May 2011

APPENDIX J

RWDI AIR QUALITY REPORT

Appendix J.1 Thor Lake Project Final Report - Air Quality Assessment RWDI File No.: 1012109, March 30, 2011

Appendix J.1

Thor Lake Project Final Report - Air Quality Assessment RWDI File No.: 1012109, March 30, 2011

Tel: 604.730.5688
Fax: 604.730.2915

RWDI AIR Inc.
830 – 999 West Broadway
Vancouver, B.C., Canada
V5Z 1K5
Email: solutions@rwdi.com

Thor Lake Project

Final Report

Air Quality Assessment

RWDI # 1012109
March 30, 2011

SUBMITTED TO
David Swisher
Vice President Operations

Avalon Rare Metals Inc.
Unit 330 – 6165 Hwy 17
Delta, BC V4K 5B8
Phone: 604-940-3800
Email: dswisher@avalonraremetals.com

SUBMITTED BY

Tina Liu, M.A.Sc., EIT
Junior Project Coordinator
tina.liu@rwdi.com

Nancy Chan, B.A.Sc., EIT
Senior Project Coordinator
nancy.chan@rwdi.com

Mark Milner, M.Eng., P.Eng.
Project Manager
mark.milner@rwdi.com

Kathy Preston, Ph.D., P.Eng.
Project Director
kathy.preston@rwdi.com

TABLE OF CONTENTS

Tables

Figures

INTRODUCTION

Avalon Rare Metals Inc. (Avalon) is proposing to develop the Thor Lake Project (the Project) in the Northwest Territories (NWT) to mine, mill and produce rare earth elements from the Nechalacho deposit. The initial expected daily production at the mine is 1,000 tpd and will be ramped up to 2,000 tpd by year four. This assessment is based on full production.

The Project has three main components located at two sites: (1) an underground mine and (2) a flotation plant, to be located at the Nechalaho Mine and Flotation Plant Site, and (3) a hydrometallurgical plant to be located at the existing brownfield site of the former Pine Point Mine (Figure 0-1). The high grade concentrate produced at the Nechalacho Mine and Flotation Plant will be barged across Great Slave Lake for further processing at the Hydrometallurgical Plant.

Figure 0-1 Locations of Main Project Components

The original Project design required coal combustion for the hydrometallurgical process. However, a large part of the hydrometallurgical process will now be conducted in the United States and therefore the use of coal has been eliminated. Other changes to the Project design relevant to the air quality assessment are provided in Section 1.4.

1 SCOPE OF ASSESSMENT

The scope of the air quality assessment of the Project was defined by the Terms of Reference in combination with discussions with Avalon. The valued components that are assessed in this section are ambient air quality and greenhouse gas emissions. The objectives of this assessment are to:

- assess potential residual effects of Project emissions during construction, operation and closure,
- prepare an air quality and dust control plan to reduce potential effects of the Project, and
- develop a monitoring plan.

1.1 Issues Scoping

The Project will be a source of criteria air contaminant (CAC) and greenhouse gas (GHG) emissions from mining equipment, generators, vehicles, barges, and aircraft. It will be a source of fugitive dust emissions from crushing, processing and handling the ore. There will also be process CAC and GHG emissions from the sulphuric acid plant, acid bake kiln and product dryer.

CACs and GHGs are the measureable parameters of this assessment and the measurement endpoints are ambient concentrations or deposition levels of CACs and total emissions of GHGs.

The specific CACs included in the scope of this assessment are:

- nitrogen dioxide (NO_2),
- sulphur dioxide (SO_2),
- carbon monoxide (CO),
- total particulate matter (TSP),
- particulate matter with diameter less than 2.5 µm ($PM_{2.5}$), and
- dustfall.

The specific GHGs included in the scope of this assessment are:

- carbon dioxide (CO_2),
- methane (CH_4), and
- nitrous oxide (N_2O).

Greenhouse gases are a concern due to their potential to affect global climate change. Increases in ambient concentrations of CACs are of concern due to their potential to affect human and wildlife health whereas increases in deposition levels of particulate matter can affect vegetation and water quality. More information on the potential effects of the CACs is provided in the following paragraphs.

Oxides of nitrogen (NO_x) are produced when fossil fuels are burned at high temperatures and are composed primarily of nitric oxide (NO) and NO_2. In humans, NO_2 acts as an irritant affecting the mucous membranes of the eyes, nose, throat, and respiratory tract. Continued exposure to NO_2 can irritate the lungs and lower resistance to respiratory infection, especially for people with pre-existing asthma and bronchitis. For this reason, ambient air quality standards are based on NO_2, not NO or NO_x. Nitrogen dioxide can combine with other air contaminants to form fine particulates, which can reduce visibility. It can be further oxidized to form nitric acid, a component of acid rain. Nitrogen dioxide also plays a major role in the secondary formation of ozone.

Sulphur dioxide is produced primarily by the combustion of fossil fuels containing sulphur. Sulphur dioxide reacts in the atmosphere to form sulphuric acid, a major contributor to acid rain, and particulate sulphates, which can reduce visibility. Sulphur dioxide is irritating to the lungs and is frequently described as smelling of burning sulphur.

Carbon monoxide is produced by incomplete combustion of fossil fuels. It is the most widely distributed and commonly occurring air pollutant and comes primarily from motor vehicle emissions. Space heating and commercial and industrial operations are also contributors. Short-term health effects related to CO exposure include headache, dizziness, light-headedness and fainting. Exposure to high CO concentrations can decrease the ability of the blood to carry oxygen and can lead to respiratory failure and death.

Particulate matter is often defined in terms of size fractions. Dustfall refers to the amount of particulate matter of all size classes that settles onto a collection surface in a given amount of time. It is a measure of the amount of particulate present in the ambient air that is deposited on the ground. Particles less than 40 µm in diameter typically remain suspended in the air for some time. This is referred to as total suspended particulate (TSP). Suspended particulate matter less than 2.5 µm in diameter is termed $PM_{2.5}$. Exposure to particulate matter aggravates a number of respiratory illnesses and may even cause premature death in people with existing heart and lung disease. The smaller particles ($PM_{2.5}$) are generally thought to be of greater concern to human health than the larger particles (TSP).

1.2 Spatial Boundaries

Two local study areas (LSAs) were defined for the air quality assessment of the Project: one for the Nechalacho Mine and Flotation Plant, and one for the Hydrometallurgical Plant. Since the two LSAs are located approximately 160 km from each other, air quality effects from the Project components at the two sites are not expected to overlap.

1.2.1 Nechalacho Mine and Flotation Plant

The LSA for the Nechalacho Mine and Flotation Plant is a 20 km by 20 km area centred on the ramp portal of the underground mine. Figure 1-1 is a map of the LSA. The Nechalacho Mine and Flotation Plant is located within the Great Slave Upland High Boreal (HB) Ecoregion.

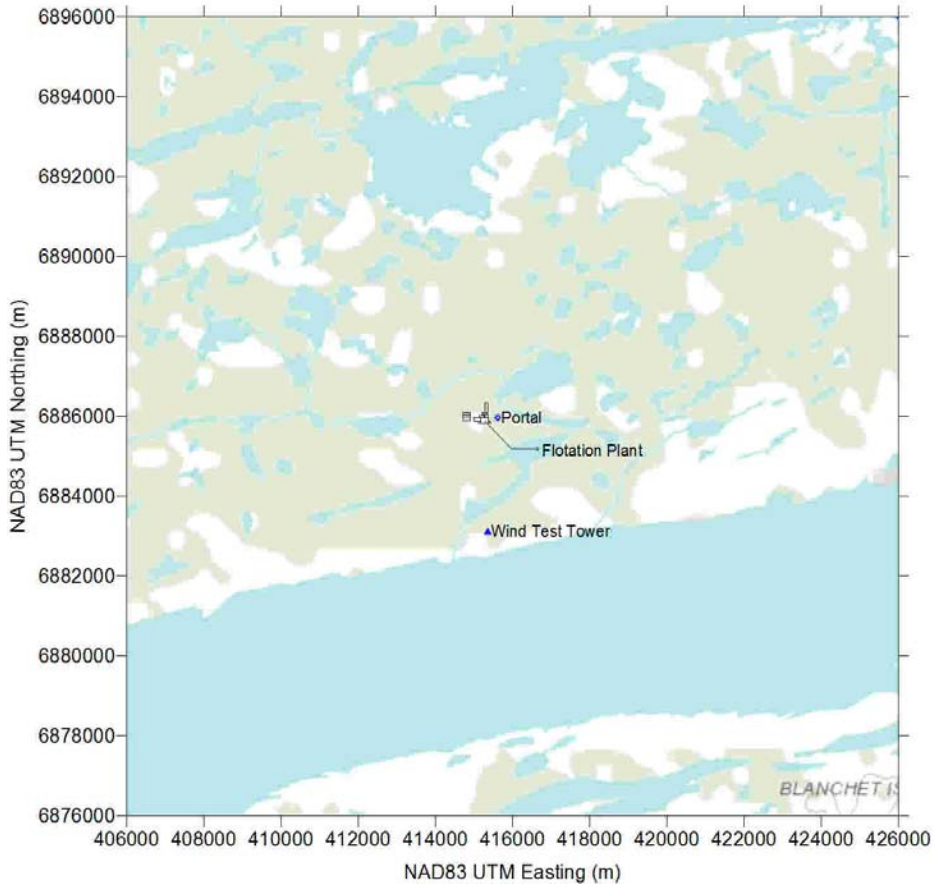

Figure 1-1 Nechalacho Mine and Flotation Plant Local Study Area

1.2.2 Hydrometallurgical Plant

The LSA for the Pine Point Hydrometallurgical Plant is a 20 km by 20 km area centred on the sulphuric acid plant, illustrated in Figure 1-2. As previously noted, the hydrometallurgical plant will be located at the former Pine Point Mine Site, which is a brownfield site.

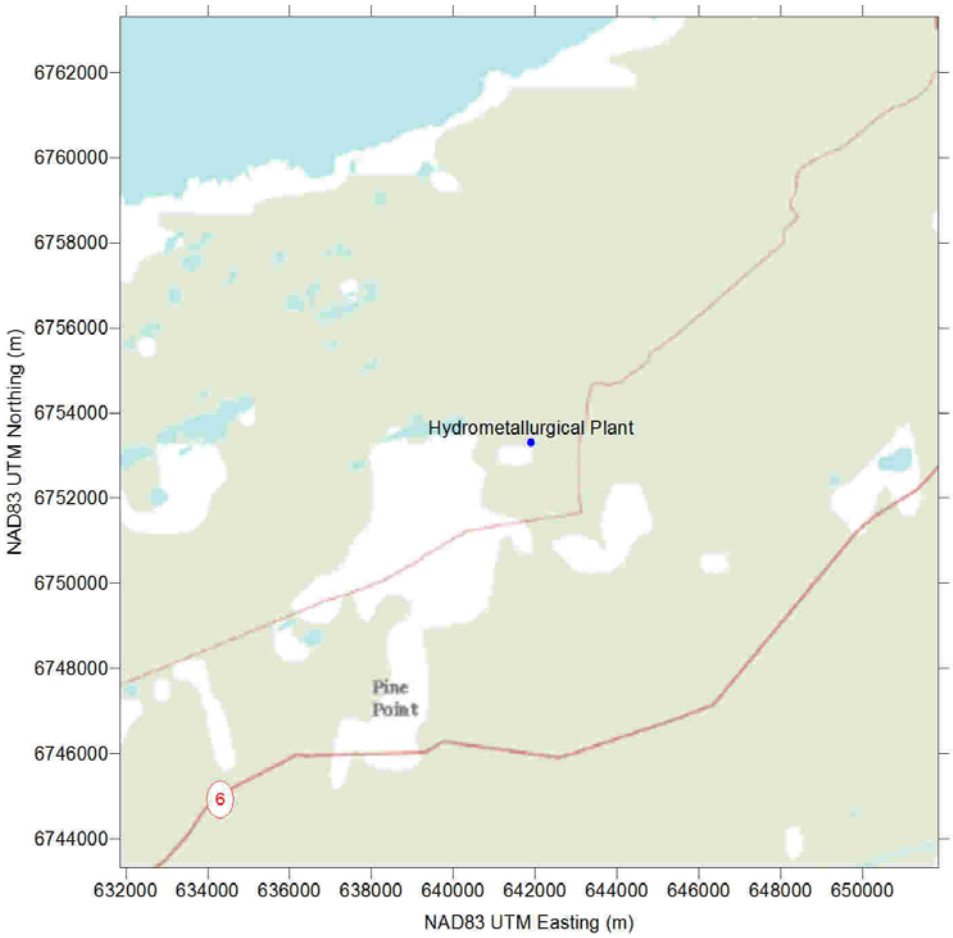

Figure 1-2 Hydrometallurgical Plant Local Study Area

1.3 Temporal Boundaries

The proposed Project is currently projected to be in service in 2014. Construction is scheduled to begin 16 to 24 months prior to operations. The mine will operate for 18 years, after which time the mine will be decommissioned and reclamation will take place.

