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13.0 SUBJECT OF NOTE: TERRAIN AND SOILS

13.1 Introduction

13.1.1 Context

This section of the Developer's Assessment Report (DAR) for the NICO Cobalt-Gold-Copper-Bismuth Project (NICO Project) consists solely of the Subject of Note (SON) for terrain and soils. In the Terms of Reference (TOR) for the NICO Project's DAR issued on 30 November 2009, the Mackenzie Valley Review Board (MVRB) identified terrain and soils as 1 of 7 top priority valued components requiring a high level of consideration by the developer (MVRB 2009).

As identified within the TOR, this SON for terrain and soils details any effects the NICO Project may have on terrain, soil, and permafrost.

All effects on terrain and soils are assessed in detail in this SON; however, issues addressed in the following Key Lines of Inquiry (KLOI) and SON may overlap with this SON:

- KLOI: Caribou and Caribou Habitat (Section 8);
- KLOI: Closure and Reclamation (Section 9);
- SON: Water Quantity (Section 11);
- SON: Vegetation (Section 14);
- SON: Wildlife (Section 15);
- SON: Human Environment (Section 16); and
- Section 18: Biophysical Environment Monitoring and Management Plans.

13.1.2 Purpose and Scope

The purpose of the SON: Terrain and Soils is to meet the TOR issued by the MVRB. The terms for the SON: Terrain and Soils are shown in Table 13.1-1. The entire TOR document is included in Appendix 1.I and the complete table of concordance for the DAR is in Appendix 1.II of Section 1, Introduction.

The SON: Terrain and Soils includes an assessment of direct effects to changes to terrain and soils (e.g., permafrost, soil quality, and erosion) in the study area. The effects assessment will evaluate all NICO Project phases, including construction, operation, and closure and reclamation. Indirect and cumulative effects have been incorporated throughout this section, where applicable. The effects from the NICO Project must be considered in combination with other developments, activities, and natural factors that influence terrain and soils within the study area.

Some information from other components of the DAR, including air quality, water quality, and water quantity as well as information from existing developments, is incorporated in the effects assessment for terrain and soils. More detailed information on the requirements of the DAR TOR for this SON can be found in Table 13.1-1.

Table 13.1-1: Subject of Note: Terrain and Soils Concordance with the Terms of Reference

Section in Terms of Reference	Requirement	Section in Developer's Assessment Report
3.1.3	**Assessing the Impacts of the Environment on Development** Potential impacts of the physical environment on the development, such as changes in the permafrost regime, other climate change impacts, seasonal flooding and melt patterns, seismic events, geological instability, and extreme precipitation must be considered in each of the applicable items of this *Terms of Reference*. Any changes to the design or management of the NICO Project as a result of considering potential impacts of the environment should be noted in the relevant sections.	19.0
3.2.3	An overall environmental assessment study area and the rationale for its boundaries;	13.1.3
	Fortune's chosen spatial boundaries for the assessment of potential impacts for each of the valued components considered; and	13.1.3
	The temporal boundaries chosen for the assessment of impacts on each valued component.	13.1.3
3.2.4	**Description of Existing Environment** The developer is encouraged to provide a description of the methods used to acquire the information used to describe baseline conditions.	13.2
3.3.8	**Terrain and Soils** The developer will:	
	• Describe the stability of the proposed mine rock management and tailings management areas and evaluate potential impacts.	3.0
	• Describe how Fortune will ensure the stability of all engineered structures against a range of climate, seismic and precipitation scenarios.	3.0
	• Describe plans to mitigate impacts on terrain, including plans for monitoring, evaluation and adaptive management of the mine rock management area, tailings management area the system of dykes and dams.	13.4
Appendix A	**Existing Environment**	
	The physical location of the proposed development and identification of associated ecozones and ecoregions.	13.1.3
	11) Terrain, surficial geology, structural geology, mineralogy, bedrock geology (type, depth, composition, and permeability), seismic activity records and risk factors, permafrost locations and types within the environmental assessment study area. In particular:	
	a. describe permafrost conditions at the site including thermal conditions and ground ice/moisture contents of underlying material, particularly if maintenance of frozen conditions is required;	13.2.2.2
	b. describe and map the ground composition underlying the proposed mine site;	13.2.2.1.1
	c. identify the location, amounts and type of granular material deposits including any information on ground ice;	13.2.2.1.1

Table 13.1-1: Subject of Note: Terrain and Soils Concordance with the Terms of Reference (continued)

Section in Terms of Reference	Requirement	Section in Developer's Assessment Report
Appendix A (continued)	d. describe the ground conditions under and around the mine site and road proposed by Fortune, with emphasis on identifying areas susceptible to erosion, and permafrost instability;	13.2.2.2, 13.2.2.3
Appendix G	**Terrain and Soil**	
	When assessing impacts and risks related to terrain:	
	12) Describe the existing geotechnical stability of the areas proposed for the mine rock management and tailings management areas, including:	
	e. soil and hydrological conditions;	Annex G, 11.0, 13.2.2.1
	f. permafrost, ground thermal conditions and ground ice conditions;	13.2.2.2
	g. description of the physical and chemical characteristics of mine rock and tailings; and	13.3.2
	h. topography and slope stability.	13.2.2.1
	13) Describe potential impacts of NICO Project operations on terrain stability and vice versa, in light of Fortune's analyses of accidents and malfunctions (see section 3.5). Consider:	
	a. geotechnical instability, especially of the mine rock management area, the tailings management area and the system of dykes and dams on site;	3.0
	b. changes to ground thermal conditions and permafrost failure at the mine site; and	13.3.2.1
	c. impacts to permafrost and ground thermal conditions from vegetation removal.	13.3.2.2
	14) Identify any plans to mitigate and monitor against impacts on terrain, including:	
	a. erosion control measures;	13.3.2, 13.4.2.2.4
	b. prevention of permafrost degradation at all mine site locations where it is found to be present;	13.3.2.2
	c. how the geotechnical stability of the mine rock management area, tailings management area and the system of dykes and dams will be monitored, and for what extent of time;	3.0
	d. how monitoring results will be reported to regulators and potentially-affected communities;	18.0
	e. how monitoring data will be used to determine if action is required including definitions of any methodologies used such as critical values, thresholds and decision trees; and	13.7, 18.0
	f. adaptive management measures and contingency plans that will be adopted if terrain stability is compromised.	3.0

Valued components (VCs) represent physical, biological, cultural, social, and economic properties of the environment that are considered to be important by society. The inter-relationships between components of the biophysical and socio-economic (human) environments provide the structure of a social-ecological system (Walker et al. 2004; Folke 2006). A range of representative VCs was selected for the NICO Project. Factors considered when selecting VCs included the following (Salmo 2006):

- concerns of aboriginal communities, the public, and government;
- required by or compatible with regulatory requirements and existing initiatives;
- represent important ecosystem processes;
- can be measured or described with one or more practical indicators (measurement endpoints); and
- allow cumulative effects to be considered.

Assessment endpoints represent the key properties of the VC that should be protected for their use by future human generations, while measurement endpoints are quantifiable (i.e., measurable) expressions of changes to assessment endpoints. Terrain and soils do not have assessment endpoints (Section 6.2). Instead, terrain and soils have measurement endpoints that are linked to changes in other VCs (e.g., vegetation) that are more directly associated with an assessment endpoint. Measurement endpoints for terrain and soils include:

- quantity and distribution of terrain units;
- topography and slope stability;
- soil quality, quantity, and distribution; and
- permafrost distribution.

13.1.3 Study Areas

13.1.3.1 General Setting

The NICO Project is approximately 160 kilometres (km) northwest of the city of Yellowknife in the Northwest Territories (NWT) (Figure 13.1-1). The NICO Project is located within the Marian River drainage basin, approximately 10 km east of Hislop Lake at a latitude of 63^{o}33’ North and a longitude of 116^{o}45’ West, and within the Taiga Shield and Taiga Plains Ecoregions (Ecosystem Classification Group 2007, 2008). The NICO Project spans 2 Level II Ecoregions: Taiga Shield and Taiga Plains.

The Taiga Shield High Boreal Level III Ecoregion within the Taiga Shield Level II Ecoregion is bedrock-dominated with jack pine (*Pinus banksiana*) and mixed spruce forests on rock outcrops. White spruce (*Picea glauca*) and trembling aspen (*Populus tremuloides*) stands are found in low-elevation areas with adequate nutrient and water supplies. Peat plateaus, shore fens, and floating fens are scattered throughout the Ecoregion (Ecosystem Classification Working Group 2008). A nearly level to rolling and hilly Precambrian bedrock is the dominant landform, with thin, bouldery, coarse-textured (sandy) veneers over much of the area. Fine-textured (clayey) lacustrine deposits can be found in low lying areas between bedrock exposures and lower elevations, predominantly along the west side of the Ecoregion. Common peatland types include peat plateaus, peat palsas, floating fens, and shore fens. Brunisolic, Organic, and organic and mineral Cryosolic (frozen) soils are the most common soils in the Taiga Shield High Boreal Ecoregion. There is no soil development on the bare bedrock exposures.

The Central Great Bear Plains Low Subarctic Level III Ecoregion within the Taiga Plains Level II Ecoregion is dominated by closed to open white and black spruce forests with shrub, moss, and lichen understories, or regenerating dwarf birch shrublands. Pond and fen complexes are scattered throughout, while closed mixed-wood, white spruce, and jack pine stands occupy rolling to ridged glacial flutings (Ecosystem Classification Group 2007). This Ecoregion includes extensive low-lying plains with upland areas characterized by hill systems with level to very gentle slopes. The dominant surficial material in this Ecoregion is level to undulating, and hummocky till that has been deeply grooved by glacial ice movement in some areas. Common peatland types include peat plateaus and polygonal peat plateaus. Permanently frozen peatlands cover vast areas, particularly in the southern part of this Ecoregion. Runnel permafrost forms are common on slopes, with permafrost occurring within 30 centimetres (cm) of the organic surface. Polygonal peat plateaus are locally common in the Keller Plain area.

LEGEND

- NICO PROJECT
- TERRITORIAL CAPITAL
- POPULATED PLACE
- HIGHWAY
- EXISTING ALL-WEATHER ROAD
- EXISTING WINTER ROAD
- PROPOSED NICO PROJECT ACCESS ROAD
- PROPOSED TŁĮCHǪ ROAD ROUTE
- RAILROAD
- TERRITORIAL/PROVINCIAL BOUNDARY
- WATERCOURSE
- WATERBODY

100 0 100

SCALE 1:3,000,000 KILOMETRES

REFERENCE

Base data obtained from Atlas of Canada, DMTI, and ESRI.
Projection: Canada Lambert Conformal Conic

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

LOCATION OF THE NICO PROJECT

Golder Associates
Edmonton, Alberta

FILE No. E-Section1-002-GIS				
PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	JG	17 Jan. 2011	FIGURE: 13.1-1	
GIS	CW	17 Jan. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

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The NICO Project is approximately 50 km northeast of Whatì and 70 km south of Gamètì, the nearest communities. Other communities include Behchokǫ̀, approximately 85 km southeast of the NICO Project site, and Wekweètì, located approximately 140 km northeast of the NICO Project site. All of these communities are within Tłı̨chǫ Land Claim. The NICO Project is surrounded by Tłı̨chǫ Land Claim. The mean annual temperature is -4.6°C (Environment Canada; Yellowknife ‘A’ Weather Station 2010). July, on average, is the warmest month, whereas January is typically the coldest month. The mean July temperature is 16.8°C while in January the mean temperature is -26.8°C. The mean annual precipitation is approximately 280.7 millimetres (mm) with 164.5 mm falling as rain and the rest as snow.

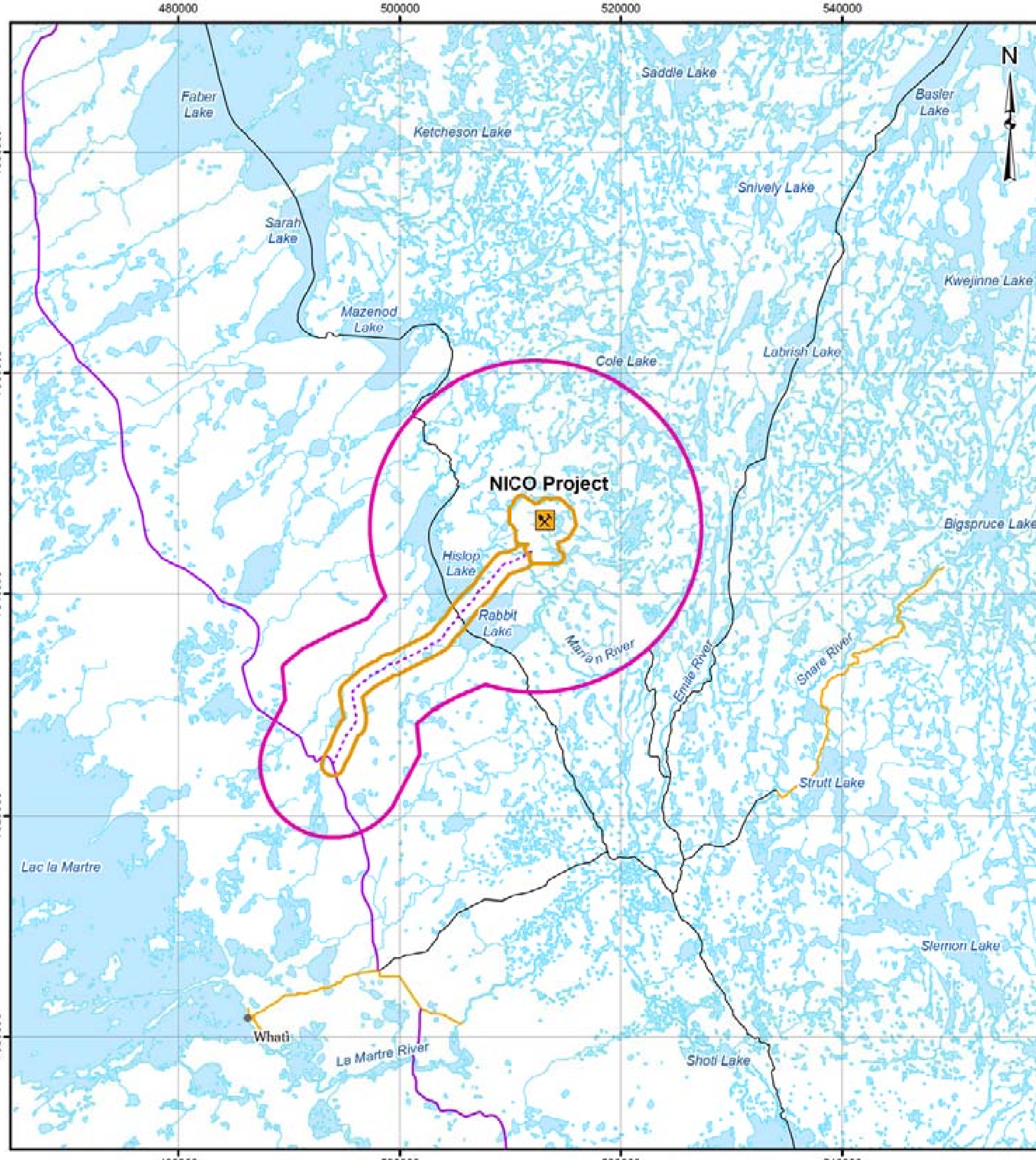
To facilitate the assessment and interpretation of potential effects associated with the NICO Project, it is necessary to define appropriate spatial boundaries. Spatial boundaries were delineated based on the predicted spatial extent of the NICO Project-related effects and the physical attributes of terrain and soils potentially influenced by the NICO Project. The following 2 spatial boundaries were used:

- regional study area for NICO Project-specific and potential cumulative effects on terrain and soils; and
- local study area for small-scale direct and indirect effects from the NICO Project (NICO mine site and 27 km NICO Project Access Road) on terrain and soils.

13.1.3.2 Regional Study Area

The regional study area (RSA) was selected to measure the existing baseline conditions at a scale large enough to capture the maximum predicted spatial extent of the combined direct and indirect effects (i.e., zone of influence) from the NICO Project on terrain and soils, vegetation, and wildlife (Figure 13.1-2). This area is intended to capture effects that extend beyond the immediate NICO Project footprint, such as fuel emissions from vehicles and aircraft, and dust deposition that can affect the environment at a distance. Cumulative effects from the NICO Project and other developments in the RSA (if present) can also be assessed at this scale for VCs that exhibit little to no movement within RSA, such as terrain and soil.

From 2003 to 2006 the RSA for the NICO Project was 314 square kilometres (km^2) (i.e., a 10 km radius centered on the proposed mine site). This area was increased in 2007 to 706 km^2 (i.e., a 15 km radius centered on the proposed mine site) because of increased knowledge about the effects from disturbance on barren-ground and woodland caribou. For example, studies on the movements of woodland caribou in the boreal forest of Newfoundland near resource extraction industries indicated that caribou avoided mining activities, with avoidance distances of up to 4 km during the summer and 6 km during the late winter, pre-calving, and calving seasons (Weir et al. 2007). Above the treeline, studies of barren-ground caribou have detected behavioural changes extending 5 to 7 km from the Ekati Diamond Mine (BHP Billiton Diamonds Inc. 2004), and avoidance from 10 to 40 km around mines (Boulanger et al. 2004; Johnson et al. 2005; Golder 2008 a, b).



LEGEND

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

10 0 10

SCALE 1:500,000 KILOMETRES

REFERENCE

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

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

LOCAL AND REGIONAL STUDY AREAS FOR TERRAIN AND SOILS

FILE NO. E-Soil-013-GIS

PROJECT No. 09-1373-0017			SCALE AS SHOWN	REV. 0
DESIGN	LV	04 Dec. 2008		
GIS	AB	03 Apr. 2011	**FIGURE: 13.1-2**	
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

Golder Associates
Edmonton, Alberta

The RSA includes a 6.5 km buffer around the proposed road alignment (Figure 13.1-2). The proposed NICO Project Access Road (NPAR) at the time of baseline studies was a 50 km predicted alignment that joined the NICO Project to the winter road between Behchokǫ̀ and Gamètì. Although the NPAR has since been reduced to 27 km, the original 50 km NPAR alignment was evaluated during baseline studies. The TOR (MVRB 2009) stipulates that the assessment for the NICO Project must include all aspects of the 27 km NPAR (e.g., physical footprint and traffic), which will connect the proposed mine to the transportation corridor between Behchokǫ̀ and Gamètì. For the remainder of the transportation corridor (from it's origin on Highway 3 to the intersection with the NPAR [approximately 110 km of road]), the DAR need only consider the effects of traffic from the NICO Project on the environment.

The RSA includes 2 Level II Ecoregions: Taiga Shield and Taiga Plains. The Taiga Shield Ecoregion is located northeast of Rabbit and Hislop lakes (Ecosystem Classification Group 2008), while the Taiga Plains Ecoregion covers the southwest portion of the RSA (Ecosystem Classification Group 2007). The NPAR is located within the Taiga Plains Ecoregion and is a more heavily treed landscape than the northeast portion of the RSA. In the summer of 2008 wildfire burned approximately 10% of the RSA.

13.1.3.3 Local Study Area

The local study area (LSA) boundary for the mine site and NPAR was defined by the expected spatial extent of the immediate direct (e.g., NICO Project footprint) and indirect effects (e.g., dust deposition) from the NICO Project on surrounding soil, vegetation, and wildlife (Figure 13.1-2). The LSA for the anticipated mine site (mine LSA) was defined as a 500 metre (m) buffer around the NICO Project Lease Boundary. The LSA for the NPAR (NPAR LSA) was defined using a 1000 m buffer on either side of the anticipated NPAR right-of-way.

The NICO Project LSA contains habitat that is characteristic of regional habitat conditions and vegetation that is typical of the Taiga Plains and Taiga Shield Ecoregions. The LSA is characterized by undulating to rolling terrain with exposed bedrock outcrops. Typical soils include Regosolic, Brunisolic, Gleysolic, Organic, and Cryosolic soils. Elevations typically range from approximately 190 to 360 meters above sea level (masl), with low-lying areas dominated by shallow and deep water lakes or peatlands.

13.1.4 Content

The general organization of this SON is outlined in Table 13.1-2. To verify that the contents of the TOR are addressed in this report, a table of concordance that cross-references the TOR to the information and location in this DAR is contained in Table 13.1-1.

