 38	**0.47**	7.15
Receptor 39	0.08	1.54
Receptor 40	0.23	2.65
Receptor 41	0.31	18.0
Receptor 42	0.31	10.4
Receptor 43	0.31	39.7
Receptor 44	0.31	**48.9**
Receptor 45	0.31	**40.9**
Receptor 46	0.30	34.4
Receptor 47	0.30	**46.4**
Receptor 48	0.30	**40.1**
Receptor 49	0.29	27.4
Receptor 50	0.29	**41.1**
Receptor 51	0.29	36.5

Notes:

Shaded + Bold = Predicted concentration exceeds screening threshold.

APPENDIX 3.II

Supporting Tables for Human Health Multi-Media Assessment

TABLE 1
Screening of Surface Water Concentrations - Marmion Reservoir - Operations

Metals	Units	Guidelines for Canadian Drinking Water Quality[a]	Canadian Water Quality Guidelines for Protection of Agricultural Water Uses[b]	U.S. EPA Regional Screening Level - Tapwater Ingestion[c]	Maximum Existing Conditions Concentrations +10%	Maximum Predicted Surface Water Concentrations	Retain for Multi-media Assessment?[c]
Alkalinity	mg/L as $CaCO_3$	—	—	n/a	24	19	No
Nitrate	mg/L as N	45,000	100,000	n/a	0.19	0.08	No
Ammonia	mg/L as N	—	—	n/a	0.03	0.25	No (non-toxic)
Aluminum	µg/L	—	5,000	n/a	48.6	30	No
Antimony	µg/L	6	—	n/a	< 5.5	0.80	No
Arsenic	µg/L	10	25	n/a	0.46	0.49	No
Barium	µg/L	1,000	—	n/a	6.1	7.2	No
Boron	µg/L	5,000	500	n/a	4.4	14	No
Cadmium	µg/L	5	5.1	n/a	0.014	0.04	No
Calcium	µg/L	—	1,000,000	n/a	7,403	6,655	No
Chloride	µg/L	—	100,000	n/a	2,035	1,777	No
Chromium	µg/L	50	4.9	n/a	0.33	0.48	No
Cobalt	µg/L	—	50	n/a	0.057	0.20	No
Copper	µg/L	—	200	n/a	2.2	2.8	No
Total Cyanide	µg/L	200	—	n/a	< 2.2	13	No
Iron	µg/L	—	5,000	n/a	447	237	No
Lead	µg/L	10	100	n/a	0.055	0.29	No
Magnesium	µg/L	—	—	n/a	1,903	1,406	No
Manganese	µg/L	—	200	n/a	113	25	No
Mercury	µg/L	1	3	n/a	0.013	0.005	No
Molybdenum	µg/L	—	10	n/a	< 1.1	1.4	No
Nickel	µg/L	—	200	n/a	0.9	1.1	No
Phosphorous	µg/L	—	—	n/a	79	13	No
Potassium	µg/L	—	—	n/a	578	1,223	No (non-toxic)
Selenium	µg/L	10	20	n/a	0.44	0.5	No
Silver	µg/L	—	—	71	< 0.22	0.09	No
Sodium	µg/L	—	—	n/a	2,882	2,668	No
Strontium	µg/L	—	—	9,300	16	18	No
Sulphate	µg/L	—	1,000,000	n/a	1,980	4,882	No
Thallium	µg/L	—	—	0.16	< 0.33	0.09	No
Tin	µg/L	—	—	9,300	< 1.1	1.1	No
Uranium	µg/L	20	10	n/a	0.03	2.3	No
Vanadium	µg/L	—	100	n/a	0.83	0.50	No
Zinc	µg/L	—	5,000	n/a	12	5.3	No

Notes:

— = Guideline for this chemical not provided by the agency

n/a = Screening levels were not listed for the U.S. EPA because values were available from Health Canada or CCME

[a] Health Canada 2012. Guidelines for Canadian Drinking Water Quality Summary Table. August 2012. Only health-based guidelines are used for screening.

[b] CCME (Canadian Council of Ministers of the Environment). Water Quality Guidelines for the Protection of Agriculture Summary Table. The lowest of the livestock and irrigation guidelines were used for screening.

[c] U.S. EPA (U.S. Environmental Protection Agency). Regional Screening Levels. Tapwater Ingestion. Accessed in November 2012 at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm. Value only provided if not available from Health Canada or CCME.

[c] Chemicals were retained for the multi-media assessment if they were above guidelines and existing conditions concentrations. Chemicals that are considered non-toxic were not retained.

TABLE 2

Screening of Surface Water Concentrations - Lizard Lake - Operations

Metals	Units	Guidelines for Canadian Drinking Water Quality(a)	Canadian Water Quality Guidelines for Protection of Agricultural Water Uses(b)	U.S. EPA Regional Screening Level - Tapwater Ingestion(c)	Maximum Existing Conditions Concentrations + 10%	Maximum Predicted Surface Water Concentrations	Retain for Multi-media Assessment?(c)
Alkalinity	mg/L as $CaCO_3$	—	—	n/a	32	—	No
Nitrate	mg/L as N	45,000	100,000	n/a	0.06	0.03	No
Ammonia	mg/L as N	—	—	n/a	0.03	0.21	No (non-toxic)
Aluminum	µg/L	—	5,000	n/a	31	18	No
Antimony	µg/L	6	—	n/a	< 0.11	0.99	No
Arsenic	µg/L	10	25	n/a	1.1	0.43	No
Barium	µg/L	1,000	—	n/a	11	—	No
Boron	µg/L	5,000	500	n/a	55	11	No
Cadmium	µg/L	5	5.1	n/a	0.11	0.03	No
Calcium	µg/L	—	1,000,000	n/a	12,650	11,000	No
Chloride	µg/L	—	100,000	n/a	484	910	No
Chromium	µg/L	50	4.9	n/a	1.1	0.49	No
Cobalt	µg/L	—	50	n/a	< 0.06	0.15	No
Copper	µg/L	—	200	n/a	1.6	2.4	No
Total Cyanide	µg/L	200	—	n/a	< 2.2	12.0	No
Iron	µg/L	—	5,000	n/a	97	53	No
Lead	µg/L	10	100	n/a	1.1	0.24	No
Magnesium	µg/L	—	—	n/a	1,100	1,100	No
Manganese	µg/L	—	200	n/a	28	—	No
Mercury	µg/L	1	3	n/a	< 0.01	0.01	No
Molybdenum	µg/L	—	10	n/a	1.1	1.2	No
Nickel	µg/L	—	200	n/a	2.2	0.9	No
Phosphorous	µg/L	—	—	n/a	12	8.4	No
Potassium	µg/L	—	—	n/a	375	1,100	No (non-toxic)
Selenium	µg/L	10	20	n/a	< 0.55	0.50	No
Silver	µg/L	—	—	71	< 0.06	0.10	No
Sodium	µg/L	—	—	n/a	770	1,900	No (non-toxic)
Strontium	µg/L	—	—	9,300	18	—	No
Sulphate	µg/L	—	1,000,000	n/a	2,783	4,500	No
Thallium	µg/L	—	—	0.16	< 0.03	—	No
Tin	µg/L	—	—	9,300	< 0.11	—	No
Uranium	µg/L	20	10	n/a	5.5	2.6	No
Vanadium	µg/L	—	100	n/a	1.1	0.37	No
Zinc	µg/L	—	5,000	n/a	9.5	5.5	No

Notes:

— = Guideline for this chemical not provided by the agency

n/a = Screening levels were not listed for the U.S. EPA because values were available from Health Canada or CCME

(a) Health Canada 2012. Guidelines for Canadian Drinking Water Quality Summary Table. August 2012. Only health-based guidelines are used for screening.

(b) CCME (Canadian Council of Ministers of the Environment). Water Quality Guidelines for the Protection of Agriculture Summary Table. The lowest of the livestock and irrigation guidelines were used for screening.

(c) U.S. EPA (U.S. Environmental Protection Agency). Regional Screening Levels. Tapwater Ingestion. Accessed in November 2012 at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm. Value only provided if not available from Health Cana CCME.

(c) Chemicals were retained for the multi-media assessment if they were above guidelines and existing conditions concentrations. Chemicals that are considered non-toxic were not retained.