1.4 Information Sources

The information sources for this assessment are the *Project Description Report, Thor Lake Project, Northwest Territories* (PDR), by Avalon Rare Metals Inc., 2010 and *Preliminary Feasibility Study on the Thor Lake Project, Northwest Territories, Canada* (PFS) by Scott Wilson Roscoe Postle Associates Inc., 2010. The PDR and PFS were written in April and September, 2010, respectively; however, there have been adjustments to the Project design since then. Most notably, a large portion of the hydrometallurgical process will be conducted in the United States rather than on site eliminating the need for coal use and lime production.

Detailed changes to the Project design that are relevant to the air quality assessment include:

- Caustic cracking is no longer required; therefore, the coal combustion and stockpile are eliminated.
- The acid bake kiln will use electric power from the Taltson Dam instead of being fuelled by coal combustion.
- The lime kiln is no longer required as the demand for lime has decreased. Lime will be shipped versus having a kiln. The limestone stockpile is reduced as the limestone demand has decreased to 30,000 tpa; therefore, limestone will be supplied daily by local sources. A small stockpile of less than 5,000 tonnes will be maintained. Since the limestone shipped to the hydrometallurgical plant is slaked, there will be negligible emissions.
- The amount of sulphuric acid to be produced in the sulphuric acid plant has decreased from 250,000 tpa to 78,840 tpa.
- There will be a small ore stockpile on the surface during construction for the first 18 months before the plant starts up.
- The rod mill grinding will be a wet process and therefore there will be negligible emissions.
- There will be two ventilation raises, not three; the primary upcast is located at the ramp portal and the secondary upcast is located approximately 500 m west of the main ramp. The dimension of the primary upcast is 5 m x 6 m instead of 5 m x 6.5 m. The secondary upcast has a diameter of 3 m instead of 4 m.
- The mine air heater will be powered by diesel, not propane. The “Indirect Fired Mine Air Heater – Arctic Diesel” by ACI-CANEFCO will be used instead of the propane air heater in the PFS.

Other information sources include meteorological data from Environment Canada for Yellowknife Airport and Hay River; upper air data from Earth System Research Laboratory (ESRL) Radiosonode Database; and meteorological data collected near the Nechalacho Mine site provided by EBA.

1.5 Assessment Endpoints

The assessment endpoints for CACs are ambient air quality standards. Air quality standards are developed by environmental and health authorities to provide guidance for environmental protection decisions. They are based on scientific studies that consider the effects of the contaminant on such receptors as humans, wildlife, vegetation, as well as aesthetic qualities such as visibility. The Government of the Northwest Territories’ (GNWT) Environmental Protection Act has ambient air quality standards for NO_2, SO_2, CO, TSP and $PM_{2.5}$ (see Table 1-1).

There are no air quality standards for dustfall in the NWT but there are objectives and guidelines for dustfall in other jurisdictions such as British Columbia, Alberta and Ontario. Table 1-2 shows the dustfall objectives and guidelines in these jurisdictions to provide context for dustfall predictions in this air quality assessment.

There are no standards for GHG emissions and therefore Project GHG emissions are assessed by comparison with territorial and national totals as well as emissions from other, similar projects. Environment Canada’s National Inventory Report (2010) provides an estimate of Canada’s GHG releases to the environment on an annual basis. In 2008, Canadians contributed about 734 Mt of GHGs while Northwest Territories and Nunavut contributed 1.81 Mt. Environment Canada has a GHG emissions reporting program: if a facility emits more than 50 kt of CO_2 equivalent (reporting threshold), the facility has to report its GHG emissions in accordance with the requirements under the Canadian Environmental Protection Act, 1999. GHG emissions from other mining projects in the NWT, including three diamond mines and one copper and zinc mine, are provided in Table 1-3.

Table 1-1 NWT Ambient Air Quality Standards for Criteria Air Contaminants

Contaminant	Averaging Period	NWT Standards ($\mu g/m^3$)
NO_2	1-hour	400
	24-hour	200
	Annual	60
SO_2	1-hour	450
	24-hour	150
	Annual	30
CO	1-hour	15,000
	8-hour	6,000
TSP	24-hour	120
	Annual	60
$PM_{2.5}$	24-hour	30

Table 1-2 Existing Dustfall Criteria

Jurisdiction	Criteria	Notes
BC	52.5 mg/dm^2/30 day	In residential areas (Equivalent to 1.75 mg/dm^2/day)
	87 mg/dm^2/30 day	In all other areas (Equivalent to 2.9 mg/dm^2/day)
Alberta	53 mg/dm^2/30 day	In residential and recreation areas
	158 mg/dm^2/30 day	In commercial and industrial areas
Ontario	0.08 mg/ dm^2	½-hour Point-of-impingement
	46 mg/ dm^2 (annual) + 70 mg/ dm^2 (30-day)	

Table 1-3 Annual GHG Emissions Summary for Mining Projects in the Northwest Territories

Project	Total Annual GHG Emissions (kt CO_2 E)	Year and Comments
Pine Point Pilot Project[1]	6	2008 estimate
Snap Lake Mine[2]	63	2008 actual
Diavik Diamond Mine[3]	159	2006 actual
Ekati Diamond Mine[4]	210	2006 actual

Sources: 1. RWDI (2008); 2. De Beers Canada (2008) 3. Diavik (2007); 4. BHP Billiton (2007).

1.6 Residual Effects Assessment Criteria

Residual Project effects are described in terms of direction, magnitude, spatial context, temporal context, reversibility, probability of occurrence, level of confidence, and significance. The specific criteria ratings used for the air quality assessment are described in Table 1-4.

Table 1-4 Air Quality Residual Effects Assessment Criteria

Assessment Criteria		Definition
DIRECTION		
Positive		The emission or ambient concentration is expected to decrease.
Negative		The emission or ambient concentration is expected to increase.
MAGNITUDE - of the residual effect		
Low		CACs: Ambient concentration or deposition level is less than half the relevant standard. GHGs: The Project will contribute less than ±1% of Territorial and less than ±0.01% of National total emissions.
Medium		CACs: Ambient concentration or deposition level is greater than half but less than relevant standard. GHGs: The Project will contribute more than ±1% but less than ±10% of Territorial and more than ±0.01% but less than ±0.1% of National total emissions.
High		CACs: Ambient concentration or deposition level is greater than relevant standard. GHGs: The Project will contribute more than ±10% of Territorial and more than ±0.1% of National total emissions.
SPATIAL CONTEXT - location of effect		
Local		The air quality effect is limited to the LSA.
Regional		The air quality effect extends beyond the LSA but is contained within the territorial boundary.
Global		Effect extends beyond the territorial boundary.
TEMPORAL CONTEXT – of the event and residual effect		
Duration (interval of the event causing the residual effect)	Short-term	The effect is longer than two days but less than or equal to two years.
	Medium-term	The effect is longer than two years but less than or equal to the lifetime of the Project.
	Long-term	The effect is evident beyond the lifetime of the Project.
Frequency (how often would the event that caused the residual effect is anticipated to occur)	Isolated	The effect is confined to a specific period (*e.g.,* construction period; less than or equal to 10% of the assessment period).
	Periodic	The effect occurs intermittently but repeatedly over the construction and operations period (estimated >10% but <80% of the assessment period).
	Continuous	The effect occurs near-continuously or continuously
REVERSIBILITY		
Reversible		The air quality effect is reversible.
Irreversible		The air quality effect is permanent.
PROBABILITY OF OCCURRENCE - likelihood of residual effect happening		
High		Strong likelihood that the effect will occur.
Low		Not likely that the effect will occur.
LEVEL OF CONFIDENCE[1] - degree of certainty related to significance evaluation		
Low		Determination of significance based on incomplete understanding of cause-effect relationships and incomplete data pertinent to the project area.
Moderate		Determination of significance based on good understanding of cause-effect relationships using data from outside the project area or incompletely understood cause-effect relationships using data pertinent to the project area.
High		Determination of significance based on good understanding of cause-effect relationships and data pertinent to the project area.

Notes: (1) Level of confidence was affected by availability of data, precedence, degree of scientific uncertainty or other factors beyond the control of the assessment team.

2 EFFECT ASSESSMENT METHODOLOGY

2.1 General Approach

The project effects assessment focused on Project operations since the majority of emissions will occur during this phase and therefore it could be used to bound the overall effects assessment, i.e., if the potential effect of emissions during operations was found to be not significant then the potential effect of construction and closure emissions, which are expected to be of lower magnitude and shorter duration, would also be not significant. Thus, the operation phase was assessed quantitatively while construction and closure were assessed qualitatively.

The quantitative assessment of emissions during operations consisted of four steps:

1. Use professional judgment to rank sources as being either major or minor.
2. Estimate emissions and other stack parameters for major sources of emissions. In general, CACs were estimated using a bottom-up approach whereas GHGs were estimated using a top-down approach based on total fuel consumption.
3. Predict ground-level concentrations of CACs in the two LSAs using a dispersion model.
4. Compare ground-level concentrations of CACs to GNWT air quality standards and compare emissions of GHGs to territorial and national totals as well as emissions from other projects.

2.2 Ranking of Emission Sources

For the estimation of CAC emissions using a bottom-up approach, sources were ranked as being either major, moderate or minor sources of emissions using professional judgment based on previous experience with similar projects. Those sources considered to be major or moderate were assessed quantitatively whereas minor sources were assessed qualitatively. Note that GHG emissions from the acid bake kiln and ammonium nitrate-fuel oil (ANFO) explosives were also assessed using a bottom-up approach and therefore are ranked as major sources. GHG emissions from most sources ranked as minor were included in the top-down approach of emission estimation based on total fuel use. Exceptions include the tugs and aircraft.

2.2.1 Nechalacho Mine and Flotation Plant

The emission sources identified at the Nechalacho Mine and Flotation Plant are listed and ranked in Table 2-1. Justification for the ranking is also provided in the table.

Table 2-1 Emission Sources at the Nechalacho Mine and Flotation Plant

Source	Type of Emissions	Rank	Comments
Underground mining activities and processing	CACs and GHGs	Major	CAC, GHG and fugitive dust emissions from all mining and crushing activities will be concentrated through two ventilation raises
Exhaust from mine air heater stacks	CACs and GHGs	Major	Mine air heater will heat 300,000 cfm when the ambient temperature is less than 0°C
Exhaust from diesel generator stacks	CACs and GHGs	Major	Six diesel generators will be used to supply all power to the mine and flotation plant
Surface equipment	GHGs	Major	Fuel combustion in equipment is a large source of GHGs
Transfer and handling of ore	CACs	Moderate	Ore transfer and handling is a moderate source of PM emissions
ANFO explosives	GHGs	Moderate	ANFO explosives are a moderate source of CO_2 emissions
Fuel combustion in vehicles	CACs and GHGs	Minor	Not a continuous source so CACs not modelled but GHG emissions estimated
Fugitive dust emissions from haul truck/roads	Fugitive dust	Minor	Fugitive dust emissions from trucks will be short-term and localized.
Waste incineration	CACs	Minor	Waste incineration is a batch process that will occur only once a day.
Fuel combustion in aircraft	CACs and GHGs	Minor	Limited effect on ground-level ambient concentrations with infrequent operating hours
Fuel combustion in tugs used to tow barges	CACs and GHGs	Minor	Operates only in the summer

2.2.2 Hydrometallurgical Plant

The emission sources identified in the Hydrometallurgical Plant are listed and ranked in Table 2-2.

