APPENDIX 10.I

Dispersion Modelling Approach

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10.I.1 INTRODUCTION

The purpose of this appendix is to present the technical information associated with air dispersion modelling that was completed for the NICO Project. The following sections provide a synopsis of the appendix:

- description of the models considered for the assessment and rationale for model selection;
- overview of the meteorology data used in the modelling;
- description of modelling domain and associated receptor locations where ground-level concentrations and deposition values were calculated; and
- description of dispersion modelling approaches, including assumptions and model options.
- emission information used in the dispersion modelling is presented in detail in Appendix 10.II.

10.I.2 REGULATORY MODEL GUIDANCE

10.I.2.1 Northwest Territories Air Dispersion Modelling Guidelines

Dispersion modelling guidelines have been established by several jurisdictions in Canada including Alberta and British Columbia. In the absence of a dispersion modelling guideline for the Northwest Territories (NWT), the dispersion modelling approach for this assessment is based on current Air Quality Model Guidance issued by Alberta Environment (AENV 2009). The purpose of the guideline is to provide uniform benchmarks and a structured approach to the selection and application of dispersion models. Furthermore, it provides a sound scientific basis for the selection of alternatives. Issues considered in the guideline include the following:

- determination of model performance by comparing model predictions to air quality observations;
- meteorological data requirements;
- receptor placement;
- consideration of permanent structure (e.g., building) downwash effects;
- incorporation of complex terrain; and
- assumptions for consideration when preparing source information.

10.I.2.2 United States Environmental Protection Agency Guidance

All dispersion models considered for the NICO Project were either developed or recommended by the United States (U.S.) Environmental Protection Agency (U.S. EPA 1992; 1999) to address regulatory modelling requirements. National (i.e., U.S.) dispersion modelling guidelines used for regulatory application have a long development history and provide consistency between air quality assessments conducted in the U.S. These guidelines are found in Appendix W of Section 40 of the Code of Federal Regulations, which describes each model accepted for regulatory use and provides guidance on the suitability of each model, which is dependent on the application (U.S. Government 2005).

10.I.2.3 Models Evaluated

The models that were evaluated for use in the NICO Project air quality assessment include the following:

- CALPUFF 3D – Lagrangian puff model in dynamic 3-dimensional (3D) mode (CALPUFF using CALMET 3-dimensional meteorology);
- CALPUFF 2D – Lagrangian model in steady-state 2-dimensional mode (CALPUFF using Industrial Source Complex Model Version 3 [ISC3] single station meteorology);
- AERMOD – a steady–state Gaussian dispersion model designed for short-range (up to 50 km) dispersion of air pollutant emissions from stationary industrial sources; and
- SCREEN3 – a steady-state Gaussian dispersion model used for screening purposes.

A brief description of each model follows.

10.I.2.3.1.1 CALPUFF 3D

The CALPUFF modelling system is a non-steady state meteorological and air quality modelling system that has been recommended for use by the U.S. EPA (U.S. EPA 1999), specifically for long-range transport (i.e., greater than 50 kilometres [km]) of air pollutants and associated effects. The CALPUFF model was developed with the following objectives:

- consideration of time varying point, line, area and volume sources;
- suitability for modelling domains ranging from tens of metres to hundreds of kilometres from a source;
- prediction of averages ranging from 1 hour to 1 year;
- incorporation of building downwash effects;
- incorporation of horizontal and vertical wind shear effects;
- applicability to inert pollutants and those subject to linear removal and chemical conversion mechanisms; and
- applicability to complex terrain scenarios.

Suitable application of the CALPUFF modelling system may include near field impacts associated with complex flow or drop areas (e.g., complex terrain, stagnation, calm wind conditions), long range transport of air pollutants, visibility assessment, criteria air pollutant (e.g., NO_X, SO_X, VOCs) modelling, buoyant area and line sources, and others.

In 3D mode, wind fields determined by the CALMET meteorological model can vary across the modelling domain on both horizontal and vertical scales. This variation often results in improved estimates of plume dispersion compared to non-varying wind fields. Additionally, terrain effects are incorporated into the wind field derivations to enable plumes to travel around or over terrain features, as appropriate, rather than impacting the terrain features directly.

10.I.2.3.1.2 CALPUFF 2-D and AERMOD

The CALPUFF model can be run in a steady-state or 2-dimensional mode, which is more indicative of historical dispersion models. Many of the CALPUFF dynamic model features are available in 2-dimensional mode such as puff splitting, long-range transport estimates, and chemical transformations; however, wind field variation is not a component of the 2-dimensional model. These dynamic features are considered to be a significant advantage over other models such as ISC3, but less of an advantage over AERMOD (Hanna et al. 2001). Consequently, CALPUFF in 2D mode was not used for this assessment.

In the U.S., AERMOD is considered the model of choice for plume travel distances less than 50 km. The AERMOD model was not considered for this assessment, because the air quality regional study area (RSA) chosen for the NICO Project is large (94 by 124 km).

10.I.2.3.1.3 SCREEN3

SCREEN3 is a single-source screening model that may be used for point, area, volume, and flare sources. Screening modelling provide conservative estimates of source impacts with a minimum of input. In SCREEN3, worst-case meteorological conditions are used to evaluate maximum ground level concentrations. Screening models are generally limited in their ability to evaluate terrain impacts and downwash effects from multiple buildings; however, for relatively simple sources, such as a single source and few downwash structures, SCREEN3 will provide conservative estimates of downwind concentrations.

10.I.2.4 Selected Model: CALPUFF 3-dimensional

For assessing air quality effects from on-site emission sources from the NICO Project, CALPUFF-3D (hereafter CALPUFF) was determined to be the most appropriate model. Key features of the CALPUFF model are presented in Table 10.I.2-1. The primary rationale for use of the CALPUFF model includes the following:

- the applicability at a range of spatial scales from a few kilometres to more than 100 km (e.g., evaluating regional and local air emission effects);
- it incorporates wet and dry removal processes (deposition);
- it includes both sulphur dioxide (SO_2) and nitrogen oxides (NO_X) chemistry, which is required for predicting potential acid input (PAI);
- it applies 3D wind speed and wind direction and time allowing for more realistic plume movement simulations;
- it is based on principles that have been explicitly documented and undergone independent peer review; and
- it incorporates plume rise model enhancement downwash algorithms.

The CALPUFF model has recently undergone improvements, to make it more suitable for application at the regional level (Scire 2007). Modifications to the CALPUFF system include the following:

- new modules to treat buoyant plume rise and dispersion from area sources;
- buoyant line sources;
- volume sources;
- improved treatment of complex terrain;
- additional model switches to facilitate its use in regulatory applications;

- enhanced treatment of wind shear through puff splitting;
- capability to model time periods shorter than 1 hour (e.g., 0.5 hour, 15 minutes, etc. [Version 6 – CALPUFF-Professional Beta 2.3.1005]); and
- capability to model plume length and frequency of fog occurrences (CALPUFF-VISTA).

Table 10.I.2-1: Major Features of the CALPUFF Model

Source Types
Point sources (constant or variable emissions)
Line sources (constant emissions)
Volume sources (constant or variable emissions)
Area sources (constant or variable emissions)
Cooling Towers (variable emissions)
Non-steady State Emissions and Meteorological Conditions (if CALMET is used)
Gridded 3D fields of meteorological variables (winds, temperature)
Spatially variable fields of mixing height, friction velocity, convective velocity scale, Monin-Obukhov length, precipitation rate
Vertically and horizontally varying turbulence and dispersion rates
Time-independent source and emissions data
Dispersion Coefficient (σ_y, σ_z) Options
Direct measurements of σ_v and σ_w
Estimated values of σ_v and σ_w based on similarity theory
Pasquill-Gifford (PG) dispersion coefficients (rural areas)
McElroy-Pooler (MP) dispersion coefficients (urban areas)
Vertical Wind Shear
Puff splitting
Differential advection and dispersion
Plume Rise
Partial penetration
Buoyant and momentum rise
Stack tip effects
Vertical wind shear
Dry Deposition
Gases and particulate matter
Three options: - Full treatment of space and time variations of deposition with a resistance model; - User-specified diurnal cycles for each pollutant; and - No dry deposition.
Chemical Transformation Options
Pseudo first order chemical mechanism for SO_2, SO_4, NO_x, HNO_3, and NO_3 (MESOPUFF II method)
User-specified diurnal cycles of transformation rates

Table 10.I.2-1: Major Features of the CALPUFF Model (continued)

Wet Removal
Scavenging coefficient approach
Removal rate a function of precipitation intensity and precipitation type
Graphical User Interface
Click and point model set-up and data input
Enhanced error checking of model inputs

The CALPUFF model was run in 3D mode for the purposes of assessing on-site emissions from the NICO Project using a wind field developed specifically for the NICO Project from regional surface meteorological data and mesoscale data for northern Canada. The RIVAD/ARM3 chemistry was used for calculations of wet and dry deposition of sulphate and nitrate compounds.

Despite many advancements of the CALPUFF modelling system over other available models, CALPUFF has some limitations. For example, predicted concentrations and deposition of airborne contaminants are known to be higher than observed near major area sources of SO_2 and NO_X, such as mine pits. This is likely due to the RIVAD/ARM3 chemical transformation algorithms used by the model (Staniaszek et al. 2006; Staniaszek and Davies 2006).

The CALPUFF model in dynamic mode was selected to meet the assessment Terms of Reference for the NICO Project Developer's Assessment Report, particularly with respect to deposition. Its use in environmental assessments in the NWT has broad support from regulators and regional stakeholders. CALPUFF Version 6.267 was used for this assessment.

10.I.2.5 Selected Model: SCREEN3

SCREEN3 was chosen to assess air quality effects from off-site emission sources (i.e., NICO Project Access Road [NPAR] and Proposed Tłı̨chǫ Road Route) resulting from the NICO Project. Off-site emissions resulting from the NICO Project will consist primarily of emissions along the proposed NPAR and Proposed Tłı̨chǫ Road Route. These emissions are expected to occur with much lower intensity than the on-site emissions, resulting in effects that are localized. In addition, the off-site emissions will be spread out over the length of each road (e.g., over a length of 27 km for the NPAR). The SCREEN3 dispersion model is well suited in the analysis of such localized air effects and hence was selected to evaluate off-site NICO Project emissions. Due to built-in conservative parameters and values, SCREEN3 modelling results are usually higher than those of refined models such as CALPUFF.

The SCREEN3 model approach of off-site sources was agreed upon with Environment Canada and presented to the GNWT (D. Fox, Environment Canada, 2010, pers. comm.). Environment Canada will be providing comments to the MVRB on air quality issues.

10.I.3 DISPERSION METEOROLOGY

10.I.3.1 CALMET Description

The 3D wind fields used in the CALPUFF dispersion modelling assessment were created using the CALMET model pre-processor developed specifically for use with the CALPUFF model. The CALMET wind fields were simulated over an area slightly larger than the modelling domain to ensure that the CALPUFF model incorporates representative wind fields in the region and that any so-called edge effect influences are minimized. One year of meteorological data covering 1 January 2005 to 31 December 2005 was generated using output from a mesoscale meteorological model in combination with local meteorological observations.

The CALMET model is composed of 2 main components: a wind field module and a boundary layer meteorological module. In Step 1 of the wind field development, an initial guess wind field is adjusted for the kinematic effects of terrain, slope flows, and blocking effects, as appropriate. Observational data are introduced in Step 2 through an objective analysis procedure. An inverse-distance squared interpolation scheme is used where observational data are weighted most heavily around the observation station.

The overland boundary layer model computes gridded fields of surface friction velocity, convective velocity scale, Monin-Obukhov length, mixing height, Pasquill-Gifford stability class, air temperature and precipitation rate using the energy balance method of Holtslag and van Ulden (1983).

The CALMET modelling domain size is 102 km in the east-west direction and 132 km in the north-south direction. The domain lies between 63.04°N and 64.21°N latitude and 117.44°W to 115.35°W longitude. The horizontal grid spacing is 2 by 2 km. This combination of grid size and number of cells was chosen to minimize run time while still capturing any large-scale (i.e., > 2 km) terrain feature influences on wind flow patterns.

The height of vertical layers is defined as the midpoint between 2 adjacent layers or interfaces (i.e., 11 interfaces for 10 layers, with the lowest layer always at ground-level). The vertical interfaces used for this project were 0, 20, 50, 100, 200, 400, 800, 1200, 1600, 2200, and 3000 metres (m) above ground level.