TABLE 3
Screening of Inorganic Soil Concentrations

Metals	CCME Guidelines (mg/kg)(a)	MOE Table 1 Standards (mg/kg)(b)	US EPA Screening Levels (mg/kg)(c)	Incremental Soil Concentration (mg/kg)	Maximum Existing Conditions Soil Concentration (mg/kg)	Maximum Existing Conditions Concentration + Incremental Soil Concentration (mg/kg)	Maximum Existing Conditions Soil Concentration + 10% (mg/kg)	Retain for Multi-media Assessment?(d)
aluminum	—	—	77,000	8.6	24,100	24,109	26,510	No
antimony	20	1	n/a	0.00003	<1.0	1.0	1.1	No
arsenic	12	11	n/a	0.0003	4.52	4.5	5.0	No
barium	750	210	n/a	0.06	101	101	111	No
beryllium	4	2.5	n/a	0.0001	<0.5	0.5	0.55	No
bismuth	—	—	—	0.00003	<1	1.0	1.1	No
cadmium	1.4	1	n/a	0.006	0.90	0.9	1.0	No
calcium	—	—	—	3.2	4,440	4,443	4,884	No
chromium	64	67	—	0.006	36.60	37	40	No
cobalt	40	19	n/a	0.001	10.10	10	11	No
copper	63	62	n/a	0.003	79.00	79	87	No
iron	—	—	55,000	3.3	25,500	25,503	28,050	No
lead	70	45	n/a	0.004	24.00	24	26	No
lithium	—	—	160	0.0009	13	13	14	No
magnesium	—	—	—	0.86	4,490	4,491	4,939	No
manganese	—	—	1,800	0.06	553	553	608	No
molybdenum	5	2	n/a	0.0006	6.80	6.8	7.5	No
nickel	50	37	n/a	0.003	38.30	38	42	No
potassium	—	—	—	2.9	710	713	781	No
selenium	1	1.2	n/a	0.0002	<1.0	1.0	1.1	No
silver	20	0.5	n/a	0.00007	0.49	0.49	0.5	No
sodium	—	—	—	2.7	310	313	341	No
strontium	—	—	47,000	0.02	16.9	17	19	No
thallium	1	1	n/a	0.00004	*<0.50*	0.50	0.6	No
tin	5	—	n/a	0.0002	*<5.0*	5.0	5.5	No
titanium	—	—	—	0.20	1140	1140	1254	No
uranium	23	1.9	n/a	0.0001	1.40	1.4	1.5	No
vanadium	130	86	n/a	0.005	66.0	66	73	No
yttrium	—	—	—	0.0008	<0.5*	0.50	0.6	No
zinc	200	290	n/a	0.01	88.4	88	97	No

Notes:

— = No guideline/standard available.

n/a = Not/applicable, screening level available but not shown because values available from CCME or MOE.

* = Ytrrium was not measured in existing conditions soil; a detection limit of 0.5 mg/kg was assumed.

(a) CCME (Canadian Council of Ministers of the Environment). 2012. Canadian Soil Quality Guidelines for the Protection of Human Health Summary Table. Agricultural land use.

(b) Ontario Ministry of the Environment (MOE). 2011. Rationale for the Development of Soil and Groundwater Standards for use at Contaminated Sites in Ontario. Standards Development Branch. April 2011. Table 1 Full Depth Background Site Condition Standards for agricultural property use.

(c) U.S. EPA 2012. Mid-Atlantic Risk Assessment Residential Screening Level Tables. Residential land use. Only provided where values not available from CCME or MOE.

(d) Chemicals were retained for the multi-media assessment if they were above guidelines and baseline concentrations + 10%.

TABLE 4
Screening of Polycyclic Aromatic Hydrocarbon Soil Concentrations

Metals	MOE Table 1 Standards (mg/kg)[a]	Incremental Soil Concentration (mg/kg)	Existing Conditions Soil Concentration (mg/kg)	Existing Conditions Concentration + Incremental Soil Concentration (mg/kg)	Existing Conditions Soil Concentration + 10% (mg/kg)	Retain for Multi-media Assessment?[b]
acenaphthene	0.05	9.2×10^{-7}	0.025	0.025	0.028	No
acenaphthylene	0.093	1.3×10^{-4}	0.025	0.025	0.028	No
anthracene	0.05	4.9×10^{-6}	0.025	0.025	0.028	No
benz(a)anthracene	0.095	5.4×10^{-6}	0.025	0.025	0.028	No
benzo(a)pyrene	0.05	1.5×10^{-6}	0.025	0.025	0.028	No
benzo(b)fluoranthene	0.3	2.5×10^{-5}	0.025	0.025	0.028	No
benzo(g,h,i)perylene	0.2	4.8×10^{-7}	0.025	0.025	0.028	No
benzo(k)fluoranthene	0.05	1.3×10^{-6}	0.025	0.025	0.028	No
chrysene	0.18	1.5×10^{-6}	0.025	0.025	0.028	No
dibenzo(a,h)anthracene	0.1	1.9×10^{-6}	0.025	0.025	0.028	No
fluoranthene	0.24	1.5×10^{-5}	0.025	0.025	0.028	No
fluorene	0.05	2.8×10^{-6}	0.025	0.025	0.028	No
indeno(1,2,3-cd)pyrene	0.11	9.3×10^{-7}	0.025	0.025	0.028	No
naphthalene	0.05	5.5×10^{-5}	0.025	0.025	0.028	No
phenanthrene	0.19	1.9×10^{-5}	0.025	0.025	0.028	No
pyrene	0.19	5.9×10^{-5}	0.025	0.025	0.028	No
thiophenes	—	2.4×10^{-6}	0.025	0.025	0.028	No

Notes:

— = No guideline/standard available.

[a] Ontario Ministry of the Environment (MOE). 2011. Rationale for the Development of Soil and Groundwater Standards for use at Contaminated Sites in Ontario. Standards Development Branch. April 2011. Table 1 Full Depth Background Site Condition Standards for agricultural property use.

[b] Chemicals were retained for the multi-media assessment if they were above guidelines and baseline concentrations + 10%.

TABLE 5
Screening of Polycyclic Aromatic Hydrocarbon Soil Concentrations using Carcinogenic Factors

PAHs	CCME B[a]P Potency Equivalency Factors[a]	Incremental Soil Concentration (mg/kg)	Existing Conditions Soil Concentration (mg/kg)	Existing Conditions Concentration + Incremental Soil Concentration (mg/kg)	Existing Conditions Soil Concentration + 10% (mg/kg)	BaP Toxic Potency	Retain for Multi-media Assessment?[b]
benz(a)anthracene	0.1	5.4×10^{-6}	0.025	0.025	0.028	0.003	No
benzo(a)pyrene	1	1.5×10^{-6}	0.025	0.025	0.028	0.025	No
benzo(b)fluoranthene	0.1	2.5×10^{-5}	0.025	0.025	0.028	0.003	No
benzo(g,h,i)perylene	0.01	4.8×10^{-7}	0.025	0.025	0.028	0.000	No
benzo(k)fluoranthene	0.1	1.3×10^{-6}	0.025	0.025	0.028	0.003	No
chrysene	0.01	1.5×10^{-6}	0.025	0.025	0.028	0.000	No
dibenzo(a,h)anthracene	1	1.9×10^{-6}	0.025	0.025	0.028	0.025	No
indeno(1,2,3-cd)pyrene	0.1	9.3×10^{-7}	0.025	0.025	0.028	0.003	No
					Total	**0.06**	**No**

PAHs	CCME IACR Factor[a]	Incremental Soil Concentration (mg/kg)	Existing Conditions Soil Concentration (mg/kg)	Existing Conditions Concentration + Incremental Soil Concentration (mg/kg)	Existing Conditions Soil Concentration + 10% (mg/kg)	IACR	Retain for Multi-media Assessment?[b]
benz(a)anthracene	0.33	5.4×10^{-6}	0.025	0.025	0.028	0.076	No
benzo(a)pyrene	0.37	1.5×10^{-6}	0.025	0.025	0.028	0.068	No
benzo(b)fluoranthene	0.16	2.5×10^{-5}	0.025	0.025	0.028	0.156	No
benzo(g,h,i)perylene	6.8	4.8×10^{-7}	0.025	0.025	0.028	0.004	No
benzo(k)fluoranthene	0.16	1.3×10^{-6}	0.025	0.025	0.028	0.156	No
chrysene	2.1	1.5×10^{-6}	0.025	0.025	0.028	0.012	No
dibenzo(a,h)anthracene	0.23	1.9×10^{-6}	0.025	0.025	0.028	0.109	No
indeno(1,2,3-cd)pyrene	2.7	9.3×10^{-7}	0.025	0.025	0.028	0.009	No
					Total	**0.59**	**No**

Notes:

[a] CCME (Canadian Council of Ministers of the Environment). 2010. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health. Polycyclic Aromatic Hydrocarbons. Carcinogenic effects of PAHs for direct soil contact are determined by multiplying the Benzo(a)pyrene (B[a]P) Potency Equivalency Factor by the soil concentration for each PAH and summing, compared to a target of 0.6 B[a]P Total Potency Equivalents for agricultural land use. Carcinogenic effects for potential ingestion of potable water is evaluated by multiplying the Index of Additive Cancer Risk (IACR) by the soil concentration for each PAH and summing, compared to a target IACR of 1 for agricultural land use.