Table 2-2 Emission Sources at the Pine Point Hydrometallurgical Plant

Source	Type of Emissions	Rank	Comments
Sulphuric acid plant	CACs and GHGs	Major	Large source of SO_2
Acid bake kiln	GHGs	Major	Large source of CO_2
Product dryers	CACs	Minor	Product dryers will be equipped with sufficient dust collection to ensure ambient air quality standards are met
Backup diesel generators	CACs and GHGS	Minor	Backup power for emergencies only
Limestone stockpile	Fugitive dust	Minor	Limestone will be slaked so fugitive emissions should be negligible

2.3 Emission Estimation

The emissions associated with this Project were estimated using a systematic approach. Since the Project has not yet been constructed, there are no direct measures of emissions. Manufacturers' specifications were used for emission estimation when available. Otherwise, industry-specific emission factors were used to calculate emission rates. An emission factor is a representative value that relates the quantity of a contaminant released into the atmosphere to an activity associated with the release of that contaminant. In most cases, emission factors from the United States Environmental Protection Agency's (US EPA) compilation of Air Pollutant Emission Factors, known as AP-42, were employed.

To estimate emissions from the underground mine ventilation stacks, it was assumed that the quality of the ambient air underground will be maintained to meet the Mine Health and Safety Standards in NWT. The Mine Health and Safety Regulations R-125-95 for NWT states that threshold limit values (TLV) set out in the handbook *Threshold Limit Values for Chemical Substances and Physical Agents* issued by American Conference of Governmental Industrial Hygienists (ACGIH) are to be followed (ACGIH, 1997). ACGIH is a professional organization of industrial hygienists and practitioners of related professions. Since the ambient air underground will meet standards outlined in the Mine Health and Safety Regulations, emission rates through the ventilation raises were conservatively estimated using the design air flow rate and the appropriate TLVs. ACGIH standards were obtained for NO_2, SO_2, CO and TSP. US EPA NONROAD2005 model was used to estimate emissions from the diesel generators.

2.4 Dispersion Modelling

Dispersion modelling was conducted using the US EPA CALPUFF dispersion model. CALPUFF is a multi-layer, multi-species, non-steady-state puff dispersion model. It simulates the effects of time- and space-varying meteorological conditions on pollutant transport, transformation and deposition. CALPUFF can use three-dimensional meteorological fields developed by the CALMET model or simple, single-station winds in a format consistent with the meteorological files used to drive the ISCST3 steady-state Gaussian model. For this study, insufficient meteorological information was available to initialize the CALMET model and therefore CALPUFF was driven using meteorology from a single station for each LSA.

Since the GNWT does not have dispersion model guidelines, CALPUFF modelling for the Project was performed in accordance with the Guidelines for Air Quality Dispersion Modelling in BC. Table 2-3 summarizes the CALPUFF model switch settings that were used. Table 2-4 summarizes the emissions source types and whether constant or variable emission profiles were used.

NOX emissions are comprised of NO_2 and NO. The primary emission is in the form of NO with reactions in the stack and atmosphere resulting in the conversion of NO to NO_2. However, ambient standards are for NO_2 not NO_x or NO_2 and therefore the conversion of NO_x to NO_2 must be determined. For this study, it was conservatively assumed that all NO_X would be converted to NO_2.

Table 2-3 CALPUFF Model Switch Settings

Parameter	Default	Project	Comments
MGAUSS	1	1	Gaussian distribution used in near field
MCTADJ	3	3	Partial plume path terrain adjustment
MCTSG	0	0	Scale-scale complex terrain not modelled
MSLUG	0	0	Near-field puffs not modelled as elongated
MTRANS	1	0	Transitional plume rise modelled
MTIP	1	1	Stack tip downwash used
MBDW	2	1	ISC type building downwash used
MSHEAR	0	0	Vertical wind shear not modelled
MSPLIT	0	0	Puffs are not split
MCHEM	1	0	Chemical transformation not modelled
MAQCHEM	0	0	Aqueous phase transformation not modelled
MWET	1	0	Wet removal modelled for fugitive dust sources
MDRY	1	0 or 1	Dry deposition modelled for fugitive dust sources
MDISP	2 or 3	2	Near-field dispersion coefficients internally calculated from sigma-v, sigma-w using micrometeorological variables
MTURBVW	3	3	This variable is not used for MDISP = 2
MDISP2	3	2	This variable is not used for MDISP = 2
MROUGH	0	0	PG σ_y and σ_z not adjusted for roughness
MPARTL	1	0	No partial plume penetration of elevated inversion
MTINV	0	0	Strength of temperature inversion computed from default gradients
MPDF	0	1	PDF used for dispersion under convective conditions as recommended for MDISP = 2
MSGTIBL	0	0	Sub-grid TIBL module not used for shoreline
MBCON	0	0	Boundary concentration conditions not modelled
MFOG	0	0	Do not configure for FOG model output
MREG	1	0	Do not test options specified to see if they conform to regulatory values

Table 2-4 CALPUFF Emission Source Types

Emission Source		CALPUFF Source Type (Point, Area or Volume)	Nature of Emissions (Constant or Variable)
Nechalacho Mine and Flotation Plant	Ventilation Raises	Point	Constant
	Mine Air Heater	Point	Variable
	Diesel Generators	Point	Constant
	Transfer and Handling of Ore	Point	Constant
Hydrometallurgical Plant	Sulphuric Acid Plant	Point	Constant

2.4.1 Nechalacho Mine and Flotation Plant

For the Nechalacho Mine and Flotation Plant, one year of site-specific surface meteorological data was used (September 2009 to September 2010). Figure 2-1 shows the joint frequency distributions of wind direction and wind speed in a polar histogram format (i.e., a wind rose) based on the pre-processed meteorological data from Nechalacho Mine and Flotation Plant. The orientation of each bar indicates the direction from which the wind is blowing; with directions being shown for the 16 compass points. The length of each bar indicates the frequency of occurrence. The most frequent winds in this area are from the east.

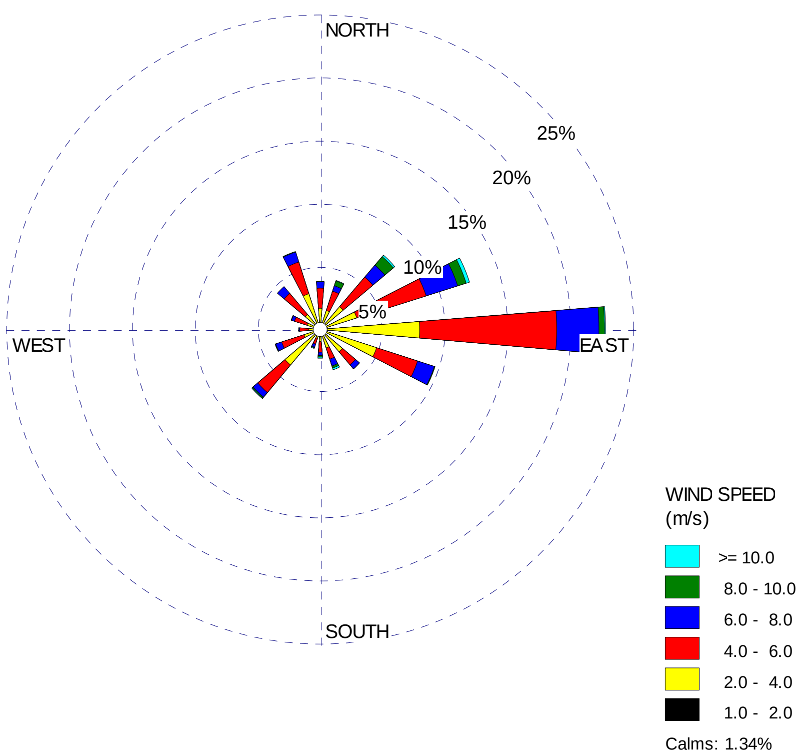

Figure 2-1 Joint Frequency Distribution of Wind Direction and Wind Speed Observed at the Nechalacho Mine and Flotation Plant from September 2009 to September 2010

Missing data from the Nechalacho Mine and Flotation Plant were filled by data obtained from the Yellowknife Airport meteorological station. Upper air data from Fort Smith was employed to determine mixing heights at both sites. These data were processed with CPrammet, the meteorological pre-processor for CALPUFF, to create an ISC-type meteorological file.

To assess the potential effect of emissions from a facility on ambient air quality, concentrations are predicted beyond the facility boundaries, where ambient air quality standards apply. Within the facility boundaries, occupational health and safety guidelines apply; therefore, receptors inside the boundaries are excluded from the modelling. In this LSA, two areas were excluded. The area above the mine was excluded as no public access is expected. The other area is the flotation plant facility boundary. A Cartesian receptor grid was adopted with the following receptor spacing:

- 20-m spacing along the plant boundaries where no public access is expected;
- 50-m spacing for a 4.0 by 4.0 km area centred on the ramp portal;
- 250-m spacing for a 7.0 by 7.0 km area centred on the ramp portal;
- 500-m spacing for a 13 by 13 km area centred on the ramp portal;
- 1000-m spacing for the remainder of the 20 km by 20 km LSA.

In addition to the Cartesian grid described above, discrete receptors were defined at the trailer camp, tent camp, and employee facilities. The terrain elevations for these receptors were extracted from 1: 250,000 scale Canadian Digital Elevation Data. A map of the LSA with the receptors is shown in Figure 2-2.

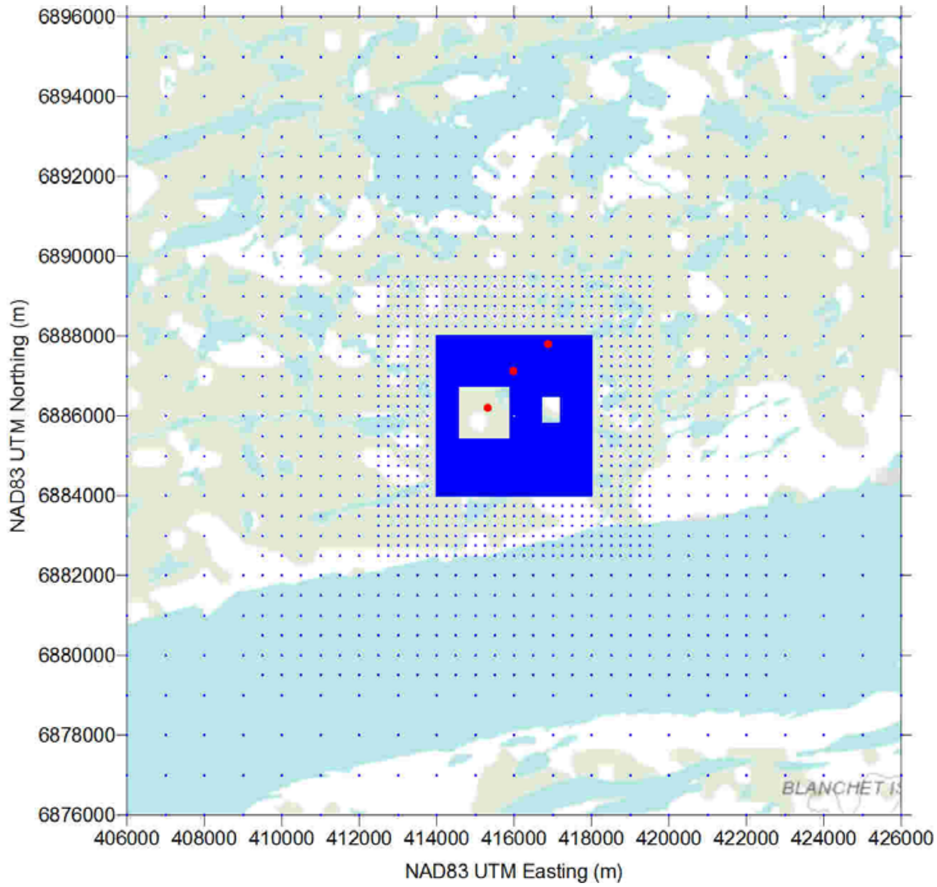

Figure 2-2 Nechalacho Mine Air Quality Local Study Area Showing Gridded Receptors (Blue Dots) and Discrete Receptors (Red Dots)

2.4.2 Hydrometallurgical Plant

For the Hydrometallurgical Plant, surface meteorological data from Hay River was judged to be the most appropriate available data set. This data set consists of five years of data from 2002 to 2006. Missing data were filled using data obtained from the Yellowknife Airport meteorological station. Upper air data from Fort Smith were used to determine mixing heights. The data were then processed with CPrammet. Figure 2-3 shows the joint frequency distribution of the wind speed and direction data collected at Hay River from 2002 to 2006. The most frequent winds in this area are from the east-northeast, the east and the northwest.