Table 13.1-2: Subject of Note: Terrain and Soils Organization

Section	Content
Section 13.1	**Introduction** – Provides an introduction to the SON: Terrain and Soil by defining the context, purpose, scope, and study areas, and providing an overview of the SON organization
Section 13.2	**Existing Environment** – Provides a summary of the baseline methods and results for terrain and soils
Section 13.3	**Pathway Analyses** – Provides a screening level assessment of all potential pathways by which the NICO Project may influence terrain and soils after applying environmental design features and mitigation that reduce or eliminate NICO Project-related effects
Section 13.4	**Effects to Terrain and Soil** – Provides a detailed assessment of the potential effects of the NICO Project on terrain and soil
Section 13.5	**Residual Effects Summary** – Summarizes the effects on terrain and soils that are predicted to remain after applying environmental design features, mitigation, and reclamation
Section 13.6	**Uncertainty** – Provides a discussion of the sources of uncertainty related to predicting effects on terrain and soils
Section 13.7	**Monitoring and Follow-up** – Summarizes the objectives of the proposed monitoring and follow-up programs used to test the predicted effects, mitigation, and reclamation on terrain and soils

In addition to the content included in this SON, the following provides additional detailed information on baseline conditions for terrain and soils and proposed monitoring and follow-up programs:

- Annex H: Soil and Terrain Resources Baseline Report
- Biophysical Environment Monitoring and Management Plans (Section 18)

13.2 Existing Environment

13.2.1 Methods

13.2.1.1 Terrain and Soil Distribution in the Regional and Local Study Areas

Detailed soil surveys in the LSA and the 50 km NPAR alignment were completed in August 2005. Reconnaissance level soil surveys of the RSA and additional points within soil map units not previously surveyed in the LSA were completed in August 2008. In addition to data on soil profile characteristics, terrain information was collected that included parent material, landform, surface expression, and slope class. Mineral soils were examined using a shovel and Dutch auger to a maximum depth of 1 m, or to “auger refusal” if gravelly or stony contacts were encountered. Organic soils were examined using a Dutch auger to the depth of peat plus 0.2 m into the underlying mineral material to a maximum depth of 2.2 m. The proposed NPAR at the time of baseline studies was a 50 km predicted alignment that joined the NICO site to the existing all-weather road east of Whatì. Although the NPAR has since been reduced to 27 km, the original 50 km alignment was evaluated during baseline studies.

Terrain and soil conditions in the RSA and LSA were classified and mapped using the principles and methods outlined by the Expert Committee on Soil Survey (1982) and the Mapping Systems Working Group (Agriculture Canada 1981). All soils were classified according to the Canadian System of Soil Classification (Soil Classification Working Group 1998).

The objective of the terrain and soil mapping was to describe and characterize the existing terrain and soil resources, the distribution across the landscape, and associated soil quality and sensitivities within the RSA and LSA. The approach to classifying and describing terrain and soil units involved a review of existing information, field surveys, soil sampling and analysis, and development of terrain and soil maps in a Geographical Information System (GIS) platform. Soil types identified during field surveys were grouped into series. The primary features used to group soil types into a series included dominant soil texture and parent material, soil moisture regime, coarse fragments, presence or absence of permafrost, and soil subgroup. As there are no published soil surveys for the RSA, soil series names were taken from the names of waterbodies in the region.

Ikonos imagery and Landsat Thematic Mapper satellite imagery were used to delineate vegetation units for Ecological Landscape Classification (ELC) mapping in the LSA and RSA, respectively. The ELC vegetation units were then used as part of the mapping process to derive correlations between field observations, terrain features and soil series, and the ELC vegetation types. Due to the resolution of the ELC data, many soil map units were presented as complexes to capture the range of soil types on the landscape and minor components of a soil series (i.e., less than 20% representation within a map unit) were not mapped. The soil map unit delineations were largely inferred from the interpretation of landscape features (i.e., elevation contours and landform), ELC units, and then correlated to soil survey results. Thus, the soil map should be viewed as a predictive model of soil distribution. The information should not be applied for predicting site-specific characteristics without collecting additional field information.

13.2.1.2 Permafrost Potential in the Regional and Local Study Areas

Permafrost potential was assigned to each soil map unit in the LSA and RSA based on soil type, drainage, general topography, and the presence or absence of frozen soil (potential permafrost) noted during field surveys. Key criteria for predicting the presence of permafrost in the discontinuous permafrost zone is the thickness of the organic horizon and soil moisture content (Williams and Burn 1996). In general, poorly to imperfectly drained soils were rated as having a moderate permafrost potential, while moderately to rapidly drained soils were rated as low potential for permafrost. Regosolic soils (typically thin soils developed on eroded bedrock) were rated as having a negligible permafrost potential and Cryosolic soils were rated as having a high potential.

13.2.1.3 Soil Sensitivity and Quality in the Local Study Area

13.2.1.3.1 Soil Erosion Risk

Soil erosion risk from water is generally determined by applying the modified Universal Soil Loss Equation as described by Tajek et al. (1985) and Transportation Association of Canada (TAC 2005). Soil erosion risk from wind was determined based on a dimensionless index described by Coote and Pettapiece (1989). Soil sensitivities to wind and water erosion were determined through an interpretation of soil characteristics (e.g., soil texture, soil structure, and soil moisture) and an evaluation of a soil erodability factor based on texture and slope characteristics associated with each soil type. A final soil erosion sensitivity rating was then assigned to each soil map unit based on the most limiting erosion factor (i.e., whether it is predominantly a wind or water erosion sensitivity) and modified based on natural factors specific to the LSA, such as organic or shallow soils and permafrost, using professional judgement.

13.2.1.3.2 Soil Sensitivity to Acidification

Mineral and organic soils for each soil type in the LSA were evaluated for sensitivity to acidification based on chemical criteria described by Holowaychuk and Fessenden (1987) and interpretations of the soil chemical and nutrient analyses. An overall soil sensitivity was derived for each soil series. For upland mineral soils, these ratings are related to the pH and cation exchange capacity values of the surface horizons (0 to 20 cm) of the soil. In general, mineral soils that have a low clay content and organic matter content have a lower cation exchange capacity and are more sensitive to acidification. Organic soil acid sensitivity is based on the type of peatland system and associated nutrient status, such that extremely nutrient poor or nutrient rich wetlands will have a lower sensitivity to acidification. Thus, both nutrient rich fens and nutrient poor bogs will be associated with a lower sensitivity to acidification. Within the LSA, soil map units were categorized as having high, medium, or low sensitivity ratings.

13.2.1.3.3 Soil Chemical and Nutrient Parameters

Soil chemical and nutrient parameters were assessed through an analysis of representative soil profiles of each of the major soil series in the LSA and at locations along the proposed 50 km NPAR alignment at the time of the field programs. Soil samples were collected from 11 sites for chemical analysis of soil productivity. Analysis included texture (particle size analysis), pH, electrical conductivity (i.e., salinity), available nitrate-N, phosphorus, and potassium, which are all considered to be potential limiting factors to plant growth. Soil samples were also collected in 2005 and 2008 during a separate field program for metals analysis to measure background metal concentrations in soils in the LSA. Soil sample collection methods for baseline metal concentrations can be found in the Soil and Vegetation Chemistry Baseline Report (Annex I).

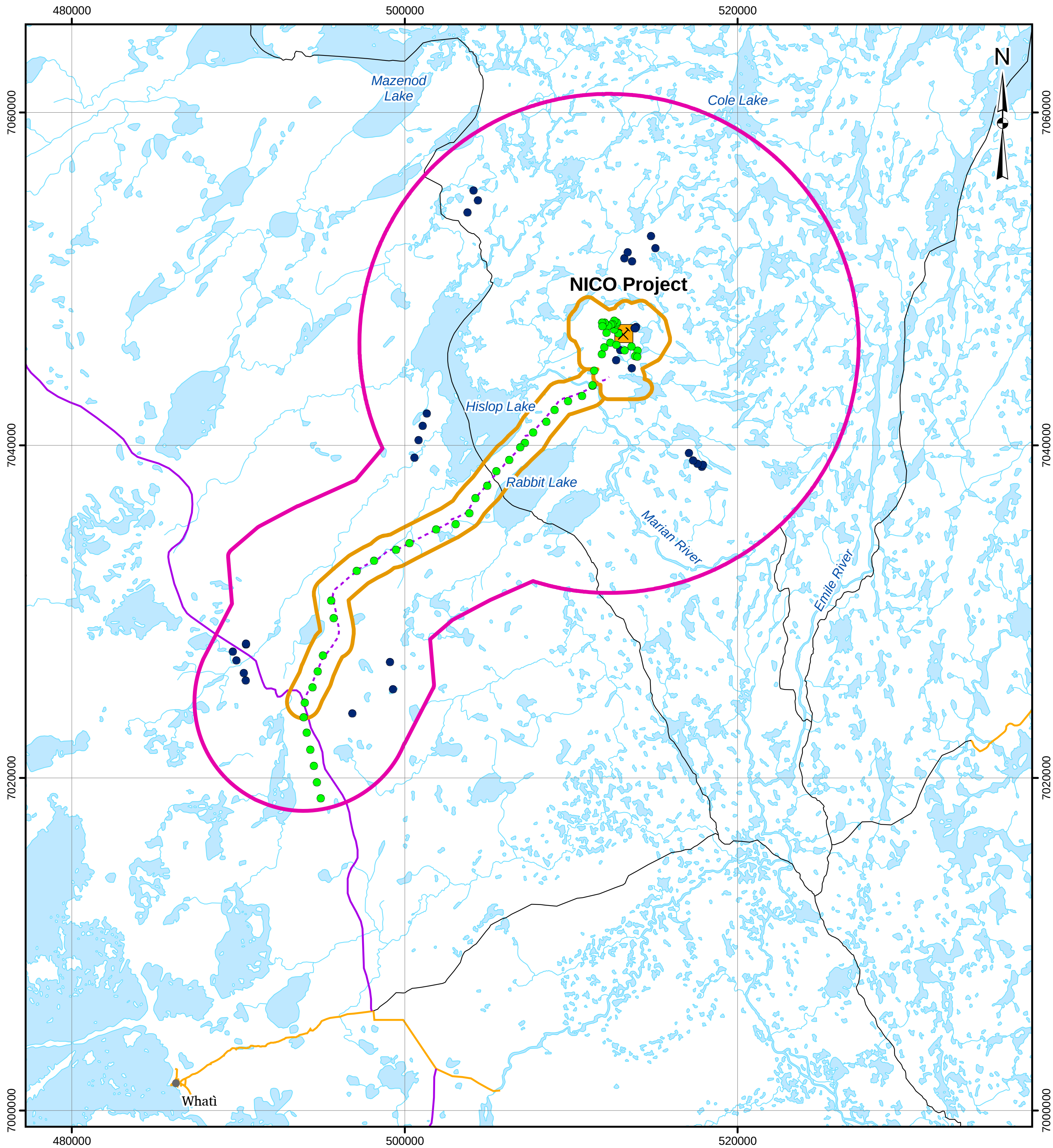
13.2.1.3.4 Soil Reclamation Suitability

The reclamation suitability of soils in the LSA was evaluated to support salvage and reclamation planning as construction activities may include the removal and salvaging of topsoil and subsoil for use in subsequent reclamation activities. Soil reclamation suitability ratings were determined by evaluating several soil properties including texture, coarse fragment content, and selective soil chemistry parameters (Alberta Agriculture 1987). Individual soil series within the LSA were then rated as G (good), F (fair), P (poor), or U (unsuitable) for topsoil and subsoil components. As organic soils can be excellent materials for use in topsoil replacement during reclamation when mixed with mineral materials, they were rated as ‘O (organic)’ to indicate their suitability for reclamation materials.

13.2.2 Results

13.2.2.1 Terrain and Soil Distribution in the Regional and Local Study Areas

In total, 88 soil inspection sites were examined in the RSA and LSA (Figure 13.2-1). In 2005, 56 soil inspection sites were examined, and included 34 sites along the 50km NPAR alignment, and 22 within the mine LSA. In 2008, 32 sites were examined, and included 26 soil inspection sites in the RSA and 6 in the mine LSA. A summary of the soil series and all soil inspection sites in the RSA and LSA are presented in Annex H, Appendix V (Table V-1).



LEGEND

- NICO PROJECT
- POPULATED PLACE
- EXISTING ALL-WEATHER ROAD
- EXISTING WINTER ROAD
- PROPOSED NICO PROJECT ACCESS ROAD
- PROPOSED TŁĮCHQ ROAD ROUTE
- WATERCOURSE
- WATERBODY
- 2005 SOIL PLOT
- 2008 SOIL PLOT
- LOCAL STUDY AREA
- REGIONAL STUDY AREA

7.5 0 7.5

SCALE 1:325,000 KILOMETRES

NOTE: Some soil plot locations may not appear on the figure because of overlap due to map scale.

REFERENCE

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

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

SOIL INSPECTION SITES IN THE LOCAL AND REGIONAL STUDY AREAS

Golder Associates
Edmonton, Alberta

FILE NO. E-Soil-014-GIS

PROJECT No. 09-1373-1004		SCALE AS SHOWN	REV. 0
DESIGN	LV	04 Dec. 2008	
GIS	SK	01 Feb. 2011	
CHECK	GRA	03 Apr. 2011	
REVIEW	GRA	03 Apr. 2011	

FIGURE: 13.2-1

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Upland mineral soils observed in the RSA included Brunisolic and Regosolic soils. Brunisolic soils identified included Orthic Brunisol, Eutric Brunisol, and Dystric Brunisol. Regosolic soils identified included Orthic Regosol. Wetland soils observed included Gleysolic, Organic, and Cryosolic soils. Gleysolic soils indentified included Rego Gleysol and peaty Rego Gleysol. Peaty refers to an organic layer less than 40 cm, but greater than 15 cm deep. Organic soils observed included Terric Mesisol, Terric Humic Mesisol, and Terric Fibrisol. Terric Organics indicate that mineral soil was encountered at depths less than 160 cm. Peat depth of Terric Organics observed in the RSA and LSA ranged from 40 to 125 cm. Cryosolic soils observed included Gleysolic Static Cryosol, Terric Mesic Organic Cryosol, Terric Fibric Organic Cryosol, Mesic Organic Cryosol and Fibric Organic Cryosol.

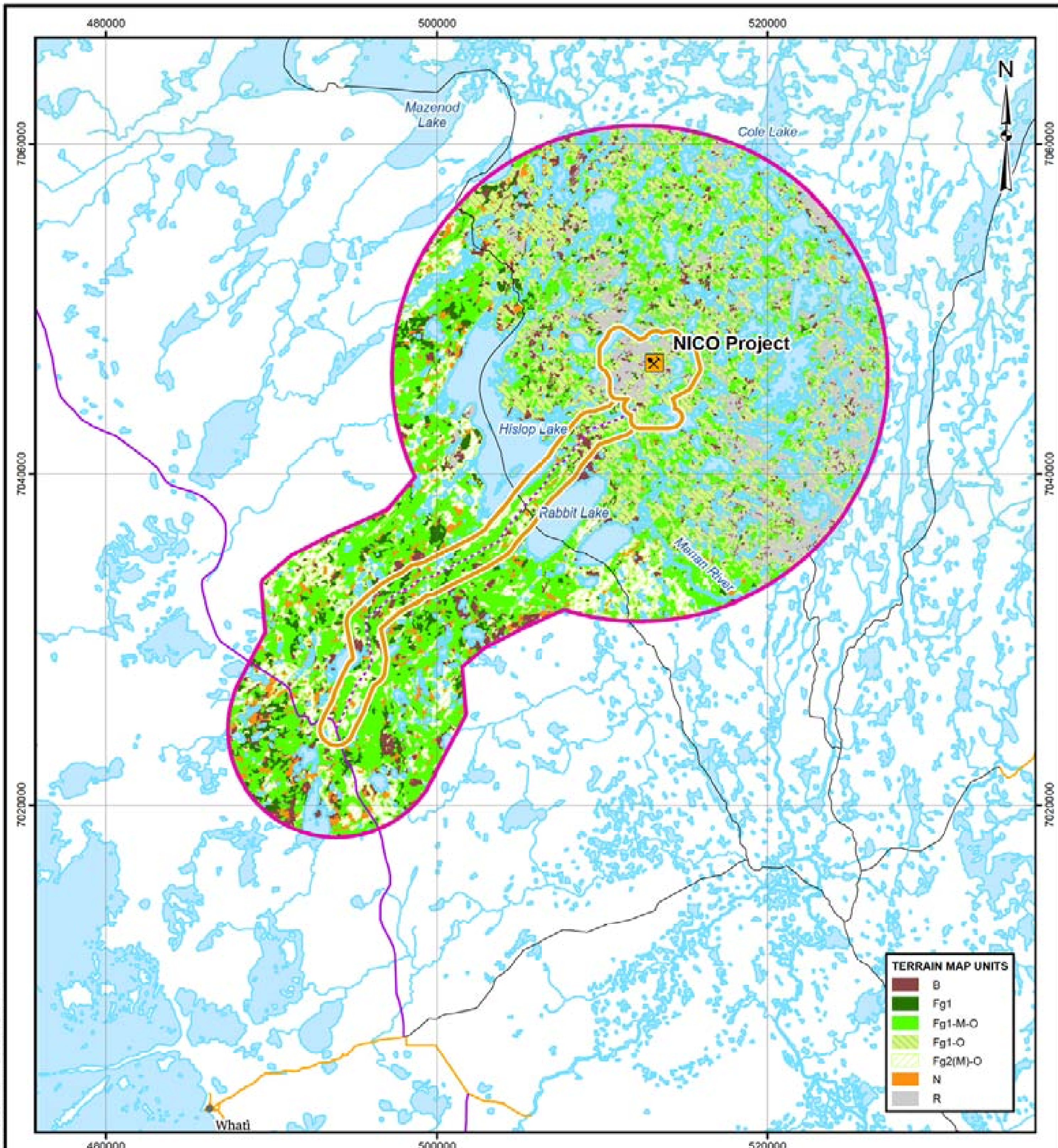
13.2.2.1.1 Terrain and Soil in the Regional Study Area

Eight terrain units were defined and mapped for the RSA (Table 13.2-1 and Figure 13.2-2). The most common terrain map unit within the RSA is the glaciofluvial, morainal/till, and organic (Fg1-M-O) complex, which covers 26 073 hectares (ha) (27.5%) of the RSA. The second most common terrain map unit encountered in the RSA is the glaciofluvial and organic (frozen) (Fg1-O) complex, which covers 19 719 ha (20.8%). The glaciofluvial (morainal/till) and organic (Fg2(M)-O) complex covers 10 384 ha (10.9%) of the RSA. The remaining terrain map units include bedrock (R), bog (B), fen (F), and glaciofluvial (Fg1) features and cover 10.1%, 6.5%, 3.9%, and 4.5% of the RSA, respectively. Water composes 15.8% (14 983 ha) of the RSA.

Table 13.2-1: Area of Terrain Map Units in the Regional Study Area

Terrain Unit	Surficial Parent Material	Landform	Area (ha)	% of RSA
Fg1	glaciofluvial	level to undulating, with minor hummocky and steep areas	4 259	4.5
Fg1-O	glaciofluvial (gravels) and organic (frozen, potential permafrost)	undulating to rolling with level areas and minor inclusions of steep areas	19 719	20.8
Fg1-M-O	glaciofluvial (gravels), morainal/till and organic	undulating with level areas and minor inclusions of steep areas	26 073	27.5
Fg2(M)-O	glaciofluvial (sands) and organic with minor morainal/till inclusions	undulating with level areas	10 384	10.9
N	Fen	level to depressional	3 681	3.9
B	Bog	level to depressional	6 181	6.5
R	Bedrock	high relief bedrock outcrops, with steep scarps and ridges	9 577	10.1
Water	surface water	Depressional	14 983	15.8
Total			**94 858**	**100**

Note: Numbers are rounded for presentation purposes; therefore; it may appear that the totals do not equal the sum of the individual values.
RSA = regional study area; % = percent; ha = hectare.



LEGEND

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

7.5 0 7.5

SCALE 1:325,000 KILOMETRES

NOTE: Terrain map unit descriptions can be found in Table 13.2-1 of the report.

REFERENCE

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

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

TERRAIN MAP UNITS IN THE REGIONAL STUDY AREA

Golder Associates
Edmonton, Alberta

FILE No. E-SOIL-001-GIS				
PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	LV	08 Dec. 2008	**FIGURE: 13.2-2**	
GIS	SK	01 Feb. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

Nine soil map units, including water, were described and mapped for the RSA (Table 13.2-2 and Figure 13.2-3). The most common soil map unit in the RSA is RAB-MAR, which covers 26 073 ha (27.5%) of the RSA (Table 13.2-2). The RAB-BUR(BEA) soil map unit is the second most abundant unit in the RSA at 19 719 ha (20.8%). The RAB(TUM)-MAR soil map unit accounts for 10 384 ha (10.9%) of the RSA and primarily occurs along the NPAR. The KIL map unit covers 9576 ha (10.1%) of the RSA. The RAB soil map unit occurs primarily along the NPAR on upland areas and accounts for 4259 ha (4.5%) of the RSA. Wetland soil map units are defined by the BUR-MUS, MAR-MUS, and MUS-MAR units, which collectively represent approximately 10.0% of the RSA.