Surface observations from 2 meteorological stations were used in CALMET. The initial guess wind field was determined from the Fifth-Generation NCAR/Penn State Mesoscale Model (MM5) model.

10.I.3.1.1 MM5 Description

The CALMET model uses 3D prognostic wind field data as the initial guess field. The prognostic data provides CALMET with surface and vertical meteorological fields, such as wind, temperature, pressure, and relative humidity. The MM5 dataset was developed for use as the initial guess field for CALMET.

10.I.3.1.1.1 Modelling Domain

The MM5 modelling domain consists of 2 nested domains at 36 and 12 km resolution. A 2-way nesting technique was used allowing the finer mesh to provide feedback to the coarser mesh. One of the advantages of using the 2-way nesting is smoother boundary values along the finer mesh, which results in minimized noise on grid cells close to the boundary. In addition, since the finer mesh has a shorter time step than the coarser mesh, it allows the finer mesh to account for coarser mesh variations at a finer time scale.

The domains are centered at 63.54° N and 116.74° W, which corresponds to the centre coordinates of the NICO Project. The domains were set up so that each nest ends far enough from the edge of the next larger domain to avoid noise on the boundary of its parent domain. The 12 km nest domain is located within 10 grid cells of the 36 km mother domain, which is double the 5 grid cells distance recommended by MM5 model developers. The MM5 meteorological fields from the 12 km domain were post-processed using CALMM5 for input to the CALMET model.

Figure 10.I.3-1 shows the location of the MM5 modelling domains. The green box represents the 12 km nested domain and covers approximately 300 by 300 km. The black box represents the CALMET modelling domain and the brown rectangular box represents CALPUFF modelling domain.

10.I.3.1.1.2 Terrain and Land Use

The MM5 model uses USGS v.2 global terrain and land use data as input. The following data resolutions were used in the modelling:

- 36 km domain: 10 min (~19 km) global terrain and land use; and
- 12 km domain: 5 min (~9 km) global terrain and land use.

10.I.3.1.1.3 Model Initialization

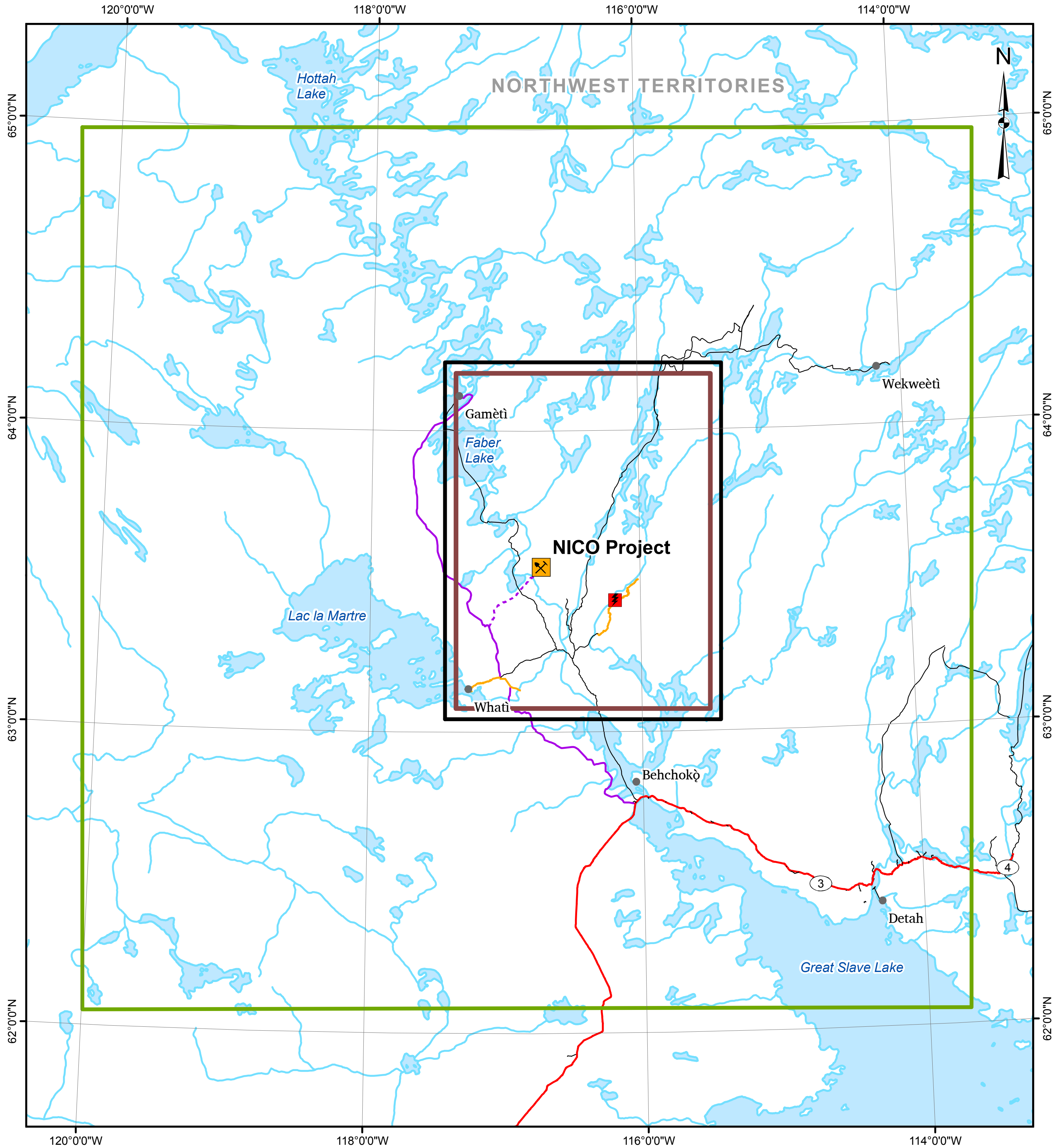
The National Centers for Environmental Prediction Final Operational Global Analysis data on 1 x 1 degree grids was used to initialize the MM5 model. The analysis data have a 6 hour temporal resolution. The analyses are available at several levels including the surface and various pressure levels from 1000 millibars to 10 millibars. Parameters include surface pressure, sea level pressure, geo-potential height, temperature, sea surface temperature, soil values, ice cover, relative humidity, horizontal wind speed (i.e., u- and v-components), vertical component, vorticity, and ozone.

The National Centers for Environmental Prediction Final analysis data provide the MM5 model with boundary and initial conditions. Since mesoscale modelling has an initial value problem, a superior boundary and initial condition has a high impact on the accuracy of model output. The above analysis was chosen because it has higher spatial resolution compared to the National Centers for Environmental Prediction Re-analysis data, which have 2.5° x 2.5° resolution.

10.I.3.1.1.4 Modelling Physics

The following model physics are incorporated into the MM5 model suite:

- Reisner graupel (Reisner2) explicit moisture scheme: This scheme is based on a mixed-phase scheme but with the addition of graupel and ice number concentration prediction equations.
- Kain-Fritsch 2 cumulus scheme: This scheme predicts both updraft and downdraft properties and also detrains cloud and precipitation. A shallow convection is also included in this new version of the Kain-Fritsch scheme. The cumulus parameterization is not recommended for a grid size less than 5 to 10 km.
- Pleim-Chang planetary boundary layer scheme: This is a high resolution scheme, with 5 layers in the lowest kilometre, and a surface layer less than 100 m thick.
- RRTM longwave scheme: This scheme is combined with the cloud-radiation shortwave scheme.
- Pleim-Xiu LSM surface scheme: This scheme handles soil surface, canopy, and evapo-transpiration moisture fluxes from and to ground that will be used by planetary boundary layer scheme to calculate surface temperature, water vapour, and surface wind.



LEGEND

- NICO PROJECT
- POPULATED PLACE
- HIGHWAY
- EXISTING ALL-WEATHER ROAD
- EXISTING WINTER ROAD
- PROPOSED NICO PROJECT ACCESS ROAD
- PROPOSED TŁĮCHQ ROAD ROUTE
- RAILROAD
- WATERCOURSE
- WATERBODY
- SNARE HYDRO LOCATION
- CALMET MODELLING DOMAIN
- CALPUFF MODELLING DOMAIN
- MM5 MODELLING DOMAIN

50 0 50

SCALE 1:2,000,000 KILOMETRES

REFERENCE

Base data obtained from Atlas of Canada, DMTI, and ESRI.
Projection: UTM Zone 11 Datum: NAD 83

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

MM5 MODELLING DOMAIN

Golder Associates
Edmonton, Alberta

FILE No. E-Air-013-GIS				
PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	DC	15 Feb. 2011	**FIGURE: 10.I.3-1**	
GIS	BS	11 Mar. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

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10.I.3.1.2 Geophysical Parameters

The CALMET model requires a physical description of the ground surface to determine meteorological parameters near the surface. The geophysical parameters are land use category, terrain elevation, roughness length, albedo, Bowen ratio, soil heat flux parameter, anthropogenic heat flux, and leaf area index. Values for all land use parameters except land use category and elevation were determined for the following periods:

- non-foliage period – 1 January 2005 to 31 May 2005 and 1 October 2005 to 31 December 2005; and
- foliage period – 1 June 2005 to 30 September 2005.

The geophysical parameters are described below and the foliage and non-foliage values are summarized in Tables 10.I.3-1 and 10.I.3-2, respectively.

Table 10.I.3-1: Geophysical Parameters for the Foliage Season

Land Use Category	Description	Roughness Length (m)	Albedo	Bowen Ratio	Soil Heat Flux (W/m^2)	Leaf Area Index	Anthropogenic Heat Flux (W/m^2)
31	Herbaceous Rangeland	0.05	0.25	1.0	0.15	0.5	0.0
32	Shrub and Bush Rangeland	0.05	0.25	1.0	0.15	0.5	0.0
33	Mixed Rangeland	0.05	0.25	1.0	0.15	0.5	0.0
41	Deciduous Forest	1.0	0.1	1.0	0.15	7.0	0.0
42	Evergreen Forest	1.0	0.1	1.0	0.15	7.0	0.0
52	Lakes	0.001	0.1	0.0	1.0	0.0	0.0
62	Nonforested Wetland	0.2	0.1	0.1	0.25	1.0	0.0
90	Snow or Ice	0.2	0.7	0.5	0.15	0.0	0.0

m = metre

Table 10.I.3-2: Geophysical Parameters for the Non-Foliage Season

Land Use Category	Description	Roughness Length (m)	Albedo	Bowen Ratio	Soil Heat Flux (W/m^2)	Leaf Area Index	Anthropogenic Heat Flux (W/m^2)
31	Herbaceous Rangeland	0.001	0.6	1.5	0.15	0.0	0.0
32	Shrub and Bush Rangeland	0.001	0.6	1.5	0.15	0.0	0.0
33	Mixed Rangeland	0.001	0.6	1.5	0.15	0.0	0.0
41	Deciduous Forest	0.5	0.5	1.5	0.15	0.0	0.0
42	Evergreen Forest	1.0	0.35	1.5	0.15	3.5	0.0
52	Lakes	0.001	0.2	1.5	1.0	0.0	0.0
62	Nonforested Wetland	0.05	0.3	1.5	0.25	0.5	0.0
90	Snow or Ice	0.2	0.7	0.5	0.15	0.0	0.0

m = metre

10.I.3.1.2.1 Land Use

Land use data were obtained from MODerate resolution Imaging Spectroradiometer satellite data. MODerate resolution Imaging Spectroradiometer measurements provide sufficient spectral information to extract land use directly at a temporal resolution of two weeks and a spatial resolution ranging from 500 m to 1 km. The MODerate resolution Imaging Spectroradiometer data were obtained from the United States Geological Survey (USGS) Land Processes Distributed Active Archive Center (USGS 2009, internet site).

The CALMET domain is comprised of 87% rangeland, 8% water, and 3% nonforested wetland. The remaining 2% of the domain is comprised of forests and snow or ice.

10.I.3.1.2.2 Roughness Length

Roughness length (z_0) is a measure of the aerodynamic roughness of a surface and is related to the height, shape, and density of the surface as well as the wind speed. It is defined as the height at which the vertical wind profile is extrapolated to zero. The CALMET default values were used for the foliage season and winter values from the AERMET model (U.S. EPA 2004) were used for the non-foliage season.