[b] Chemicals were retained for the multi-media assessment if they were above guidelines and baseline concentrations + 10%.

APPENDIX 4.I

Supporting Tables for Ecological Multi-Media Assessment

TABLE 1

Soil Loss Constants (Ks)

Parameter	**Soil Loss Constant (Ks)[a] (1/yr)**
Benzo(a)pyrene	0.48
Naphthalene	5.27
Phenanthrene	1.26
Anthracene	0.55
Fluorene	4.22
Pyrene	0.13
Thiophenes	NA
Benz(a)anthracene	0.37
Acenaphthene	2.48
Acenaphthylene	NA
Fluoranthene	0.57
Benzo(b)fluoranthene	0.41
Benzo(g,h,i)perylene	NA
Benzo(k)fluoranthene	0.12
Chrysene	0.25
Dibenzo(a,h)anthracene	0.27
Indeno(1,2,3-cd)pyrene	0.35

Notes:

NA = Not available. Ks conservatively set at 0 as loss constants are not available.

[a] Soil loss constants taken from Howard et al. 1991 as cited in US EPA (2005).

TABLE 2
Estimation of Soil Concentrations

Chemical	**Existing Conditions Soil Concentration[a] (mg/kg)**	**Wet Deposition Rate[b] ($g/m^2/yr$)**	**Dry Deposition Rate[b] ($g/m^2/yr$)**	**Incremental Soil Concentration[c] (mg/kg)**	**Predicted Soil Concentration[d] (mg/kg)**
Total Metals					
Aluminum (Al)	24,100	0.03	7.5	3,889	27,989
Antimony (Sb)	*<1*	0.0000001	0.00002	0.01	1.0
Arsenic (As)	4.52	0.000001	0.0003	0.14	4.7
Barium (Ba)	101	0.0002	0.05	26	127
Beryllium (Be)	*0.5*	0.0000005	0.0001	0.06	0.56
Bismuth (Bi)	<1	0.0000001	0.00002	0.01	1.0
Cadmium (Cd)	0.9	0.00001	0.0008	0.42	1.3
Calcium (Ca)	4,440	0.01	2.8	1,438	5,878
Chromium (Cr)	36.6	0.00002	0.004	2.3	39
Cobalt (Co)	10.1	0.000005	0.001	0.54	11
Copper (Cu)	79	0.00001	0.002	1.2	80
Iron (Fe)	25,500	0.01	2.9	1,481	26,981
Lead (Pb)	24	0.00001	0.003	1.3	25
Lithium (Li)	13	0.000004	0.0008	0.43	13
Magnesium (Mg)	4,490	0.004	0.76	393	4,883
Manganese (Mn)	553	0.0002	0.05	25	578
Molybdenum (Mo)	6.8	0.000002	0.0005	0.26	7
Nickel (Ni)	38.3	0.00001	0.003	1.5	40
Potassium (K)	710	0.01	2.6	1,330	2,040
Selenium (Se)	*<1*	0.0000007	0.0002	0.08	1.1
Silver (Ag)	0.49	0.0000003	0.00006	0.03	0.52
Sodium (Na)	310	0.01	2.3	1,215	1,525
Strontium (Sr)	16.9	0.00007	0.02	8.3	25
Thallium (Tl)	*<0.5*	0.0000002	0.00003	0.02	0.52
Tin (Sn)	*<5*	0.0000006	0.0001	0.07	5.1
Titanium (Ti)	1140	0.0008	0.17	91	1231
Uranium (U)	1.4	0.0000006	0.0001	0.07	1.5
Vanadium (V)	66	0.00002	0.005	2.3	68
Yttrium (Y)**	23	0.000003	0.0007	0.38	23
Zinc (Zn)	88	0.00004	0.01	3.6	92
Polycyclic Aromatic Hydrocarbons					
Benzo(a)pyrene*	0.025	0.00000003	0.000001	0.0002	0.025
Naphthalene*	0.025	0.00001	0.0006	0.06	0.084
Phenanthrene*	0.025	0.0000008	0.00005	0.005	0.030
Anthracene*	0.025	0.00000009	0.000005	0.0005	0.026
Fluorene*	0.025	0.0000004	0.00002	0.002	0.027
Pyrene*	0.025	0.0000003	0.00002	0.001	0.026
Thiophene*	0.025	0.000000005	0.0000003	0.0002	0.025
Benzo(a)anthracene*	0.025	0.00000001	0.0000007	0.00007	0.025
Acenapthene*	0.025	0.00000008	0.000005	0.0005	0.025
Acenapthylene*	0.025	0.0000003	0.00002	0.009	0.034
Fluoranthene*	0.025	0.0000003	0.00002	0.002	0.027
Benzo(b)fluoranthene*	0.025	0.00000006	0.000003	0.0003	0.025
Benzo(g,h,i)perylene*	0.025	0.000000001	0.00000006	0.00003	0.025
Benzo(k)fluoranthene*	0.025	0.000000006	0.0000004	0.00002	0.025
Chrysene*	0.025	0.00000001	0.0000008	0.00008	0.025
Dibenzo(a,h)anthracene*	0.025	0.00000002	0.000001	0.0001	0.025
Indeno(1,2,3-c,d)pyrene*	0.025	0.00000001	0.0000007	0.00007	0.025

Notes:

* = There is no measured existing conditions soil concentration for this parameter. The predicted soil concentration is shown as the sum of 1/2 the typical method detection limit (typical method detection limit = 0.05 mg/kg) and the incremental soil concentration from particulate deposition.

** = There is no measured existing conditions soil concentration for this parameter. The predicted soil concentration is shown as the sum of the typical average soil concentration and the incremental soil concentration from particulate deposition.

mg/kg = milligram per kilogram; $g/m^2/yr$ = gram per square metre per year.

[a] Maximum measured existing conditions soil concentration.

[b] The maximum wet/dry deposition rate of all modelled locations.

[c] The maximum incremental soil concentration of all modelled locations.

[d] The predicted soil concentration is calculated as the sum of the maximum measured existing conditions soil concentration and the incremental soil concentration from particulate deposition.