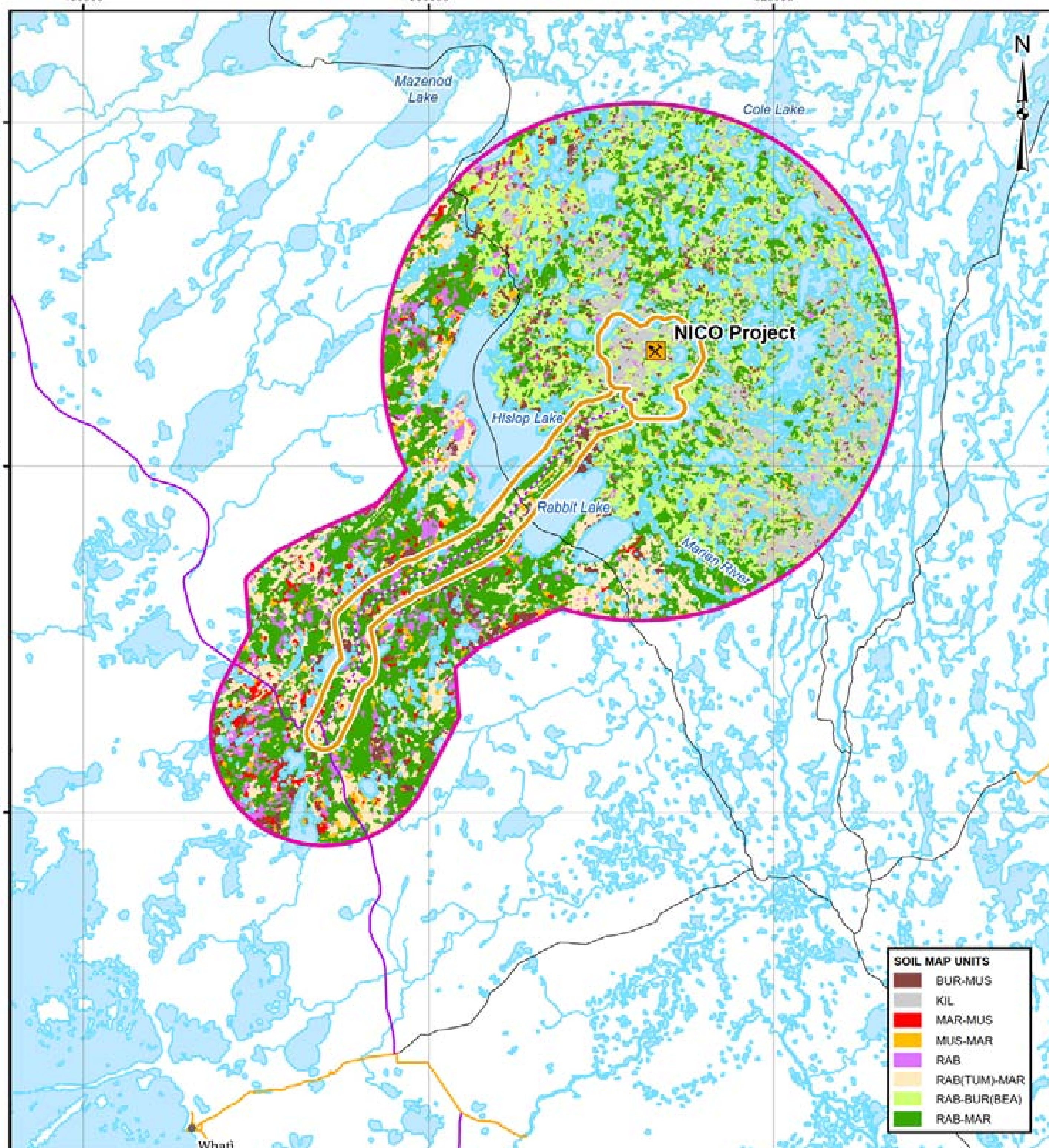
Table 13.2-2: Area of Soil Map Units in the Regional Study Area

Soil Map Unit	Map Unit Name	Soil Patterns[a]	Area (ha)	% of RSA
BUR-MUS	Burke	D: Cryosolic Organics (BUR)	4 862	5.1
	Muskeg	S: Wetlands-Organic (MUS)		
KIL	Killam	D: Thin veneers over Bedrock (KIL)	9 577	10.1
MAR-MUS	Marian	D: Wetlands-Gleysolic (MAR)	1 953	2.1
	Muskeg	S: Wetlands-Organic (MUS)		
MUS-MAR	Muskeg	D: Wetlands-Organic (MUS)	3 047	3.2
	Marian	S: Wetlands-Gleysolic (MAR)		
RAB	Rabbit	D: Brunisolic (RAB)	4 259	4.5
RAB(TUM)-MAR	Rabbit	D: Brunisolic (RAB)	10 384	10.9
	Marian	C: Wetlands-Gleysolic (MAR)		
	Tumi	S: Brunisolic (TUM)		
RAB-BUR(BEA)	Rabbit	D: Brunisolic (RAB)	19 719	20.8
	Burke	C: Cryosolic Organics (BUR)		
	Bea	C: Wetlands-Cryosolic (BEA)		
RAB-MAR	Rabbit	D: Brunisolic (RAB)	26 073	27.5
	Marian	C: Wetlands-Gleysolic (MAR)		
Water	NA	NA	14 983	15.8
Total			**94 858**	**100**

Note: Numbers are rounded for presentation purposes; therefore, it may appear that the totals do not equal the sum of the individual values.

[a] D = Dominant; C = Co-dominant; and S = Sub-dominant (Refer to Annex H for more details).

RSA = regional study area; NA = not applicable; % = percent; ha = hectare.



LEGEND

- NICO PROJECT
- POPULATED PLACE
- EXISTING ALL-WEATHER ROAD
- EXISTING WINTER ROAD
- PROPOSED NICO PROJECT ACCESS ROAD
- PROPOSED TŁĮCHQ ROAD ROUTE
- WATERCOURSE
- WATERBODY
- LOCAL STUDY AREA
- REGIONAL STUDY AREA

7.5 0 7.5

SCALE 1:325,000 KILOMETRES

NOTE: Soil map unit descriptions can be found in Table 13.2-2 of the report.

REFERENCE

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

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

SOIL MAP UNITS IN THE REGIONAL STUDY AREA

Golder Associates
Edmonton, Alberta

FILE NO. E-Soil-002-GIS				
PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	LV	08 Dec. 2008	**FIGURE: 13.2-3**	
GIS	SK	01 Feb. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

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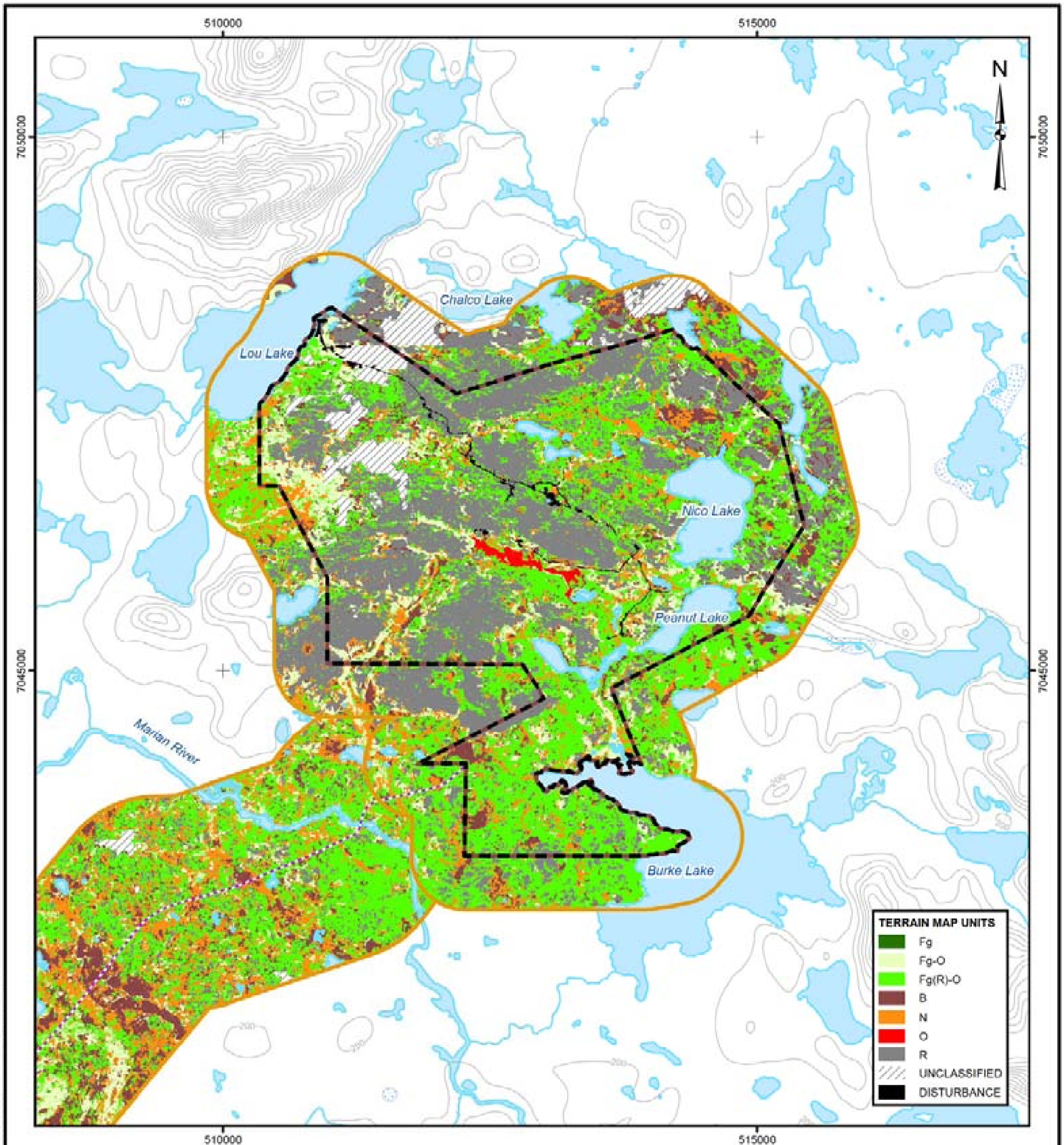
13.2.2.1.2 Terrain and Soil in the Local Study Area

Ten terrain units have been defined and mapped for the LSA and include disturbance, unclassified, and water (Table 13.2-3 and Figure 13.2-4a, b). The most common terrain map unit encountered in the LSA is the glaciofluvial and organic (Fg-O) terrain unit, and covers 3166 ha (37.7%) of the LSA. The second most abundant terrain unit is the glaciofluvial, bedrock and organic (Fg(R)-O) unit, and covers 1338 ha (15.9%) of the LSA. The bedrock (R) terrain unit covers 749 ha (8.9%) of the LSA. Fen (N) and bog (B) terrain map units are widespread throughout the LSA and compose 1304 ha (15.5%) and 867 ha (10.3%), respectively. The remaining terrain units compose less than 5.0% of the LSA. Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference (i.e., cloud, haze, and shadow). Because the terrain and soil map unit delineations are largely inferred from the interpretation of landscape features (i.e., elevation contours and landform), ELC vegetation classes, and correlated to soil survey results, areas without an ELC vegetation class could not be assigned a terrain or soil map unit. Water covers 627 ha (7.5%) of the LSA.

Table 13.2-3: Area of Terrain Map Units in the Local Study Area

Terrain Map Unit	Terrain Map Unit Description	Surficial Parent Material	Landform	Mine LSA		NPAR LSA		Total LSA	
				Area (ha)	%	Area (ha)	%	Area (ha)	%
Fg	glaciofluvial	glaciofluvial (gravels)	level to undulating, with minor steep areas	1	<0.1	228	4.0	229	2.7
Fg-O	glaciofluvial and organic	glaciofluvial (gravels), and organic	undulating and level, with minor hummocky and steep areas	219	8.3	2 947	51.2	3 166	37.7
Fg(R)-O	glaciofluvial, bedrock and organic	glaciofluvial (gravels), bedrock, and organic	undulating to rolling with level areas and inclusions of high relief bedrock outcrops, with steep scarps and ridges	882	33.3	456	7.9	1 338	15.9
O	shallow organic veneers and shallow to deep bogs (frozen, potential permafrost)	frozen shallow organic veneers and shallow to deep frozen bogs	level to depressional	9	0.3	0	0	9	0.1
N	fen	fen	level to depressional	206	7.8	1 098	19.1	1 304	15.5
B	bog	bog	level to depressional	189	7.2	678	11.8	867	10.3
R	bedrock	bedrock	high relief bedrock outcrops, with steep scarps and ridges	696	26.3	53	0.9	749	8.9
Disturbance	exploration facilities and roads/trails	NA	NA	12	0.5	1	<0.1	13	0.2
Unclassified	unclassified	NA	NA	83	3.1	18	0.3	101	1.2
Water	Water	water (lakes)	depressional	347	13.1	280	4.9	627	7.5
Total				**2 644**	**100**	**5 761**	**100**	**8 405**	**100**

Note: Numbers are rounded for presentation purposes; therefore, it may appear that the totals do not equal the sum of the individual values.
LSA = local study area; NPAR = NICO Project Access Road; NA = not applicable; % = percent; ha = hectare; < = less than.



LEGEND

- PROJECT LEASE BOUNDARY
- CONTOUR (10 METRE INTERVAL)
- PROPOSED NICO PROJECT ACCESS ROAD
- WATERCOURSE
- WATERBODY
- WETLAND
- LOCAL STUDY AREA

NOTE: Terrain map unit descriptions can be found in Table 13.2-3 of the report. Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference.

REFERENCE

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

1 0 1
SCALE 1:50,000 KILOMETRES

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

TERRAIN MAP UNITS IN THE LOCAL STUDY AREA

Golder Associates
Edmonton, Alberta

FILE No. E-Soil-005-GIS				
PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	**FIGURE: 13.2-4a**	
GIS	SK	01 Feb. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

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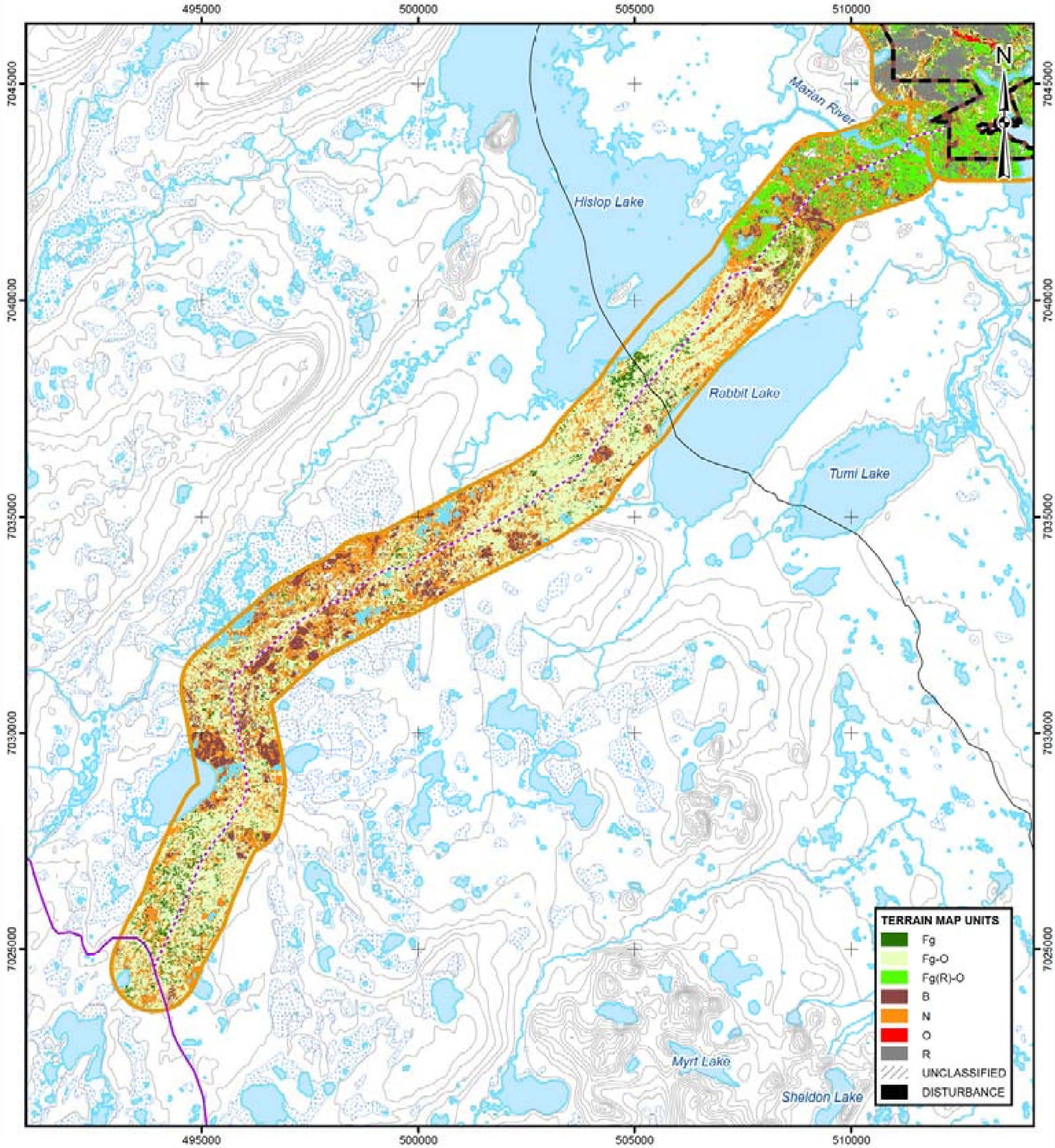

LEGEND

- PROJECT LEASE BOUNDARY
- CONTOUR (10 METRE INTERVAL)
- EXISTING WINTER ROAD
- PROPOSED NICO PROJECT ACCESS ROAD
- PROPOSED TŁĮCHǪ ROAD ROUTE
- WATERCOURSE
- WATERBODY
- WETLAND
- LOCAL STUDY AREA

NOTE: Terrain map unit descriptions can be found in Table 13.2-3 of the report. Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference.

REFERENCE

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

3 0 3
SCALE 1:125,000 KILOMETRES

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

TERRAIN MAP UNITS IN THE LOCAL STUDY AREA

Golder Associates
Edmonton, Alberta

FILE NO. E-Soil-008-GIS				
PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	**FIGURE: 13.2-4b**	
GIS	SK	01 Feb. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

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Twelve soil map units were described and mapped for the LSA and includes disturbed, unclassified (satellite land mapping interference), and water (Table 13.2-4 and Figure 13.2-5a, b). The most common upland soil map units (i.e., mineral soil) in the LSA are the RAB-TUM-MAR, followed by RAB-KIL-MAR, which account for 2345 ha (27.9%) and 1338 ha (15.9%) of the LSA, respectively. The RAB-TUM-MAR map unit occurs exclusively within the NPAR LSA. The RAB-MAR soil map unit covers 822 ha (9.8%) of the LSA. The KIL and RAB upland soil map units cover approximately 12.0% of the LSA. The KIL map unit occurs almost exclusively within the mine LSA, whereas the RAB map unit occurs almost exclusively within the NPAR LSA. The MUS wetland map unit is also prevalent within the LSA and it covers 1554 ha (18.5%) and is scattered throughout the LSA. The remaining wetland soil map units are defined by the BEA-BUR, BUR-MAR, MUS-MAR units, which collectively represent less than 8.0% of the LSA. Disturbance and unclassified areas compose the remainder of the soil map units in the LSA. Water covers 627 ha (7.5%) of the LSA.