10.I.3.1.2.3 Albedo

Albedo is defined as the ratio of reflected solar radiation to the total incoming solar radiation received at the surface. CALMET default values were used for the foliage season and values from the AERMET model (U.S. EPA 2004) were used for the non-foliage season.

10.I.3.1.2.4 Bowen Ratio

The Bowen ratio is defined as the ratio of sensible heat flux to latent heat flux. The CALMET default values were used for the foliage season and values from the AERMET model (U.S. EPA 2004) were used for the non-foliage season.

10.I.3.1.2.5 Soil Heat Flux Constant and Anthropogenic Heat Flux

The soil heat flux constant is a function of the surface properties and is used to compute the flux of heat into the soil. The CALMET default values were used for both seasons.

Anthropogenic heat flux is a function of population density and energy usage. Since there are no large population centres in the CALMET domain, the anthropogenic heat flux was set to the CALMET default value of 0 W/m^2 for all land use categories.

10.I.3.1.2.6 Leaf Area Index

Leaf area index is defined as the ratio of leaf area to soil surface area. The CALMET default values were used for the foliage season. The leaf area index values for the non-foliage season for deciduous forest and nonforested wetland categories were set to half the CALMET default values to account for snow cover. The remaining land use categories were set to zero.

10.I.3.1.3 Surface and Precipitation Data

The CALMET model requires hourly values of the following observed parameters for at least one surface station in the domain:

- wind speed and direction;

- temperature;
- relative humidity;
- cloud (ceiling height and cloud opacity);
- station pressure; and
- precipitation rate and code.

Meteorological observations from the on-site meteorological station and the Lac La Martre Environment Canada station located in Whatì were included in CALMET.

Since precipitation observations were not complete or available from the on-site station or the Lac La Martre station, data from the MM5 model were used.

10.I.3.1.4 CALMET Model Options

Tables 10.I.3-3 to 10.I.3-7 provide the model input options used for the CALMET model. Since upper air observations were not available in the region of the modelling domain, MM5 data were used for upper air (NOOBS = 1). Default options were used where applicable.

Table 10.I.3-3: CALMET Input Group 2 - Map Projection and Grid Control Parameters

Parameter	Description	Default	NICO Project
PMAP	map projection = UTM	UTM	UTM
IUTMZN	UTM zone	-	11
UTMHEM	hemisphere for UTM projection	N	N
DATUM	datum region for output coordinates	WGS-84	NAR-C
NX	number of X grid cells	-	51
NY	number of Y grid cells	-	66
DGRIDKM	grid spacing (km)	-	2
NZ	number of vertical layers	-	10
ZFACE	cell face heights in vertical grid (m)	-	0, 20, 50, 100, 200, 400, 800, 1200, 1600, 2200, and 3000

UTM = Universal Transverse Mercator; km = kilometre; m = metre

Table 10.I.3-4: CALMET Input Group 4 - Meteorological Data Options

Parameter	Description	Default	NICO Project
NOOBS	use surface and overwater observations (no upper air observations)	0	1
NSSTA	number of surface stations	-	2
NPSTA	number of precipitation stations - use MM5 precipitation data	-	-1
ICLOUD	gridded cloud cover from prognostic relative humidity at all levels	0	4

Table 10.I.3-5: CALMET Input Group 5 - Wind Field Options and Parameters

Parameter	Description	Default	NICO Project
IWFCOD	diagnostic wind module	1	1
IFRADJ	compute Froude number adjustment effects	1	1
IKINE	do not compute kinematic effects	0	0
IOBR	do not use O'Brien procedure for adjustment of the vertical velocity	0	0
ISLOPE	compute slope flows	1	1
IEXTRP	similarity theory used, surface wind observations not extrapolated to upper layers	-4	-4
ICALM	do not extrapolate surface winds if calm	0	0
BIAS	layer-dependant biases for modifying the weights of surface and upper air stations	NZ*0	-1,0,0,0,0,0,0,0,0,0
RMIN2	minimum distance from nearest upper air station to surface station for which extrapolation of surface winds at surface station will be allowed. Set to -1 when all surface stations should be extrapolated	4	-1
IPROG	winds from MM5/M3D.dat used as initial guess field	0	14
ISTEPPG	time step of the prognostic model input data (seconds)	3600	3600
IGFMET	use coarse CALMET fields as initial guess	0	0
LVARY	do not use varying radius of influence	F	T
RMAX1	maximum radius of influence over land in the surface layer (km)	-	20
RMAX2	maximum radius of influence over land aloft (km)	-	50
RMAX3	maximum radius of influence over water	-	100
RMIN	minimum radius of influence used in the wind field interpolation (km)	0.1	0.1
TERRAD	radius of influence of terrain features	-	20
R1	relative weighting of the first guess field and observations in the surface layer (km)	-	2
R2	relative weighting of the first guess field observations in the layers aloft (km)	-	5
RPROG	relative weighting parameter of the prognostic wind field data (km). Used only if IPROG=1.	-	-
DIVLIM	maximum acceptable divergence in the divergence minimization procedure	0.000005	0.000005
NITER	maximum number of iterations in the divergence minimization procedure	50	50
NSMTH	number of passes in the smoothing procedure	2, (mxnz-1)*4	2,4,4,4,4,4,4,4
NINTR2	maximum number of stations used in each layer for the interpolation of data to a grid point	99	NZ*99
CRITFN	critical Froude number	1	1

Table 10.I.3-5: CALMET Input Group 5 - Wind Field Options and Parameters (continued)

Parameter	Description	Default	NICO Project
ALPHA	empirical factor controlling the influence of kinematic effects	0.1	0.1
FEXTR2	multiplicative scaling factor for extrapolation of surface observations to upper layers. Used only if IEXTRP = 3 or -3.	NZ*0	NZ*0
NBAR	number of barriers to interpolation of the wind fields	0	0
IDIOPT1	compute surface temperature internally from hourly surface observations	0	0
ISURFT	surface meteorological station to use for the surface temperature (on-site station)	-	1
IDIOPT2	compute domain-averaged temperature lapse rate internally from twice-daily upper air observations	0	0
IUPT	upper air station to use for domain-scale lapse rate - use 2D spatially varying lapse rate	-1	-1
ZUPT	depth through which the domain-scale lapse rate is computed	200	200
IDIOPT3	compute domain-averaged wind components internally from twice-daily upper air observations	0	0
IUPWIND	upper air station to use for the domain-scale winds	-1	-1
ZUPWND	bottom and top of layer through which the domain-scale winds are computed	1, 1000	1, 3000
IDIOPT4	read wind speed and wind direction from a surface data file for observed surface wind components for wind field module	0	0
IDIOPT5	read WS and WD from an upper air data file for observed upper air wind components for wind field module	0	0
LLBREZE	do not use lake breeze module	F	F

km = kilometre

Table 10.I.3-6: CALMET Input Group 6 - Mixing Height, Temperature, and Precipitation Parameters

Parameter	Description	Default	NICO Project
CONSTB	constant for neutral mechanical equation	1.41	1.41
CONSTE	constant for convective mixing height equation	0.15	0.15
CONSTN	constant for stable mixing height equation	2400	2400
CONSTW	constant for overwater mixing height equation	0.16	0.16
FCORIOL	absolute value of Coriolis parameter	0.0001	0.00012
IAVEZI	conduct spatial averaging of mixing heights	1	1
MNMDAV	maximum search radius in averaging process (grid cells)	1	1
HAFANG	half-angle of upwind looking cone for averaging	30	30
ILEVZI	layer of winds used in upwind averaging	1	1
IMIXH	convective mixing height option = Maul-Carson for land and water cells	1	1

Table 10.I.3-6: CALMET Input Group 6 - Mixing Height, Temperature, and Precipitation Parameters (continued)

Parameter	Description	Default	NICO Project
THRESHL	threshold buoyancy flux required to sustain convective mixing height growth overland (expressed as a heat flux per metre of boundary layer W/m³)	0	0
THRESHW	threshold buoyancy flux required to sustain convective mixing height growth overwater (expressed as a heat flux per metre of boundary layer W/m³)	0.05	0.05
ITWPROG	use SEA.DAT lapse rates and deltaT or assume neutral conditions if missing	0	0
ILUOC3D	land use category ocean in 3D.dat datasets	16	16
DPTMIN	minimum potential temperature lapse rate in the stable layer above the current convective mixing height (K/m)	0.001	0.001
DZZI	depth of layer above current convective mixing height through which lapse rate is computed	200	200
ZIMIN	minimum overland mixing height (m)	50	50
ZIMAX	maximum overland mixing height (m)	3000	3000
ZIMINW	minimum overwater mixing height (m)	50	50
ZIMAXW	maximum overwater mixing height (m)	3000	3000
ICOARE	use COARE with no wave parameterization for overwater surface fluxes	10	10
DSHELF	coastal/shallow water length scale (km) (COARE fluxes only)	0	0
IWARM	COARE warm layer computation off	0	0
ICOOL	COARE cool skin layer computation off	0	0
IRHPROG	3D relative humidity from surface observations	0	0
ITPROG	use surface stations for 3D temperature. Use MM5 for upper air data.	0	1
IRAD	use 1/R for temperature interpolation	1	1
TRADKM	radius of influence for temperature interpolation (km)	500	500
NUMTS	maximum number of stations to include in temperature interpolation	5	5
IAVET	conduct spatial averaging of temperatures	1	1
TGDEFB	default temperature gradient below the mixing height over water (K/m)	-0.0098	-0.0098
TGDEFA	default temperature gradient above the mixing height over water (K/m)	-0.0045	-0.0045
JWAT1, JWAT2	beginning and ending land use categories for temperature interpolation over water	-	55,55
NFLAGP	use $1/R^2$ for precipitation interpolation	2	2
SIGMAP	radius of influence for precipitation interpolation (km)	100	100
CUTP	minimum precipitation rate cut-off (mm/h)	0.01	0.01

m = metre; km = kilometre; mm/h = millimetre per hour

Table 10.I.3-7: Surface Station Parameters

Station	X Coordinate (km)	Y Coordinate (km)	Time Zone	Anemometer Height (m)
NICO On-site Station	512.647	7,046.463	7	10
Lac La Martre Station	484.927	7,110.051	7	10

Note: Coordinates are in NAD83 UTM Zone 11.
km = kilometre; m = metre

10.I.4 DISPERSION MODELLING APPROACH

10.I.4.1 Dispersion Modelling Assumptions

The air quality assessment for the NICO Project included several assumptions regarding assessment scenarios, emission rates, and dispersion modelling approaches. Whenever possible, assumptions were made such that model predictions were not underestimated. The main assumptions included in the air quality assessment are as follows:

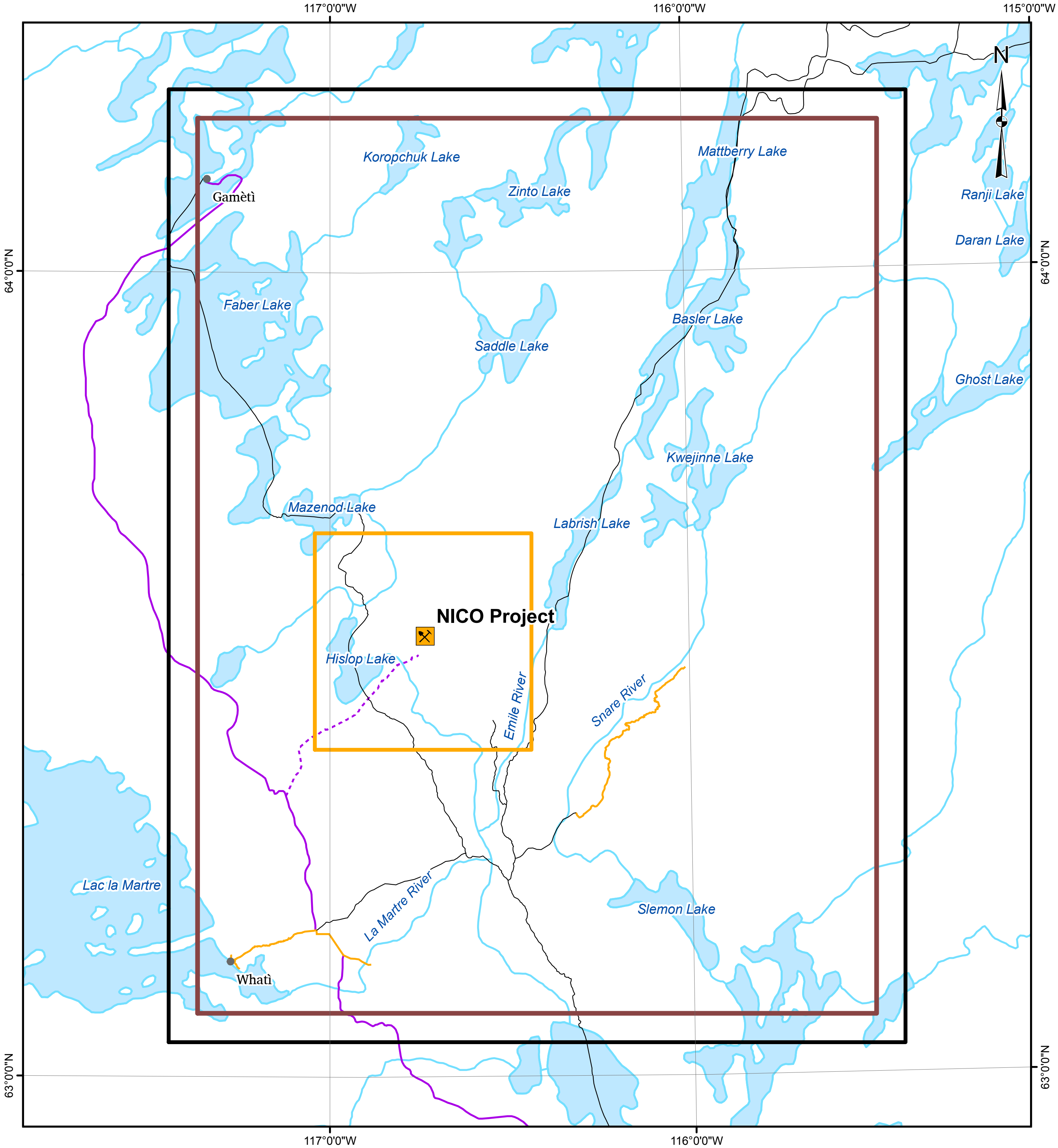
- The dispersion modelling was performed per the Alberta Air Quality Model Guideline (AENV 2009). There is no air quality modelling guideline for NWT.
- For each on-site modelling scenario, it was assumed that all emission sources were emitting continuously at their maximum emission rates. In reality, some sources such as waste incinerators operate intermittently.
- The 2005 MM5 meteorological data was appropriate for use in preparing the 3D meteorological data set.
- It was assumed that 100% of the airborne sulphates and nitrates were in the form of secondary aerosols, resulting in conservative estimations of $PM_{2.5}$ concentrations.

10.I.4.1.1 Modelling Domain

The air quality assessment of the NICO Project was based on the following regions (Figure 10.I.4-1):

- Modelling domain: The air quality modelling domain defines the region over which air dispersion modelling were performed. The modelling domain chosen for the air quality assessment of the NICO Project is presented in Figure 10.I.4-1.
- Regional Study Area: The RSA defines the region over which modelling results are presented and is typically smaller than the modelling domain. The RSA for the NICO Project is defined by an area of 94 km in an east-west direction and 124 km in a north-south direction. The RSA is large enough to capture the impacts of the NICO Project on the nearest communities, namely Whatì and Gamètì, which are located approximately 50 km and 70 km from the NICO Project, respectively.
- Local Study Area: The LSA defines the area in the immediate vicinity of the NICO Project where the majority of air quality effects are expected to occur. The LSA is a subset of the RSA and allows a more focused assessment of the effects associated with the NICO Project. The LSA is defined by an area of about 30 by 30 km, encompassing the NICO Project.

  NICO Project Lease Boundary: This boundary envelops all major emission sources associated with the NICO Project and includes areas that will be physically disturbed due to the construction, operation and reclamation of the NICO Project. The area outside of this boundary is used to determine compliance with applicable ambient air quality standards.



LEGEND

- NICO PROJECT
- POPULATED PLACE
- EXISTING ALL-WEATHER ROAD
- EXISTING WINTER ROAD
- PROPOSED NICO PROJECT ACCESS ROAD
- PROPOSED TŁĮCHǪ ROAD ROUTE
- WATERCOURSE
- WATERBODY
- CALPUFF MODELLING DOMAIN
- LOCAL STUDY AREA
- REGIONAL STUDY AREA

25 0 25

SCALE 1:750,000 KILOMETRES

REFERENCE

Base data obtained from Atlas of Canada, DMTI, and ESRI.
Projection: UTM Zone 11 Datum: NAD 83

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

AIR QUALITY MODELLING DOMAIN AND STUDY AREA

Golder Associates
Edmonton, Alberta

FILE No. E-Air-015-GIS				
PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	DC	03 Feb. 2011	FIGURE: 10.I.4-1	
GIS	BS	08 Mar. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

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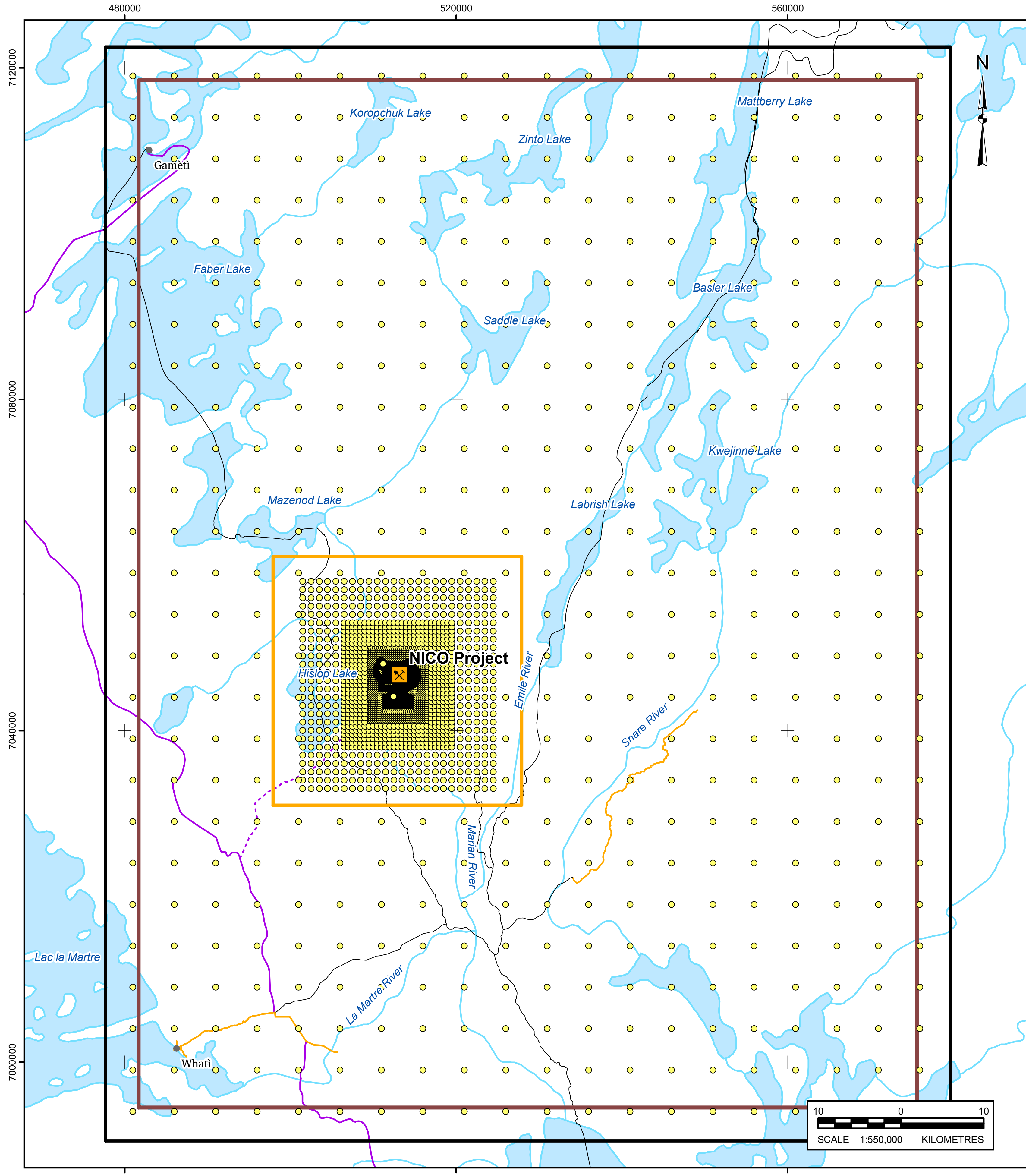
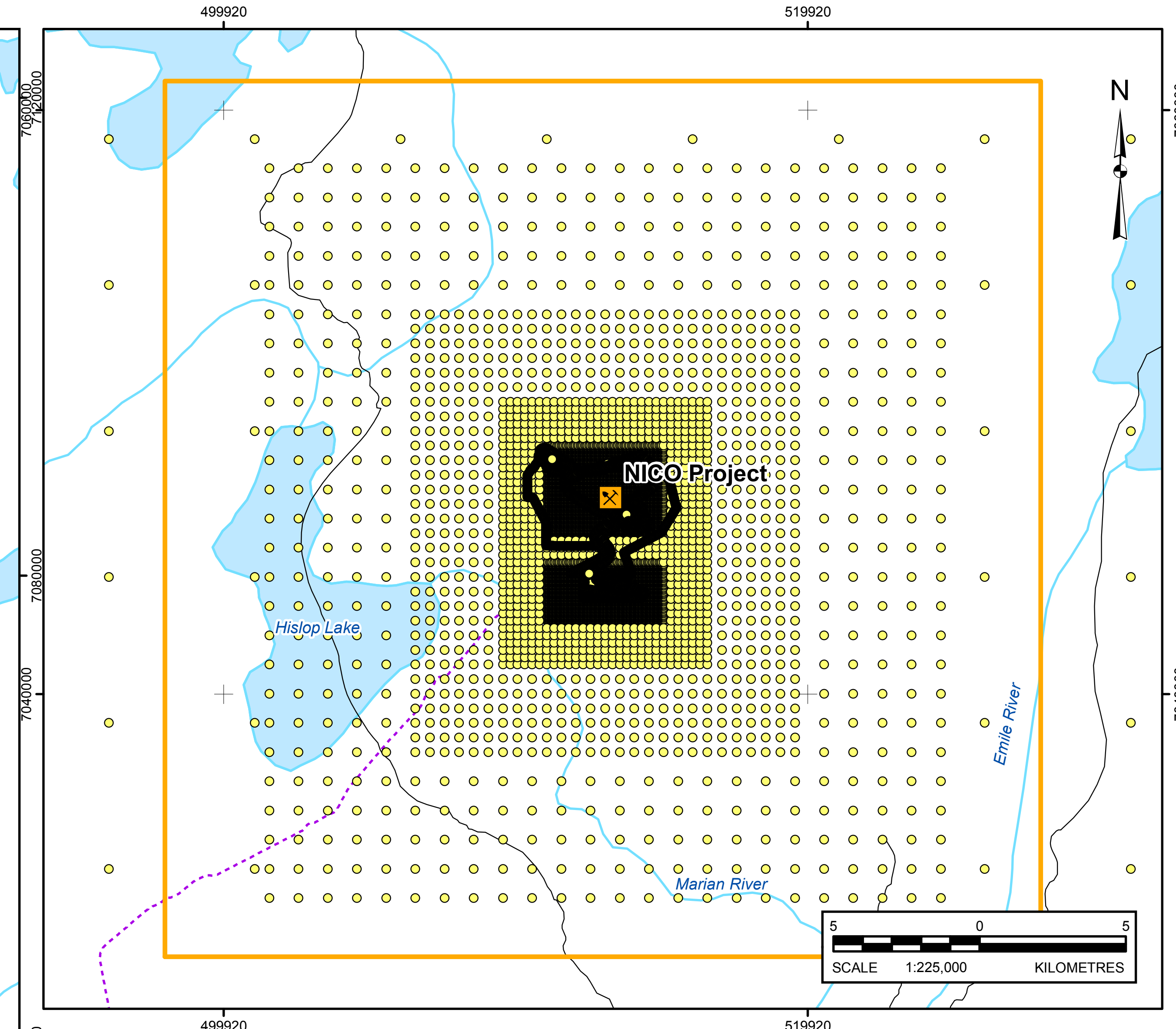
10.I.4.2 Receptors

The regional receptor scheme is shown in Figure 10.I.4-2 and the location of health receptors is shown in Figure 10.I.4-3. The health receptors include 2 communities (Whatì and Gamètì), the on-site work camp, 18 local points of interest, and along the NICO Project Lease Boundary. The potential impacts to the air quality at other communities (i.e., Behchokǫ̀, Wekweetì, and Yellowknife) that are outside of the RSA were evaluated using the predictions at the surrogate regional receptors within the RSA that are closest to these communities.