TABLE 3
Screening of Chemicals in Soil

Chemical	MOE Table 1 SCS[a] (mg/kg)	Existing Conditions Soil Concentration + 10%[b] (mg/kg)	CCME SQG_E[c] (mg/kg)	Predicted Soil Concentration[d] (mg/kg)	COPC?[e]	Rationale
Total Metals						
Aluminum (Al)	30,000[f]	26,510	—	27,989	No	<S
Antimony (Sb)	1	1.1	—	1.01	No	<EC+10%
Arsenic (As)	11	5.0	—	4.7	No	<S
Barium (Ba)	210	111	—	127	No	<S
Beryllium (Be)	2.5	0.55	—	0.56	No	<S
Bismuth (Bi)	NV	1.1	—	1.0	No	NS, <EC+10%
Cadmium (Cd)	1	1.0	3.8	1.32	No	<G
Calcium (Ca)	54,000	4,884	—	5,878	No	<S
Chromium (Cr)	67	40	—	39	No	<S
Cobalt (Co)	19	11	—	11	No	<S
Copper (Cu)	62	87	—	80	No	<EC+10%
Iron (Fe)	36,000[f]	28,050	—	26,981	No	<S
Lead (Pb)	45	26	—	25	No	<S
Lithium (Li)	NV	14	—	13	No	NS, <EC+10%
Magnesium (Mg)	19,000[f]	4,939	—	4,883	No	<S
Manganese (Mn)	1,900[f]	608	—	578	No	<S
Molybdenum (Mo)	2	7.5	—	7	No	<EC+10%
Nickel (Ni)	37	42	—	40	No	<EC+10%
Potassium (K)	6,500[f]	781	—	2,040	No	<S
Selenium (Se)	1.2	1.1	—	1.1	No	<S
Silver (Ag)	0.5	0.54	—	0.52	No	<EC+10%
Sodium (Na)	690[f]	341	—	1,525	No	ubiquitous, essential, non-toxic
Strontium (Sr)	63[f]	19	—	25	No	<S
Thallium (Tl)	1	0.6	—	0.52	No	<S
Tin (Sn)	NV	5.5	—	5.1	No	NS, <EC+10%
Titanium (Ti)	4,500[f]	1,254	—	1,231	No	<S
Uranium (U)	1.9	1.5	—	1.5	No	<S
Vanadium (V)	86	73	—	68	No	<S
Yttrium (Y)**	NV	25	—	23	No	NS, <EC+10%
Zinc (Zn)	290	97	—	92	No	<S
Polycyclic Aromatic Hydrocarbons						
Benzo(a)pyrene*	0.05	0.028	—	0.025	No	<S
Naphthalene*	0.05	0.028	8.8[g]	0.084	No	<G
Phenanthrene*	0.19	0.028	—	0.030	No	<S
Anthracene*	0.05	0.028	—	0.026	No	<S
Fluorene*	0.05	0.028	—	0.027	No	<S
Pyrene*	0.19	0.028	—	0.026	No	<S
Thiophene*	NV	0.028	—	0.025	No	NS, <EC+10%
Benzo(a)anthracene*	0.095	0.028	—	0.025	No	<S
Acenapthene*	0.05	0.028	—	0.025	No	<S
Acenapthylene*	0.093	0.028	—	0.034	No	<S
Fluoranthene*	0.24	0.028	—	0.027	No	<S
Benzo(b)fluoranthene*	0.3	0.028	—	0.025	No	<S
Benzo(g,h,i)perylene*	0.2	0.028	—	0.025	No	<S
Benzo(k)fluoranthene*	0.05	0.028	—	0.025	No	<S
Chrysene*	0.18	0.028	—	0.025	No	<S
Dibenzo(a,h)anthracene*	0.1	0.028	—	0.025	No	<S
Indeno(1,2,3-c,d)pyrene*	0.11	0.028	—	0.025	No	<S

Notes:

NV = no value; COPC = chemical of potential concern; mg/kg = milligram per kilogram; — = value not required; < = less than; EC = maximum measured existing conditions soil concentration; S = MOE Table 1 SCS/OTR$_{98}$; G = CCME SQG_E; NS = no standard.

* = There is no measured existing conditions soil concentration for this parameter. The predicted soil concentration is shown as the sum of 1/2 the typical method detection limit (typical method detection limit = 0.05 mg/kg) and the incremental soil concentration from particulate deposition.

** = There is no measured existing conditions soil concentration for this parameter. The predicted soil concentration is shown as the sum of the typical average soil concentration and the incremental soil concentration from particulate deposition.

[a] Ontario Ministry of the Environment (MOE), Table 1 Full Depth Background Site Condition Standards (SCS) for Soil for Agricultural or Other Property Use (MOE 2011).

[b] Maximum measured existing conditions soil concentration + 10%.

[c] Canadian Council of Ministers of the Environment (CCME) Canadian Soil Quality Guidelines for the Protection of Environmental Health (SQG_E) (CCME 2012, internet site). Agricultural land use.

[d] The predicted soil concentration is calculated as the sum of the maximum measured existing conditions soil concentration and the incremental soil concentration from particulate deposition.

[e] Yes = the predicted soil concentration is greater than the standard and the maximum measured existing conditions soil concentration +10% and therefore the chemical was identifed as a COPC; No = the predicted soil concentration is less than the standard and/or maximum measured existing conditions soil concentration +10% and therefore the chemical was not identifed as a COPC.

[f] Ontario Ministry of the Environment (MOE), Background Concentrations for Soils, Table 8.3 Soil - Rural Parks, OTR$_{98}$ (MOE 2011).

[g] SQG_E for soil and food ingestion.

TABLE 4
Surface Water Screening for Marmion Reservoir for Effluent Discharge

Chemical	Units	PWQO(a)	Existing Conditions Concentration + 10%(b)	Predicted Concentration(c)	COPC(d)	Rationale
Physical-Chemical						
pH	N/A	6.5-8.5	5.65-7.59	7.0	No	Within range of PWQO
Alkalinity	mg/L as CaCO$_3$	Alkalinity should not be decreased by more than 25% of the natural concentration	24	19	No	Within range of PWQO
Major Ions						
Calcium	mg/L	NV	7.4	6.7	No	No PWQO, <EC
Chloride	mg/L	NV	2.0	1.8	No	No PWQO, <EC
Magnesium	mg/L	NV	1.9	1.4	No	No PWQO, <EC
Potassium	mg/L	NV	0.58	1.2	No	Essential nutrient/ameliorates metal toxicity
Sodium	mg/L	NV	2.9	2.7	No	No PWQO, <EC
Sulphate	mg/L	NV	2.0	4.9	No	Less than BCMOE guideline of 50 mg/L
Hardness	mg/L	NV	23	22	No	No PWQO, <EC
Free Cyanide	mg/L	0.005	0.006	0.02	No	>PWQO, >EC, <SSWQO under most likely Project conditions
Total Cyanide	mg/L	NV	<0.002	0.01	No	Free cyanide is the most toxicologically relevant
Nutrients						
Nitrate	mg/L as N	NV	0.19	0.08	No	No PWQO, <EC
Ammonia	mg/L as N	NV	0.03	0.25	No	N(e)
Un-ionized ammonia	mg/L	0.02	0.00003	0.01	No	<PWQO
Phosphorus	mg/L -P	0.01	0.08	0.01	No	<PWQO
Dissolved Metals						
Aluminum	µg/L	75(f)	49	30	No	<PWQO
Antimony	µg/L	20	< 5.5	0.80	No	<PWQO
Arsenic	µg/L	5	0.5	0.49	No	<PWQO
Barium	µg/L	NV	6.1	7.2	No	Less than BCMOE guideline of 1000 µg/L
Boron	µg/L	200	4.4	14	No	<PWQO
Cadmium	µg/L	0.1(g)	0.014	0.04	No	<PWQO
Chromium	µg/L	1(j)	0.33	0.48	No	<PWQO
Cobalt	µg/L	0.9	0.06	0.20	No	<PWQO
Copper	µg/L	2(h)	2.2	2.8	No	Less than SSWQO of 7.9 ug/L
Iron	µg/L	300	447	237	No	<PWQO
Lead	µg/L	1(i)	0.055	0.29	No	<PWQO
Manganese	µg/L	NV	113	25	No	No PWQO, <EC
Mercury	µg/L	0.2	0.013	0.01	No	<PWQO
Molybdenum	µg/L	40	<1.1	1.4	No	<PWQO
Nickel	µg/L	25	0.88	1.1	No	<PWQO
Selenium	µg/L	100	0.44	0.50	No	<PWQO
Silver	µg/L	0.1	< 0.22	0.09	No	<PWQO
Strontium	µg/L	NV	16	18	No	Less than MDDEP criterion of 21,000 ug/L
Thallium	µg/L	0.3	<0.33	0.09	No	<PWQO
Tin	µg/L	NV	<1.1	1.1	No	No PWQO, equivalent to EC
Uranium	µg/L	5	0.03	2.3	No	<PWQO
Vanadium	µg/L	6	0.83	0.50	No	<PWQO
Zinc	µg/L	20	12	5.3	No	<PWQO

Notes:

NV = no value; COPC = chemical of potential concern; mg/L = milligram per litre; ug/L = microgram per litre; — = value not required; < = less than;
EC = maximum measured existing conditions surface water concentration + 10%; SSWQO = site-specific water quality objective.

(a) Provincial Water Quality Objectives (PWQO) of the Ministry of Environment and Energy. July 1994

(b) Maximum measured existing conditions surface water concentration + 10%.

(c) Predicted maximum surface water concentration.

(d) Yes = the predicted surface water concentration is greater than the objective and the maximum measured existing conditions surface water concentration + 10% and therefore the chemical was identified as a COPC; No = the predicted surface water concentration is less than the objective and/or maximum measured existing conditions surface water concentration + 10% and therefore the chemical was not identified as a COPC.

(e) The guideline for total ammonia is the Canadian Council of Ministers of the Environment Canadian Water Qualtiy Guideline for the Protection of Freshwater Aquatic Life (CCME 2012). The guideline is based on a maximum baseline temperature of 21.16 °C and a pH of 7.59.

(f) PWQO for aluminum is based on pH. At pH 4.5 to 5.5 the PWQO is 15 µg/L; at pH > 6.5 to 9.0 the PWQO is 75 µg/L.