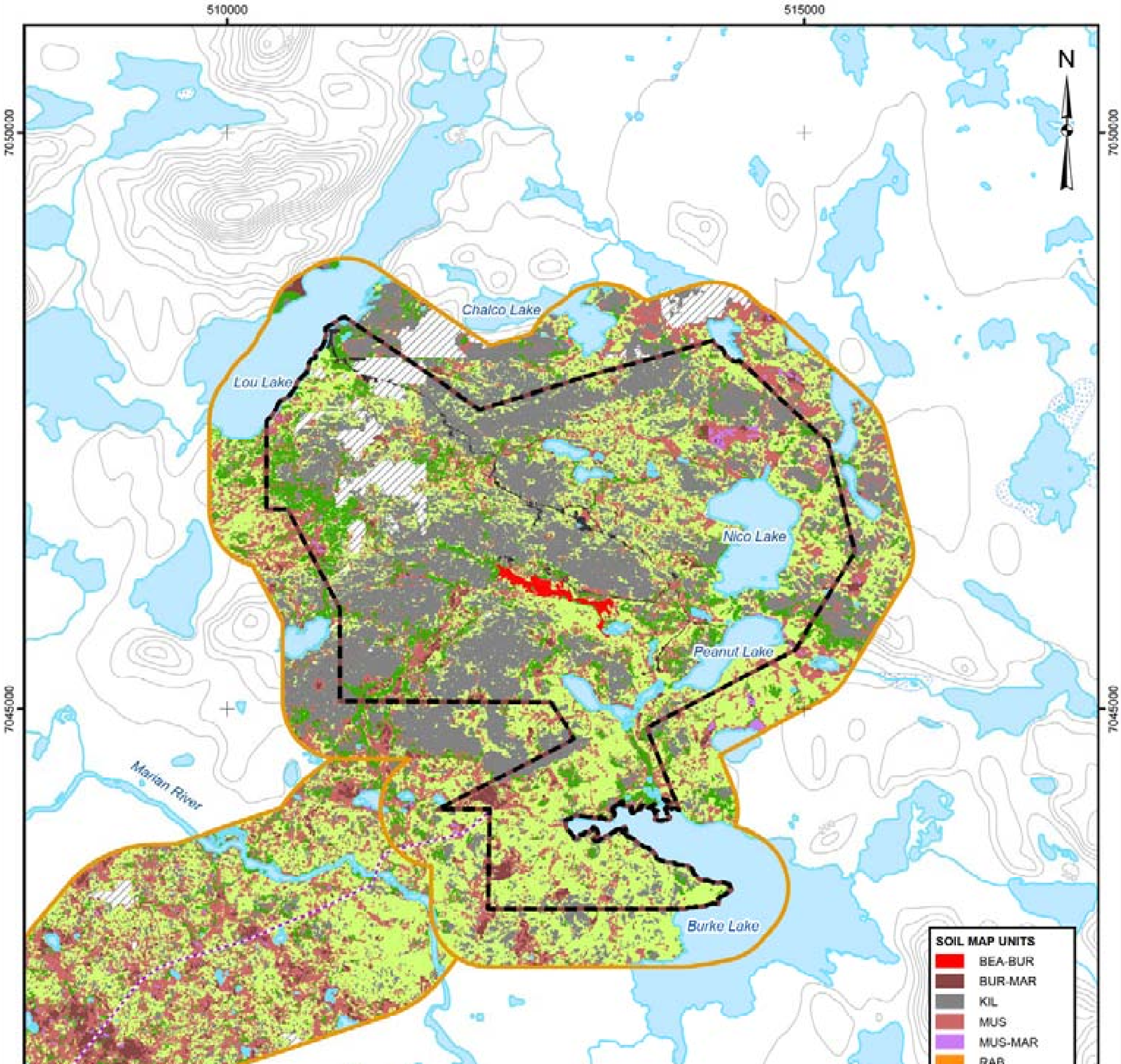
Table 13.2-4: Area of Soil Map Units in the Local Study Area

Soil Map Unit	Map Unit Name	Soil Patterns[a]	Mine LSA		NPAR LSA		Total LSA	
			Area (ha)	%	Area (ha)	%	Area (ha)	%
BEA-BUR	Bea	D: Wetlands-Cryosolic (BEA)	9	0.4	0	0	9	0.1
	Burke	C: Cryosolic Organics (BUR)						
BUR-MAR	Burke	D: Cryosolic Organics (BUR)	55	2.1	357	6.2	412	4.9
	Marian	C: Wetlands-Gleysolic (MAR)						
KIL	Killam	D: thin veneers over Bedrock (KIL)	696	26.3	53	0.9	749	8.9
MUS	Muskeg	D: Wetlands-Organic (MUS)	331	12.5	1 223	21.2	1 554	18.5
MUS-MAR	Muskeg	D: Wetlands-Organic (MUS)	9	0.4	197	3.4	206	2.4
	Marian	C: Wetlands-Gleysolic (MAR)						
RAB	Rabbit	D: Brunisolic (RAB)	1	<0.1	228	4.0	229	2.7
RAB-KIL-MAR	Rabbit	D: Brunisolic (RAB)	882	33.3	456	7.9	1 338	15.9
	Killam	C: thin veneers over Bedrock (KIL)						
	Marian	S: Wetlands-Gleysolic (MAR)						
RAB-MAR	Rabbit	D: Brunisolic (RAB)	219	8.3	603	10.5	821	9.8
	Marian	C: Wetlands-Gleysolic (MAR)						
RAB-TUM-MAR	Rabbit	D: Brunisolic (RAB)	0	0	2 345	40.7	2 345	27.9
	Tumi	C: Brunisolic (TUM)						
	Marian	S: Wetlands-Gleysolic (MAR)						
Disturbance	NA	exploration facilities and roads/trails	12	0.5	1	<0.1	13	0.2
Unclassified	NA	NA	83	3.1	18	0.3	101	1.2
Water	NA	NA	347	13.1	280	4.9	627	7.5
Total			**2 644**	**100**	**5 761**	**100**	**8 405**	**100**

Note: Numbers are rounded for presentation purposes; therefore, it may appear that the totals do not equal the sum of the individual values.

[a] D = Dominant; C = Co-dominant; and S = Sub-dominant (Refer to Annex H for more details).

LSA = local study area; NPAR = NICO Project Access Road; NA = not applicable; % = percent; ha = hectare; < = less than.



LEGEND

- PROJECT LEASE BOUNDARY
- CONTOUR (10 METRE INTERVAL)
- PROPOSED NICO PROJECT ACCESS ROAD
- WATERCOURSE
- WATERBODY
- WETLAND
- LOCAL STUDY AREA

NOTE: Soil map unit descriptions can be found in Table 13.2-4 of the report. Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference.

REFERENCE

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

1 0 1
SCALE 1:50,000 KILOMETRES

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

SOIL MAP UNITS WITHIN THE LOCAL STUDY AREA

FILE NO. E-Soil-007-GIS				
PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	**FIGURE: 13.2-5a**	
GIS	SK	01 Feb. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

Golder Associates
Edmonton, Alberta

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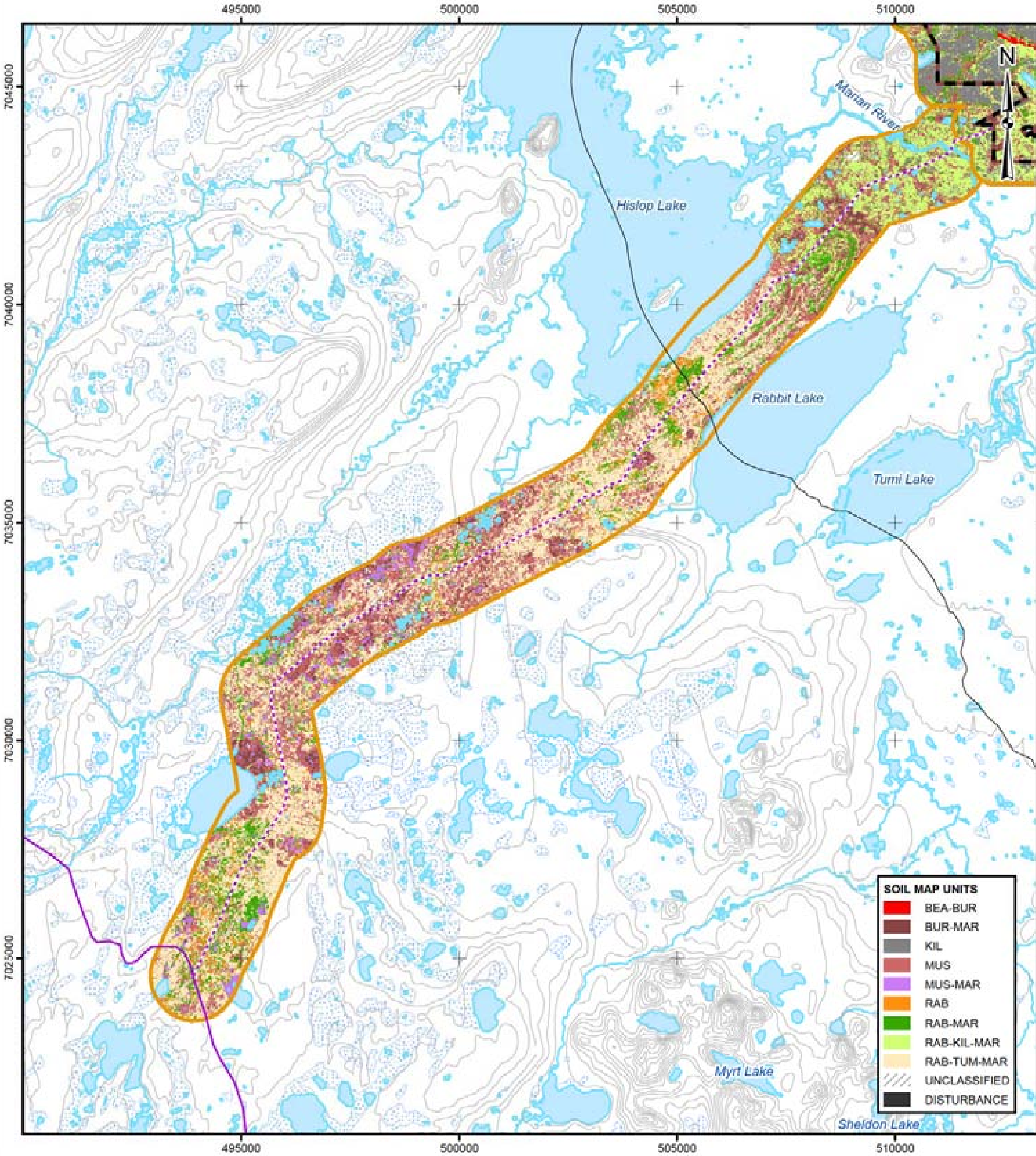

LEGEND

- PROJECT LEASE BOUNDARY
- CONTOUR (10 METRE INTERVAL)
- EXISTING WINTER ROAD
- PROPOSED NICO PROJECT ACCESS ROAD
- PROPOSED TŁĮCHǪ ROAD ROUTE
- WATERCOURSE
- WATERBODY
- WETLAND
- LOCAL STUDY AREA

NOTE: Soil map unit descriptions can be found in Table 13.2-4 of the report. Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference.

REFERENCE

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

3 0 3
SCALE 1:125,000 KILOMETRES

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

SOIL MAP UNITS WITHIN THE LOCAL STUDY AREA

Golder Associates
Edmonton, Alberta

FILE No. E-Soil-008-GIS				
PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	**FIGURE: 13.2-5b**	
GIS	SK	01 Feb. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

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13.2.2.2 Permafrost Potential in the Regional and Local Study Areas

13.2.2.2.1 Regional Study Area

Permafrost across the landscape that contains the RSA has been described as extensive discontinuous permafrost (Natural Resources Canada 1993). The ice content of the upper 10 to 20 m of the ground is described as having low to moderate ice content with sparse areas that contain ice wedges and pingo ice (i.e., ice-rich permafrost) (Natural Resources Canada 1993). Though most bogs typically contain permafrost, many fens are free of permafrost (Zoltai 1995). Within the RSA, soils with high potential to contain permafrost are typically poorly-drained organic soils within treed bogs and poorly-drained low-lying mineral soils associated with wetlands. The distribution of permafrost across the landscape is highly variable, with variations in ice content occurring over small scales (i.e., within several metres).

The majority of the RSA has been characterized as having a moderate or low potential for permafrost occurrence, and represent 26.1% and 42.9% of the RSA, respectively (Table 13.2-5). Areas rated as having a high permafrost potential tend to be scattered in isolated pockets throughout the RSA, as they are almost exclusively associated with poorly drained organic soils within treed bogs (i.e., BUR-MUS and RAB-BUR[BEA] map units, specifically BUR and BEA series). Frozen ground (potential permafrost) was observed at depths between 30 to 75 cm within BEA soils, with an average thaw depth of 45 cm. Frozen ground was observed at depths between 22 to 100 cm within BUR soils, with an average thaw depth of 54 cm. Areas of high permafrost potential represent 4862 ha (5.1%) of the RSA.

Table 13.2-5: Permafrost Potential of Soils in the Regional Study Area

Permafrost Potential	Area (ha)	% of RSA
High	4 862	5.1
Moderate	24 719	26.1
Low	40 717	42.9
Negligible	9 577	10.1
Water	14 983	15.8
Total	**94 858**	**100**

Note: Numbers are rounded for presentation purposes; therefore, it may appear that the totals do not equal the sum of the individual values.

RSA = Regional Study Area; % = percent; ha = hectare

13.2.2.2.2 Local Study Area

Permafrost in the LSA is associated with poorly-drained organic soils within treed bogs and low-lying mineral soils associated with wetlands. The BEA-BUR map unit is a unique unit defined by frozen mineral soils (potential permafrost) (i.e., Gleysolic Static Cryosol), with minor inclusions of organic soils that were frozen (potential permafrost) (i.e., Organic Cryosol). This map unit is only found in the central portion of the LSA in a low-lying area between 2 major bedrock ridges (Figure 13.2-6a). The BUR-MAR map unit is closely associated with treed bogs, which have well developed peat layers that may contain permafrost. Frozen ground (potential permafrost) was observed at depths of 22 to 45 cm within the mine LSA, with an average thaw depth of 34 cm. Frozen ground was observed at depths between 32 to 100 cm along the NPAR, with an average thaw depth of 62 cm. Of the 8 boreholes installed with thermistors that were drilled in the LSA, 4 of the boreholes had permafrost present at depth, and all 4 were located centrally in low-lying valleys (Golder 2010).

Within the LSA, the majority of the area 4733 ha (56.3%) is classified as having a low potential for permafrost (Table 13.2-6 and Figure 13.2-6a, b). Areas of moderate potential cover 1760 ha (20.9%) of the total LSA. Approximately 421 ha (5.0%) of the total LSA is classified as high permafrost potential, with the majority of this area occurring along the NPAR LSA. Disturbance and unclassified areas that cover approximately 1.4% of the LSA were not assigned a permafrost potential class.

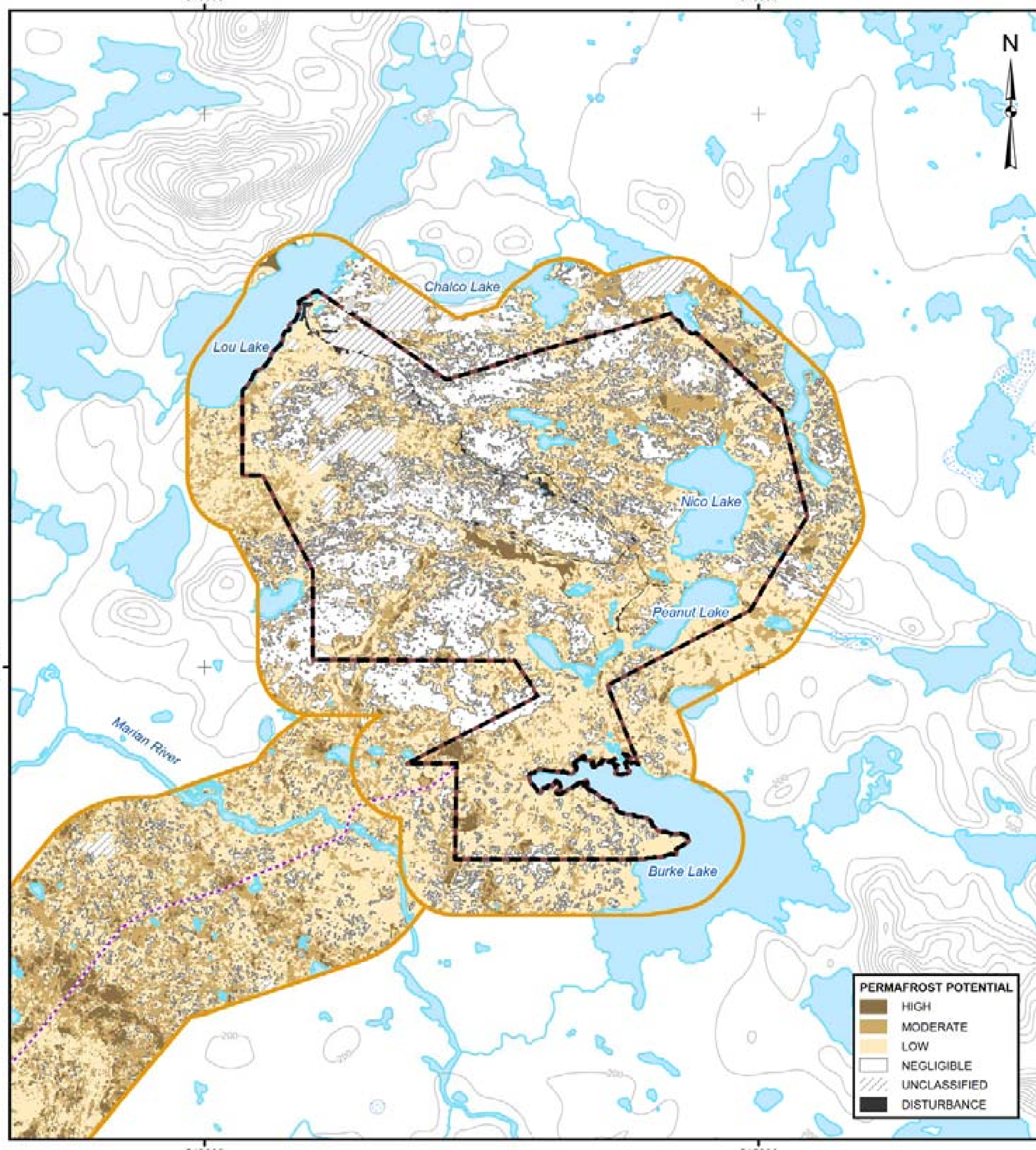
Table 13.2-6: Permafrost Potential of Soils within the Local Study Area

Permafrost Potential	Mine LSA		NPAR LSA		Total LSA	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
High	64	2.4	357	6.2	421	5.0
Moderate	340	12.9	1 419	24.6	1 760	20.9
Low	1 101	41.6	3 632	63.0	4 733	56.3
Negligible	696	26.3	53	0.9	749	8.9
Water	347	13.1	280	4.9	627	7.5
Disturbance[a]	12	0.5	1	<0.1	13	0.2
Unclassified	83	3.1	18	0.3	101	1.2
Total	**2 644**	**100**	**5 761**	**100**	**8 405**	**100**

Note: Numbers are rounded for presentation purposes; therefore, it may appear that the totals do not equal the sum of the individual values.

[a] exploration facilities and roads/trails.

LSA = local study area; NPAR = NICO Project Access Road; % = percent; ha = hectare; < = less than.



LEGEND

- PROJECT LEASE BOUNDARY
- CONTOUR (10 METRE INTERVAL)
- PROPOSED NICO PROJECT ACCESS ROAD
- WATERCOURSE
- WATERBODY
- WETLAND
- LOCAL STUDY AREA

NOTE: Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference.

REFERENCE

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

1 0 1
SCALE 1:50,000 KILOMETRES

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

PERMAFROST POTENTIAL OF SOILS IN THE LOCAL STUDY AREA

FILE NO. E-Soil-009-GIS

PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008		
GIS	SK	01 Feb. 2011	**FIGURE: 13.2-6a**	
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

Golder Associates
Edmonton, Alberta

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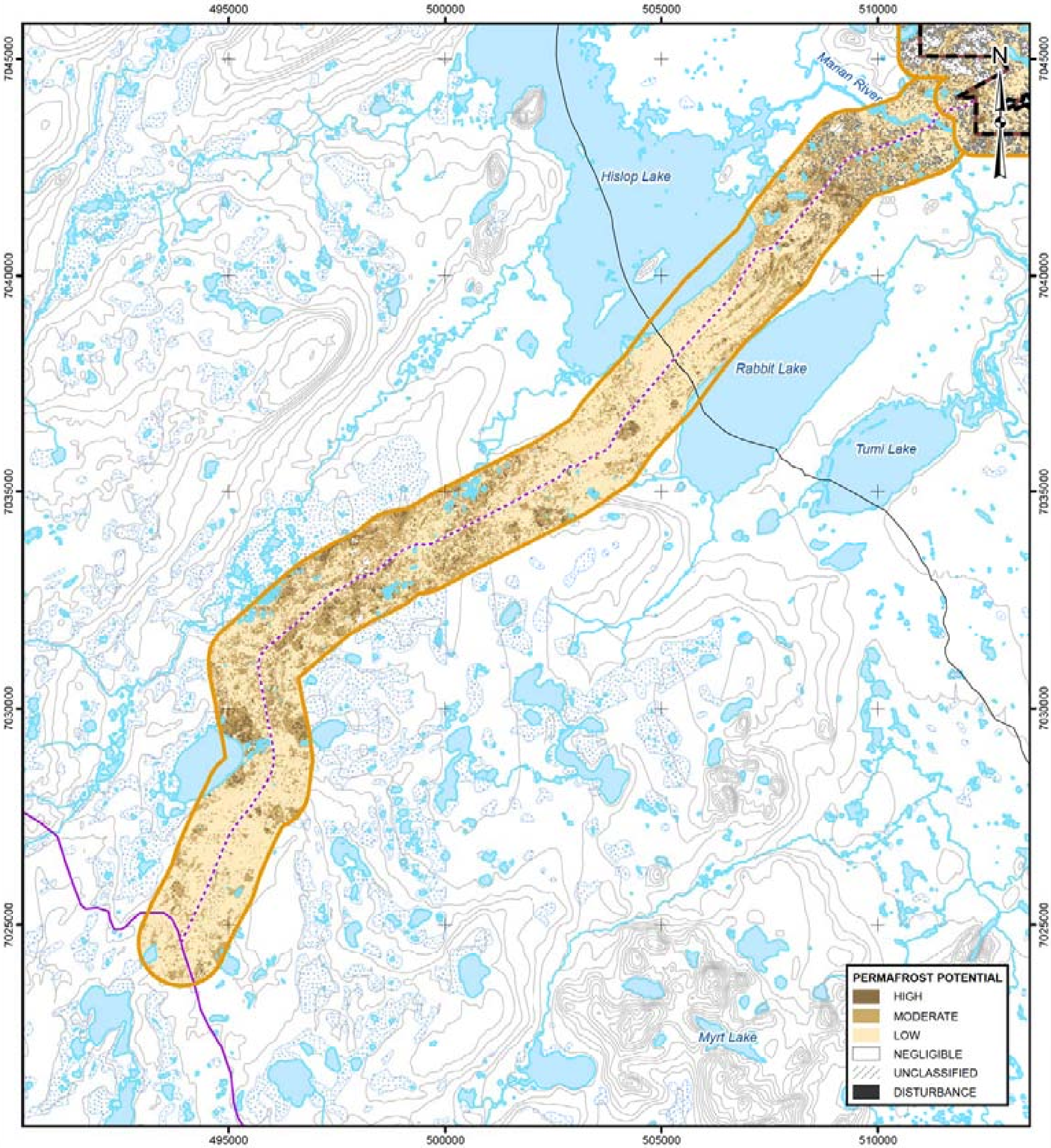

3 0 3

SCALE 1:125,000 KILOMETRES

LEGEND

- PROJECT LEASE BOUNDARY
- CONTOUR (10 METRE INTERVAL)
- EXISTING WINTER ROAD
- PROPOSED NICO PROJECT ACCESS ROAD
- PROPOSED TŁĮCHQ ROAD ROUTE
- WATERCOURSE
- WATERBODY
- WETLAND
- LOCAL STUDY AREA

NOTE: Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference.