LEGEND

- NICO PROJECT
- POPULATED PLACE
- EXISTING ALL-WEATHER ROAD
- EXISTING WINTER ROAD
- PROPOSED NICO PROJECT ACCESS ROAD
- PROPOSED TŁICHǪ ROAD ROUTE
- WATERCOURSE
- WATERBODY
- AIR QUALITY RECEPTOR
- CALPUFF MODELLING DOMAIN
- LOCAL STUDY AREA
- REGIONAL STUDY AREA

REFERENCE

Base data obtained from GeoGratis.
Projection: UTM Zone 11 Datum: NAD 83

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

REGIONAL RECEPTOR MODEL LOCATIONS

Golder Associates
Edmonton, Alberta

FILE No. E-Air-016-GIS

PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	DC	03 Feb. 2011		
GIS	BS	08 Mar. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

FIGURE: 10.I.4-2

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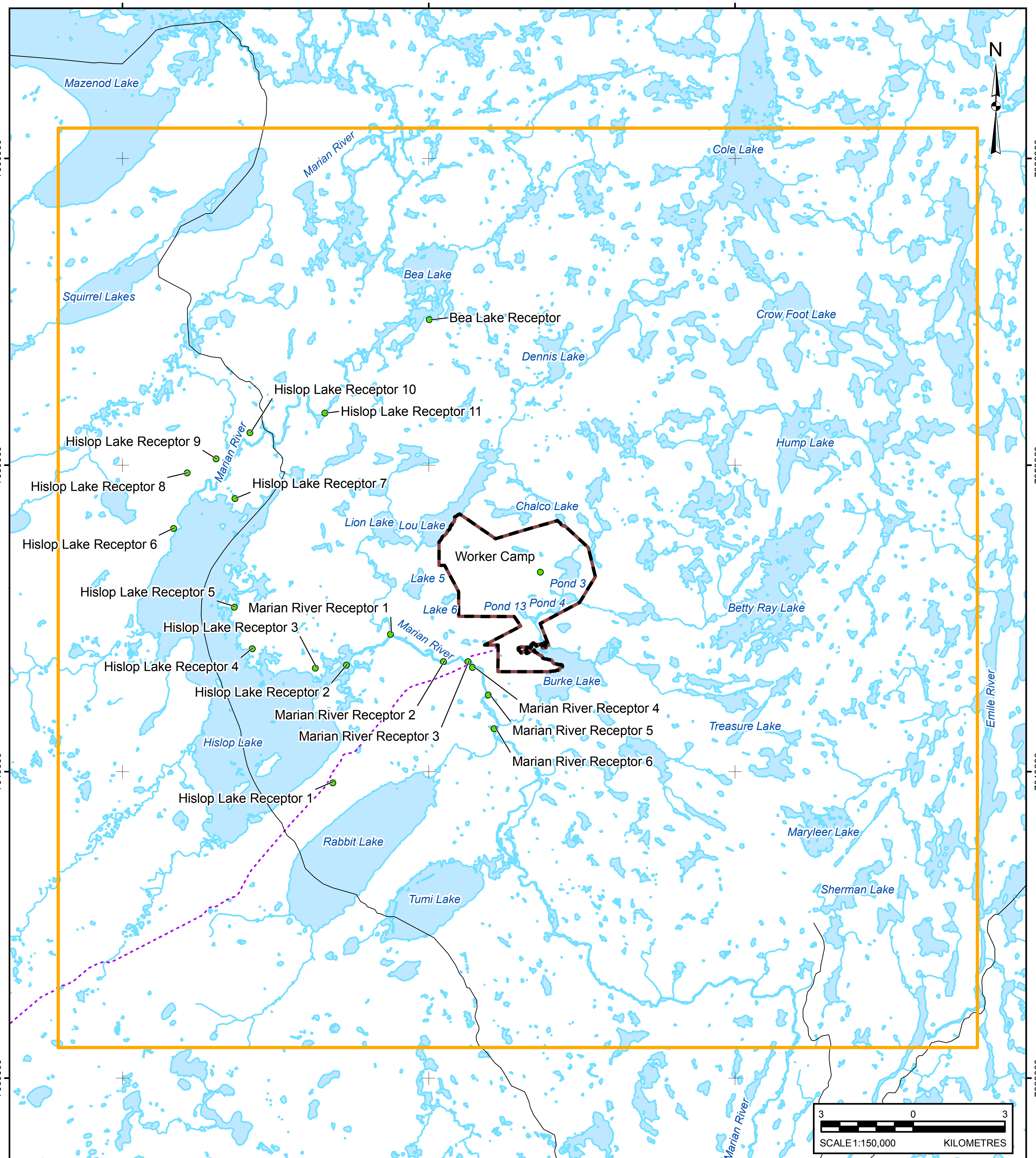

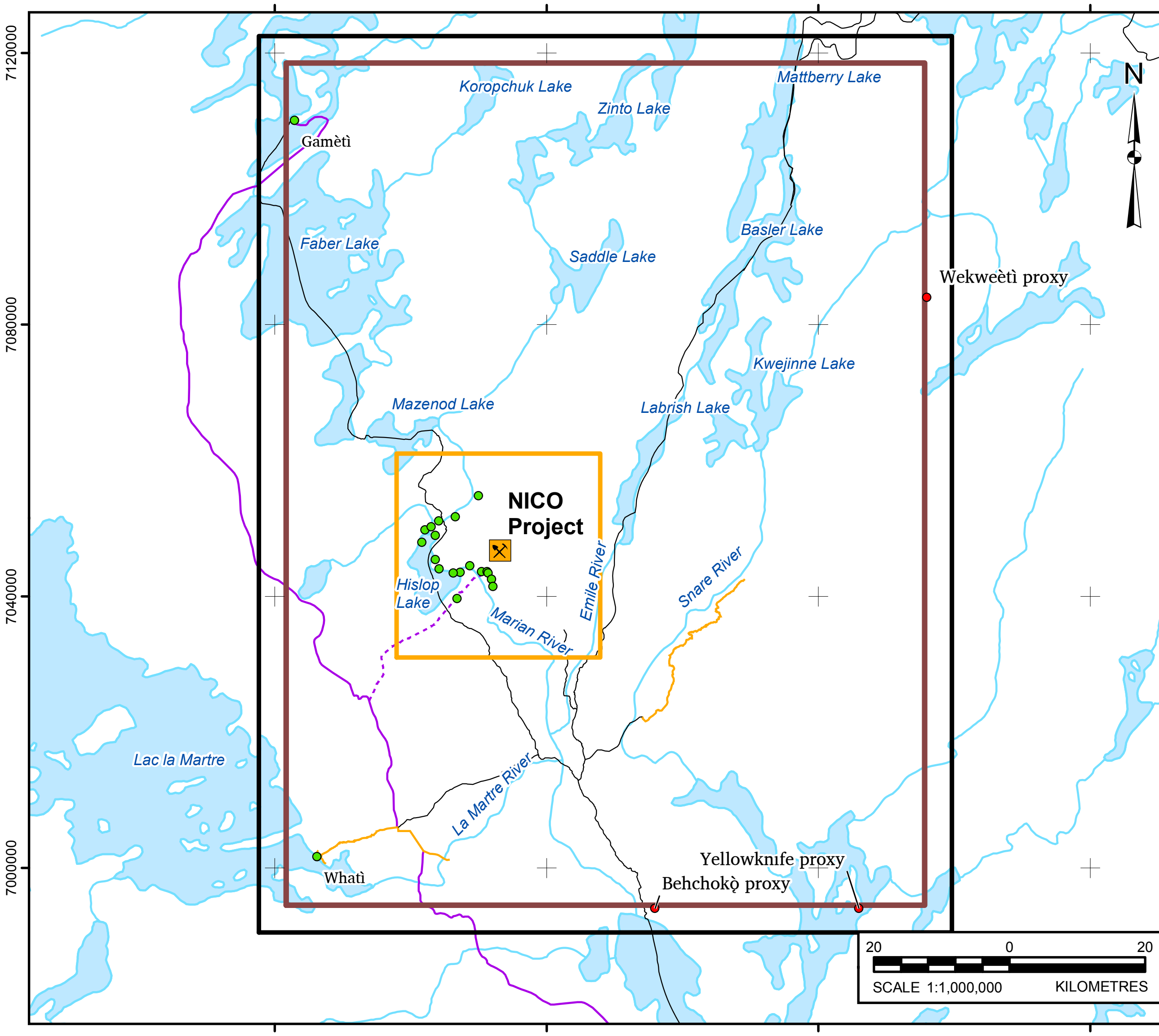

LEGEND

- NICO PROJECT
- PROJECT LEASE BOUNDARY
- EXISTING ALL-WEATHER ROAD
- EXISTING WINTER ROAD
- PROPOSED NICO PROJECT ACCESS ROAD
- PROPOSED TŁĮCHǪ ROAD ROUTE
- WATERCOURSE
- WATERBODY
- HEALTH RECEPTOR
- SURROGATE RECEPTOR FOR COMMUNITIES OUTSIDE THE REGIONAL STUDY AREA
- CALPUFF MODELLING DOMAIN
- LOCAL STUDY AREA
- REGIONAL STUDY AREA

REFERENCE

Base data obtained from GeoGratis.
Projection: UTM Zone 11 Datum: NAD 83

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

LOCATIONS OF HEALTH RECEPTORS

Golder Associates
Edmonton, Alberta

FILE No. E-Air-018-GIS

PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	DC	03 Feb. 2011		
GIS	BS	08 Mar. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

FIGURE: 10.I.4-3

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10.I.4.3 Model Options

The CALPUFF dispersion model is a sophisticated tool that uses numerous user-specified options. The selection of options used in the analysis requires great care and understanding of the underlying model algorithms. Most of the modelling options used in the model are U.S. EPA default CALPUFF model options as recommended by the Alberta Air Quality Model Guideline (AENV 2009). Table 10.I.4-2 provides a sample of model input options that were used in the modelling completed for the NICO Project. Several non-default model options were selected and each is discussed below.