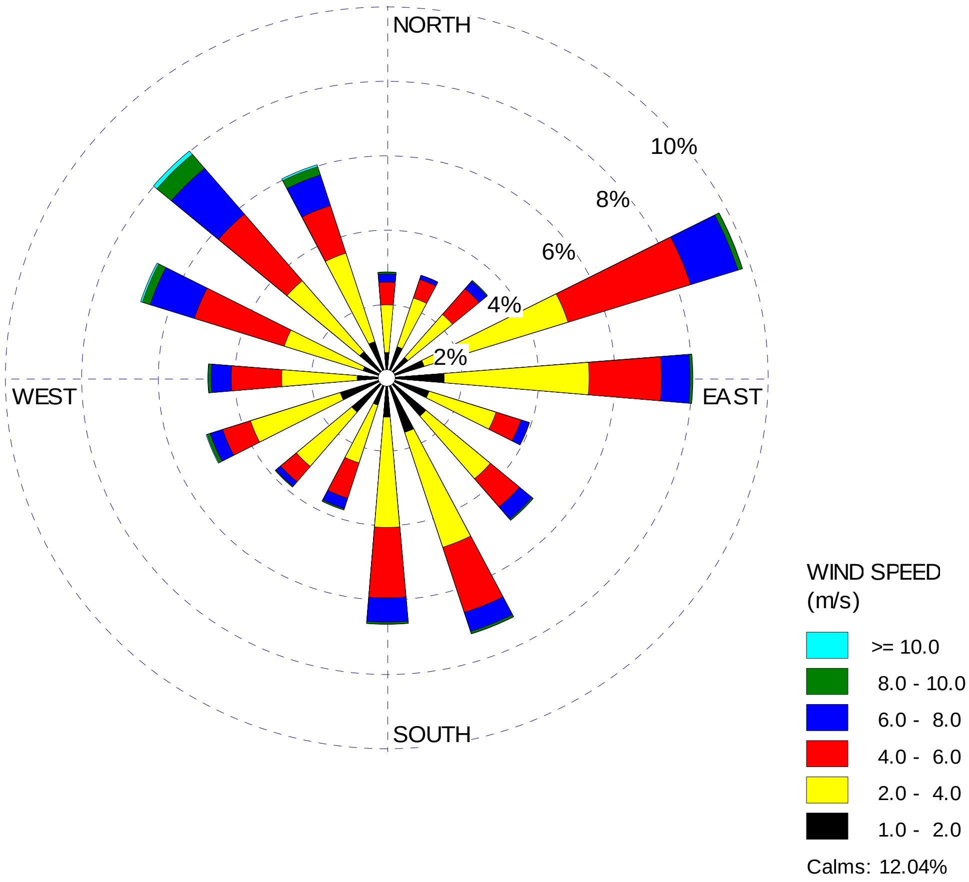

Figure 2-3 Joint Frequency Distribution of Wind Direction and Wind Speed Observed at the Hay River Airport for the years 2002 to 2006.

A Cartesian receptor grid was adopted with the following receptor spacing:

- 20-m spacing along the plant boundaries where no public access is expected;
- 50-m spacing for a 2.2 by 2.2 km area centred on the sulphuric acid plant;
- 250-m spacing for a 5.2 by 5.2 km area centred on the sulphuric acid plant;
- 500-m spacing for a 11.2 by 11.2 km area centred on the sulphuric acid plant
- 1000-m spacing for the remainder of the 20 km by 20 km LSA.

The terrain elevations for these receptors were extracted from 1: 250,000 scale Canadian Digital Elevation Data. A map of the LSA with the receptors is shown in Figure 2-4. No discrete receptors were used for this LSA since workers are expected to commute from Hay River, approximately 75 km west of the LSA.

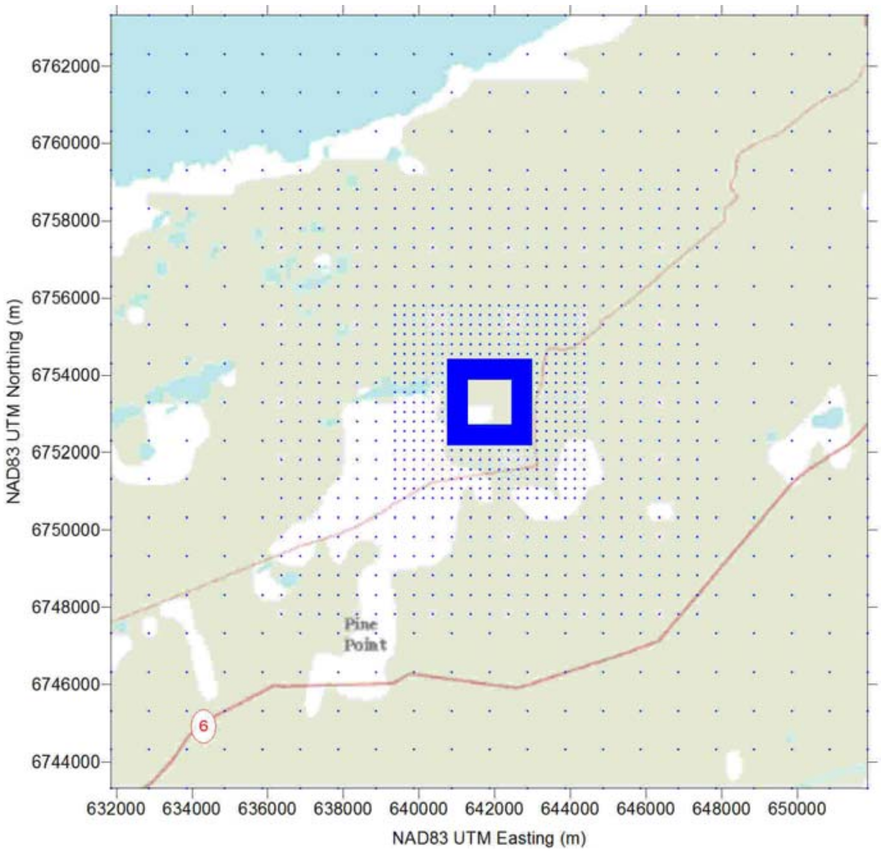

Figure 2-4 Hydrometallurgical Plant Air Quality Local Study Area Showing Receptors (Blue Dots)

3 PROJECT EFFECTS ASSESSMENT

3.1 Construction

Equipment and vehicles used for site preparation, access road development and construction of Project infrastructure will emit CACs and GHGs. These activities will also be sources of fugitive dust. A small ROM stockpile that will be developed on the surface during the construction phase before the flotation plant is commissioned will also be a short-term source of fugitive dust. Based on previous experience and professional judgment, it is expected that Project construction emissions will be of smaller magnitude and shorter duration than emissions during operation. Therefore, it is assumed that potential effects due to construction are bounded by the potential effects due to Project operations. Thus, residual effects due to construction emissions are assessed qualitatively in Section 5.1 Furthermore, emissions during Project construction will be managed using best practices outlined in Air Quality and Dust Control Plan (Section 6).

3.2 Operation

3.2.1 Criteria Air Contaminants

As discussed in Section 2.2.1, there are four main sources of CAC emissions at the Nechalacho Mine and Flotation Plant: underground mining activities, mine air heater, diesel generators, and transfer and handling of ore. The main source of CAC emissions at the Hydrometallurgical Plant is the sulphuric acid plant (Section 2.2.2). There are no CAC emissions expected from the acid bake kiln since it is electric.

3.2.1.1 Nechalacho Mine and Flotation Plant

In this section, the main sources of CAC emissions at the Nechalacho Mine and Flotation Plant are assessed quantitatively by first estimating emission rates and then predicting ground-level concentrations that could result from those emissions using the CALPUFF dispersion model.

Ventilation Raises

There are two ventilation raises: the primary upcast is located at the ramp portal and the secondary upcast is located approximately 500 m west of the main ramp. The stack heights for both upcasts were assumed to be 1 m above ground. The primary upcast will have dimensions of 6 m x 5 m. The secondary upcast has a diameter of 3 m. The ventilation rate for the mine is expected to be 300,000 cfm. Sixty-seven percent (67%) of this air will be vented through the primary upcast (the mine portal) and 33% through the secondary upcast. The exit velocities were calculated based on the air flow and the cross-sectional area of the upcasts. Since the primary upcast will be at a 15% decline, only the vertical component of the exit velocity was included in momentum flux calculations in the modelling.

Emissions from the ventilation raises were estimated by assuming that the ACGIH standards for NO_2, SO_2, CO and TSP, shown in Table 3-1, would be met. $PM_{2.5}$ was assumed to be 7.5% of TSP according to Particulate Matter Speciation Profiles by California Emission Inventory and Reporting System

(CEIDARS, 2009) for mineral crushing and screening. The estimated emissions of the two ventilation upcasts are shown in Table 3-2.

Table 3-1 Threshold Limit Values for Mine Health and Safety Standards in NWT

	NO_2	SO_2	CO	TSP	$PM_{2.5}$
ACGIH TLV (mg/m3)	5.6	5.2	29	10	0.75

Table 3-2 Annual CAC Emissions from Ventilation Upcasts

	Air Flow Rate (cfm)	Emissions (t/y)				
		NO_2	SO_2	CO	TSP	$PM_{2.5}$
Primary ventilation upcast (ramp portal)	201,000	17	15	86	30	2
Secondary ventilation upcast	99,000	8	8	42	15	1
Total	**300,000**	**25**	**23**	**128**	**44**	**3**

Mine Air Heater

The mine air heater will only operate when the temperature is less than 0°C. According to the temperatures measured at the onsite meteorological station, there were 4,516 hours per year when the temperature is less than 0°C, mostly in the period from October to May. Emissions from the mine air heater were estimated using emission factors obtained from US EPA AP-42, based on a fuel consumption rate of 969 L/hr and a diesel heating value of 145,000 BTU/gal (ACI-CANEFCO, 2011). Emissions of SO_2 were estimated using a 15 ppm sulphur content in diesel that came into effect in October 2010. The mine air heater annual emissions are presented in Table 3-3.

Table 3-3 Annual CAC Emissions from Mine Air Heater

	Emissions (t/y)				
	NO_x	SO_2	CO	TSP	$PM_{2.5}$
Mine Air Heater	10	0.1	3	2	1

The diesel air heater was modelled using two stacks with a stack height of 7.5 m and a stack diameter of 0.6 m. The exit velocity was assumed to be 10 m/s and it was assumed that the heater only operates when the temperature is less than 0 °C. Modelling of hourly-variable emissions depending on the ambient temperature was conducted using an external PTEMARB file. This file is large and therefore not included in this report but is available upon request.

Diesel Generators

Six 1.45-MW CAT 3516 diesel generators are required to operate continuously to meet the power demand of 8.4 MW. Two additional diesel generators will be available for emergency standby. Since the standby diesel generators will not operate continuously, emissions associated with the standby generators were not assessed.

Emissions from the diesel generators were estimated using the US EPA NONROAD2005 model. A load factor of 43% was assumed, which is the US EPA's default load factor for diesel generators. The annual emissions from the diesel generators are shown in Table 3-4. The diesel generators were assumed to have a stack height of 20 m. The exit temperature of 404.3°C and exit velocity of 24.3 m/s were provided by Finning.