REFERENCE

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

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

PERMAFROST POTENTIAL OF SOILS IN THE LOCAL STUDY AREA

Golder Associates
Edmonton, Alberta

FILE NO. E-Soil-010-GIS				
PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	**FIGURE: 13.2-6b**	
GIS	SK	01 Feb. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

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13.2.2.3 Soil Sensitivity and Quality in the Local Study Area

13.2.2.3.1 Soil Erosion Risk

Soil erosion risk is one of the primary concerns for disturbed soils because the limited amount of vegetation cover exposes soil materials to the elements (e.g., wind and water). With continuous exposure to wind or rain, the uppermost portions of the soil profile may be eroded, washed, or blown away, depending on terrain and soil characteristics, resulting in loss of topsoil and subsequent soil quality. Most soil map units in the LSA are rated as having low erosion sensitivity, with the exception of those with special management concerns (i.e., organic or shallow soils, and frozen soils [potential permafrost]). Erosion sensitivities for Cryosolic soils (i.e., permafrost soils; BEA and BUR) were raised to moderate to reflect the sensitivity of these soils to disturbance and the potential for changes in the thermal regime to de-stabilize soil structure and increase pore water pressures. The erosion sensitivity for KIL soils was also raised to moderate because any loss of this thin soil may have implications for plant growth. A summary of soil characteristics and the overall erosion sensitivity for each soil map unit is presented in Table 13.2-7.

Table 13.2-7: Erosion Sensitivity of Soil Map Units in the Local Study Area

Soil Map Unit	Map Unit Name	Soil Patterns[a]	Parent Material	Soil Erosion Sensitivity
BEA-BUR	Bea Burke	D: Wetlands-cryosolic (BEA) S: Wetlands-crysolic organics (BUR)	Shallow to deep frozen organics	Moderate[b]
BUR-MAR	Burke Marian	D: Cryosolic organics (BUR) C: Wetlands (MAR)	Frozen bog peat and shallow organics over coarse glaciofluvial materials	Low (Moderate)[b]
KIL	Killam	D: Thin veneers over Bedrock (KIL)	Thin sandy veneers over bedrock	Moderate[c]
MUS	Muskeg	D: Wetlands-organic (MUS)	Moderately deep bog and fen peat	Low
MUS-MAR	Muskeg Marian	D: Wetlands-organic (MUS) C: Wetlands-gleysolic (MAR)	Moderately deep fen peat and shallow organics over coarse glaciofluvial materials	Low
RAB	Rabbit	D: Brunisolic (RAB)	Coarse textured glaciofluvial deposits	Low
RAB-KIL-MAR	Rabbit Killam Marian	D: Brunisolic (RAB) C: thin veneers over Bedrock (KIL) S: Wetlands-gleysolic (MAR)	Coarse textured glaciofluvial deposits and thin sandy veneers over bedrock; shallow organics over medium to coarse textured glaciofluvial materials and till	Low (Moderate)[c]
RAB-MAR	Rabbit Marian	D: Brunisolic (RAB) C: Wetlands-gleysolic (MAR)	Coarse textured glaciofluvial deposits and shallow organics over medium to coarse textured glaciofluvial materials and till	Low
RAB-TUM-MAR	Rabbit Tumi Marian	D: Brunisolic (RAB) C: Brunisolic (TUM) S: Wetlands-gleysolic (MAR)	Coarse textured glaciofluvial deposits and shallow organics over medium to coarse textured glaciofluvial materials and till	Low (Moderate)[c]

[a] D = Dominant; C = Co-dominant; and S = Sub-dominant (refer to Annex H for more details).

[b] Primarily precipitation (water) erosion sensitivities.

[c] Primarily wind erosion sensitivities.

The majority of the LSA is classified as low (moderate) and low soil erosion risk at 4095 ha (48.7%) and 2810 ha (33.4%), respectively (Table 13.2-8). No areas in the LSA were identified as having high soil erosion risk and

758 ha (9.0%) of the LSA was identified as having a moderate erosion risk. Areas of moderate risk are found primarily in the central part of the LSA and are typically associated with Cryosolic soils (i.e., BEA-BUR soil map unit) and thin soil veneers (i.e., KIL soil map unit) that are more sensitive to disturbance.

Table 13.2-8: Soil Erosion Risk in the Local Study Area

Soil Erosion Risk	Mine LSA		NPAR LSA		Total LSA	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
High	0	0	0	0	0	0
Moderate	705	26.7	53	0.9	758	9.0
Low(Moderate)	937	35.4	3 158	54.8	4 095	48.7
Low	560	21.2	2 251	39.1	2 810	33.4
Water	347	13.1	280	4.9	627	7.5
Disturbance[a]	12	0.5	1	<0.1	13	0.2
Unclassified	83	3.1	18	0.3	101	1.2
Total	**2 644**	**100**	**5 761**	**100**	**8 405**	**100**

Note: Numbers are rounded for presentation purposes; therefore, it may appear that the totals do not equal the sum of the individual values.
[a] exploration facilities, and roads/trails.
LSA = local study area; NPAR = NICO Project Access Road; % = percent; ha = hectare; < = less than.

13.2.2.3.2 Soil Sensitivity to Acidification

Within the LSA, soil map units were assigned an acidification sensitivity rating such that, where a single soil series represents 80% or more of the map unit, only the sensitivity rating for that soil association is shown. Where a soil association represents 50 to 80% of the map unit area, the sensitivity rating of the co-dominant (40 to 50%) or sub-dominant (20 to 30%) association is presented in brackets.

The majority (53.6%) of the map units within the LSA was categorized as being sensitive (moderate) to acidification (Table 13.2-9). Soils classified as sensitive to acidification include the KIL and RAB map units, which account for 978 ha (11.6%) of the LSA, with the majority of this area (697 ha) occurring within the mine LSA. Soils in these map units are characterized by a low clay content and low organic matter content, which results in a low buffering capacity and a higher sensitivity to acidification. Wetland organic and peaty Gleysolic soils (e.g., BEA-BUR, BUR-MAR, MUS, and MUS-MAR) were categorized as having a moderate to low sensitivity to acidification. Within these map units the sensitivity decreases from moderate to low because nutrient poor bogs or nutrient rich fens have higher buffering capacities and are therefore more resistant to acidification. The moderate to low acidification sensitivity accounts for 2181 ha (25.9%) of the LSA with the majority of this area (1776 ha) occurring along the NPAR LSA.

Table 13.2-9: Acidification Sensitivity of Soils in the Local Study Area

Soil Map Unit[a]	Acidification Sensitivity	Mine LSA		NPAR LSA		Total LSA	
		Area (ha)	%	Area (ha)	%	Area (ha)	%
KIL; RAB	Sensitive	697	26.3	281	4.9	978	11.6
RAB-MAR; RAB-KIL-MAR; RAB-TUM-MAR	Sensitive (Moderate)	1 100	41.6	3 404	59.1	4 504	53.6
BEA-BUR; BUR-MAR; MUS[b]; MUS[b]-MAR	Moderate to Low	404	15.3	1 776	30.8	2 181	25.9
Water	NA	347	13.1	280	4.9	627	7.5
Disturbance	NA	12	0.5	1	<0.1	13	0.2
Unclassified	NA	83	3.1	18	0.3	101	1.2
Total		**2 644**	**100**	**5 761**	**100**	**8 405**	**100**

Note: Numbers are rounded for presentation purposes; therefore, it may appear that the totals do not equal the sum of the individual values.

[a] BEA-BUR = Bea-Burke; BUR-MAR = Burke-Marian; KIL = Killam; MUS = Muskeg; MUS-MAR = Muskeg-Marian; RAB = Rabbit; RAB_KIL_MAR = Rabbit-Killam-Marian; RAB-MAR = Rabbit-Marian; RAB-TUM-MAR = Rabbit-Tumi-Marian; Disturbance = exploration facilities and roads/trails; Unclassified = unclassified due to cloud, haze, and shadow.

[b] in areas where nutrient poor bogs and rich fens occur, the sensitivity rating will decrease to low.

LSA = local study area; NPAR = NICO Project Access Road; NA = not applicable; % = percent; < = less than

13.2.2.3.3 Soil Chemical and Nutrient Parameters

Detailed information on soil chemical and nutrient parameters can be found in the Soil and Terrain Baseline Report (Annex H). Soil nutrient availability along the proposed NPAR and within the mine LSA is generally poor. This is reflected by the low values for available nitrate-N and phosphorus in the mineral soils that are found in the LSA. Available nitrate-N, ranged from less than 1 milligram/kilogram (mg/kg) (i.e., below the detection limit) to 1.4 mg/kg in soils in the LSA. Available nitrate-N in soils along the proposed NPAR ranged from less than 1 to 6 mg/kg. Available phosphorus ranged from less than 5 to 6 mg/kg in soils in the mine LSA, and ranged from less than 1 to 6 mg/kg along the proposed NPAR. Subarctic soils are characterized by a low nutrient status (Moore 1980) and the soils sampled in the LSA and RSA reflect this as they have low values for available nitrate and phosphorus in the mineral soil. Native subarctic plant species are adapted to low nutrient content in soils.

Soil pH values varied considerably between soils in the mine LSA and soils along the proposed NPAR. Soil pH levels of the LFH (duff) horizons along the NPAR tend to be in the neutral range (pH 6.8 to 7.4), with mineral soils being neutral to slightly alkaline (pH 7.3 to 7.9) with alkalinity increasing with soil depth. In contrast, soil samples from the mine LSA are all acidic with the majority of the mineral subsoil layers falling into the strongly acidic (pH 4.5 to 5.0) to moderately acidic (pH 5.1 to 5.5) categories. These very low soil pH values likely reflect the acidic rock origin of the parent materials. Subarctic soils are typically acidic (Moore 1980) and subarctic native plant species are adapted to the acidity of these soils.

Sampling for baseline metal chemistry of soils was also completed in 2005 and 2008; however, this was completed during a separate field program. Results from the baseline metal chemistry sampling program can be found in Soil and Vegetation Chemistry Baseline Report (Annex I).

13.2.2.3.4 Soil Reclamation Suitability

Topsoils in the LSA generally have poor to fair suitability for reclamation, with 9% of the topsoils in the LSA being unsuitable for reclamation. Subsoils were predominantly categorized as poor and unsuitable for reclamation. However, the subsoil of Marian soil was rated as good for reclamation suitability, along with any soils that have developed on glacial till. Soils developed on glacial till have higher reclamation suitability because of the low stone content and fine soil textures. The extensive Organics and Organic Cryosols in the area are not given a rating and are classified as an organic category, because these materials are valuable in reclamation due to higher nutrient contents and soil moisture holding capacities and may be used as an amendment during reclamation.

The results of the baseline metal chemistry can be found in the Soil and Vegetation Chemistry Baseline Report (Annex I). The results from the metal analyses indicate there are areas (e.g., adjacent to the Grid Ponds in a marsh graminoid fen) where arsenic concentrations are naturally higher than Canadian Soil Quality Guidelines (CCME 2007). Additional sampling may be required to better evaluate the locations and/or extent of soils containing naturally high arsenic concentrations.

13.3 Pathway Analyses

13.3.1 Methods

Pathway analysis identifies and assesses the linkages between NICO Project components or activities, and the correspondent potential residual effects to terrain and soils. Potential pathways through which the NICO Project could affect terrain and soils were identified from a number of sources including:

- review of the development description and scoping of potential effects by the environmental and engineering teams for the NICO Project;
- scientific knowledge and experience with other mines in the NWT;
- engagement with the public, Aboriginal people, communities, and government; and
- consideration of potential effects identified from the TOR for the NICO Project.

The first part of the analysis is to produce a list of all potential effects pathways for the NICO Project (Section 6.4). Each pathway is initially considered to have a linkage to potential effects on terrain and soils. This step is followed by the development of environmental design features and mitigation that can be incorporated into the development description to remove a pathway or limit (mitigate) the effects to terrain and soils. Environmental design features include NICO Project design elements, environmental best practices, management policies and procedures, and social programs. Environmental design features are developed through an iterative process between the NICO Project’s engineering and environmental teams to avoid or mitigate effects.

Knowledge of the ecological system and environmental design features and mitigation is then applied to each of the pathways to determine the expected amount of NICO Project-related changes to the environment and the associated residual effects (i.e., effects after mitigation) on terrain and soils. Changes to the environment can alter measurement endpoints such as soil chemistry and quantity. For an effect to occur there has to be a source (Project component or activity) that results in a measurable environmental change (pathway) and a correspondent effect on terrain and soils.

Project activity → change in environment → effect to terrain and soils

Pathway analysis is a screening step that is used to determine the existence and magnitude of linkages from the initial list of potential effects pathways for the NICO Project. This screening step is largely a qualitative assessment, and is intended to focus the effects analysis on pathways that require a more comprehensive assessment of effects on terrain and soils. Pathways are determined to be primary, secondary (minor), or as having no linkage using scientific and traditional knowledge, logic, and experience with similar developments and environmental design features. Each potential pathway is assessed and described as follows:

- no linkage – pathway is removed by environmental design features and mitigation so that the NICO Project results in no detectable environmental change and residual effects to terrain and soils relative to baseline or guideline values;
- secondary – pathway could result in a measurable and minor environmental change, but would have a negligible residual effect on terrain and soils relative to baseline or guideline values; or
- primary – pathway is likely to result in a measurable environmental change that could contribute to residual effects on terrain and soils relative to baseline or guideline values.

Primary pathways require further effects analysis from the NICO Project on terrain and soils. Pathways with no linkage to terrain and soils or that are considered secondary (minor) are not analyzed further in the DAR because environmental design features and mitigation will remove the pathway (no linkage) or residual effects to terrain and soils can be determined to be negligible through a simple qualitative evaluation of the pathway. Pathways determined to have no linkage to terrain and soils or those that are considered secondary are not predicted to result in environmentally significant effects on terrain and soils. All primary pathways are assessed in the DAR.

13.3.2 Results

Potential pathways through which the NICO Project could affect terrain and soils are presented in Table 13.3-1. Environmental design features and mitigation incorporated into the NICO Project Description (Section 3) to remove a pathway or limit the effects to terrain and soils are listed, and pathways are determined to be primary, secondary, or as having no linkage. The following section discusses the potential pathways relevant to the terrain and soil environment.

Table 13.3-1: Potential Pathways for Effects to Terrain and Soils

<table>
<tr><th>NICO Project Component/Activity</th><th>Effects Pathways</th><th>Environmental Design Features and Mitigation</th><th>Pathway Assessment</th></tr>
<tr><td rowspan="6">Mine infrastructure footprint (e.g., Open Pit, site roads, Co-Disposal Facility, and Airstrip)

NICO Project Access Road footprint</td><td>Site clearing, contouring, and excavation can cause admixing, compaction, and increase erosion potential of soils, and change terrain</td><td rowspan="3">The current layout of the mine footprint will limit the area that is disturbed (updated from 30 January 2009).

The NICO Project Access Road will be as narrow as possible, while maintaining safe construction and operation practices.

Erosion control practices will limit wind and water erosion on soil and overburden stockpiles (e.g., vegetation, erosion mats).

Admixing of topsoil with subsoil during salvage and reclamation will be limited.

Topsoil horizons may be stripped from the mine area and then stored in stockpiles along the perimeter of the site for eventual replacement upon decommissioning and closure of the NICO Project.</td><td>Primary</td></tr>
<tr><td>Soil disturbance can change physical, biological, and chemical properties of soils, and increase erosion potential</td><td>Primary</td></tr>
<tr><td>Physical loss or alteration of local soils from the NICO Project footprint</td><td>Primary</td></tr>
<tr><td>Physical loss or alteration of permafrost from the NICO Project footprint can cause changes to terrain and soils</td><td>The current layout of the mine footprint will limit the area that is disturbed (updated from 30 January 2009).

Plant site infrastructure (buildings) foundations will be built on bedrock not susceptible to frost heave and to minimize thawing of permafrost.

The access road will be as narrow as possible, while maintaining safe construction and operation practices.

Construction will likely be completed during winter months, when possible.

Organic and/or topsoil horizons will not be stripped in areas containing ice-rich permafrost to reduce potential for an increase in thaw depth and related thaw subsidence.</td><td>Secondary</td></tr>
<tr><td>Loss or alteration of local flows, drainage patterns (distribution), and drainage areas from the NICO Project footprint can cause changes to soils</td><td>Use of culverts and other design features that reduce changes to local flows, drainage patterns and drainage areas.</td><td>Secondary</td></tr>
<tr><td>Blasting and excavation of the Open Pit can change terrain</td><td></td><td>Primary</td></tr>
</table>

Table 13.3-1: Potential Pathways for Effects to Terrain and Soils (continued)

NICO Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Operation of Co-Disposal Facility	Vertical and lateral seepage from the Co-Disposal Facility may cause changes to groundwater and surface water quality, which may affect soils	Runoff from the Co-Disposal Facility will be captured in seepage collection ponds and diverted to the Mineral Process Plant for recycling or to the Effluent Treatment Facility. At closure, runoff will flow to constructed wetlands or the Open Pit.	No Linkage
	Leaching of dissolved metals from mine rock may cause changes to groundwater and surface water quality, which may affect soils	Any potential acid-generating waste rock will be sequestered within the interior of the Co-Disposal Facility Overburden directed to the Co-Disposal Facility will be used to cover all areas in the pile where potentially metal leaching waste rock is to be sequestered to reduce any infiltration. Runoff from Co-Disposal Facility will be captured and diverted to the Effluent Treatment Facility or the Mineral Process Plant.	No Linkage
General construction and operation of mine and supporting infrastructure	Air emissions and dust deposition can cause changes to the chemical properties of soils	Watering of site roads will suppress dust production. Enforcing speed limits will assist in reducing dust. Equipment and fleet equipped with industry-standard emission control systems. Enclosing conveyance systems and processing facilities. Processing equipment with high efficiency bag houses to reduce emissions of particulate matter Operating procedures will be developed that reduce dust generation and air emissions (e.g., regular maintenance of equipment to meet emission standards).	Secondary

Table 13.3-1: Potential Pathways for Effects to Terrain and Soils (continued)

NICO Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
General construction and operation of mine and supporting infrastructure (continued)	Surface water runoff from the core mine facilities area can affect surface water quality and soils	The Water Management Plan will control surface water management on site. Runoff from the mine site will be captured and diverted to the Effluent Treatment Facility or the Mineral Process Plant. The site will have sufficient storage capacity in Surge Ponds to store both operating flows and storm events. Sewage will be treated in the Sewage Treatment Plant and the effluent will either be re-used during processing or discharged to Peanut Lake through the Effluent Treatment Facility,	No Linkage
	Spills on the mine site or along the NICO Project Access Road can affect soils	Hazardous materials and fuel will be stored according to regulatory requirements to protect the environment and workers (i.e., Materials and Waste Management Plan). Smaller storage tanks (e.g., engine oil, hydraulic oil, and waste oil and coolant) will be double walled, and located in lined and bermed containment areas. Reagents and fuel Enviro-Tanks will be located in larger, double-walled containers. Separate areas will be established for the handling and temporary storage of hazardous wastes. Domestic and recyclable waste dangerous goods will be stored on site in appropriate containers to prevent exposure until they are shipped off site to an approved facility. Individuals working on site and handling hazardous materials will be trained in the Transportation of Dangerous Goods. Soils from petroleum spill areas will be deposited and spread in a lined landfarm cell for bioremediation. An Emergency Response and Spill Contingency Plan has been developed and will be implemented. Emergency spill kits will be available wherever toxic materials or fuel are stored and transferred.	No Linkage

Table 13.3-1: Potential Pathways for Effects to Terrain and Soils (continued)

NICO Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
General construction and operation of mine and supporting infrastructure (continued)		Construction and mining equipment, machinery, and vehicles will be regularly maintained.	
	Terrain instability due to changes in the ground thermal conditions and permafrost failure may affect the NICO Project.	All mine infrastructure will be designed to be physically stable, even if the existing permafrost thaws. Plant site infrastructure (buildings) foundations will be built on bedrock not susceptible to frost heave, where possible.	Secondary
Post-closure	Residual ground disturbance can cause permanent alteration of terrain and soils.	Limit size of NICO Project footprint (footprint will be smaller than that proposed in 2009 application). Soil salvage and reclamation. Develop a closure and reclamation plan Co-Disposal Facility will be capped during closure to isolate Mine Rock and tailings and prevent leaching. Constructed wetlands will be established to treat seepage water.	Primary
	Long-term seepage from the Co-Disposal Facility can change ground water and surface water quality, which can affect soils	Co-Disposal Facility will be capped during closure to isolate Mine Rock and tailings and minimize leaching. Constructed wetlands will be established to treat seepage water.	No Linkage

13.3.2.1 Pathways with No Linkage

A pathway may have no linkage if the pathway is removed by environmental design features and mitigation so that the NICO Project results in no detectable environmental change and no residual effects to terrain and soils relative to baseline or guideline values. The pathways described in the following bullets have no linkage to terrain and soils, and will not be carried through the effects assessment.