Table 10.I.4-2: CALPUFF Model Input Options

Input Group	Parameter	NICO Project	Description
Group 1 - General Run Control Parameters	METRUN	0	run period explicitly defined below
	IBYR	2005	starting year for run if METRUN = 0
	IBMO	1	starting month for run if METRUN = 0
	IBDY	1	starting day for run if METRUN = 0
	IBHR	0	starting hour for run if METRUN = 0
	IBSEC	0	starting hour for run if METRUN = 0
	IEYR	2005	ending year for run if METRUN = 0
	IEMO	12	ending month for run if METRUN = 0
	IEDY	31	ending day for run if METRUN = 0
	IEHR	23	ending hour for run if METRUN = 0
	IEMIN	0	ending minute for run if METRUN = 0
	IESEC	3600	ending hour for run if METRUN = 0
	XBTZ	7	base time zone
			(PST = 8, MST = 7, CST = 6, EST = 5)
	NSPEC	6	number of chemical species
	NSE	3	number of chemical species to be emitted
	ITEST	2	program is executed after SETUP phase
	MRESTART	0	does not read or write a restart file
	NRESPD	0	restart file written only at last period
	METFM	1	CALMET binary file (CALMET.MET)
	MPRFFM	1	meteorological profile data format
	AVET	60	Averaging time (minutes)
	PGTIME	60	PG Averaging Time (minutes)
Group 2 - Technical Options	MGAUSS	1	Gaussian distribution used in near field
	MCTADJ	3	partial plume path terrain adjustment
	MCTSG	0	subgrid-scale complex terrain not modelled

Table 10.I.4-2: CALPUFF Model Input Options (continued)

Input Group	Parameter	NICO Project	Description
Group 2 - Technical Options (continued)	MSLUG	0	near-field puffs not modelled as elongated
	MTRANS	1	transitional plume rise modelled
	MTIP	1	stack tip downwash used
	MBDW	2	method to simulate building downwash (PRIME method)
	MRISE	1	Briggs plume rise used
	MSHEAR	0	vertical wind shear not modelled
	MSPLIT	0	puffs are not split
	MCHEM	3	transformation rates computed internally using RIVAD/ARM3 scheme
	MAQCHEM	0	aqueous phase transformation rates not modelled
	MWET	1	wet removal modelled
	MDRY	1	dry deposition modelled
	MTILT	0	Gravitational settling not modelled
	MDISP	2	dispersion coefficients from internally calculated sigma v, sigma w using micrometeorological variables (u*, w*, L, etc.)
	MTURBVW	3	use both sigma-(v/theta) and sigma-w from PROFILE.DAT to compute sigma-y and sigma-z (valid for METFM = 1,2,3,4)
	MDISP2	3	PG dispersion coefficients for RURAL areas (computed using the ISCST multi-segment approximation) and MP coefficients in urban areas
	MTAULY	0	Method used for Lagrangian timescale for Sigma-y (used only if MDISP=1,2 or MDISP2=1,2)
			Draxler default 617.284 (s)
	MTAUADV	0	Method used for Advective-Decay timescale for Turbulence (used only if MDISP=2 or MDISP2=2)
			0 = No turbulence advection
	MCTURB	1	Method used to compute turbulence sigma-v & sigma-w using micrometeorological variables (Used only if MDISP = 2 or MDISP2 = 2)
			Standard CALPUFF subroutines
	MROUGH	0	PG sigma-y and sigma-z not adjusted for roughness
	MPARTL	1	partial plume penetration of elevated inversion

Table 10.I.4-2: CALPUFF Model Input Options (continued)

Input Group	Parameter	NICO Project	Description
Group 2 - Technical Options (continued)	MPARTLBA	1	Partial plume penetration of Default: 1 ! MPARTLBA = 1 !
			elevated inversion modeled for
			buoyant area sources
	MTINV	0	strength of temperature inversion not computed from measured/default gradients
	MPDF	1	PDF used for dispersion under convective conditions
	MSGTIBL	0	sub-grid TIBL module not used for shoreline
	MBCON	0	boundary conditions not modelled
	MSOURCE	0	Individual source contributions are not saved
	MFOG	0	do not configure for FOG Model output
	MREG	0	do not test options specified to see if they conform to regulatory values
Group 3 - Species List	CSPEC	SO_2, SO_4 , NO, NO_2, HNO_3, NO_3	list of chemical species
		1,1,1,1,1,1	is SO_2, SO_4, NO, NO_2, HNO_3, NO_3 modelled? (0=no, 1=yes)
		1,0,1,1,0,0	is SO_2, SO_4, NO, NO_2, HNO_3, NO_3 emitted? (0=no, 1=yes)
		1,2,1,1,1,2	SO_2, SO_4, NO, NO_2, HNO_3, NO_3 dry deposition method (1=computed-gas, 2=computed-particle)
		0,0,0,0,0,0	SO_2, SO_4, NO, NO_2, HNO_3, NO_3 output group number
Group 4 - Map Projection and Grid Control Parameters	PMAP	UTM	map projection
	FEAST	0	false Easting (km) at the projection origin
	FNORTH	0	false Northing (km) at the projection origin
	IUTMZN	11	UTM zone
	UTMHEM	N	hemisphere for UTM projection
			(N = north, S = south)
	RLAT0	40N	latitude of projection origin
			(not used if PMAP = UTM)
	RLON0	90W	longitude of projection origin
			(not used if PMAP = UTM)

Table 10.I.4-2: CALPUFF Model Input Options (continued)

Input Group	Parameter	NICO Project	Description
Group 4 - Map Projection and Grid Control Parameters (continued)	XLAT1	30N	matching parallel(s) of latitude (decimal degrees) for projection (used only if PMAP = LCC or PS)
	XLAT2	60N	matching parallel(s) of latitude (decimal degrees) for projection (used only if PMAP = LCC or PS)
	DATUM	NAR-C	datum-region for output coordinates
	NX	51	number of X grid cells in meteorological grid
	NY	66	number of Y grid cells in meteorological grid
	NZ	10	number of vertical layers in meteorological grid
	DGRIDKM	2	grid spacing in kilometres
	ZFACE	0, 20, 50, 100, 200, 400, 800, 1200, 1600, 2200, 3000	cell face heights in meteorological grid (m)
	XORIGKM	477.660	reference X coordinate for south-west corner of grid cell (1,1) of meteorological grid (km)
	YORIGKM	6990.500	reference Y coordinate for south-west corner of grid cell (1,1) of meteorological grid (kilometres)
	IBCOMP	1	X index of lower left corner of the computational grid
	JBCOMP	1	Y index of lower left corner of the computational grid
	IECOMP	51	X index of upper right corner of the computational grid
	JECOMP	66	Y index of upper right corner of the computational grid
	LSAMP	F	sampling grid is not used
	IBSAMP	-	X index of lower left corner of the sampling grid
	JBSAMP	-	Y index of lower left corner of the sampling grid
	IESAMP	-	X index of upper right corner of the sampling grid
	JESAMP	-	Y index of upper right corner of the sampling grid
	MESHDN	1	nesting factor of the sampling grid

Table 10.I.4-2: CALPUFF Model Input Options (continued)

Input Group	Parameter	NICO Project	Description
Group 5 – Output Options	ICON	1	output file CONC.DAT containing concentration fields is created
	IDRY	1	output file DFLX.DAT containing dry flux fields is created
	IWET	1	output file WFLX.DAT containing wet flux fields is created
	IVIS	0	output file containing relative humidity data is not created
	IQAPLOT	1	QA plot file output option
	IPFTRAK	0	Diagnostic puff-tracking output option
	LCOMPRS	F	do not perform data compression in output files
	IMFLX	0	mass flux across specified boundaries for selected species not reported hourly
	IMBAL	0	mass balance for each species not reported hourly
	ICPRT	0	do not print concentration fields to the output list file
	IDPRT	0	do not print dry flux fields to the output list file
	IWPRT	0	do not print wet flux fields to the output list file
	ICFRQ	1	concentration fields are printed to output list file every 1 hour
	IDFRQ	1	dry flux fields are printed to output list file every
			1 hour
	IWFRQ	1	wet flux fields are printed to output list file every
			1 hour
	IPRTU	3	units for line printer output are in μg/m^3 for concentration and μg/m^2/s for deposition
	IMESG	2	messages tracking the progress of run are written on screen
		0,0,0,0,0,0	concentrations printed to output list file
			(0 = no, 1 = yes)
		1,1,1,1,1,1	concentrations saved to disk (0=no, 1=yes)
		0,0,0,0,0,0	dry fluxes printed to output list file (0=no, 1=yes)
		1,1,1,1,1,1	dry fluxes saved to disk (0=no, 1=yes)
		0,0,0,0,0,0	wet fluxes printed to output list file (0=no, 1=yes)

Table 10.I.4-2: CALPUFF Model Input Options (continued)

Input Group	Parameter	NICO Project	Description
Group 5 – Output Options (continued)		1,1,1,1,1,1	wet fluxes saved to disk (0=no, 1=yes)
		0,0,0,0,0,0	mass fluxes saved to disk (0=no, 1=yes)
	LDEBUG	F	logical value for debug output
	IPFDEB	1	first puff to track
	NPFDEB	1	number of puffs to track
	NN1	1	meteorological period to start output
	NN2	10	meteorological period to end output
Group 6 - Subgrid Scale Complex Terrain Inputs	NHILL	0	number of terrain features
	NCTREC	0	number of special complex terrain receptors
	MHILL	0	input terrain and receptor data for CTSG hills input in CTDM format not used
	XHILL2M	1	conversion factor for changing horizontal dimensions to metres
	ZHILL2M	1	conversion factor for changing vertical dimensions to metres
	XCTDMKM	-	X origin of CTDM system relative to CALPUFF coordinate system in kilometres
	YCTDMKM	-	Y origin of CTDM system relative to CALPUFF coordinate system in kilometres
Group 7 - Chemical Parameters for Dry Deposition of Gases	YCTDMKM	0.1509	diffusivity for SO_2 (cm^2/s)
		1000.00	alpha star for SO_2
		8	reactivity for SO_2
		0	mesophyll resistance for SO_2 (s/cm)
		0.04	Henry's Law coefficient for SO_2
		0.1345	diffusivity for NO (cm^2/s)
		1	alpha star for NO
		2	reactivity for NO
		25	mesophyll resistance for NO (s/cm)
		18	Henry's Law coefficient for NO
		0.1656	diffusivity for NO_2 (cm^2/s)
		1	alpha star for NO_2
		8	reactivity for NO_2
		5	mesophyll resistance for NO_2 (s/cm)
		3.5	Henry's Law coefficient for NO_2

Table 10.I.4-2: CALPUFF Model Input Options (continued)

Input Group	Parameter	NICO Project	Description
Group 7 - Chemical Parameters for Dry Deposition of Gases (continued)		0.1628	diffusivity for HNO_3 (cm^2/s)
		1	alpha star for HNO_3
		18	reactivity for HNO_3
		0	mesophyll resistance for HNO_3 (s/cm)
Group 8 - Size Parameters for Dry Deposition of Particles	YCTDMKM	0.00000008	Henry's Law coefficient for HNO_3
		0.48	geometric mass mean diameter of SO_4 (µm)
		2.0	geometric standard deviation of SO_4 (µm)
		0.48	geometric mass mean diameter of NO_3 (µm)
		2.0	geometric standard deviation of NO_3 (µm)
Group 9 - Miscellaneous Dry Deposition Parameters	RCUTR	30	reference cuticle resistance in seconds/centimetre (s/cm)
	RGR	10	reference ground resistance in s/cm
	REACTR	8	reference pollutant reactivity
	NINT	9	number of particle size intervals used to evaluate effective particle deposition velocity
	IVEG	2	vegetation in un-irrigated areas is active and stressed
Group 10 – Wet Deposition Parameters	IVEG	0.00003	the SO_2 scavenging coefficient for liquid precipitation (1/second [1/s])
		0	the SO_2 scavenging coefficient for frozen precipitation (1/s)
		0.0001	the SO_4^{2-} scavenging coefficient for liquid precipitation (1/s)
		0.00003	the SO_4^{2-} scavenging coefficient for frozen precipitation (1/s)
		0.00006	the HNO_3 scavenging coefficient for liquid precipitation (1/s)
		0	the HNO_3 scavenging coefficient for frozen precipitation (1/s)
		0.0001	the NO_3^- scavenging coefficient for liquid precipitation (1/s)
		0.00003	the NO_3^- scavenging coefficient for frozen precipitation (1/s)

Table 10.I.4-2: CALPUFF Model Input Options (continued)

Input Group	Parameter	NICO Project	Description
Group 11 – Chemistry Parameters	MOZ	0	a monthly background ozone value is used in chemistry calculation
	BCKO3	25,26,28,35,33, 28,23,20,19,20, 25,25	average monthly maximum ozone concentrations from Yellowknife from 2005 to 2009
	BCKNH3	12*0.22	monthly ammonia concentration
	RNITE1	0.2	nighttime SO_2 loss rate in percent/hour
	RNITE2	2	nighttime NO_X loss rate in percent/hour
	RNITE3	2	nighttime HNO_3 formation rate in percent/hour
	MH202	1	H_2O_2 data input option not used since
			MAQCHEM = 0
	BCKH2O2	12*1	monthly H_2O_2 concentrations in ppb
Group 12 – Miscellaneous Dispersion and Computational Parameters	SYTDEP	550	horizontal size of a puff in metres beyond which the time dependant Heffter dispersion equation is used
	MHFTSZ	0	do not use Heffter formulas for sigma z
	JSUP	5	stability class used to determine dispersion rates for puffs above boundary layer
	CONK1	0.01	vertical dispersion constant for stable conditions
	CONK2	0.1	vertical dispersion constant for neutral/unstable conditions
	TBD	0.5	use ISC transition point for determining the transition point between the Schulman-Scire to Huber-Snyder Building Downwash scheme
	IURB1	10	lower range of land use categories for which urban dispersion is assumed
	IURB2	19	upper range of land use categories for which urban dispersion is assumed
	ILANDUIN	20	land use category for modelling domain
	Z0IN	0.25	roughness length in metres for modelling domain
	XLAIXN	3	leaf area index for modelling domain
	ELEVIN	0	elevation above sea level in (m)
	XLATIN	–999	latitude of station in degrees (°)
	XLONIN	–999	longitude of station in degrees (°)
	ANEMHT	10	anemometer height in (m)
	ISIGMAV	1	sigma-v is read for lateral turbulence data
	IMIXCTDM	0	predicted mixing heights are used