(g) PWQO for cadmium is based on hardness. The minimum hardness of the samples included in the assessment was 17.1 mg/L as CaCO$_3$ so a PWQO of 0.1 µg/L was used.

(h) PWQO for copper is based on hardness. The minimum hardness of the samples included in the assessment was 17.1 mg/L as CaCO$_3$ so a PWQO of 2 µg/L was used.

(i) PWQO for lead is based on hardness. The minimum hardness of the samples included in the assessment was 17.1 mg/L as CaCO$_3$ so a PWQO of 1 µg/L was used.

(j) PWQO for chromium is for hexavalent chromium (Cr VI).

TABLE 5

Surface Water Screening for the Tailings Management Area Reclaim Pond

Chemical	Units	PWQO[a]	Predicted Concentration[b]	COPC[c]	Rationale
pH	s.u.	6.5 – 8.5	7.8	No	Within range of PWQO
Alkalinity	mg/L (as $CaCO_3$)	Alkalinity should not be decreased by more than 25% of the natural concentration	112	No	No direct impact on wildlife health
Nitrate	mg/L (as N)	NV	0.000005	No	Less than the BCMOE guideline for the protection of wildlife of 100 mg/L (as N)
Ammonia	mg/L (as N)	NV	4.1	No	Lack of toxicity data/non-toxic
Aluminum	ug/L	75[d]	14	No	< PWQO
Antimony	ug/L	20	1.8	No	< PWQO
Arsenic	ug/L	5	0.03	No	< PWQO
Boron	ug/L	200	0.78	No	< PWQO
Barium	ug/L	NV	12	No	Less than the Sample et al. (1996) toxicological benchmark of 23,100 ug/L
Calcium	ug/L	NV	22,810	No	Essential nutrient/ ameliorates metal toxicity
Cadmium	ug/L	0.1[e]	0.02	No	< PWQO
Chloride	ug/L	NV	23,148	No	Less than the CCME guideline for the protection of aquatic life of 120,000 ug/L
Cobalt	ug/L	0.9	2.2	No	Less than the CCME guideline for the protection of livestock of 1,000 ug/L
Chromium	ug/L	1[f]	0.21	No	< PWQO
Copper	ug/L	1[g]	82	No	Less than the CCME guideline for the protection of livestock of 500 ug/L [i]
Iron	ug/L	300	0.07	No	< PWQO
Mercury	ug/L	0.2	0.10	No	< PWQO
Potassium	ug/L	NV	30,804	No	Less than BCMOE guideline for the protection of aquatic life of 194,000 to 225,000 µg/L
Magnesium	ug/L	NV	12,332	No	Essential nutrient/ ameliorates metal toxicity
Manganese	ug/L	NV	37	No	Less than the Sample et al. (1996) toxicological benchmark of 377,000 ug/L
Molybdenum	ug/L	40	62	No	Less than the CCME guideline for the protection of livestock of 500 ug/L
Sodium	ug/L	NV	79,797	No	Essential nutrient/ ameliorates metal toxicity
Nickel	ug/L	25	8.4	No	< PWQO
Phorphorous	ug/L-P	20 – 30	20	No	Within range of PWQO
Lead	ug/L	1[h]	0.13	No	< PWQO
Selenium	ug/L	100	0.95	No	< PWQO
Silver	ug/L	0.1	0.01	No	< PWQO
Sulphate	ug/L	NV	183,235	No	Less than the aquatic toxcity benchmark of 200,000 ug/L (Davies, 2007)
Strontium	ug/L	NV	244	No	Less than the Sample et al. (1996) toxicological benchmark of 1,127,000 ug/L
Tin	ug/L	NV	25	No	Less than the Sample et al. (1996) toxicological benchmark of 29,200 ug/L
Vanadium	ug/L	6	0.02	No	< PWQO
Thallium	ug/L	0.3	0.16	No	< PWQO
Uranium	ug/L	5	5.5	No	Less than the CCME guideline for the protection of livestock of 200 ug/L
Zinc	ug/L	20	2.0	No	< PWQO
Cyanide	ug/L	NV	825	No	Less than the Sample et al. (1996) toxicological benchmark of 276,600 ug/L

Notes:

NV = no value; COPC = chemical of potential concern; mg/L = milligram per litre; ug/L = microgram per litre; < = less than; PWQO = Provincial Water Quality Objective.

[a] Provincial Water Quality Objectives (PWQOs) of the Ministry of Environment and Energy. July 1994.

[b] Predicted surface water concentration for Scenario 1 - Steady State

[c] Yes = the predicted water concentration is greater than the PWQO and therefore the chemical was identified as a COPC; No = the predicted water concentration is less than the PWQO and therefore the chemical was not identified as a COPC.

[d] PWQO for aluminum is based on pH. At pH 4.5 to 5.5 the PWQO is 15 µg/L; at pH > 6.5 to 9.0 the PWQO is 75 µg/L.

[e] PWQO for cadmium is based on hardness as $CaCO_3$. Hardness was not predicted, therefore the most conservative PWQO for cadmium was used (0.1 µg/L).

[f] PWQO for chromium is for hexavalent chromium (Cr VI).

[g] PWQO for copper is based on hardness as $CaCO_3$. Hardness was not predicted, therefore the most conservative PWQO for copper was used (1 µg/L).

[h] PWQO for lead is based on hardness as $CaCO_3$. Hardness was not predicted, therefore the most conservative PWQO for lead was used (1 µg/L).

[i] Most stringent of the guidelines provided (for sheep).

Prepared by: SG
Checked by: TMG

TABLE 6

Surface Water Screening for Lizard Lake for Seepage from the TMF during Operations

Chemical	Units	PWQO[a]	Existing Conditions Concentration + 10%[b]	Predicted Concentration[c]	COPC[d]	Rationale
Physical-Chemical						
pH	N/A	6.5-8.5	6.7-7.6	7.3	No	Within range of PWQO
Major Ions						
Calcium	mg/L	NV	13	11	No	No PWQO, <EC
Chloride	mg/L	NV	0.48	0.91	No	Less than the CCME guideline for aquatic life of 120 mg/L
Magnesium	mg/L	NV	1.1	1.1	No	No PWQO, <EC
Potassium	mg/L	NV	0.38	1.1	No	Essential nutrient/ameliorates metal toxicity
Sodium	mg/L	NV	0.77	1.9	No	Essential nutrient/ameliorates metal toxicity
Sulphate	mg/L	NV	2.8	4.5	No	Less than BCMOE guideline of 50 mg/L
Hardness	mg/L	NV	33	32	No	No PWQO, <EC
Free Cyanide	mg/L	0.005	0.006	0.006	No	>PWQO, <EC
Total Cyanide	mg/L	NV	0.002	0.012	No	Free cyanide is the most toxicologically relevant
Nutrients						
Nitrate	mg/L as N	NV	0.06	0.034	No	No PWQO, <EC
Ammonia	mg/L as N	NV	0.03	0.21	No	Less than CCME guideline of 1.27 mg/L as N[e]
Un-ionized ammonia	mg/L	0.02	0.0003	0.0019	No	<PWQO
Phosphorus	mg/L -P	0.01	0.01	0.0084	No	<PWQO
Dissolved Metals						
Aluminum	µg/L	75[f]	31	18	No	<PWQO
Antimony	µg/L	20	< 0.11	0.99	No	<PWQO
Arsenic	µg/L	5	1.1	0.43	No	<PWQO
Boron	µg/L	200	55	11	No	<PWQO
Cadmium	µg/L	0.1[g]	0.11	0.03	No	<PWQO
Chromium	µg/L	1[j]	1.1	0.49	No	<PWQO
Cobalt	µg/L	0.9	< 0.055	0.15	No	<PWQO
Copper	µg/L	5[h]	1.6	2.4	No	< PWQO
Iron	µg/L	300	97	53	No	<PWQO
Lead	µg/L	1[i]	1.1	0.24	No	<PWQO
Mercury	µg/L	0.2	< 0.011	0.005	No	<PWQO
Molybdenum	µg/L	40	1.1	1.2	No	<PWQO
Nickel	µg/L	25	2.2	0.89	No	<PWQO
Selenium	µg/L	100	< 0.55	0.50	No	<PWQO
Silver	µg/L	0.1	< 0.055	0.10	No	<PWQO
Uranium	µg/L	5	5.5	2.6	No	<PWQO
Vanadium	µg/L	6	1.1	0.37	No	<PWQO
Zinc	µg/L	20	9.5	5.5	No	<PWQO

Notes:

NV = no value; COPC = chemical of potential concern; mg/L = milligram per litre; ug/L = microgram per litre; — = value not required; < = less than; EC = maximum measured existing conditions surface water concentration + 10%; SSWQO = site-specific water quality objective.