- **Vertical and lateral seepage from the Co-Disposal Facility may cause changes to groundwater and surface water quality, which may affect soils.**
- **Leeching of dissolved metals from Mine Rock may cause changes to groundwater and surface water quality, which may affect soils.**
- **Long-term seepage from the Co-Disposal Facility can change ground water and surface water quality, which can affect soils.**

During the life of the NICO Project, there is the potential for leachate (e.g., metals) from the tailings and mine rock Co-Disposal Facility (CDF) to seep through the co-disposed materials and report as seepage into the Seepage Collection Ponds. Additionally, there is potential for arsenic as well as other metals (i.e., aluminum, arsenic, cadmium, cobalt, lead, selenium, and uranium) to be present in the leachate. Such water-borne elements could adversely affect soils through surface water runoff and seepage. Environmental design features and mitigation have been incorporated into the NICO Project to reduce the potential for water to contact metal leaching Mine Rock, tailings, and potentially acid generating rock and thus, reducing potential effects to the environment from surface water runoff and seepage from the CDF (Table 13.3-1).

The CDF is designed to limit runoff and seepage from contacting tailings and metal leaching Mine Rock by placing this material in the interior of the CDF interlayered with tailings. The cover placed on the top of the CDF at closure, will limit infiltration into the interior of the CDF where potentially acid generating and metal leaching rock is located.

Runoff and seepage from the CDF will not be released directly to the environment during construction, operations, closure, and post closure. Runoff and seepage from the CDF will report to 1 of 5 Seepage Collection Ponds (SCPs). During operations, water in the SCPs will be pumped to the Surge Pond. Water from the Surge Pond will be pumped for use in the Mineral Process Plant (Plant) or pumped to the Effluent Treatment Facility for treatment prior to release into Peanut Lake.

At closure, the entire surface of the CDF will be covered; thereafter, runoff from the CDF will not be in contact with the Mine Rock or tailings materials. Seepage out of the toe of the CDF will continue to be collected in the Seepage Collection Ponds. Water from Seepage Collection Ponds No.s. 1, 2, 3, and 5 and the Surge Pond will pass through constructed Wetland Treatment Systems prior to release into Nico Lake. The use of wetland treatment will be subject to demonstration of its technical feasibility by testing during the operating life of the mine. The Open Pit will slowly flood after closure. The water level is expected to reach Elev. 260 m roughly 120 years after closure, at which point it will overflow. At that time the Flooded Open Pit overflow water will be directed through a ditch to Wetland Treatment System No. 4, which will discharge into Peanut Lake.

At closure, the top surface of the CDF will be covered with a 0.5 m layer of glacial till underlain by a 0.25 m layer of sand. The top surface of the CDF will be sloped towards the west to shed water and to reduce net infiltration of precipitation. The sand layer will serve as a capillary break to limit the potential for upward flux of tailings pore water. This will reduce the potential for metal contamination of soils.

The Grid ponds area currently produces measureable natural arsenic loadings into Nico Lake. After construction, all releases from the NICO Project site into Nico or Peanut Lake will be subject to monitoring and treatment by active or passive means. Overall, release of runoff and long-term seepage from the CDF is not expected result in a detectable change to soils relative to baseline conditions. Consequently, these pathways were determined to have no linkage to effects on soils.

- **Surface water runoff from the core mine facilities area can affect surface water quality and soils**

Surface water runoff from the Open Pit and the Plant facilities area could potentially affect soils. These facilities incorporate several environmental design features to prevent release of untreated site water into the receiving environment (Table 13.3-1).

During operations, water that collects in the Open Pit sump, which will include seepage into the Open Pit as well as runoff from rainfall and snow, will be pumped to the Surge Pond. Runoff from the Plant will be collected in a site runoff collection pond and then transferred to the Surge Pond. Sewage will be treated in a Sewage Treatment Plant and treated liquid will also be discharged into the Surge Pond. Water collected in the Surge Pond will be reclaimed to the Plant to the extent that it is needed; all excess water will be pumped to the Effluent Treatment Facility. Following treatment, the water will be discharged through a diffuser into Peanut Lake.

After closure, dewatering of the Open Pit will cease and the Open Pit will slowly fill with water. The water level is expected to reach Elev. 260 m roughly 120 years after closure, at which point it will overflow. At that time, the overflow water from the Open Pit will be treated by one of several potential methods described in Section 3.9.4.3. After treatment, the Open Pit water will discharge into Peanut Lake. At closure, the Plant will be demolished and the area will be covered with till and re-vegetated. Runoff from part of the area will drain into the Surge Pond and then into Wetland Treatment System No. 4. Runoff from the remainder of the area will drain directly into Wetland treatment System No. 4, which will discharge into Nico Lake. Closure of the CDF will focus on reducing the risk of wind and water erosion of tailings. The exposed tailings will be covered with a 0.5 m thick layer of glacial till underlain by a 0.25 m layer of sand. Erosion control practices (e.g., erosion mats) will be used to limit erosion of topsoil stockpiles.

Implementation of these environmental design features is expected to result in no detectable changes to soil adjacent to the NICO Project. Subsequently, this pathway was determined to have no linkage to effects on soils.

- **Spills on the mine site or along the NICO Project Access Road can affect soils**

Chemical spills on other northern mine sites are usually localized, and are quickly reported and managed (Tahera 2008; BHP Billiton Diamonds Inc. 2010; Diavik Diamond Mines Inc. 2010; De Beers 2010). Mitigation identified in the Emergency Response and Spill Contingency Plan (Appendix 3.VI) and environmental design features will be in place to limit the frequency and extent of spills that result from NICO Project activities (Table 13.3-1). Hazardous materials and fuel will be stored according to regulatory requirements to protect the environment and workers (i.e., Hazardous Substances Management Plan; Appendix 3.V). Smaller storage tanks (e.g., engine oil, hydraulic oil, waste oil, and coolant) will be double walled, and located in lined and bermed containment areas. Individuals working on site and handling hazardous materials will be trained in the

Transportation of Dangerous Goods. Emergency spill kits will be available wherever toxic materials or fuel are stored and transferred.

The implementation of the Emergency Response and Spill Contingency Plan and environmental design features are anticipated to reduce the frequency, spatial extent, and severity of spills on the environment. Thus, spills in the mine area and on the NPAR are predicted to result in no detectable changes to soil quality. Consequently, this pathway was determined to have no linkage to effects on soils.

13.3.2.2 Secondary Pathways

In some cases, both a source and a pathway exist, but the change caused by the NICO Project is anticipated to result in a minor environmental change, and would have a negligible residual effect on terrain and soils relative to baseline or guideline values (Table 13.3-1). The pathways described in the following bullets are expected to be secondary and will not be carried through the effects assessment.

- **Physical loss or alteration of permafrost from the NICO Project footprint can cause changes to terrain and soils**
- **Terrain instability due to changes in the ground thermal conditions and permafrost failure may affect the NICO Project.**

Permafrost across the landscape that contains the RSA has been mapped and described as extensive discontinuous permafrost (Natural Resources Canada 1993). Freeze induced displacement of soil (i.e., frost jacking) and thaw induced displacement (i.e., subsidence) of soil are the main issues related to permafrost degradation (i.e., loss or alteration). Changes to thaw penetration and thickness of the active layer can influence surface stability through thaw settlement, frost heave, and bearing capacity, as well as slope stability (Tarnoicai et al. 2004). Changes can also affect hydrology, soil moisture, and nutrient availability, thereby influencing the ecology of an area by affecting vegetation.

The ice content of the upper 10 to 20 m of the ground within the RSA is described as having low to moderate ice content with sparse areas that contain ice wedges and pingo ice (i.e., ice-rich permafrost) (Natural Resources Canada 1993). Permafrost that occurs within the NICO Project footprint is described as having low ice content, and is limited in spatial extent and thickness (Golder 2010). The amount of ground ice present within the permafrost is important for assessing the response of permafrost to clearing, construction, and subsequent recovery of ice conditions following disturbance (Jorgenson et al. 2010). The magnitude of changes to permafrost thermal regimes and potential thaw settlement is directly related to the nature and abundance of ground ice and the type and severity of disturbance at the surface (Lawson 1986; Pullman et al. 2007). Knowledge of the potential magnitude of thaw settlement is important for assessing placement and construction of NICO Project components, the long term recovery of disturbed areas, and developing reclamation and rehabilitation plans. Warmer permafrost, as in the discontinuous permafrost zone, is susceptible to long term degradation as a result of surface disturbances (Nolte et al. 1998). Clearing of an area and subsequent construction activities are anticipated to cause permafrost to slowly degrade due to ground thermal changes resulting from removal and disturbance of vegetation. Once permafrost degrades, it can result in changes to surface relief, and subsequently influence the surface drainage of an area (Lawson 1986). Areas with high ground ice content (i.e., terrain with abundant ice wedges) should be avoided where possible. These areas are more sensitive to thaw-settlement and can result in longer-term changes in terrain, soils, and surface hydrology

(Jorgenson et al. 2010). Conversely, areas with small volumes of ground ice are not as sensitive to thaw settlement (Lawson 1986).

Numerous factors affect the magnitude of changes to permafrost areas and influence recovery of an area following disturbance, and include: type of construction activities, site infrastructure, vegetation, soil type, soil texture, density, water content, and snow depth (Lawson 1986; Nolte et al. 1998; Jorgenson et al. 2010). For example, soil type influences the thermal regime of permafrost because heat loss tends to be more rapid from mineral soils as the thermal conductivity of a mineral soil is usually higher than in an organic soil (Woo and Winter 1993). Thaw settlement caused by disturbance and subsequent melting of permafrost can initially lead to water impoundment, decreased albedo, and an increase in heat flux, which in turn causes more thaw settlement (Jorgenson et al. 2010). This can result in a change in surface hydrology that shifts recovery patterns towards new plant communities, further influencing permafrost. The depth of the active layer may continue to increase as a result of disturbance (Burgess and Harry 1990; Burn and Smith 1993; Hayhoe and Tarnocai 1993). Jorgenson et al. (2010) found that the thaw depth continued to increase for 3 to 8 years after disturbance prior to stabilizing and recovering. Stabilization or re-establishment of equilibrium between climate and permafrost will eventually occur but may take decades, depending on the severity of the disturbance (Nolte et al. 1998; Jorgenson et al. 2010).

Mitigation and environmental design features to reduce the potential for permafrost melting, and subsequent thaw subsidence of areas include:

- clear areas for construction from a snow packed surface, during winter months;
- re-vegetate disturbed areas as soon as possible;
- use culverts to maintain surface drainage and reduce pooling of water at the surface;
- limit the mine footprint disturbance area;
- limit the road footprint disturbance area, while maintaining safe construction and operation practices;
- insulate infrastructure, where possible;
- build the foundations of buildings on bedrock not susceptible to frost heave to minimize thawing of permafrost in sensitive areas; and
- do not strip organic and/or topsoil horizons in areas containing ice-rich permafrost to reduce potential for an increase in thaw depth and related thaw subsidence.

The CDF and the dams associated with the Seepage Collection Ponds are not expected to be affected by changes to ground thermal conditions and permafrost as these structures do not rely on permafrost to operate correctly. They are designed to be physically stable even if the existing permafrost beneath the foundations of the structures thaws. The creation of permanent Seepage Collection Ponds will change the local thermal regime and thaw any permafrost in the soils below them. Geotechnical investigations within the NICO Project footprint indicate that the presence of permafrost is limited in spatial extent, and thickness (Golder 2010). The resulting differential settlements or subsidence due to the thawing of permafrost are expected to be minor and are not expected to affect the integrity of the dams and infrastructure. The construction of the CDF will change the thermal regime that pre-existed in the Grid Ponds area. After closure, the active freeze-thaw zone will be at the surface of the raised CDF structure. Permafrost may eventually form and accumulate within the CDF, which would result in decreased water infiltration and oxygen into the tailings and mine rock materials.

Mitigation and environmental design features to reduce the potential effects of permafrost melting on the NICO Project include the following:

- all mine infrastructure will be designed to be physically stable, even if existing permafrost thaws; and
- infrastructure (buildings) foundations will be built on bedrock not susceptible to frost heave, where possible.

The NICO Project infrastructure has been designed to withstand minor thaw settlements due to potential permafrost melting. Change in the local thermal regime and permafrost distribution is expected to result in a negligible effect on the NICO Project. In addition, by implementing mitigation practices and environmental design features, the change to permafrost from the NICO Project is anticipated to be minor relative to baseline conditions (secondary; Table 13.3-1); therefore, the residual effects to terrain and soils are predicted to be negligible.

- **Loss or alteration of local flows, drainage patterns (distribution), and drainage areas from the NICO Project footprint can cause changes to soils**

Water diversions are not required for the development of the NICO Project infrastructure footprint, as the footprint is located near the top of a watershed; however, the CDF will eliminate the Grid Ponds, which are situated in a runoff catchment. The loss of the Grid Ponds is expected to result in represent minor fluctuations in water level relative to baseline values of Nico Lake (Section 11.3.2.2).

Because treated effluent will immediately mix with water from Peanut Lake, flows from Peanut Lake into Burke Lake will be increased during periods of effluent discharge. In general, the influence of discharge from the NICO Project to Peanut Lake is anticipated to result in little to no effect on water levels in downstream waterbodies, including Ponds 11, 12, and 13, and Burke Lake relative to baseline conditions (Section 11.3.2.2). The water management system for the NICO Project has been optimized in terms of internal recycling within the Plant, thickening of the tailings, and high level of reclaim water from the CDF back to the Plant. The implementation of the mitigation practices and environmental design features is expected to result in a minor change (secondary pathway) to the hydrology in the LSA from the NICO Project relative to baseline conditions, which should have a negligible effect on Peanut Lake and downstream waterbodies such as Pond 11, 12, and 13, and Burke Lake.

The NPAR will cross 9 streams. To mitigate effects to local flows, drainage patterns, and drainage areas along the NPAR, a bridge will be built to cross the Marian river, while all other streams, because they are ephemeral, will be culverted.The mine infrastructure and NPAR footprints are not predicted to change local flows, drainage patterns, and drainage areas outside the range of baseline values. Therefore, the residual effects to soil are predicted to be negligible.

- **Air emissions and dust deposition can cause changes to the chemical properties of soils**

Accumulation of dust (i.e., particulate matter [PM] and total suspended particulate [TSP] deposition) and concentrations of air emissions produced from the NICO Project may result in a local indirect change on the quality of soil within the LSA. Air quality modelling was completed to predict the spatial extent of dust deposition and air emissions from the NICO Project (Section 10.4). Sources of dust deposition and air emissions modelled in the application case (maximum effect case) include blasting activities, haul roads, the Plant, activities at the

Open Pit and other ancillary facilities (e.g., CDF), and vehicle traffic along the NPAR and Proposed Tłįchǫ Road Route. Environmental design features and mitigation have been incorporated into the NICO Project to reduce potential effects from dust deposition (Table 13.3-1). For example, the watering of roads, Airstrip, and laydown areas during the non-winter period will facilitate dust suppression. In addition, programs will be implemented to review power and heat use to reduce energy use. Although these environmental design features and mitigation should reduce dust deposition and air emissions, assumptions incorporated into the model are expected to contribute to conservative estimates of emission concentrations and deposition rates (Section 10.4).

Trucks travelling on the winter roads, NPAR, and the Proposed Tłįchǫ Road Route have the potential to transfer dust from vehicles and loads (e.g., dust deposited on wheels and undercarriage while at the NICO Project and in Yellowknife); however, the relative contribution of these loads to the overall dust accumulation in the area along the roads is considered to be negligible (Section 10.4). Similarly, dust generation from NICO Project vehicles along the NPAR and Proposed Tłįchǫ Road Route would occur annually, but would likely be higher during the non-winter period and not continuous (i.e., would occur less frequently during wet and cool conditions). Dust deposition is expected to result in minor and localized changes to vegetation along the right-of-ways for the NPAR and Tłįchǫ Road Route. For example, Walker and Everett (1987) and Everett (1980) reported that effects were confined to a 50 m buffer on either side of a road. Moreover, Meininger and Spatt (1988) found that most of effects occurred within 5 to 50 m of a road, with less obvious effects observed between 50 m and 500 m from a road. Dust deposition from vehicles along the NPAR and the Proposed Tłįchǫ Road Route are predicted to result in negligible residual effects to the persistence of plant populations and communities.

Air emissions from vehicles along the NPAR and existing winter roads were included in the application case and assumed that winter roads were in operation for 63 days for construction, after which the NPAR and the Proposed Tłįchǫ Road Route would be open all year round. In general, emissions from the roads are small, and if extended over the whole year, a negligible effect from annual depositions was predicted (Section 10.4). Annual emissions from the roads are anticipated to result in no detectable changes to soils.

The results of the air quality modelling predicted that the maximum annual dust deposition resulting from the NICO Project is 1083 grams per square metres per year ($g/m^2/y$) within the NICO Project Lease Boundary, and 151 $g/m^2/y$ outside of the NICO Project Lease Boundary (Table 13.3-2). Further, modelling showed minimal dust deposition (i.e., <79 $g/m^2/y$) beyond approximately 280 m from the NICO Project Lease Boundary (i.e. there should be limited dust deposition outside of the LSA) (Figure 13.3-1). The only area that is predicted to receive dust (i.e., TSP) beyond the NICO Project Lease Boundary is a small area north of the NICO Project Lease Boundary (Figure 13.3-1). The major sources of dust will be associated with the Open Pit and haul roads. The major sources of dust will be associated with the Open Pit and haul roads. The strongest effects from dust are generally confined to the immediate area adjacent to the dust source, such as roads (Walker and Everett 1987). Walker and Everett (1987) and Everett (1980) reported that effects were confined to a 50 m buffer on either side of a road.

Acid deposition from air emissions includes the deposition of sulphur oxides, nitrogen oxides, hydrogen, metals, and some organic compounds (Rusek and Marshall 2000) onto soil and vegetation. Potential acid input from air emissions can change the chemical properties of soil and water. For potential acid input and the application case, air quality modelling showed that maximum deposition rates reach 2.29 kiloequivalent per hectare per year (keq/ha/y) within the NICO Project Lease Boundary, and 0.34 keq/ha/y for areas beyond the NICO Project Lease Boundary (Table 13.3-2). The maximum deposition rates occur in the middle of the NICO Project Lease

Boundary in the vicinity of the Plant, Open Pit, and haul roads. The area outside the NICO Project Lease Boundary that is predicted to be above the critical load of 0.25 keq/ha/y is entirely within the LSA and only includes a small section extending up to about 300 m from the north/northwest boundary of the lease (Figure 13.3-2). The majority of the soils in the LSA (53.6%) were categorized as being sensitive (moderate) to acidification, and 25.9% of soils in the LSA were categorized as having a moderate to low sensitivity to acidification (Section 13.2.2). At potential acid input levels below 0.25 keq/ha/y, it is expected that sensitive soils would likely not be affected by acid deposition relative to baseline conditions.

Table 13.3-2: Summary of Predicted Annual Deposition Rates from the NICO Project

Substance	Criteria	Maximum Predicted Deposition Rate			
		Local Study Area Baseline	Application		
			Outside NICO Project Lease Boundary	Distance to Maximum from Project Centre (km)	Approximate Direction to Maximum
TSP	None	0.00 $g/m^2/y$	151 $g/m^2/y$	1.7	NW
PM_{10}	None	0.00 $g/m^2/y$	60 $g/m^2/y$	1.7	NW
$PM_{2.5}$	None	0.00 $g/m^2/y$	0.6 $g/m^2/y$	1.7	NW
PAI	0.25 keq/ha/y[a]	0.06 keq/ha/y	0.3 keq/ha/y	1.7	NW

[a] criteria is based on the Clean Air Strategic Alliance (CASA 1999)

m = metre; $g/m^2/y$ = grams per square metres per year; keq/ha/y = kiloequivalent per hectare per year; TSP = total suspended particulate; $PM_{2.5}$ = fine particles of 2.5 micrometres or less in size; PM_{10} = fine particles of 10 micrometres or less in size; PAI = potential acid input.