Table 3-4 Annual CAC Emissions from Diesel Generators

	Emissions (t/y)				
	NO_x	SO_2	CO	TSP	$PM_{2.5}$
Diesel Generators	123	0.2	4	4	3

Transfer and Handling

There are two transfer points of dry ore; the first one is mid-point along the ramp from the underground mine and the other one is inside the process plant. Since the first transfer is underground, it is included in the modelling of the ventilation raises. The second transfer point from the ramp conveyor to the mill feed conveyor located in the process plant was included in the modelling of the building ventilation stack of the flotation plant building. The building ventilation stack was assumed to be 10 m high with an exit velocity of 20 m/s. The ventilation flow rate through the stack is three building exchanges per hour and therefore the stack diameter was calculated to be 3.1 m. After this transfer point, all the processes will be wet, and emissions will be negligible. The emissions from the second transfer point from the ramp conveyor to the mill feed conveyor were estimated using emission factors from AP-42 Section 11.24. Emissions of $PM_{2.5}$ were assumed to be 7.5% of TSP according to particle size distribution for rock screening and handling (CEIDARS, 2009). The annual emissions for transfer and handling are presented in Table 3-5.

Table 3-5 Annual CAC Emissions from Transfer and Handling

	Emissions (t/y)				
	NO_x	SO_2	CO	TSP	$PM_{2.5}$
Transfer and handling	-	-	-	44	3

Summary of Emissions and Other Dispersion Model Inputs

Table 3-6 summarizes the total annual emissions for the Nechalacho Mine and Flotation Plant from the four main sources. Diesel generators are the largest source of NO_x emissions and ventilation raises are the largest sources of SO_2 and CO emissions. Ventilation raises and the transfer and handling of dry ore are the largest sources of TSP and $PM_{2.5}$.

Table 3-6 Summary of Annual CAC Emissions for Nechalacho Mine

Source	Emissions (t/y)				
	NO_x	SO_2	CO	TSP	$PM_{2.5}$
Ventilation Raises	25	23	128	44	3
Mine Air Heater	10	0.1	3	2	1
Diesel Generator	123	0.2	4	4	3
Transfer and Handling	-	-	-	44	3
Total	**158**	**23**	**134**	**93**	**10**

The hourly emission rates that were used as input to the dispersion modelling for the Nechalacho Mine and Flotation Plant are summarized in Table 3-7. The hourly emissions rates were calculated using design capacities (maximum obtainable output) when available. For the sources without maximum design capacities, annual production rates were converted to hourly emission rates based on operating 365 days per year. The stack parameters use in the modelling, including stack height, stack diameter, exhaust exit velocity and temperature, are summarized in Table 3-8.

Table 3-7 Nechalacho Mine Emission Rates Used for Dispersion Modelling

Sources	Emissions Rate (g/s)				
	NO_2	SO_2	CO	TSP	$PM_{2.5}$
Primary Ventilation Upcast (ramp portal)	0.53	0.49	2.75	0.95	0.07
Secondary Ventilation Upcast	0.26	0.24	1.35	0.47	0.04
Mine Air Heater1	0.65	0.01	0.16	0.11	0.05
Diesel Generator	3.89	0.01	0.12	0.11	0.11
Transfer and Handling	-	-	-	1.67	0.13

Note: (1) Mine air heater emissions shown indicate emission rates while mine air heater is operating. Mine air heater will operate approximately 4516 h/y.

Table 3-8 Stack Parameters used for Nechalacho Mine Dispersion Modelling

Sources	Stack Height (m)	Stack Inner Diameter (m)	Stack Exit Temperature (°C)	Stack Exit Velocity (m/s)
Primary Ventilation Upcast (ramp portal)	1	6.2	0	0.5
Secondary Ventilation Upcast	1	3	0	6.6
Mine Air Heater	7.5	0.6	0	10
Diesel Generator1	20	0.4	404.3	24.3
Transfer and Handling	16.1	3.1	15	20

Note: (1) Stack parameters indicated for diesel generators are for one stack. There are six stacks for diesel generators.

As the stacks are relatively short, the associated plumes may be influenced by building downwash. For this reason, building downwash effects were assessed in the dispersion modelling. Table 3-9 and Table 3-10 summarize the building dimensions that were used.

Table 3-9 Building Parameters Used for Nechalacho Mine Dispersion Modelling – Part 1

Buildings	Units	Fuel Storage	Laydown Yard	Employee Facilities	Dry	Maintenance	Power
Base Elevation	(m)	244	244	244	244	244	244
Height	(m)	6.1	6.1	6.1	6.1	6.1	6.1
Vertices:							
Corner1	(mE)	414710	414712	415273	415273	415273	415217
	(mN)	6886012	6886040	6886345	6886096	6886066	6886092
Corner2	(mE)	414898	414898	415362	415362	415362	415245
	(mN)	6886012	6886040	6886345	6886096	6886066	6886092
Corner3	(mE)	414898	414898	415362	415362	415362	415245
	(mN)	6885995	6885892	6886096	6886066	6885967	6886040
Corner4	(mE)	414710	414712	415273	415273	415273	415217
	(mN)	6885995	6885892	6886096	6886066	6885967	6886040

Table 3-10 Building Parameters Used for Nechalacho Mine Dispersion Modelling – Part 2

Buildings	Units	Warehouse	Paste Plant	Process Plant	Reagent Storage	Container Facility	Mine air heater
Base Elevation	(m)	244	244	244	244	244	232
Height	(m)	6.1	6.1	6.1	6.1	6.1	8
Corner1	(mE)	415126	415367	415168	415120	414995	415226
	(mN)	6886017	6885875	6885967	6885880	6885965	6886072
Corner2	(mE)	415271	415417	415366	415165	415165	415240
	(mN)	6886017	6885875	6885967	6885880	6885965	6886072
Corner3	(mE)	415271	415417	415366	415165	415165	415240
	(mN)	6885969	6885816	6885820	6885819	6885880	6886056
Corner4	(mE)	415126	415367	415168	415120	414995	415226
	(mN)	6885969	6885816	6885820	6885819	6885880	6886056

Predicted Ambient CAC Concentrations and Dustfall Levels

The maximum ambient concentrations of CACs and dustfall levels predicted using the CALPUFF model are shown in Table 3-11 and Table 3-12, respectively. The maximum predicted CAC concentrations are less than the corresponding NWT Air Quality Standards for all contaminants. The maximum predicted 30-day and annual dustfall deposition levels for Nechalacho Mine and Flotation Plant are much less than the most stringent criteria. Maximum predicted concentrations at the trailer camp, tent camp and employee facilities were all less than the ambient AQ standards.

Table 3-11 Maximum Predicted CAC Concentrations for Nechalacho Mine and Flotation Plant

Pollutant	Averaging Period	Maximum Concentration (µg/m3)	NWT AQ Standard (µg/m3)
NO_2	1-hour	185	400
	24-hour	134	200
	Annual	8	60
SO_2	1-hour	101	450
	24-hour	35	150
	Annual	2	30
CO	1-hour	561	15,000
	8-hour	350	6,000
TSP	24-hour	68	120
	Annual	4	60
$PM_{2.5}$	24-hour	10	30

Table 3-12 Maximum Predicted Dustfall Deposition Levels for Nechalacho Mine and Flotation Plant

Dustfall	Averaging Period	Maximum Deposition Level (mg/dm2)	Most Stringent Criteria (mg/dm2)
	30-day	0.03	52.5
	Annual	0.009	46

The spatial distribution of maximum predicted concentrations and dustfall levels is presented in the form of isopleth maps. Since all predicted concentrations are less than the ambient standards, only one plot is shown per contaminant for the shortest relevant averaging period.

The highest one-hour NO_2 concentration were predicted to occur immediately north of the employee facilities, power, dry, and maintenance/administration buildings, at the ramp portal, and approximately 1 km north-northeast of the power generation building (Figure 3-1).

The highest one-hour SO_2 (Figure 3-2), one-hour CO (Figure 3-3) and 24-hour TSP (Figure 3-4) concentrations, were predicted to occur immediately east of the mine ramp portal.

The highest 24-hour $PM_{2.5}$ concentrations were predicted to occur approximately 1 km north-northwest of the power generation building (Figure 3-5).

The highest 30-day dustfall levels were predicted to occur west of all the flotation plant buildings at the fenceline (Figure 3-6).