[a] Provincial Water Quality Objectives (PWQO) of the Ministry of Environment and Energy. July 1994

[b] Maximum measured existing conditions surface water concentration + 10%.

[c] Predicted maximum surface water concentration.

[d] Yes = the predicted surface water concentration is greater than the objective and the maximum measured existing conditions surface water concentration + 10% and therefore the chemical was identified as a COPC; No = the predicted surface water concentration is less than the objective and/or maximum measured existing conditions surface water concentration + 10% and therefore the chemical was not identified as a COPC.

[e] The guideline for total ammonia is the Canadian Council of Ministers of the Environment Canadian Water Qualtiy Guideline for the Protection of Freshwater Aquatic Life (CCME 2012). The guideline is based on a maximum existing conditions temperature of 20 °C and a pH of 7.6.

[f] PWQO for aluminum is based on pH. At pH 4.5 to 5.5 the PWQO is 15 µg/L; at pH > 6.5 to 9.0 the PWQO is 75 µg/L.

[g] PWQO for cadmium is based on hardness. The minimum hardness of the samples included in the assessment was 26 mg/L as $CaCO_3$ so a PWQO of 0.1 µg/L was used.

[h] PWQO for copper is based on hardness. The minimum hardness of the samples included in the assessment was 26 mg/L as $CaCO_3$ so a PWQO of 5 µg/L was used.

[i] PWQO for lead is based on hardness. The minimum hardness of the samples included in the assessment was 26 mg/L as $CaCO_3$ so a PWQO of 1 µg/L was used.

[j] PWQO for chromium is for hexavalent chromium (Cr VI).

TABLE 7

Surface Water Screening for Lizard Lake
for Seepage from the TMF during Post-Closure

Chemical	Units	PWQO[a]	Existing Conditions Concentration + 10%[b]	Predicted Concentration[c]	COPC[d]	Rationale
Physical-Chemical						
pH	—	6.5-8.5	8.0	7.3	No	Within range of PWQO
Major Ions						
Calcium	mg/L	NV	11	10	No	No PWQO, < EC
Chloride	mg/L	NV	0.28	0.25	No	No PWQO, < EC
Magnesium	mg/L	NV	1.0	0.91	No	No PWQO, < EC
Potassium	mg/L	NV	0.72	0.66	No	No PWQO, < EC
Sodium	mg/L	NV	0.74	0.67	No	No PWQO, < EC
Sulphate	mg/L	NV	2.1	1.9	No	No PWQO, < EC
Hardness	mg($CaCO_3$)/L	NV	33	30	No	No PWQO, < EC
Nutrients						
Nitrate-N	mg/L	NV	0.04	0.034	No	No PWQO, < EC
Un-ionized ammonia	mg/L	0.02	0.00005	0.00005	No	<PWQO
Phosphorus	mg/L	0.02	0.01	0.0082	No	< PWQO
Dissolved Metals						
Aluminum	ug/L	75[e]	31	18	No	<PWQO
Antimony	ug/L	20	< 0.11	0.97	No	<PWQO
Arsenic	ug/L	5	1.1	0.43	No	<PWQO
Boron	ug/L	200	55	11	No	< PWQO
Cadmium	ug/L	0.1[f]	0.11	0.03	No	< PWQO
Chromium (total)	ug/L	1[g]	1.1	0.49	No	< PWQO
Cobalt	ug/L	0.9	< 0.055	0.12	No	< PWQO
Copper	ug/L	5[h]	1.6	0.87	No	< PWQO
Iron (total)	ug/L	300	97	53	No	< PWQO
Lead	ug/L	3[i]	1.1	0.24	No	< PWQO
Manganese	ug/L	NV	28	9.4	No	No PWQO, < EC
Mercury	ug/L	0.2	< 0.01	0.01	No	< PWQO
Molybdenum	ug/L	40	1.1	0.33	No	< PWQO
Nickel	ug/L	25	2.2	0.80	No	< PWQO
Selenium	ug/L	100	< 0.6	0.5	No	< PWQO
Silver	ug/L	0.1	< 0.06	0.10	No	< PWQO
Uranium	ug/L	5	5.5	2.5	No	< PWQO
Zinc	ug/L	20	9.5	5.5	No	< PWQO

Notes:

NV = no value; COPC = chemical of potential concern; mg/L = milligram per litre; ug/L = microgram per litre; < = less than; EC = existing conditions surface water concentration + 10%.

[a] Provincial Water Quality Objectives (PWQO) of the Ministry of Environment and Energy. July 1994

[b] Maximum measured existing conditions surface water concentration + 10%.

[c] Predicted surface water concentration.

[d] Yes = the predicted surface water concentration is greater than the objective and the maximum meaaured existing conditions surface water concentration + 10% and therefore the chemical was identified as a COPC; No = the predicted surface water concentration is less than the objective and/or the maximum measured surface water concentration + 10% and therefore the chemical was not identified as a COPC.

[e] PWQO for aluminum is based on pH. At pH 4.5 to 5.5 the PWQO is 15 µg/L; at pH > 6.5 to 9.0 the PWQO is 75 µg/L.

[f] PWQO for cadmium is based on hardness. The existing conditions hardness was 30 mg/L as $CaCO_3$ so a PWQO of 0.1 µg/L was used.

[g] PWQO is for hexavalent chromium (Cr VI).

[h] PWQO for copper is based on hardness. The existing conditions hardness was 30 mg/L as $CaCO_3$ so a PWQO of 5 µg/L was used.

[i] PWQO for lead is based on hardness. The existing conditions hardness was 30 mg/L as $CaCO_3$ so a PWQO of 3 µg/L was used.

TABLE 8

Surface Water Screening for Marmion Reservoir for Pit Flood Effluent

Chemical	Units	PWQO(a)	Existing Conditions Concentration + 10%(b)	Predicted Concentration(c)	COPC(d)	Rationale
Physical-Chemical						
pH	—	6.5-8.5	7.6	6.9	No	Within range of PWQO
Major Ions						
Calcium	mg/L	NV	7.1	6.5	No	No PWQO, < EC
Chloride	mg/L	NV	1.2	1.1	No	No PWQO, < EC
Magnesium	mg/L	NV	1.4	1.3	No	No PWQO, < EC
Potassium	mg/L	NV	0.74	0.68	No	No PWQO, < EC
Sodium	mg/L	NV	1.4	1.3	No	No PWQO, < EC
Sulphate	mg/L	NV	1.8	1.6	No	No PWQO, < EC
Hardness	mg($CaCO_3$)/L	NV	23	21	No	No PWQO, < EC
Nutrients						
Nitrate-N	mg/L	NV	0.07	0.063	No	No PWQO, < EC
Un-ionized ammonia	mg/L	0.02	0.00007	0.0018	No	< PWQO
Phosphorus	mg/L	0.02	0.01	0.013	No	< PWQO
Dissolved Metals						
Aluminum	ug/L	75(e)	49	30	No	<PWQO
Antimony	ug/L	20	< 5.5	0.78	No	<PWQO
Arsenic	ug/L	5	0.46	0.49	No	<PWQO
Boron	ug/L	200	4.4	14	No	< PWQO
Cadmium	ug/L	0.1(f)	0.014	0.036	No	< PWQO
Chromium (total)	ug/L	1(g)	0.33	0.49	No	< PWQO
Cobalt	ug/L	0.9	0.06	0.17	No	< PWQO
Copper	ug/L	5(h)	2.2	1.1	No	< PWQO
Iron (total)	ug/L	300	447	237	No	< PWQO
Lead	ug/L	1(i)	0.055	0.29	No	< PWQO
Manganese	ug/L	NV	113	24	No	No PWQO, < EC
Mercury	ug/L	0.2	0.013	0.005	No	< PWQO
Molybdenum	ug/L	40	< 1.1	0.37	No	< PWQO
Nickel	ug/L	25	0.88	0.99	No	< PWQO
Selenium	ug/L	100	0.44	0.5	No	< PWQO
Silver	ug/L	0.1	< 0.22	0.087	No	< PWQO
Uranium	ug/L	5	0.03	2.2	No	< PWQO
Zinc	ug/L	20	12.0	5.2	No	< PWQO

Notes:

NV = no value; COPC = chemical of potential concern; mg/L = milligram per litre; ug/L = microgram per litre; < = less than; EC = existing conditions water concentration + 10%.