The air emission modelling results show that predicted peak concentrations for SO_2 during operations are below the Ambient Air Quality Standards for NWT (Table 13.3-3); however, annual peak concentrations for NO_2 are predicted to slightly exceed guidelines outside of the NICO Project footprint, reaching levels of 68 micrograms per cubic metre ($\mu g/m^3$). The predicted distance to maximum NO_2 predictions is 1.7 km from the NICO Project centre. The spatial extent that is predicted to exceed the NWT standard is 4 ha in size and located north/northwest of the NICO Project Lease Boundary and within the LSA. Nitrogen dioxide concentrations exceed guidelines for a distance of about 250 m from the NICO Project Lease Boundary (Figure 13.3-2). For TSP, the maximum predicted dust concentration rate will occur within 1.7 km of the NICO Project centre (Table 13.3-3). Total suspended particulate air concentrations are predicted to exceed guidelines within 500 m of the NICO Project Lease Boundary, but total suspended particulate concentrations will be below recommended guidelines outside of the LSA (Figure 13.3-1).

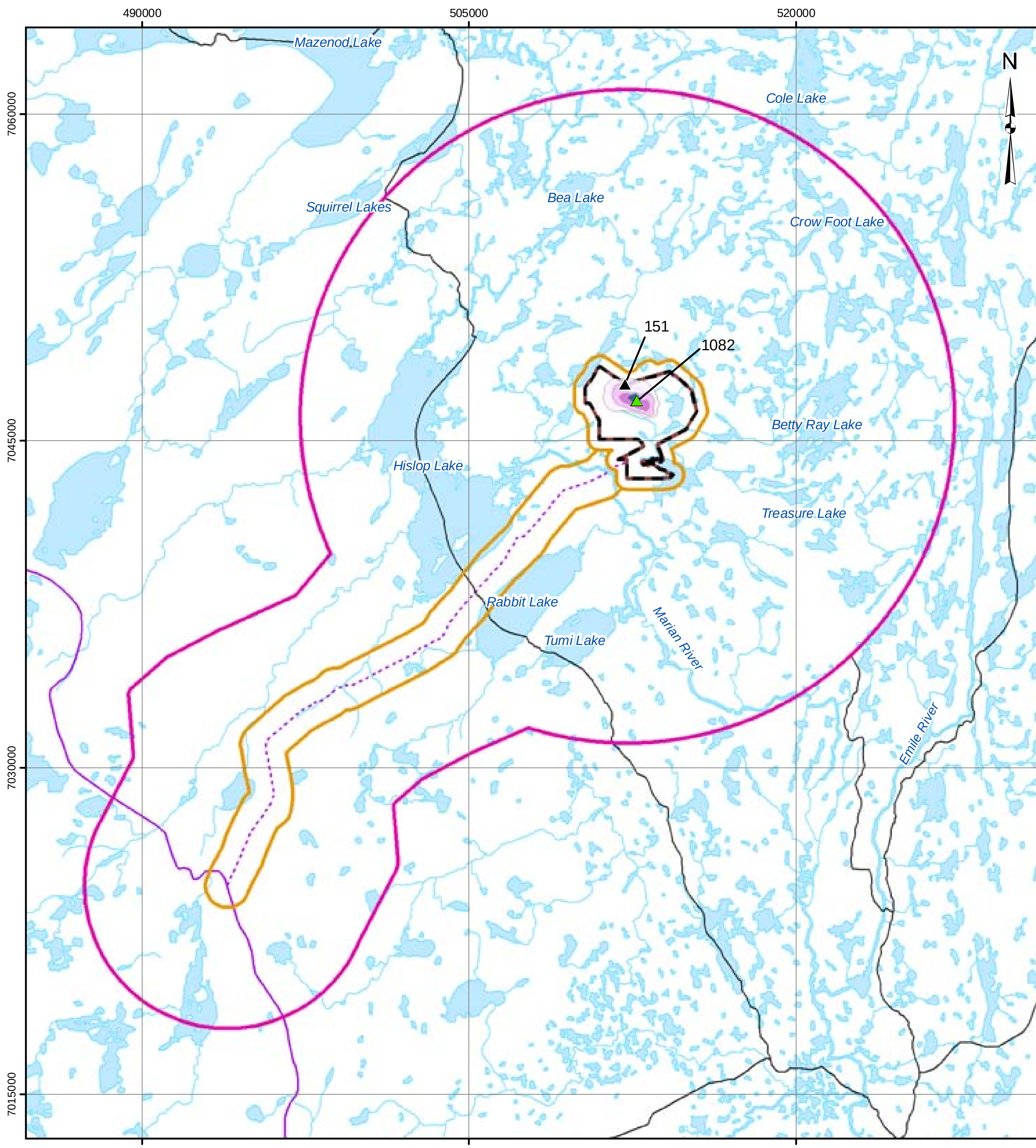
Table 13.3-3: Summary of Predicted Annual Air Quality Concentrations from the NICO Project

Substance	Criteria ($\mu g/m^3$)[a]	Maximum Predicted Concentration			
		Baseline	Application		
		Concentrations in the Regional Study Area ($\mu g/m^3$)	Concentrations Outside NICO Project Lease Boundary ($\mu g/m^3$)	Distance to Peak Predictions from Project Centre (km)	Approximate Direction to Maximum
NO_2	60	2	68.4	1.7	NW
SO_2	30	0.5	1.0	1.7	NW
TSP	60	2.2	166.0	1.7	NW

[a] standard based on Ambient Air Quality Standards for NWT.

$\mu g/m^3$ = micrograms per cubic metre;NO_2 = nitrogen dioxide. SO_2 = sulphur dioxide.

Although concentrations are predicted to be above baseline conditions, the anticipated changes to soils are localized and considered minor, which should have a negligible effect on soil quality. Maximum reported values are, in part, a consequence of local topography and a small area northwest of the NICO Project where there were moderate changes in elevation (e.g., hill or cliff). Deposition patterns depend mainly on local topography and plant cover (Rusek and Marshall 2000). The maximum predicted annual deposition rate of potential acid input and maximum concentration of NO_2 are both expected to occur within 1.7 km of the NICO Project centre and have values exceeding guidelines for only a short distance outside the north/northwest of the NICO Project Lease Boundary (i.e., all values are below recommended guidelines outside of the LSA). The deposition predictions are considered to be conservative, and therefore the presented deposition rates are likely overestimated. Overall, changes in soil quality due to dust deposition and air emissions are anticipated to be minor relative to baseline conditions (secondary pathway; Table 13.3-1).



LEGEND

- PROJECT LEASE BOUNDARY
- EXISTING WINTER ROAD
- PROPOSED NICO PROJECT ACCESS ROAD
- PROPOSED TŁICHO ROAD ROUTE
- WATERCOURSE
- WATERBODY
- LOCAL STUDY AREA
- REGIONAL STUDY AREA
- MAXIMUM PREDICTION WITHIN LOCAL STUDY AREA EXCLUDING PROJECT LEASE BOUNDARY
- MAXIMUM PREDICTION WITHIN LOCAL STUDY AREA

DEPOSITION (g/m^2/yr)

- >= 631
- 316 to < 631
- 158 to < 316
- 79 to < 158
- 0 to < 79

5 0 5

SCALE 1:250,000 KILOMETRES

REFERENCE

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

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

DISTRIBUTION OF ANNUAL TOTAL SUSPENDED PARTICULATE DEPOSITION RATE DURING NICO PROJECT OPERATIONS

Golder Associates
Edmonton, Alberta

FILE No. E-Soil-024-GIS

PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	JV	15 Feb. 2011	FIGURE: 13.3-1	
GIS	MK	23 Feb. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

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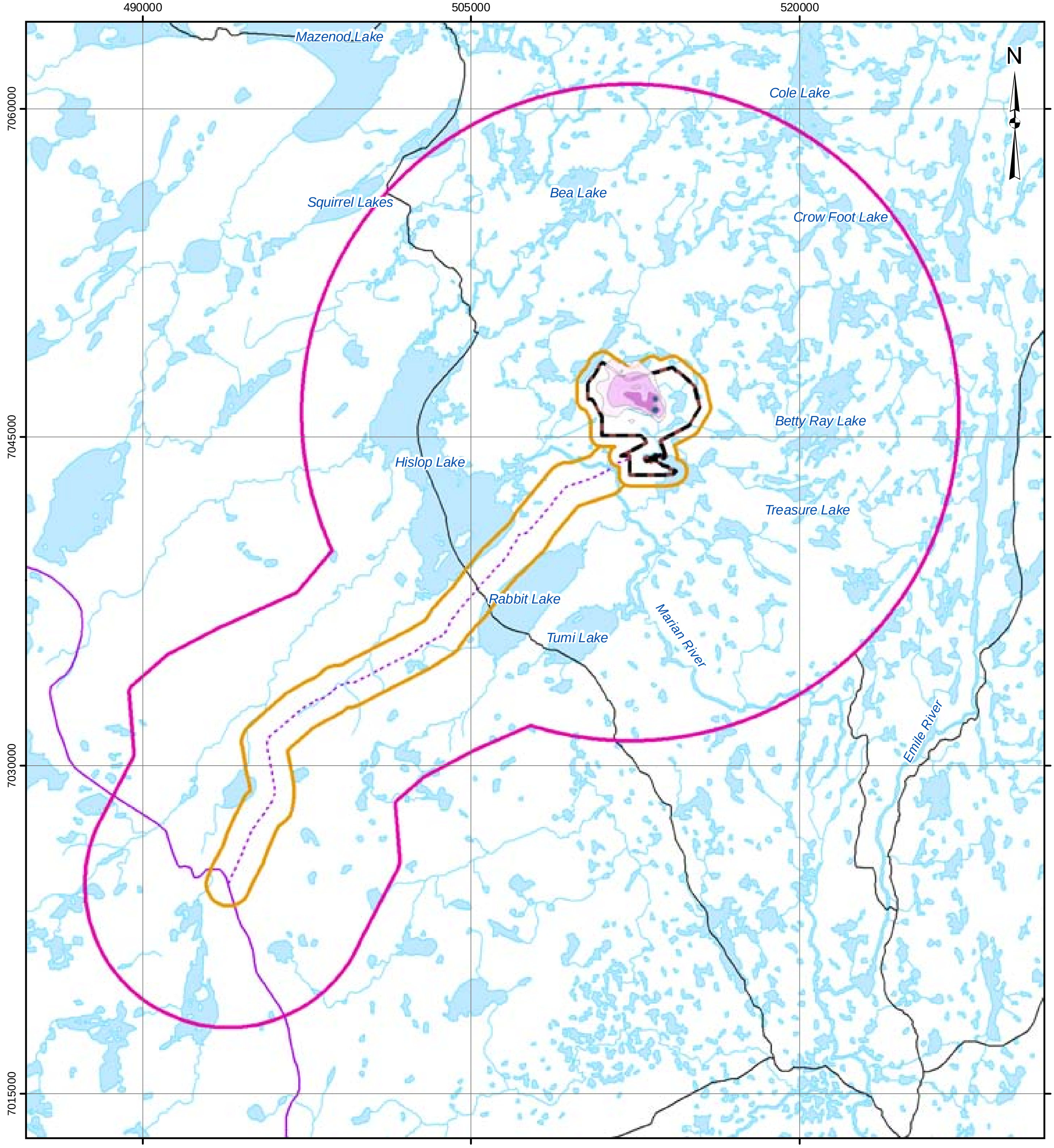

5 0 5

SCALE 1:250,000 KILOMETRES

LEGEND

- PROJECT LEASE BOUNDARY
- EXISTING WINTER ROAD
- PROPOSED NICO PROJECT ACCESS ROAD
- PROPOSED TŁĮCHǪ ROAD ROUTE
- WATERCOURSE
- WATERBODY
- LOCAL STUDY AREA
- REGIONAL STUDY AREA

DEPOSITION (keq/ha/yr)

- >= 1
- 0.5 to < 1
- 0.25 to < 0.5
- 0.17 to < 0.25
- 0 to < 0.17

REFERENCE

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

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

DISTRIBUTION OF ANNUAL POTENTIAL ACID INPUT DURING NICO PROJECT OPERATIONS

Golder Associates
Edmonton, Alberta

FILE No. E-Soil-025-GIS			
PROJECT No. 09-1373-1004		SCALE AS SHOWN	REV. 0
DESIGN	JV	15 Feb. 2011	FIGURE: 13.3-2
GIS	ANK	16 Feb. 2011	
CHECK	GRA	13 Apr. 2011	
REVIEW	GRA	13 Apr. 2011	

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13.3.2.3 Primary Pathways

The following primary pathways are analysed in the effects assessment:

- site clearing, contouring, and excavation can cause admixing, compaction, thawing of permafrost, and increase erosion potential, and change terrain;
- soil disturbance can change physical, biological, and chemical properties of soils, and increase erosion potential;
- physical loss or alteration of soils from the NICO Project footprint;
- blasting and excavation of the Open Pit and construction of the CDF can change terrain; and
- residual ground disturbance can cause permanent alteration of terrain and soils.

13.4 Effects to Terrain and Soils

13.4.1 Effects to Terrain Units, Soil Quantity, and Distribution

Site clearing and construction for the NICO Project, particularly through the processes of soil stripping and storage, will result in changes to soil quantity and distribution, and changes to terrain. Soil removal will occur mainly during the construction phase of the NICO Project, and to a much lesser extent during operation (e.g., as Open Pit blasting activities will occur primarily on bare bedrock). During closure and reclamation, the soil (i.e., growth media) will be re-constructed as outlined in the KLOI Closure and Reclamation (Section 9).

Areas that are expected to be reclaimed at closure include the CDF and associated areas of disturbance, the laydown area and mine portal, the Plant, Camp, Airstrip, growth media stockpiles, Borrow Sites, mine site access roads, and associated site infrastructure. Closure is the period during the decommissioning and reclamation phase of the NICO Project when infrastructure is dismantled and initial reclamation of the NICO Project surface footprint is completed. Areas that are expected not to be reclaimed include the Open Pit, constructed wetlands, Seepage Collection/Surge Ponds, and excavated ditch. Following closure, it is anticipated that the CDF will be covered; the NPAR, Airstrip, buildings, and related structures will be dismantled or demolished and removed.

With appropriate soil salvage and reclamation techniques, soils can be returned to the landscape and support natural plant communities. Terrain can be contoured, to the extent practical, to blend the residual footprint with the surrounding landscape. However, terrain and soil can be altered or lost through the following NICO Project components and activities:

- wind and water erosion during construction and reclamation phases;
- changes to terrain during blasting and excavation of the Underground Mine and Open Pit; an
- residual ground disturbance from permanent NICO Project components.

13.4.1.1 Methods

Changes to terrain (i.e., terrain map units) and soil quantity and distribution (i.e., soil map units) are assessed for the maximum predicted point of development of the NICO Project footprint (application case), which should have the largest geographic extent of effects on terrain and soil. Changes to terrain and soil distribution directly affected by the NICO Project were quantified by GIS analysis using the following process:

- the GIS quantified areas of terrain and soil map units within the LSA for the baseline case, application case, and closure; and
- the net changes in terrain and soil map unit distribution were calculated between the baseline case and closure.

13.4.1.2 Results

13.4.1.2.1 Effects to Terrain Units and Distribution

The maximum amount of disturbance area from the NICO Project footprint is predicted to be approximately 486 ha (5.8% of the LSA) (Table 13.4-1 and Figure 13.4-1 a, b). The area of net change for each terrain map unit is described in relation to the LSA (Table 13.4-1; Figure 13.4-2 a, b). For example, approximately 11.5% of the glaciofluvial, bedrock, and organic (Fg(R)-O) terrain map unit within the LSA will be disturbed. Following reclamation, the Fg(R)-O terrain map unit will be altered and subsequently gained within the reclaimed terrain map unit (Table 13.4-1 and Figure 13.4-2 a, b). An area of approximately 402 ha (4.8% of the LSA) within the NICO Project footprint is expected to be reclaimed following closure (Table 13.4-1; Figure 13.4-2 a, b). The area of residual ground disturbance (i.e., Flooded Open Pit, constructed wetlands, Seepage Collection/Surge Ponds, and excavated ditch) is predicted to be approximately 84 ha (1.0% of the LSA) as these areas will not be reclaimed at closure. The Open Pit will eventually fill with water and the constructed wetlands, Seepage Collection/Surge Ponds, and excavated ditch will also contain water following closure (Figure 13.4-2 a, b).

Table 13.4-1: Comparison of Terrain Map Unit Distribution between the Baseline Case and Closure Case in the Local Study Area

Terrain Map Unit[a]	Baseline Case		Application Case		Area of Maximum Disturbance[b] (ha)	Closure Case (ha)	Closure Net Change (ha)	Closure Net Change (% unit)	Closure Net Change (% of LSA)
	Area (ha)	Proportion of LSA (%)	Mine Footprint[b] (ha)	NPAR[b] (ha)					
Fg	229	2.7	<0.1	5	5	224	-5	-2.2	-0.1
Fg-O	3 166	37.7	23	69	93	3 073	-93	-2.9	-1.1
Fg(R)-O	1 338	15.9	140	13	153	1 185	-153	-11.5	-1.8
O	9	0.1	<1	0	<1	9	<-1	-3.3	<-0.1
N	1 304	15.5	33	18	50	1 254	-50	-3.9	-0.6
B	867	10.3	27	9	37	831	-37	-4.2	-0.4
R	749	8.9	125	1	126	623	-126	-16.9	-1.5
W	627	7.5	7	<1	7	621	-7	-1.1	-0.1
Disturbance	13	0.2	9	<1	9	5	-9	-66.1	-0.1
Unclassified	101	1.2	5	<1	5	96	-5	-5.3	-0.1
Following Closure									
Reclaimed	--	--	--	--	--	402	402	100.0	4.8
Residual Disturbance[c]	--	--	--	--	--	84	84	100.0	1.0
Total	**8 405**	**100**	**370**	**116**	**486**	**8 405**	**0**	**na**	**0**

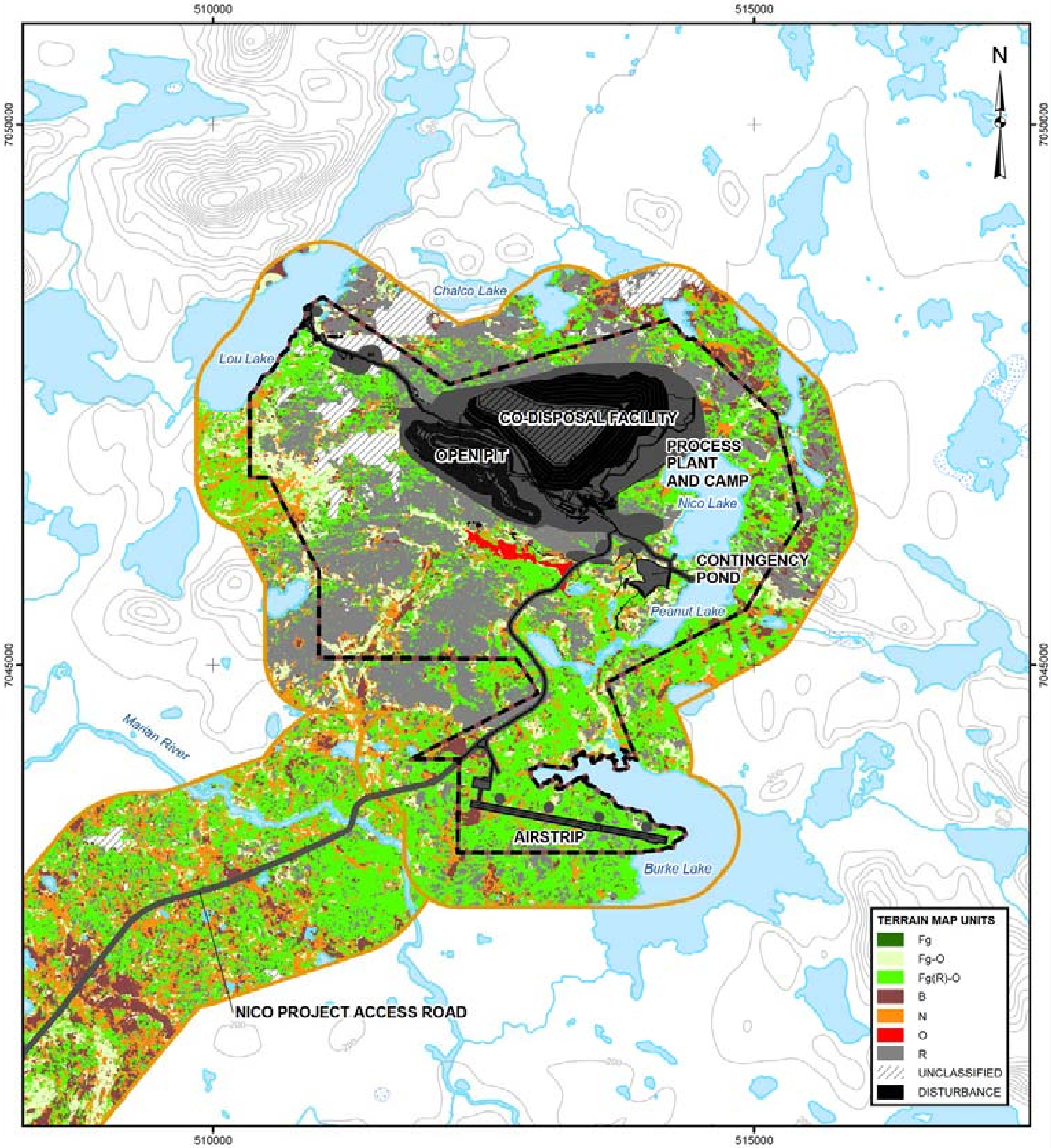
Note: Numbers are rounded for presentation purposes; therefore, it may appear that the totals do not equal the sum of the individual values.