Table 10.I.4-2: CALPUFF Model Input Options (continued)

Input Group	Parameter	NICO Project	Description
Group 12 – Miscellaneous Dispersion and Computational Parameters (continued)	XMXLEN	1	maximum length of emitted slug in meteorological grid units
	XSAMLEN	1	maximum travel distance of slug or puff in meteorological grid units during one sampling unit
	MXNEW	50	maximum number of puffs or slugs released from one source during one time step
	MXSAM	99	maximum number of sampling steps during one time step for a puff or slug
	NCOUNT	2	number of iterations used when computing the transport wind for a sampling step that includes gradual rise
	SYMIN	1	minimum sigma y in metres for a new puff or slug
	SZMIN	1	minimum sigma z in metres for a new puff or slug
	SVMIN	0.5	minimum turbulence (σ_v) for A stability (m/s)
		0.5	minimum turbulence (σ_v) for B stability (m/s)
		0.5	minimum turbulence (σ_v) for C stability (m/s)
		0.5	minimum turbulence (σ_v) for D stability (m/s)
		0.5	minimum turbulence (σ_v) for E stability (m/s)
		0.5	minimum turbulence (σ_v) for F stability (m/s)
	SWMIN	0.2	minimum turbulence (σ_w) for A stability (m/s)
		0.12	minimum turbulence (σ_w) for B stability (m/s)
		0.08	minimum turbulence (σ_w) for C stability (m/s)
		0.06	minimum turbulence (σ_w) for D stability (m/s)
		0 03	minimum turbulence (σ_w) for E stability (m/s)
		0.016	minimum turbulence (σ_w) for F stability (m/s)
	CDIV	0.0, 0.0	divergence criteria for dw/dz in met cells
	NLUTIDL	4	Search radius in number of cells for nearest land and water cells used in the subgrid TIBL module
	WSCALM	0.5	minimum wind speed allowed for non-calm conditions (m/s)
	XMAXZI	3,000	maximum mixing height (m)
	XMINZI	50	minimum mixing height (m)
	WSCAT	1.54	wind speed category 1 (m/s)
		3.09	wind speed category 2 (m/s)

Table 10.I.4-2: CALPUFF Model Input Options (continued)

Input Group	Parameter	NICO Project	Description
Group 12 – Miscellaneous Dispersion and Computational Parameters (continued)		5.14	wind speed category 3 (m/s)
		8.23	wind speed category 4 (m/s)
		10.8	wind speed category 5 (m/s)
	PLX0	0.07	wind speed profile exponent for A stability
		0.07	wind speed profile exponent for B stability
		0.1	wind speed profile exponent for C stability
		0.15	wind speed profile exponent for D stability
		0.35	wind speed profile exponent for E stability
		0.55	wind speed profile exponent for F stability
	PTG0	0.02	potential temperature gradient for E stability (K/m)
		0.035	potential temperature gradient for F stability (K/m)
	PPC	0.5	plume path coefficient for A stability
		0.5	plume path coefficient for B stability
		0.5	plume path coefficient for C stability
		0.5	plume path coefficient for D stability
		0.35	plume path coefficient for E stability
		0.35	plume path coefficient for F stability
	SL2PF	10	slug-to-puff transition criterion factor equal to sigma y/length of slug
	NSPLIT	2	number of puffs that result every time a puff is split (not used since NSPLIT=0)
	IRESPLIT	0,0,0,0,0,0,0,0, 0,0,0,0,0,0,0,0, 0,1,0,0,0,0,0,0	time(s) of day when split puffs are eligible to be split once again
	ZISPLIT	100	minimum allowable last hour's mixing height for puff splitting (m)
	ROLDMAX	0.25	maximum allowable ratio of last hour's mixing height and maximum mixing height experienced by the puff for puff splitting
	NSPLITH	5	number of puffs that result every time a puff is split
	SYSPLITH	1	minimum sigma-y (grid cells units) of puff before it may be split
	SHSPLITH	2	minimum puff elongation rate (SYSPLITH/h) due to wind shear before it may be split

Table 10.I.4-2: CALPUFF Model Input Options (continued)

Input Group	Parameter	NICO Project	Description
Group 12 – Miscellaneous Dispersion and Computational Parameters (continued)	CNSPLITH	1.0E–07	minimum concentration (g/m^3) of each species in puff before it may be split
	EPSSLUG	1.00E–04	fractional convergence criterion for numerical SLUG sampling integration
	EPSAREA	1.00E–06	fractional convergence criterion for numerical AREA source integration
	DSRISE	1	trajectory step-length (m) used for numerical rise integration
	HTMINBC	500.0	Minimum height (m) to which BC puffs are mixed as they are emitted.
	RSAMPBC	10.0	Search radius (km) about a receptor for sampling nearest BC puff.
	MDEPBC	1	Near-surface depletion adjustment to concentration profile used when sampling BC puffs.
Group 13 -Point Source Parameters	NPT1	4	number of point sources
	IPTU	1	units for point source emission rates is grams per second (g/s)
	NSPT1	0	number of source-species combinations with variable emissions scaling factors
	NPT2	0	number of point sources with variable emission parameters provided in external file
Group 14 - Area Source Parameters	NAR1	0	number of polygon area sources
	IARU	1	area source emission rates (g/m^2/s)
	NSAR1	0	number of source-species combinations with variable emissions scaling factors
	NAR2	0	number of buoyant polygon area sources with variable location and emission parameters
Group 15 - Line Source Parameters	NLN2	0	number of buoyant line sources with variable location and emission parameters
	NLINES	0	number of buoyant line sources
	ILNU	1	line source emission rates (g/s)
	NSLN1	0	number of source-species combinations with variable emissions scaling factors
	MXNSEG	0	maximum number of segments used to model each line
	NLRISE	0	number of distances at which transitional rise is computed
	XL	0	average line source length (m)

Table 10.I.4-2: CALPUFF Model Input Options (continued)

Input Group	Parameter	NICO Project	Description
Group 15 - Line Source Parameters (continued)	HBL	0	average height of line source height (m)
	WBL	0	average building width (m)
	WML	0	average line source width (m)
	DXL	0	average separation between buildings (m)
	FPRIMEL	0	average buoyancy parameter
Group 16 - Volume Source Parameters	NVL1	0	number of volume sources
	IVLU	1	volume source emission rates (g/s)
	NSVL1	0	number of source-species combinations with variable emissions scaling factors
	NSVL2	0	number of volume sources with variable location and emission parameters
Group 17 - Non-Gridded Receptor Information	NREC	15618	number of non-gridded receptors

10.I.4.3.1 MCHEM

The RIVAD/ARM3 scheme (MCHEM=3) is used for chemical transformation as opposed to the default MESOPUFF II method. The RIVAD/ARM3 method models NO and (NO_2 separately, whereas MESOPUFF II models only total NO_X.

10.I.4.3.2 MDISP

Dispersion coefficients are calculated internally using similarity theory and micrometeorological variables instead of the default ISC3 multi-segment approximation method. The similarity theory is a more sophisticated and precise method of determining dispersion coefficients.

10.I.4.3.3 MPDF

The probability distribution function (MPDF=1) approach accounts for downdrafts that occur under convective conditions. The probability distribution function approach may increase the predicted concentrations resulting from stacks under convective conditions. Although the U.S. EPA default option does not use probability distribution function, using PDF in CALPUFF will provide more accurate predictions and, at the same time, be consistent with the regulatory dispersion model AERMOD as well.

The U.S. EPA does not approve the use of CALPUFF for near-field applications (i.e., distances less than 50 km) at this time; therefore, the U.S. EPA default option in CALPUFF is not to use the probability distribution function for long-range modelling; however in this assessment, the importance of near-field (i.e., local effects due to the NICO Project) prediction accuracy was ranked higher than the long-range transport (i.e., regional cumulative effects) prediction accuracy. Therefore, the PDF was used to meet the needs of the assessment.

The Alberta (AENV 2009), British Columbia (BC Ministry of Environment 2008), and Ontario (OMOE 2009) modelling guidelines permit the use of CALPUFF for near-field applications. However, the BC and Ontario guidelines recommend non-EPA default MPDF (and MDISP) settings. The final decision to use the non-default U.S. EPA option for MDISP and MPDF was made based on professional judgement (Onder, 2010).

10.I.4.3.4 MREG

MREG is an optional check to see if model options conform to regulatory values. This check was not used (MREG=0).

10.I.4.3.5 DATUM

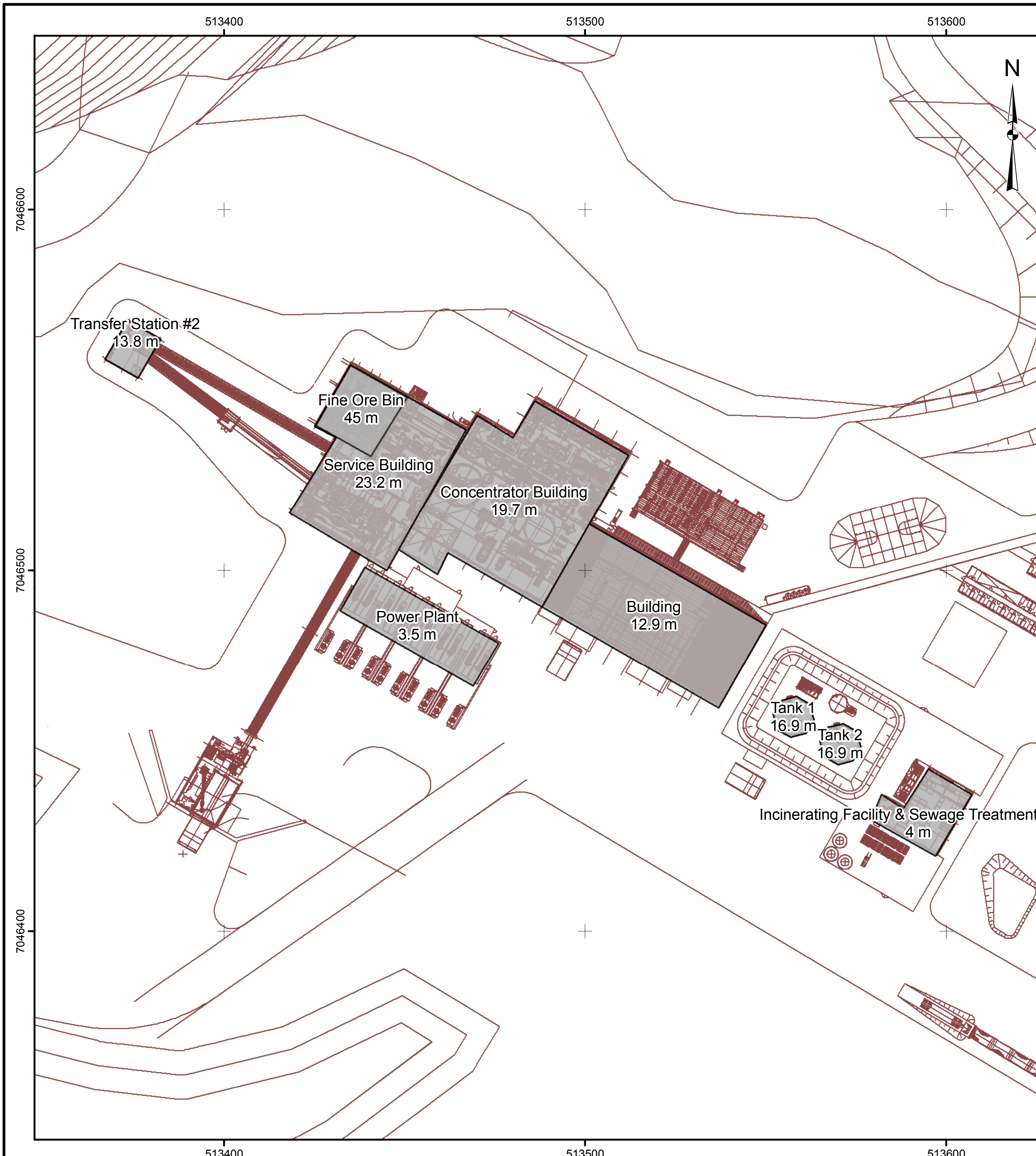
The DATUM option was set to NAR-C (DATUM=NAR C) since the coordinates used in the assessment are in NAD83 (North American 1983 GRS 80 Spheroid) datum. NAD83 uses the same GRS 80 spheroid as WGS 84.