(a) Provincial Water Quality Objectives (PWQO) of the Ministry of Environment and Energy. July 1994

(b) Maximum measured existing conditions surface water concentration + 10%.

(c) Predicted worst-case water concentration in Marmion Reservoir.

(d) Yes = the predicted water concentration is greater than the objective and the maximum measured existing conditions surface water concentration + 10% and therefore the chemical was identified as a COPC; No = the predicted water concentration is less than the objective and/or maximum measured existing conditions surface water concentration + 10% and therefore the chemical was not identified as a COPC.

(e) PWQO for aluminum is based on pH. At pH 4.5 to 5.5 the PWQO is 15 µg/L; at pH > 6.5 to 9.0 the PWQO is 75 µg/L.

(f) PWQO for cadmium is based on hardness. The existing conditions hardness was 21 mg/L as $CaCO_3$ so a PWQO of 0.1 µg/L was used.

(g) PWQO is for hexavalent chromium (Cr VI).

(h) PWQO for copper is based on hardness. The existing conditions hardness was 21 mg/L as $CaCO_3$ so a PWQO of 5 µg/L was used.

(i) PWQO for lead is based on hardness. The existing conditions hardness was 21 mg/L as $CaCO_3$ so a PWQO of 1 µg/L was used.

TABLE 9
Surface Water Screening for Marmion Reservoir for Site Runoff

Chemical	Units	PWQO[a]	Existing Conditions Concentration + 10%[b]	Predicted Concentration[c]	COPC[d]	Rationale
Physical-Chemical						
pH	—	6.5-8.5	7.6	6.9	No	Within range of PWQO
Major Ions						
Calcium	mg/L	NV	7.1	7.0	No	No PWQO, < EC
Chloride	mg/L	NV	1.2	1.1	No	No PWQO, < EC
Magnesium	mg/L	NV	1.4	1.3	No	No PWQO, < EC
Potassium	mg/L	NV	0.74	0.68	No	No PWQO, < EC
Sodium	mg/L	NV	1.4	1.3	No	No PWQO, < EC
Sulphate	mg/L	NV	1.8	1.7	No	No PWQO, < EC
Hardness	mg(CaCO$_3$)/L	NV	23	23	No	No PWQO, < EC
Nutrients						
Nitrate-N	mg/L	NV	0.07	0.063	No	No PWQO, < EC
Un-ionized ammonia	mg/L	0.02	0.00007	0.000067	No	< PWQO
Phosphorus	mg/L	0.02	0.01	0.014	No	< PWQO
Dissolved Metals						
Aluminum	ug/L	75[e]	49	50	No	<PWQO
Antimony	ug/L	20	< 5.5	0.89	No	<PWQO
Arsenic	ug/L	5	0.46	0.50	No	<PWQO
Boron	ug/L	200	4.4	14	No	< PWQO
Cadmium	ug/L	0.1[f]	0.014	0.037	No	< PWQO
Chromium (total)	ug/L	1[g]	0.33	0.52	No	< PWQO
Cobalt	ug/L	0.9	0.06	0.20	No	< PWQO
Copper	ug/L	5[h]	2.2	1.1	No	< PWQO
Iron (total)	ug/L	300	447	332	No	> PWQO, < EC
Lead	ug/L	1[i]	0.055	0.30	No	< PWQO
Manganese	ug/L	NV	113	24	No	No PWQO, < EC
Mercury	ug/L	0.2	0.013	0.005	No	< PWQO
Molybdenum	ug/L	40	< 1.1	0.38	No	< PWQO
Nickel	ug/L	25	0.88	0.99	No	< PWQO
Selenium	ug/L	100	0.44	1.2	No	< PWQO
Silver	ug/L	0.1	< 0.22	0.09	No	< PWQO
Uranium	ug/L	5	0.03	2.2	No	< PWQO
Zinc	ug/L	20	12.0	5.2	No	< PWQO

Notes:

NV = no value; COPC = chemical of potential concern; mg/L = milligram per litre; ug/L = microgram per litre; < = less than; EC = existing conditions surface water concentration + 10%.

[a] Provincial Water Quality Objectives (PWQO) of the Ministry of Environment and Energy. July 1994

[b] Maximum measured existing conditions surface water concentration + 10%.

[c] Predicted surface water concentration.

[d] Yes = the predicted surface water concentration is greater than the objective and the maximum measured existing conditions surface water concentration + 10% and therefore the chemical was identified as a COPC; No = the predicted surface water concentration is less than the objective and/or maximum measured existing conditions surface water concentration + 10% and therefore the chemical was not identified as a COPC.

[e] PWQO for aluminum is based on pH. At pH 4.5 to 5.5 the PWQO is 15 µg/L; at pH > 6.5 to 9.0 the PWQO is 75 µg/L.

[f] PWQO for cadmium is based on hardness. The existing conditions hardness was 21 mg/L as CaCO$_3$ so a PWQO of 0.1 µg/L was used.

[g] PWQO is for hexavalent chromium (Cr VI).

[h] PWQO for copper is based on hardness. The existing conditions hardness was 21 mg/L as CaCO$_3$ so a PWQO of 5 µg/L was used.

[i] PWQO for lead is based on hardness. The existing conditions hardness was 21 mg/L as CaCO$_3$ so a PWQO of 1 µg/L was used.

TABLE 10
Pit Lake Water Screening

			East Pit			West Pit		
Chemical	**Units**	**PWQO[a]**	**Predicted Concentration[b]**	**COPC[c]**	**Rationale**	**Predicted Concentration[b]**	**COPC[c]**	**Rationale**
pH	N/A	6.5 – 8.5	6.8 – 7.0	No	Within range of PWQO	6.9 – 7.1	No	Within range of PWQO
Sulphate	µg/L	NV	740 – 1500	No	Less than BCMOE guideline of 50,000 ug/L and Minnesota guideline of 10,000 ug/L	1000 – 1600	No	Less than BCMOE guideline of 50,000 ug/L and Minnesota guideline of 10,000 ug/L
Nitrate	mg/L (as N)	NV	0.0003-0.0005	No	Less than the CCME guideline of 3 mg/L (as N)	0.0003-0.0005	No	Less than the CCME guideline of 3 mg/L (as N)
Ammonium	mg/L (as N)	NV	0.05	No	Less than CCME guideline for total ammonia-N of 1.9 mg/L	0.12	No	Less than CCME guideline for total ammonia-N of 1.9 mg/L
Chloride	µg/L	NV	3000 – 3600	No	Less than the CCME guideline of 120,000 ug/L	3200 – 3900	No	Less than the CCME guideline of 120,000 ug/L
Mercury	µg/L	0.2	0.05 – 0.07	No	< PWQO	0.1 – 0.2	No	< PWQO
Silver	µg/L	0.1	0.02 – 0.07	No	< PWQO	0.03 – 0.08	No	< PWQO
Aluminum	µg/L	75[d]	1	No	< PWQO	1	No	< PWQO
Arsenic	µg/L	5	0.03 – 0.1	No	< PWQO	0.8 – 1.0	No	< PWQO
Boron	µg/L	200	2.0 – 10	No	< PWQO	2.0 – 10	No	< PWQO
Calcium	µg/L	NV	7900 – 9500	No	Essential nutrient/ ameliorates metal toxicity	11000 – 13000	No	Essential nutrient/ ameliorates metal toxicity
Cadmium	µg/L	0.1[e]	0.01 – 0.03	No	< PWQO	0.01 – 0.03	No	< PWQO
Cobalt	µg/L	0.9	0.2 – 0.3	No	< PWQO	0.1 – 0.3	No	< PWQO
Chromium	µg/L	1[f]	0.001 – 0.05	No	< PWQO	0.5	No	< PWQO
Copper	µg/L	1[g]	0.09 – 0.3	No	< PWQO	0.6 – 0.7	No	< PWQO
Iron	µg/L	300	0.7 – 1.0	No	< PWQO	0.4 – 0.6	No	< PWQO
Potassium	µg/L	NV	360 – 650	No	Essential nutrient/ ameliorates metal toxicity	600 – 870	No	Essential nutrient/ ameliorates metal toxicity
Magnesium	µg/L	NV	1100 – 1400	No	Essential nutrient/ ameliorates metal toxicity	1100 – 1600	No	Essential nutrient/ ameliorates metal toxicity
Molybdenum	µg/L	40	0.2 – 0.6	No	< PWQO	0.2 – 1.0	No	< PWQO
Sodium	µg/L	NV	680 – 900	No	Essential nutrient/ ameliorates metal toxicity	680 – 1000	No	Essential nutrient/ ameliorates metal toxicity
Nickel	µg/L	25	0.6 – 0.8	No	< PWQO	0.6 – 0.8	No	< PWQO
Phosphorus	µg/L	20 – 30	6.0 – 7.0	No	< PWQO	20	No	< PWQO
Lead	µg/L	1[h]	0.0002 – 0.02	No	< PWQO	0.03 – 0.05	No	< PWQO
Antimony	µg/L	20	0.1 – 1.0	No	< PWQO	0.3 – 1.0	No	< PWQO
Selenium	µg/L	100	0.6 – 0.8	No	< PWQO	1.0 – 2.0	No	< PWQO
Uranium	µg/L	5	0.1 – 2.0	No	< PWQO	0.5 – 2.0	No	< PWQO
Vanadium	µg/L	6	0.1 – 0.2	No	< PWQO	0.3 – 0.4	No	< PWQO
Zinc	µg/L	20	2	No	< PWQO	3	No	< PWQO