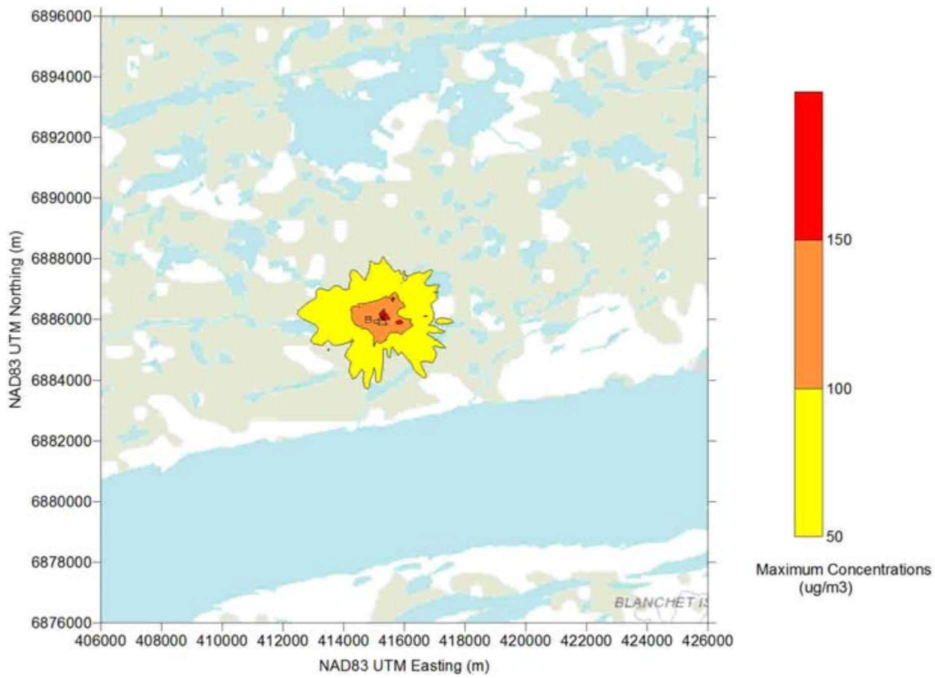

Figure 3-1 Isopleths of Maximum Predicted One-Hour Average NO_2 Concentrations

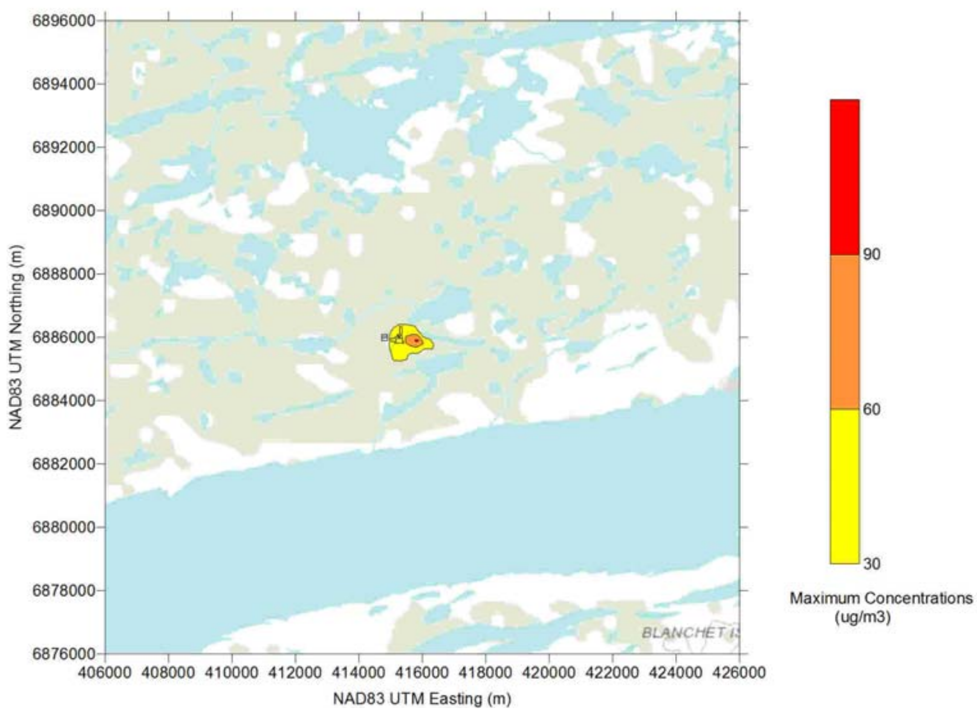

Figure 3-2 Isopleths of Maximum Predicted One-Hour Average SO_2 Concentrations

CONSULTING ENGINEERS & SCIENTISTS

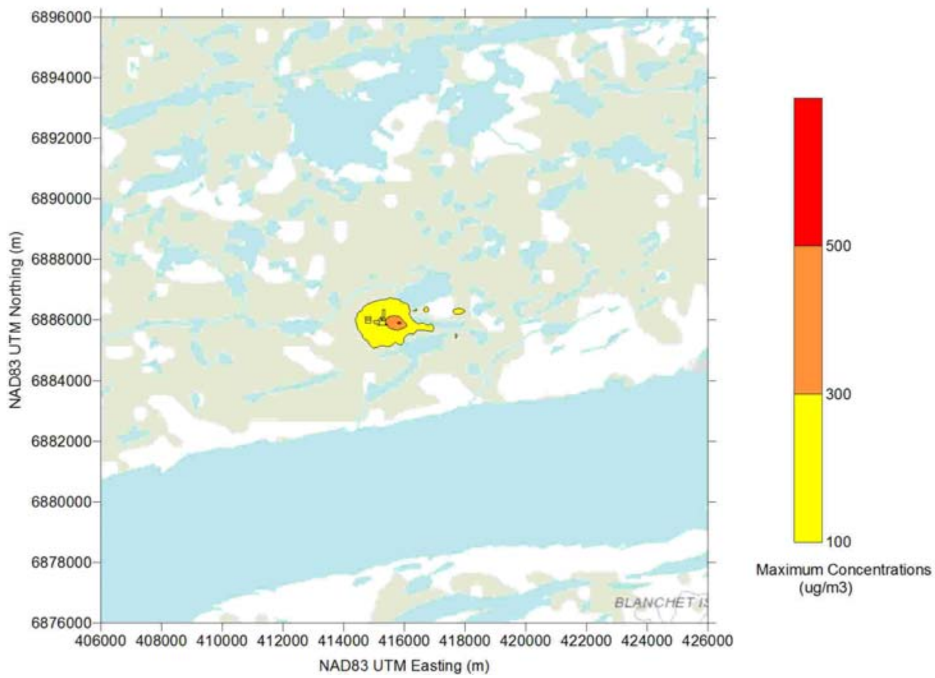

Figure 3-3 Isopleths of Maximum Predicted One-Hour Average CO Concentrations

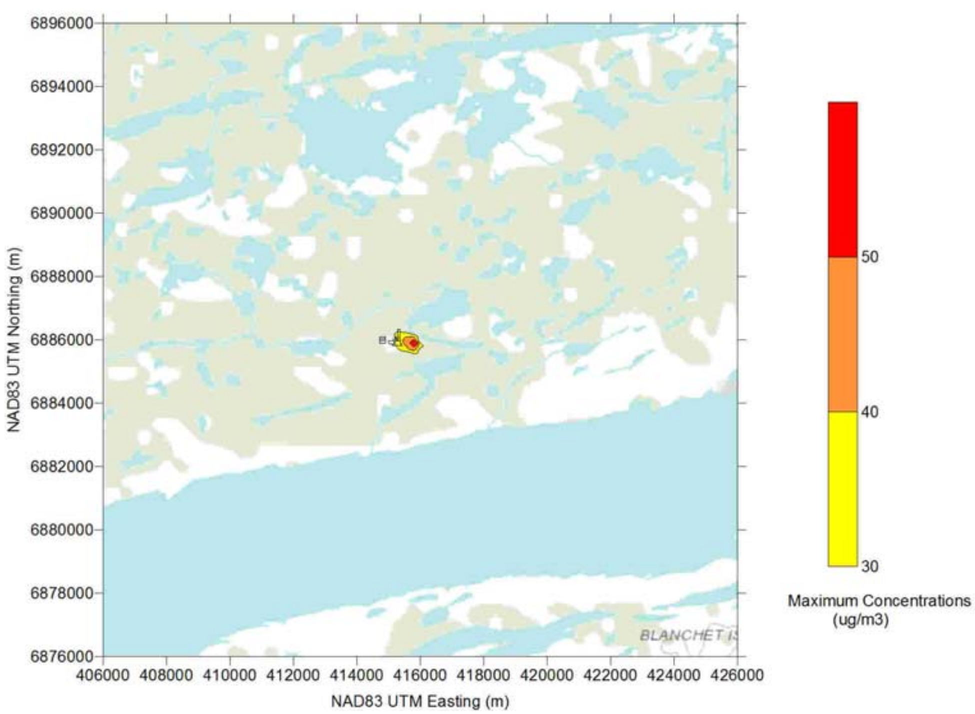

Figure 3-4 Isopleths of Maximum Predicted 24-Hour Average TSP Concentrations

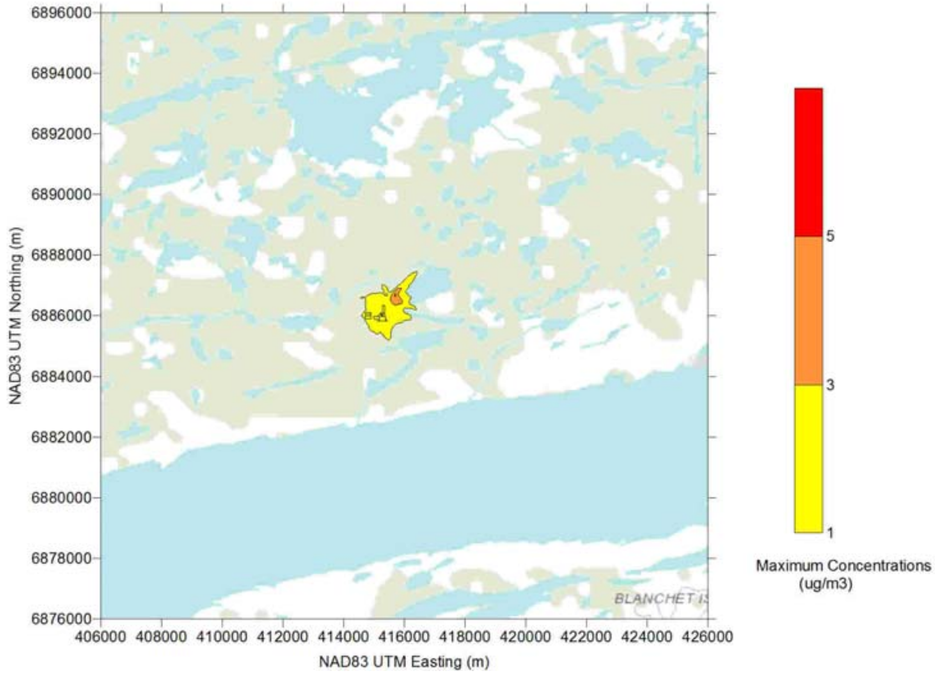

Figure 3-5 Isopleths of Maximum Predicted 24-Hour Average $PM_{2.5}$ Concentrations

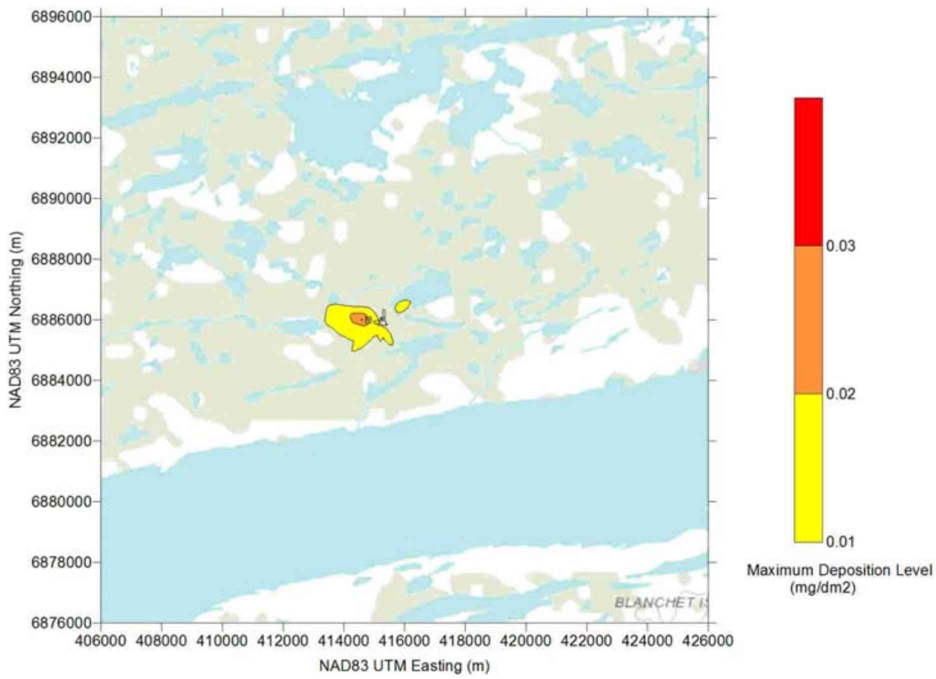

Figure 3-6 Isopleths of Maximum Predicted 30-day Average Dustfall Deposition Levels

3.2.1.2 Hydrometallurgical Plant

Due to the changes in project design, there is only one major source of CAC emissions at the Hydrometallurgical Plant which was assessed quantitatively. The sulphuric acid plant emits sulphur dioxide due to chemical reaction rather than combustion. Emission of other CACs from the sulphuric acid plant is not expected.

The Project requires a double absorption sulphuric acid plant to produce 78,840 tpa of sulphuric acid on a 100% acid basis, at an acid strength of about 93%, using elemental sulphur as feed. The Hydrometallurgical Plant is scheduled to operate 351 days per year with a full production rate of 225 tpd of sulphuric acid. It is expected that 2 kg of SO_2 will be emitted for every tonne of sulphuric acid produced, which is equivalent to the sulphur dioxide emission factor for double absorption outlined in US EPA AP-42 Section 8.10. The annual sulphur dioxide emission from the Hydrometallurgical Plant was estimated to be 158 tpa. The hourly SO_2 emission rate of 5.2 g/s was converted from the annual emission rate assuming a constant production rate 351 days per year.

The sulphuric acid plant was modelled using a stack height of 30 m and stack diameter of 1.5 m. The SO_2 flow rate is expected to be 26 Nm3/h. The exit velocity was calculated to be less than 0.1 m/s and therefore the minimum exit velocity that the model will accept, 0.1 m/s, was used. Exit temperature was assumed to be 430ºC based on typical reaction temperatures in sulphuric acid production. Source parameters are summarized in Table 3-13.

Table 3-13 Source Parameters used for Hydrometallurgical Plant Dispersion Modelling

Sources	SO_2 Emission Rate (g/s)	Stack Height (m)	Stack Inner Diameter (m)	Stack Exit Temperature (°C)	Stack Exit Velocity (m/s)
Sulphuric Acid Plant	5.2	30	1.5	430	0.1

As the stack is relatively short, the associated plume may be influenced by building downwash. For this reason, building downwash effects were assessed in the dispersion modeling Table 3-14 and Table 3-15 summarize the building dimensions that were used.

Table 3-14 Building Parameters Used for Hydrometallurgical Plant Dispersion Modelling – Part 1

Buildings	Units	Temporary Concentrate Storage	Limestone Handling	Thaw Shed	Cracking Facility	Acid Storage
Base Elevation	(m)	206.5	206.5	206.5	206.5	206.5
Height	(m)	6.1	6.1	6.1	6.1	6.1
Vertices:						
Corner1	(mE)	641648	641688	641784	641819	641855
	(mN)	6753384	6753273	6753352	6753392	6753324
Corner2	(mE)	641755	641792	641824	641899	641917
	(mN)	6753420	6753314	6753365	6753422	6753344
Corner3	(mE)	641792	641835	641833	641925	641937
	(mN)	6753314	6753200	6753346	6753355	6753290
Corner4	(mE)	641688	641723	641794	641846	641877
	(mN)	6753273	6753161	6753333	6753326	6753270

Table 3-15 Building Parameters Used for Hydrometallurgical Plant Dispersion Modelling – Part 2

Buildings	Units	Leach/Neutralization Facility	Solvent Extraction Facility	Precipitation and Packaging	Temporary Product Storage
Base Elevation	(m)	206.5	206.5	206.5	206.5
Height	(m)	6.1	6.1	6.1	6.1
Corner1	(mE)	641899	641975	642026	641986
	(mN)	6753422	6753446	6753344	6753329
Corner2	(mE)	641972	642090	642121	642024
	(mN)	6753446	6753484	6753380	6753340
Corner3	(mE)	641995	642128	642142	642041
	(mN)	6753379	6753386	6753331	6753300
Corner4	(mE)	641925	642015	642042	642005
	(mN)	6753355	6753341	6753298	6753283

The maximum predicted SO_2 concentrations are compared to NWT standards in Table 3-16. The maximum predicted one-hour, 24-hour and annual SO_2 concentrations are 270, 74, and 7.8 µg/m3, respectively. These concentrations are less than the corresponding NWT AQ standards. The spatial distribution of maximum predicted hourly average SO_2 concentrations is shown in Figure 4.7. The highest SO_2 concentration was predicted to occur immediately southeast of the sulphuric acid plant.