10.I.4.3.6 IVEG

The IVEG option was set to 2 (IVEG=2) to represent the unirrigated land as stressed.

10.I.4.4 Building Downwash

Building downwash is a phenomenon caused by air movement around buildings. Buildings or other solid structures may affect the flow of air in the vicinity of a source and cause eddies to form on the downwind side of a building. In some situations, the stack emissions may be trapped in the wake of a building or other structures which may result in elevated ground-level concentrations. In this assessment, building downwash was simulated using the Plume Rise Model Enhancements model and Building Profile Input Program (BPIP). The locations of buildings and stacks included in the building downwash analysis are shown in Figure 10.I.4-4.



LEGEND

- MINE SITE FEATURES
- BUILDING

50 0 50

SCALE 1:1,500 METRES

REFERENCE

Base data obtained from GeoGratis.
Projection: UTM Zone 11 Datum: NAD 83

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

BUILDINGS INCLUDED IN BUILDING PROFILE INPUT PROGRAM

Golder Associates
Edmonton, Alberta

FILE No. E-Air-017-GIS

PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	DC	03 Feb. 2011	FIGURE: 10.I.4-4	
GIS	BS	08 Mar. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

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10.I.4.5 Potential Acid Input

Deposition includes both wet and dry processes and can result in the long-term accumulation of compounds in aquatic and terrestrial ecosystems. Wet processes involve the removal of emissions vented into the atmosphere by precipitation. Dry processes involve the removal by direct contact with surface features (e.g., vegetation). Both wet and dry deposition values are expressed as a flux in units of mass per area per time (e.g., µg/m²/s).

Because several chemical species of nitrogen, sulphur, and base cations are considered in the estimate of deposition, the flux is expressed in "keq/ha/y" where "keq" refers to the number of equivalent hydrogen ions (1 keq = 1 kmol H^+). For sulphur species, each molecule is equivalent to 2 hydrogen ions. Each molecule of nitrogen species is equivalent to one hydrogen ion. The deposition of sulphur and nitrogen compounds to these systems has been associated with changes in water and soil chemistry, and with the acidification of water and soil.

The calculation of PAI is based on the wet and dry deposition of sulphur compounds (e.g., SO_2 gas, SO_4^{2-} particle), nitrogen compounds (e.g., NO gas, NO_2 gas, HNO_3 gas, NO_3^- particle), chlorine ions (Cl^- gas), ammonium ions (NH_4^+ particle) and base cations (e.g., Ca_2^+ particle, Mg^+ particle, K^+ particle, and Na^+ particle). Since PAI combines both sulphur and nitrogen, the individual deposition rates need to be converted to a common measure, namely "keq/ha/y", given these molecules have different equivalences to hydrogen ions as discussed above. The steps for completing the calculations are as follows:

The PAI resulting from sulphur species is calculated from the annual sulphur deposition rates (expressed as kilograms per hectare per year [kg/ha/y]). These are converted to keq/ha/y by dividing the predicted deposition by the molecular weight and multiplying by the hydrogen ion equivalents, according to the following equation:

$$PAI_{sulphur} = \frac{\left([\mathrm{SO_2}]_{dep,wet} + [\mathrm{SO_2}]_{dep,dry}\right) \times 2}{64} + \frac{\left([\mathrm{SO_4^{2-}}]_{dep,wet} + [\mathrm{SO_4^{2-}}]_{dep,dry}\right) \times 2}{96}$$

The PAI resulting from nitrogen species is calculated from the annual nitrogen deposition rates (expressed as kg/ha/y). These are converted to keq/ha/y by dividing the predicted deposition by the molecular weight and multiplying by the hydrogen ion equivalents, as follows:

$$\begin{aligned}\boldsymbol{PAI}_{\mathrm{nitrogen}} &\\ = {} & \frac{\left([\mathrm{NO}]_{\boldsymbol{dep},wet} + [\mathrm{NO}]_{\boldsymbol{dep},dry}\right)}{30} + \frac{\left([\mathrm{NO_2}]_{\boldsymbol{dep},wet} + [\mathrm{NO_2}]_{\boldsymbol{dep},dry}\right)}{46} \\ & + \frac{\left([\mathrm{HNO_3}]_{\boldsymbol{dep},wet} + [\mathrm{HNO_3}]_{\boldsymbol{dep},dry}\right)}{63} + \frac{\left([\mathrm{NO_3^-}]_{\boldsymbol{dep},wet} + [\mathrm{NO_3^-}]_{\boldsymbol{dep},dry}\right)}{62}\end{aligned}$$

The total PAI is calculated as the sum of the sulphur and nitrogen deposition rates from sources within the study area together with the background PAI for the region.

$$PAI = PAI_{sulphur} + PAI_{nitrogen} + PAI_{background}$$

In this equation, the $PAI_{background}$ accounts for the background sulphur, nitrogen, Cl^-, NH_4^+, and base cations. Background PAI levels for the modelling domain were determined using the National Atmospheric Chemistry Precipitation Database (NAtChem) for Snare Rapids, NWT (NAtChem 2003, 2004, 2005, 2006, and 2007) and through the Regional Acid Deposition modelling completed by AENV (Cheng 2009, pers. comm.). A detailed discussion of background PAI is provided in the following section.

10.I.4.6 Background Levels of Acid-Forming Compounds

Selecting the background PAI that best represents the background conditions is important. Ideally this background value should not include the influence of industrial activities within the region of the NICO Project. The background PAI for the region was determined using a combination of 2 data sources:

- the NAtChem precipitation data for wet deposition; and
- the regional acid deposition data for dry deposition.

The NAtChem/Precipitation Chemistry Database system is a Canadian central database and analysis facility set up to accommodate and maintain diverse and variable network data and combine them together into one database. The purpose of the system is to determine the chemistry of regional scale precipitation in Canada and the U.S. Snare Rapids is the only location in the NWT for which NAtChem precipitation data are available and, therefore, was used to determine the background PAI for the assessment. The NAtChem data provides wet deposition values for sulphur, nitrogen, Cl^-, NH_4^+, and base cations.

Regional acid deposition model data were used to determine the dry deposition values of sulphur and nitrogen. AENV has used the regional acid deposition model (Cheng et al. 1997, 1995; Cheng and Angle 1996, 1993; McDonald et al. 1996) to determine background sulphur, nitrogen, PAI, and base cation values for the Alberta Oil Sands Region. To find the background values that would occur in the absence of oil sands activities, all of the Oil Sands Region emission sources were excluded from the modeling. The resulting data considered in this assessment was provided by AENV (Cheng 2009, personal communication). These data were considered suitable for determining background values for the NICO Project modelling domain as the contribution of Oil Sands sources in the NICO Project modeling domain can be expected to be minimal.

The following equations demonstrate the background PAI calculation:

$$PAI_{background} = PAI_{acidifying\ substances} + PAI_{base\ cations}$$

The PAI from acidifying substances can be expressed as:

$$PAI_{acidifying\ substances} = \frac{\left([SO_4^{2-}]_{dep,wet} + [SO_4^{2-}]_{dep,dry}\right) \times 2}{96} + \frac{[NO_3^-]_{dep,wet} + [NO_3^-]_{dep,dry}}{62} + \frac{[NH_4^+]_{dep,wet}}{18} + \frac{[Cl^-]_{dep,wet}}{35.5}$$

The buffering capacity of base cations would be calculated according to the following equation:

$$PAI_{base\ cation} = -\left(\frac{[Ca^{2+}]_{dep,back} \times 2}{40} + \frac{[Mg^{2+}]_{dep,back} \times 2}{24} + \frac{[K^+]_{dep,back}}{39} + \frac{[Na^+]_{dep,back}}{23}\right)$$

The regional acid deposition model is an appropriate tool for assessing acid deposition on a provincial or continental scale. The data generated by the model is at a resolution of 1° of latitude by 1° of longitude, and covered between 53º and 60º in latitude and 109º and 114° in longitude. Cells 60° x 109° to 60° x 114° compass the border between Alberta and NWT. It is reasonable to assume that the contribution of industrial emissions to background PAI in these cells will be negligible and similar to background PAI within the modeling domain. Since regional acid deposition data are not available for the NWT, the average background deposition values in these cells were used as surrogates for the dry and wet deposition rations in the modeling domain.

The NAtChem data only provides wet deposition values. To determine dry deposition values for the modelling domain, it was assumed that on average the ratio of dry deposition to wet deposition for nitrogen and sulphur in the cells 60° x 109° through 60° x 114° will be applicable for the region of the NICO Project. This dry-to-wet deposition ratio for nitrogen and sulphur was then applied to NAtChem wet nitrogen and sulphur deposition values to determine the dry nitrogen and sulphur deposition values for the modeling domain.

A background PAI value of 0.064 keq/ha/y was used in the assessment.

10.I.4.7 Background Concentrations

As part of the cumulative air quality assessment, background concentrations were added to predicted ground-level concentrations due to the NICO Project and existing sources in the region. Background concentrations include the contributions of natural sources, nearby sources and unidentified distant sources.

A summary of background SO_2, NO_X, TSP, PM_{10}, and $PM_{2.5}$ concentrations used in the air quality assessment is presented in Table 10.I.4-3. The SO_2 and NO_X background concentrations are based on the average of the data collected at the 3 baseline air quality monitoring stations at the NICO Project site in 2006 and 2007 (Annex F).

Table 10.I.4-3: Background Concentrations Used in Air Quality Assessment

Parameters	Concentration [µg/m³]
SO_2	0.5
NO_X	1.0
CO	346
TSP	2.2
PM_{10}	2.2
$PM_{2.5}$	2.2

µg/m³ = microgram per cubic metre; SO_2 = sulphur dioxide; NO_x = nitrogen oxides; CO = carbon monoxide; TSP = total suspended particulates; PM = particulate matter

The baseline air quality monitoring program does not include collection of particulate matter data at the NICO Project site; therefore, the particulate matter background concentrations are based on data collected by Environment Canada at the NWT Tundra Ecological Research Station at Daring Lake. Unlike the other stations in the GNWT Air Quality Monitoring Network that are located within or near the communities of Yellowknife, Inuvik, Fort Liard, and Norman Wells, the Daring Lake station provides air quality monitoring data that are representative of the air quality in the Canadian Tundra without the influence of anthropogenic emission sources; therefore, the particulate matter data from Daring Lake were considered representative of conditions at the NICO Project. The Daring Lake station monitored PM_{10} in the summer of 2002 and monitors $PM_{2.5}$ during the summer months beginning in 2003. A summary of the data collected from 2002 and 2008 are presented in Annex F.

A $PM_{2.5}$ background concentration of 2.2 µg/m³ was selected based on an average of the concentrations monitored in 2007 and 2008 (0.9 and 3.5 µg/m³). PM_{10} was monitored in 2002 with an average of 1.6 µg/m³. PM_{10} concentrations should always be equal to or larger than $PM_{2.5}$ concentrations because $PM_{2.5}$ is a subset of PM_{10}; therefore, the PM_{10} background concentration was set to be equal to the $PM_{2.5}$ background concentration of 2.2 µg/m³ rather than the 1.6 µg/m³ monitored in 2002. Total suspended particulates is not being monitored by any regional air quality monitoring network in NWT; therefore, the TSP background concentration was assumed to be equal to the PM_{10} and $PM_{2.5}$ background concentrations.

Concentrations of metals, VOCs, and PAHs were assumed to be primarily from industrial sources and their background concentrations were assumed to be negligible.

The hourly, daily, and annual ozone concentrations used in the assessment are 34.7, 33.3, and 23.9 ppb, respectively. These values were determined based on hourly ozone monitoring data collected in Yellowknife between 2007 through 2009 (GNWT 2010). Hour-by-hour ozone values were not used in the ozone limited method calculations as they were not available for the region for the time period of interest.

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