Notes:

NV = no value; N/A = not applicable; COPC = chemical of potential concern; mg/L = milligram per litre; ug/L = microgram per litre; < = less than; PWQO = Provincial Water Quality Objective.

[a] Provincial Water Quality Objectives (PWQOs) of the Ministry of Environment and Energy. July 1994.

[b] Predicted maximum surface water concentration of the two modelled scenarios: (1) assuming diversion of water from tailings management facility to open pits and adiversion and (2) assuming no diversion of water from tailings management facility to open pits. Predicted concentrations are for the stratified (top of pit) condition.

[c] Yes = the predicted water concentration is greater than the PWQO and therefore the chemical was identified as a COPC; No = the predicted water concentration is less than the PWQO and therefore the chemical was not identified as a COPC.

[d] PWQO for aluminum is based on pH. At pH 4.5 to 5.5 the PWQO is 15 µg/L; at pH > 6.5 to 9.0 the PWQO is 75 µg/L.

[e] PWQO for cadmium is based on hardness as $CaCO_3$. Hardness was not predicted, therefore the most conservative PWQO for cadmium was used (0.1 µg/L).

[f] PWQO for chromium is for hexavalent chromium (Cr VI).

[g] PWQO for copper is based on hardness as $CaCO_3$. Hardness was not predicted, therefore the most conservative PWQO for copper was used (1 µg/L).

[h] PWQO for lead is based on hardness as $CaCO_3$. Hardness was not predicted, therefore the most conservative PWQO for lead was used (1 µg/L).

APPENDIX 4.II

Biotic Ligand Model for Copper

TABLE 1

Water Quality Parameters for the Copper Biotic Ligand Model

Water Body	Sample ID	Sampling Date	Temperature	pH	DOC	HA[a]	Ca	Mg	Na	K	SO_4	Cl	Alkalinity	S[a]
			°C		mg C/L	%	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L $CaCO_3$	mg/L
Sawbill Bay - Surface (1m)	HRWQP-2A	Sep-10	15.19	7.25	8	10	6.06	1.45	1.38	***1***	1.69	1.31	18.7	1E-10
Sawbill Bay - Surface (1m)	HRWQP-2A	Nov-10	7.77	6.95	7.3	10	6.7	1.45	2.62	***1***	1.47	1.09	21.7	1E-10
Sawbill Bay - Surface (1m)	HRWQP-2A	Jun-11	14.47	7.29	10	10	5.82	1.33	1.35	0.464	1.8	1.35	17.1	1E-10
Sawbill Bay - Surface (1m)	HRWQP2A	13-APR-12	3.89	7.11	6.6	10	5.97	1.43	1.49	0.449	1.65	1.23	18	1E-10
Sawbill Bay - Bottom (24m)	HRWQP-2B	Sep-10	8.37	6.95	8.6	10	5.98	1.45	1.36	***1***	1.8	1.34	17.9	1E-10
Sawbill Bay - Bottom (24m)	HRWQP-2B	Nov-10	7.14	6.95	7.4	10	6.52	1.39	1.35	***1***	1.68	1.28	20.8	1E-10
Sawbill Bay - Bottom (24m)	HRWQP-2B	Jun-11	7.94	7.01	9.2	10	5.76	1.39	1.34	0.427	1.74	1.28	17.7	1E-10
Sawbill Bay - Bottom (24m)	HRWQP2B	13-APR-12	3.85	7.15	7.3	10	5.85	1.41	1.48	0.447	1.63	1.24	17.6	1E-10
Lynxhead Bay - Surface (1m)	HRWQP-7A	Sep-10	13.92	7.32	10.7	10	6.6	1.61	1.66	***1***	1.59	1.34	18.7	1E-10
Lynxhead Bay - Surface (1m)	HRWQP-7A	Nov-10	6.46	7.02	8.5	10	5.56	1.46	1.58	***1***	1.59	1.85	18.1	1E-10
Lynxhead Bay - Surface (1m)	HRWQP-7A	Jun-11	15.39	7.12	10.4	10	5.01	1.25	1.41	0.455	1.64	1.39	14.4	1E-10
Lynxhead Bay - Surface (1m)	HRWQP7A	12-APR-12	4.75	6.93	12.3	10	5.51	1.42	1.59	0.525	1.43	1.61	16.6	1E-10
Lynxhead Bay - Bottom (15m)	HRWQP-7B	Sep-10	7	7.07	11	10	6.47	1.66	1.67	***1***	1.62	1.4	18.6	1E-10
Lynxhead Bay - Bottom (15m)	HRWQP-7B	Nov-10	6.44	6.96	8.8	10	5.81	1.49	1.55	***1***	1.28	1.39	18.5	1E-10
Lynxhead Bay - Bottom (15m)	HRWQP-7B	Jun-11	10.3	6.96	10.8	10	5	1.23	1.44	0.453	1.51	1.51	15.7	1E-10
Lynxhead Bay - Bottom (15m)	HRWQP7B	12-APR-12	4.59	6.94	9.9	10	5.35	1.34	1.51	0.492	1.44	1.61	16.5	1E-10
Lynxhead Bay	HRWQ32	12-APR-12	6.63	7.1	7.7	10	6.26	1.38	1.38	0.513	1.68	1.17	18	1E-10

Notes:

mg/L = milligrams per litre.

[a] Assumed value (BLM User's Guide and Reference manual, February 2007).

TABLE 2

Site-specific Water Quality Objective for Copper for Marmion Reservoir

Water Body	Sample ID	Sampling Date	CMC[(a)] (ug/L)	CCC[(b)] (ug/L)
Sawbill Bay - Surface (1m)	HRWQP-2A	Sep-10	22	14
Sawbill Bay - Surface (1m)	HRWQP-2A	Nov-10	13	7.9
Sawbill Bay - Surface (1m)	HRWQP-2A	Jun-11	30	18
Sawbill Bay - Surface (1m)	HRWQP2A	Apr-12	14	9.0
Sawbill Bay - Bottom (24m)	HRWQP-2B	Sep-10	15	9.3
Sawbill Bay - Bottom (24m)	HRWQP-2B	Nov-10	13	7.9
Sawbill Bay - Bottom (24m)	HRWQP-2B	Jun-11	18	11
Sawbill Bay - Bottom (24m)	HRWQP2B	Apr-12	17	11
Lynxhead Bay - Surface (1m)	HRWQP-7A	Sep-10	33	20
Lynxhead Bay - Surface (1m)	HRWQP-7A	Nov-10	17	10
Lynxhead Bay - Surface (1m)	HRWQP-7A	Jun-11	25	15
Lynxhead Bay - Surface (1m)	HRWQP7A	Apr-12	22	14
Lynxhead Bay - Bottom (15m)	HRWQP-7B	Sep-10	23	15
Lynxhead Bay - Bottom (15m)	HRWQP-7B	Nov-10	16	9.8
Lynxhead Bay - Bottom (15m)	HRWQP-7B	Jun-11	20	13
Lynxhead Bay - Bottom (15m)	HRWQP7B	Apr-12	18	11
Lynxhead Bay	HRWQ32	Apr-12	17	10
		5th Percentile	**13**	**7.9**

Notes:

ug/L = micrograms per litre.

(a) CMC = Criterion Maximum Concentration; CMC = Final Acute Value/2 (ug/L).

(b) CCC = Criterion Continuous Concentration; CCC = Final Acute Value/Acute to Chronic Ratio (ug/L).