Table 3-16 Maximum Predicted SO_2 Concentrations for Hydrometallurgical Plant

Pollutant	Averaging period	Maximum Concentration (µg/m3)	NWT AQ Standard (µg/m3)
SO_2	1 –hour	270	450
	24-hour	74	150
	Annual	7.8	30

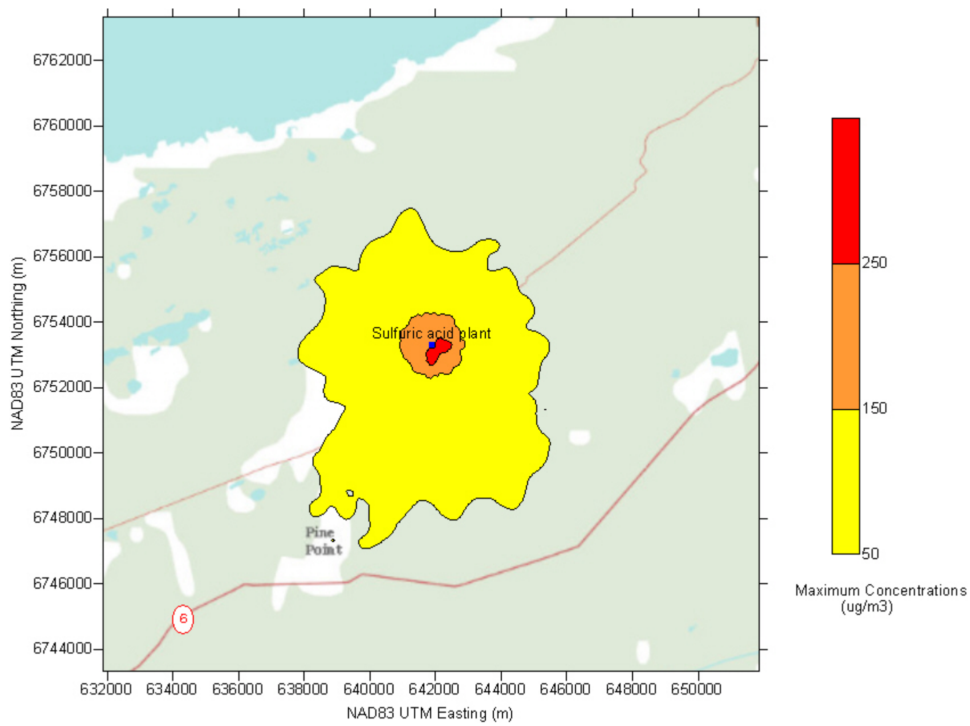

Figure 3-7 Isopleths of Maximum Predicted One-Hour Average SO_2 Concentrations

3.2.2 Greenhouse Gases

Greenhouse gases are generally aggregated into “CO_2 equivalents” (CO_2E). The equivalence factor has generally been agreed to be the relative global warming potentials (GWP) of the gas as estimated by the Intergovernmental Panel on Climate Change (IPCC), the major international science body that is co-ordinating research on the climate change issue. The IPCC estimates GWPs for a number of GHGs for various time periods related to the effect of a quantity of the gas released on future atmospheric temperature rise. These numbers vary widely from gas to gas, and they also vary from time period to time periods for a given gas, depending on physical and chemical properties. The 100-year GWPs are generally used. The most recent estimates of 100-year GWPs used by Environment Canada are sanctioned by the IPCC and are shown in Table 3-17.

Table 3-17 Global Warming Potentials

	CO_2	CH_4	N_2O
Global Warming Potential	1	21	310

These numbers mean, for example, that a kilogram of N_2O has 310 times the global warming effect of a kilogram of CO_2 over a period of 100 years from the year of release.

For this Project, GHGs are expected to be emitted from six main sources: underground and surface equipment, mine air heater, diesel generators, ANFO explosives, acid bake kiln, and sulphuric acid plant.

Underground and Surface Equipment

The GHG emissions for underground and surface equipment were estimated using emission factors from National Inventory Report – Greenhouse Gas Sources and Sinks in Canada (Environment Canada, 2010) based on the expected fuel consumption. It was indicated by Avalon that underground equipment will consume 1,800,000 L/yr of diesel while surface equipment will consume 200,000 L/yr of diesel. The annual GHG emissions from underground and surface equipment are presented in Table 3-18.

Table 3-18 Annual GHG Emissions from Underground and Surface Equipment

	Emissions (t/y)			
	CO_2	CH_4	N_2O	CO_2E
Underground Equipment	4,793	0.2	0.7	5,022
Surface Equipment	533	<0.1	0.1	558
Total Equipment	5,326	0.3	0.8	5,580

Mine Air Heater

The mine air heater is expected to have a fuel consumption of 969 L/hr (ACI-CANEFCO, 2011) and will operate for approximately 4,516 hr/yr. GHG emissions from the mine air heater, shown in Table 3-19, were estimated using emission factors obtained from Environment Canada (2010).

Table 3-19 Annual GHG Emissions from Mine Air Heater

	Emissions (t/y)			
	CO_2	CH_4	N_2O	CO_2E
Mine Air Heater	11,653	0.6	2	12,208

Diesel Generators

CO_2 emissions associated with diesel generators were estimated in accordance with the US EPA NONROAD2005 model. Emissions of CH_4 and N_2O were estimated by scaling the CO_2 emissions based on Environment Canada emission factors for non-road diesel. The GHG emissions associated with diesel generators are shown in Table 3-20.

Table 3-20 Annual GHG Emissions from Diesel Generators

	Emissions (t/y)			
	CO_2	CH_4	N_2O	CO_2E
Diesel Generators	27,152	2	11	30,661

ANFO Explosive

The Project requires approximately 292 tpa of ANFO explosives. Explosives are identified as one of the common sources of GHG emissions in the mining sector (The Mining Association of Canada, 2009). The Energy and GHG Emissions Management Guidance Document by the Mining Association of Canada indicates that 0.189 tonne of CO_2 is emitted for each tonne of ANFO explosives used. With 292 tpa of ANFO explosive used, approximately 55 tpa of CO_2 will be emitted.

Sulphuric Acid Plant

GHG emissions from the sulphuric acid plant were estimated following the methodology described in US EPA AP-42 Section 8.10. For a double absorption plant, 4.05 kg of CO_2 is emitted for each tonne of sulphuric acid produced. It was estimated that 1,013 tpa of CO_2 will be emitted for the production rate of 78,840 tpa of sulphuric acid.

Acid bake kiln

It was estimated by Avalon that the acid bake kiln will emit approximately 11,000 tpa of CO_2 in the acid leach/bake system.

Summary of GHG Emissions

Total GHG emissions from the Project are summarized in Table 3-21. The Project is expected to emit 60.5 kt/y of CO_2 E or 0.06 Mt/yr during normal operation. The diesel generators are expected to be the largest source, contributing approximately half of total Project-related GHG emissions.

Total Project-related emissions could represent a 0.008% increase compared to the estimated Canadian total emissions in 2008 (see Section 1.5) and a 3% increase compared to Northwest Territories and Nunavut's total reported GHG emissions in 2008. The expected GHG emissions during operation are greater than the Environment Canada reporting threshold of 50,000 tonnes.

Greenhouse gas emissions from several other potential and existing mines in the NWT are presented in Table 1-3. Total Project GHG emissions during operations are roughly equivalent to total GHG emissions from Snap Lake Mine (63 kt/y) and less than half the GHG emissions from Diavik Diamond Mine (159 kt/y) and Ekati Diamond Mine (210 kt/y). Project GHG emissions during operations are expected to be an order of magnitude greater than GHG emissions from the Pine Point Pilot Project; however, this is likely because the latter is a pilot project.

Table 3-21 Summary of Annual GHG Project-Related Emissions

	Emissions (t/y)			
	CO_2	CH_4	N_2O	CO_2E
Underground Equipment	4,793	0.2	0.7	5,022
Surface Equipment	533	<0.1	0.1	558
Mine Air Heater	11,653	0.6	2	12,208
Diesel Generators	27,152	2	11	30,661
ANFO Explosive	55	-	-	-
Subtotal - Mine	*44,187*	*2*	*14*	*48,504*
Sulphuric Acid Plant	1,013	-	-	1,013
Acid Bake Kiln	11,000	-	-	11,000
Subtotal – Hydrometallurgical Plant	*12,013*	-	-	*12,013*
Total	56,199	2	14	60,516

3.3 Closure

The reclamation of the Project site will include site decommissioning activities such as the removal of facilities. Equipment and vehicles used for Project site decommissioning will emit CACs and GHGs; however, these emissions will be of smaller magnitude and shorter duration than emissions during operation. Therefore, it is assumed that potential effects due to closure are bounded by the potential effects due to Project operations. Thus, residual effects due to emissions of CACs and GHGs during the closure phase are assessed qualitatively in Section 5.3. In addition, emissions during Project closure will be managed using best practices outlined in Air Quality and Dust Control Plan (Section 6)

4 MITIGATION MEASURES

Various mitigation measures have been incorporated into the revised Project design. Most notably, coal combustion has been eliminated. Dust emissions will be mitigated by crushing and transferring ore in the underground mine. There will be sufficient dust control devices on the mining and processing equipment to meet the Mine Health and Safety Regulations in the underground mine. Grinding will be a wet process with negligible emissions of fugitive dust. The open ore stockpile on the surface during operations has been eliminated thereby reducing potential fugitive dust emissions. The sulphuric acid plant will be equipped with a scrubber to reduce emission released to the ambient air. The acid bake kiln will be powered by electricity rather than to coal or diesel. The concentrate will be shipped in containers thereby minimizing fugitive dust emissions.

5 RESIDUAL EFFECTS ASSESSMENT

The residual effects were assessed using the assessment endpoints presented in Section 1.5 and the residual effects assessment criteria presented in Section 1.6. As discussed in Section 3, based on professional judgment, it is expected that the majority of emissions will occur during operations and therefore the assessment of the operations phase will bound both the construction and closure phases. Therefore operations are assessed quantitatively whereas construction and closure are assessed qualitatively in this section. The residual effects of the Project are summarized in Table 5-1 and discussed in the following subsections.

5.1 Construction

Construction of the mine, flotation plant and hydrometallurgical plant is expected to result in an increase in ambient concentrations of CACs and an increase in GHG emissions; therefore the direction of effect is negative for both potential residual effects. Based on previous experience and professional judgment, the magnitude of effect is expected to be low for both CACs and GHGs. The spatial extent of the potential increase in CAC concentrations is expected to be limited to the LSAs and therefore is rated local. Whereas an increase in GHG emissions has the potential to affect global climate change and therefore the spatial extent is rated global for GHGs. The construction phase is less than two years and thus duration of effect is rated short-term for the potential increase in CAC concentrations. By contrast, GHGs have a long atmospheric lifetime and therefore the potential effect of an increase in GHG emissions is rated long term. The frequency of CAC and GHG emissions during construction is expected to be periodic. Since CACs and GHGs have finite atmospheric lifetimes, the potential effects are rated reversible. The probability of occurrence is high since construction of the Project would result in emissions of CACs and GHGs. Since the assessment of the construction phase is qualitative but bounded by a quantitative assessment of the operations phase, the level of confidence is low to moderate for both CACs and GHGs. Due to the low magnitude, periodic nature and reversibility of emissions during construction, the potential residual effects on ambient air quality and GHG emissions are considered to be not significant.

5.2 Operation

5.2.1 Criteria Air Contaminants

As shown in Table 3-11, Table 3-12 and Table 3-16, the maximum predicted CAC concentrations due to emissions from the major sources at the Nechalacho Mine, the Flotation Plant and the Hydrometallurgical Plant are less than the corresponding NWT AQ Standards. In addition, the maximum predicted dustfall levels are less than criteria of other Canadian jurisdictions. The contribution of other minor sources is assessed qualitatively in this section.

Mobile sources, including fuel combustion in aircraft, tugs used to tow barges, and vehicles will emit CACs; however, the emissions are expected to be relatively low in magnitude and periodic. Concentrates will be shipped by approximately 60 barge trips during the summer. Aircraft will operate year-round and will emit CACs at high elevation with minimal effect expected on ground-level concentrations. Tugs used to tow barges will emit CACs on Great Slave Lake and therefore the spatial extent is considered regional.

Road dust emissions tend to be deposited within several hundred metres of the roads and are not considered transportable particulate matter; therefore the spatial extent is local and the magnitude of potential effect on ambient CAC concentrations is low. Incineration of waste is expected to occur once a day, thus the duration is short term and frequency is periodic.

The product dryers at the Hydrometallurgical Plant will be equipped with sufficient dust collection systems to meet ambient air quality standards and therefore the magnitude of their potential effect is considered low. A small limestone stockpile may contribute to fugitive dust emissions; however, limestone will be slaked and therefore the magnitude of effect is expected to be low, duration short term and spatial context local. The backup diesel generators at the Hydrometallurgical Plant will operate only during emergency when the Taltson Dam is unable to supply electricity; therefore, the duration is short term and frequency is isolated.

In summary, considering both the quantitative assessment of the major sources and qualitative assessment of the minor sources, the Project has the potential to result in an increase in ambient CAC concentrations or deposition levels and therefore the direction is negative. Most of the Project CACs will be emitted in the two LSAs; however there will be emissions from tugs and aircraft outside the LSAs and therefore the spatial context is rated local to regional. CACs will be emitted throughout the operations phase but will cease at the end of operations and therefore the duration is medium term. There are a number of major sources of continuous CAC emissions and therefore the frequency is rated continuous. Ambient CAC concentrations and deposition levels are expected to return to background levels when operations cease and therefore the effect is reversible. All maximum predicted CAC concentrations and deposition levels are less than ambient air quality standards; however, the maximum predicted 24-hour TSP and NO_2 concentrations are greater than half the corresponding NWT standards and therefore the magnitude is rated low to medium. The probability that ambient CAC concentrations will increase as a result of the Project is high. The overall level of confidence is rated moderate since only major sources of emissions were included in the quantitative assessment; emissions were estimated using emission factors; and a considerable degree of professional judgment was exercised. Due to the low to medium magnitude, local to regional extent, and reversibility, the potential residual effect of CAC emissions during operations on ambient air quality is considered to be not significant.

5.2.2 Greenhouse Gases

Since Project operations will result in an increase in GHG emissions, the direction is negative. Greenhouse gas emissions affect global climate change and therefore the spatial extent is global. GHGs have a long atmospheric lifetime that will extend beyond the life of the project and therefore the duration is rated long term. Emissions will occur continuously for the life of the Project. The lifetime of GHGs is long but finite and therefore the potential effect of GHGs is reversible. Since the GHG emissions associated with the Project are approximately 3% in the Northwest Territories and less than 0.01% of the total emissions in Canada, the magnitude of emission is rated medium. Since GHGs will be emitted during the operation of the mine, the probability of occurrence is high. The level of confidence is rated moderate because emissions were estimated using a top-down approach based on total fuel consumption and emission factors from Environment Canada. Since the magnitude is medium and the effect is reversible, the potential residual effect of Project GHG emissions is considered not significant.

5.3 Closure

CACs and GHGs will be emitted by equipment and vehicles used during the closure phase. Therefore the direction of effect is negative and the probability of occurrence is high for both potential effects. The spatial extent of CAC emissions is expected to be limited to the LSAs and therefore is local; whereas the potential effect of GHG emissions is global in nature. The closure phase is expected to be less than two years and thus the potential change in ambient CAC concentration or deposition is rated short term; whereas the potential effect of GHG emissions is rated long-term due to the long atmospheric lifetime of GHGs. The frequency of CAC and GHG emissions during closure is expected to be isolated to those times when equipment or vehicles are used. The atmospheric lifetimes of CACs and GHGs are finite and therefore the effects are rated reversible. Based on previous experience and professional judgment, the magnitude of CAC and GHG emissions during closure is expected to be low. Since the potential residual effects during closure were assessed qualitatively but are expected to be bounded by operations, the level of confidence is rated low to moderate. Due to the low magnitude, periodic nature and reversibility of emissions during closure, the potential residual effects on ambient air quality and GHG emissions are considered to be not significant.

Table 5-1 Summary of Residual Effects on Ambient Air Quality

Phase	Potential Residual Effect	Direction	Spatial Extent	Temporal Extent			Magnitude	Probability of Occurrence	Level of Confidence
				Duration	Frequency	Reversibility			
Construction	Change in ambient CAC concentration or deposition	Negative	Local	Short term	Periodic	Reversible	Low	High	Low to Moderate
	Change in GHG emissions	Negative	Global	Long term	Periodic	Reversible	Low	High	Low to Moderate
Operation	Change in ambient CAC concentration or deposition	Negative	Local to Regional	Medium term	Continuous	Reversible	Low to Medium	High	Moderate
	Change in GHG emissions	Negative	Global	Long term	Continuous	Reversible	Medium	High	Moderate
Closure	Change in ambient CAC concentration or deposition	Negative	Local	Short term	Isolated	Reversible	Low	High	Low to Moderate
	Change in GHG emissions	Negative	Global	Long term	Isolated	Reversible	Low	High	Low to Moderate

6 CUMULATIVE EFFECTS ASSESSMENT

There are no known other major sources of emissions located in either LSA. The closest known other source of emissions is the proposed Pine Point Pilot Project, located approximately 40 km west-southwest of the Hydrometallurgical Plant (See Figure 0-1). The main CAC emission that both facilities have in common is SO_2. As shown in Figure 3-7, maximum predicted SO_2 concentrations due to emissions from the Hydrometallurgical Plant are expected to be less than 10% of the NWT ambient air quality standard (approximately 50 µg/m3) beyond 6 km from the sulphuric acid plant. Maximum predicted SO_2 concentrations due to emissions from the Pine Point Pilot Project were predicted to be less than 10% of the NWT ambient air quality standard beyond 2 km from that facility (RWDI, 2008). Thus, the potential for cumulative effects due to emissions from the Project in combination with the Pine Point Pilot Project is expected to be negligible.

The proposed Pine Point Pilot Project GHG emissions are 0.3% of the total GHG emissions in the NWT and 0.0008% of Canada's GHG Emissions. These emissions combined with the Project total less than 4% of GHG emissions in the NWT and less than 0.01% of GHG emissions in Canada. The cumulative effect of the Project and the Pine Point Pilot Project on GHG emissions is considered not significant due to the medium magnitude of emissions relative to the territorial total and that the effect is reversible.

7 AIR QUALITY AND DUST CONTROL PLAN

The air quality and dust control plan for the Project outlines the best management practices and mitigation measures that can be undertaken to minimize the air quality effects associated with Project activities. Additional mitigation measures that could be considered to reduce emissions of CACs and GHGs as well as fugitive dust emissions include the following:

- Employ wet suppression systems (spray nozzles) to maintain relatively high material moisture content during the process;
- Cover the conveyor system and connect it to a baghouse dust collection system;
- Connect the process building vent to a baghouse dust collection system;
- Restrict unnecessary idling of Project equipment and vehicles; and
- Inspect and maintain vehicles and equipment regularly.

8 AIR QUALITY MONITORING PLAN

The assessment of criteria air contaminant emissions during operations was based on emission estimates. To confirm the input parameters used in the dispersion modelling, it is recommended that stack testing be conducted on the diesel generators, mine air heater, and sulphuric acid plant after commissioning.

The dispersion modelling results indicate that the maximum predicted concentrations are much less than the NWT Ambient Air Quality Standards. Therefore, as long as the actual stack parameters and measured emission rates are consistent with the modelling assumptions, on-going ambient monitoring should not be necessary

9 CONCLUSIONS

The Thor Lake Project consists of three main components: the Nechalacho Mine, Flotation Plant and the Hydrometallurgical Plant. The valued components assessed were ambient air quality and greenhouse gas emissions. The potential residual effects on these valued components were a change in ambient concentration of criteria air contaminants, a change in dustfall deposition level or a change in greenhouse gas emissions. This air quality assessment was focussed on Project operations since all air quality impacts for the construction and closure phases are expected to be bounded by air quality impacts associated with the operations phase.

Project operations will result in emissions of CACs and GHGs. The main sources of CACs from the Nechalacho Mine and Flotation Plant include the ventilation raises, diesel generators, mine air heaters, and transfer and handling of dry ore. The main source of CACs from the Hydrometallurgical Plant is the sulphuric acid plant. Emissions of CACs were estimated for these main sources, and subsequently modelled using the CALPUFF model. Dispersion model results show that maximum predicted concentrations within the two 20 km by 20 km local study areas are expected to be less than the NWT Ambient Air Quality Standards. Annual GHG emissions from the Project during the operation are expected to be 60.5 kt, which represents a 3% increase in the territorial total and less than 0.01% of total national emissions.

For all three phases of the Project (construction, operation and closure) the potential for a residual effect on ambient air quality or greenhouse gas emissions was found to be not significant. In addition, the potential for cumulative effects was found to be negligible.

10 REFERENCES

ACI-CANEFCO. 2011. Personal Communication with Peter J. Terkovices on February 15, 2011.

American Conference of Governmental Industrial Hygienists (ACGIH). 1997. Threshold Limit Values for Chemical Substances and Physical Agents

Avalon Rare Earth Metals Inc. 2010. Project Description Report – Thor Lake Project, Northwest Territories.

BHP Billiton 2007. BHP Billiton Sustainbility Report 2006.

California Emission Inventory and Reporting System (CEIDARS). 2009. Summary of Overall Size Fractions and Reference Documentation

De Beers Canada Inc. 2008. Gahcho Kue Diamond Mine - Environmental Impact Statement (EIS) Section 11.13

Diavik Diamond Mines Inc. 2007. Diavik Diamond Mine Sustainable Development Report 2006.

DieselNet 2011. Fuel Sulfur Regulations. Access link: http://www.dieselnet.com/standards/ca/fuel.php

Earth System Research Laboratory 2010. Fort Smith Upper Air Data, NOAA/ESRL Radiosonde Database. Access link: http://esrl.noaa.gov/raobs/

Environment Canada 2008. Hourly Weather Data from Hay River 2002 – 2006.

Environment Canada 2010. National Inventory Report – Greenhouse Gas Sources and Sinks in Canada 1990-2008

Environment Canada 2010. Hourly Weather Data from Yellowknife Airport 2009 – 2010.

Finning Canada 2011. Personal Communication with Parm Sandhu on January 25, 2011.

Indian and Northern Affairs Canada 2002. Mine Site Reclamation Policy for the Northwest Territories

Indian and Northern Affairs Canada 2004. Thor Lake – Hydrometallurgical Plant, Memorandum to Avalon, December 20, 2009

Northwest Territories, Department of Justice. 2003. Mine Health and Safety Regulations R-125-95

RWDI 2008. Pine Point Pilot Project - EA0607-002 [2006]. Access link: http://www.reviewboard.ca/registry/project.php?project_id=38

Scott Wilson Roscoe Postle Associates Inc. 2010. Preliminary Feasibility Study on the Thor Lake Project, Northwest Territories, Canada NI43-101 Report.

The Mining Association of Canada. 2009. Energy and GHG Emissions Management Guidance Document. Access link: http://www.mining.ca/www/media_lib/TSM_Publications/2009GHG_Guidance_document_Final_Version_July_2009.pdf

US EPA. 2009. AP-42, Fifth Edition Compilation of Air Pollutant Emission Factors.