[a] Fg = glaciofluvial; Fg-O = glaciofluvial and organic; Fg(R)-O = glaciofluvial, bedrock, and organic; O = shallow organic veneers and shallow to deep bogs (frozen); N = fen; B = bog; R = bedrock; W = water; Disturbance = anthropogenic disturbance; Unclassified = unclassified due to cloud, haze, and shadow.

[b] maximum amount of disturbance during the NICO Project.

[c] areas of residual disturbance are those areas that will not be reclaimed

LSA = Local Study Area; NPAR = NICO Project Access Road; na = not applicable; ha = hectare; % = percent; < = less than.



1 0 1

SCALE 1:50,000 KILOMETRES

LEGEND

- PROJECT LEASE BOUNDARY
- PROPOSED NICO MINE SITE
- CONTOUR (10 METRE INTERVAL)
- WATERCOURSE
- WATERBODY
- WETLAND
- LOCAL STUDY AREA
- AREA OF MAXIMUM DISTURBANCE FOR NICO PROJECT

NOTE: Terrain map unit descriptions can be found in Table 13.2-3 of the report. Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference.

REFERENCE

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

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

TERRAIN MAP UNIT DISTRIBUTION AT MAXIMUM DISTURBANCE

Golder Associates
Edmonton, Alberta

FILE NO. E-Soil-016-GIS				
PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	FIGURE: 13.4-1a	
GIS	SK	01 Feb. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

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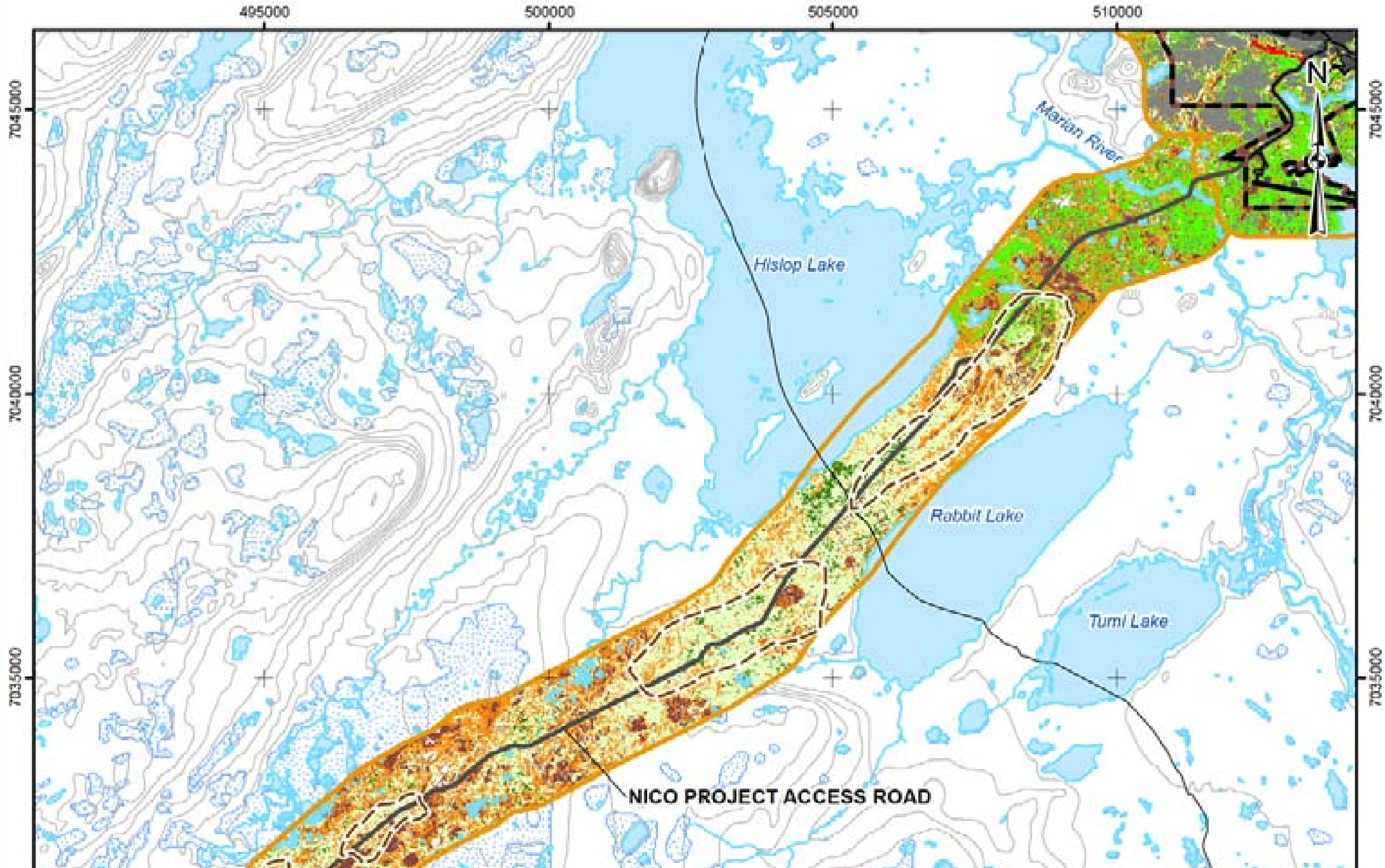

LEGEND

- PROJECT LEASE BOUNDARY
- PROPOSED NICO MINE SITE
- CONTOUR (10 METRE INTERVAL)
- EXISTING WINTER ROAD
- PROPOSED TŁICHQ ROAD ROUTE
- WATERCOURSE
- WATERBODY
- WETLAND
- LOCAL STUDY AREA
- POTENTIAL BORROW AREA
- AREA OF MAXIMUM DISTURBANCE FOR NICO PROJECT

NOTE: Terrain map unit descriptions can be found in Table 13.2-3 of the report. Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference.

3 0 3

SCALE 1:125,000 KILOMETRES

REFERENCE

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

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

TERRAIN MAP UNIT DISTRIBUTION AT MAXIMUM DISTURBANCE

Golder Associates
Edmonton, Alberta

FILE NO. E-Soil-019-GIS			
PROJECT No. 09-1373-1004		SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	
GIS	AB	03 Apr. 2011	
CHECK	GRA	03 Apr. 2011	
REVIEW	GRA	03 Apr. 2011	

FIGURE: 13.4-1b

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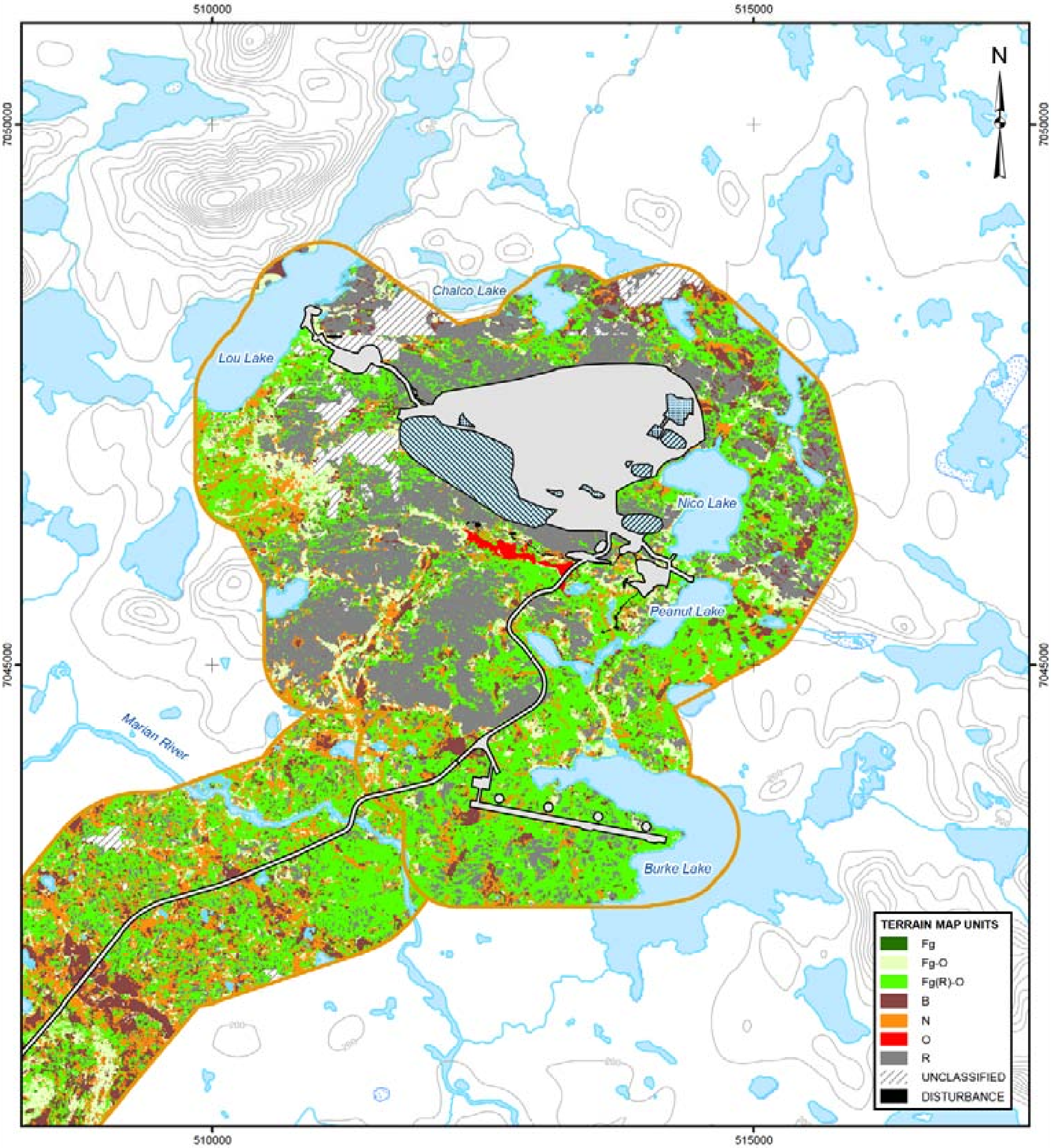


1 0 1

SCALE 1:50,000 KILOMETRES

LEGEND

- CONTOUR (10 METRE INTERVAL)
- WATERCOURSE
- WATERBODY
- WETLAND
- LOCAL STUDY AREA
- RECLAIMED AREA

NON-RECLAIMED AREA

- CONSTRUCTED WETLANDS
- FLOODED OPEN PIT
- SEEPAGE COLLECTION/SURGE PONDS AND EXCAVATED DITCH

NOTE: Terrain map unit descriptions can be found in Table 13.2-3 of the report. Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference.

REFERENCE

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

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

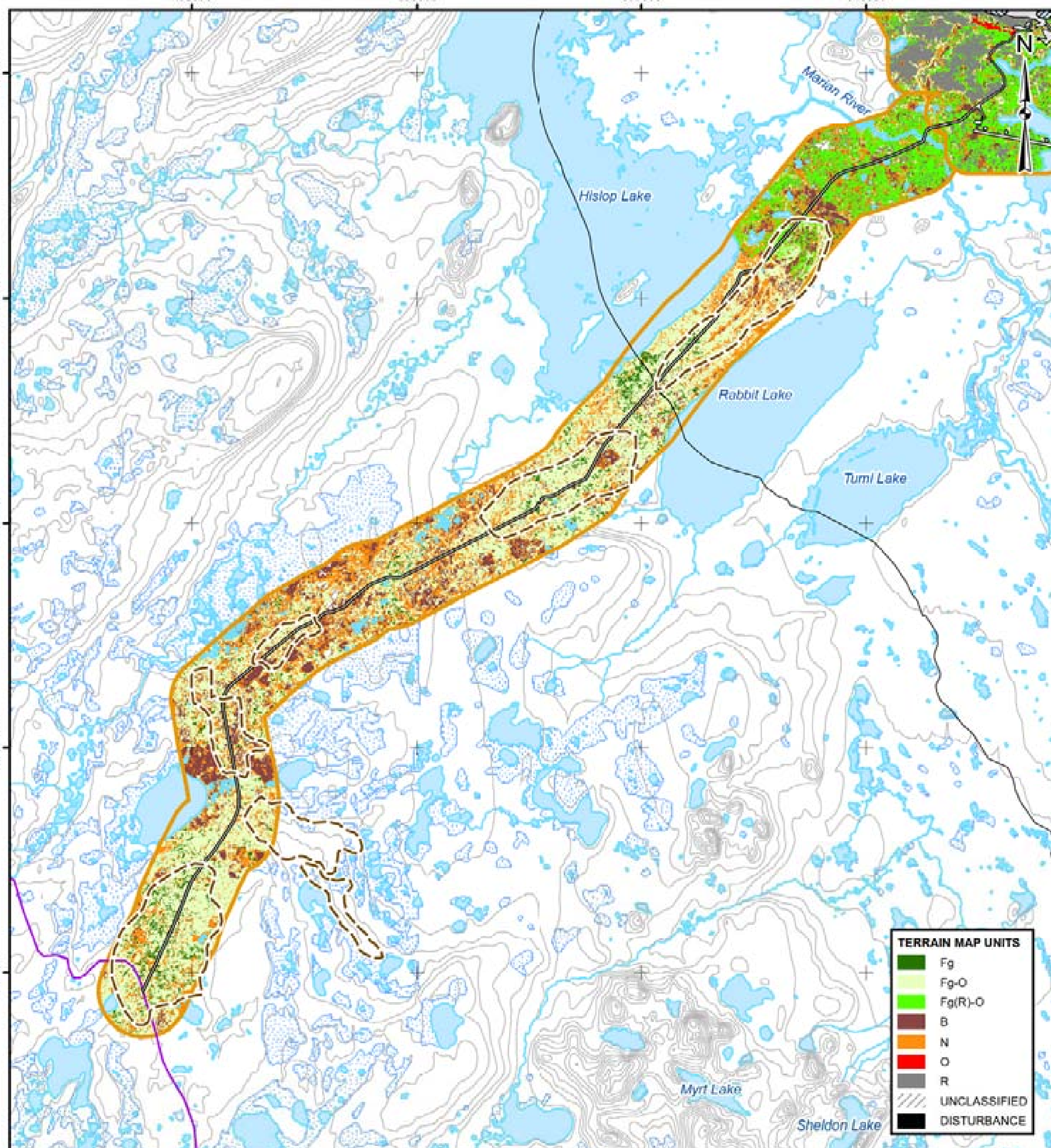
TITLE

TERRAIN MAP UNIT DISTRIBUTION FOLLOWING MINE CLOSURE

Golder Associates
Edmonton, Alberta

FILE NO. E-Soil-018-GIS

PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	FIGURE:13.4-2a	
GIS	AB	03 Apr. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		



LEGEND

- CONTOUR (10 METRE INTERVAL)
- EXISTING WINTER ROAD
- PROPOSED TŁICHO ROAD ROUTE
- WATERCOURSE
- WATERBODY
- WETLAND
- LOCAL STUDY AREA
- POTENTIAL BORROW AREA
- RECLAIMED AREA

NON-RECLAIMED AREA

- CONSTRUCTED WETLANDS
- FLOODED OPEN PIT

NOTE: Terrain map unit descriptions can be found in Table 13.2-3 of the report. Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference.

REFERENCE

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

3 0 3

SCALE 1:125,000 KILOMETRES

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

TERRAIN MAP UNIT DISTRIBUTION FOLLOWING MINE CLOSURE

Golder Associates
Edmonton, Alberta

FILE NO. E-Soil-020-GIS

PROJECT No. 09-1373-1004		SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	FIGURE: 13.4-2b
GIS	AB	03 Apr. 2011	
CHECK	GRA	03 Apr. 2011	
REVIEW	GRA	03 Apr. 2011	

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13.4.1.2.2 Effects to Soil Quantity and Distribution

The maximum amount of disturbance area from the NICO Project footprint is predicted to be approximately 486 ha (5.8% of the LSA) (Table 13.4-2 and Figures 13.4-3a, b). The area of net change for each soil map unit is described in relation to the LSA (Table 13.4-2 and Figures 13.4-4a, b). For example, approximately 16.9% of the KIL soil map unit within the LSA will be disturbed. The soils within the KIL soil map unit will be altered and therefore gained within the reclaimed map unit following closure (Table 13.4-2 and Figures 13.4-4a, b). An area of approximately 402 ha (4.8% of the LSA) within the NICO Project footprint is considered to be land that is expected to be reclaimed following closure (Figure 13.4-4a, b). The area of residual ground disturbance (i.e., Flooded Open Pit, constructed wetlands, Seepage Collection/Surge Ponds, and excavated ditch) is predicted to be approximately 84 ha (1.0% of the LSA) as these areas will not be reclaimed at closure (Table 13.4-2 and Figures 13.4-4 a, b). The Open Pit will eventually fill with water and the constructed wetlands, Seepage Collection/Surge Ponds, and excavated ditch will also contain water following closure (Figures 13.4-4 a, b).

During the processes of soil salvage and stockpiling, and storage of topsoils and subsoils over a number of years, the quantity of soils available for site reclamation may also be reduced due to wind and water erosion. The potential and extent of wind and water erosion beyond the NICO Project footprint is not expected to change because there will be no physical disturbance of soils outside of the NICO Project footprint. Erosion is a concern within the NICO Project footprint during soil salvage and stockpiling due to removal of the vegetation cover. Also, stockpiles maintained through the operation phase may be susceptible to erosion due to factors such as steep slopes and desiccation.

Overall, most soil map units in the LSA are rated as having low erosion sensitivity, with the exception of those with special management concerns (i.e., organic or shallow soils, and frozen soils [potential permafrost]). Because erosion is a concern mainly with respect to disturbed soils, the effect will be confined to the NICO Project footprint. Environmental design features and mitigation (i.e., erosion control practices) will be applied to control wind and water erosion on topsoil and overburden stockpiles (Table 13.3-1). Mitigation will include the implementation of erosion and sedimentation control structures, creation of a stable and favourable landscape that will encourage natural colonization, and seeding or fertilizing, where required, as outlined in the KLOI: Closure and Reclamation (Section 9). The potential decrease in local soil quantity from wind and water erosion is expected to be within the range of baseline conditions, and not result in a substantial loss of soil material available for reclamation.

Table 13.4-2: Comparison of Soil Map Unit Distribution between the Baseline Case and Closure Case in the Local Study Area

Soil Map Unit[a]	Baseline Case		Application Case		Area of Maximum Disturbance[b] (ha)	Closure Case (ha)	Closure Net Change (ha)	Closure Net Change (% unit)	Closure Net Change (% of LSA)
	Area (ha)	Proportion of LSA (%)	Mine Footprint[b] (ha)	NPAR[b] (ha)					
BEA-BUR	9	0.1	<1	0	<1	9	<-1	-3.3	<-0.1
BUR-MAR	412	4.9	8	5	14	398	-14	-3.3	-0.2
KIL	749	8.9	125	1	126	623	-126	-16.9	-1.5
MUS	1 554	18.5	50	21	71	1 483	-71	-4.5	-0.8
MUS-MAR	206	2.4	2	1	3	203	-3	-1.3	<-0.1
RAB	229	2.7	<1	5	5	224	-5	-2.2	-0.1
RAB-KIL-MAR	1 338	15.9	140	13	153	1 185	-153	-11.5	-1.8
RAB-MAR	821	9.8	23	14	37	784	-37	-4.5	-0.4
RAB-TUM-MAR	2 345	27.9	0	56	56	2 289	-56	-2.4	-0.7
Water	627	7.5	7	<1	7	621	-7	-1.1	-0.1
Disturbance	13	0.2	9	<1	9	5	-9	-66.1	-0.1
Unclassified	101	1.2	5	<1	5	96	-5	-5.3	-0.1
Following Closure									
Reclaimed	--	--	--	--	--	402	402	100.0	4.8
Residual Disturbance[c]	--	--	--	--	--	84	84	100.0	1.0
Total	**8 405**	**100**	**370**	**116**	**486**	**8 405**	**0**	**na**	**0**

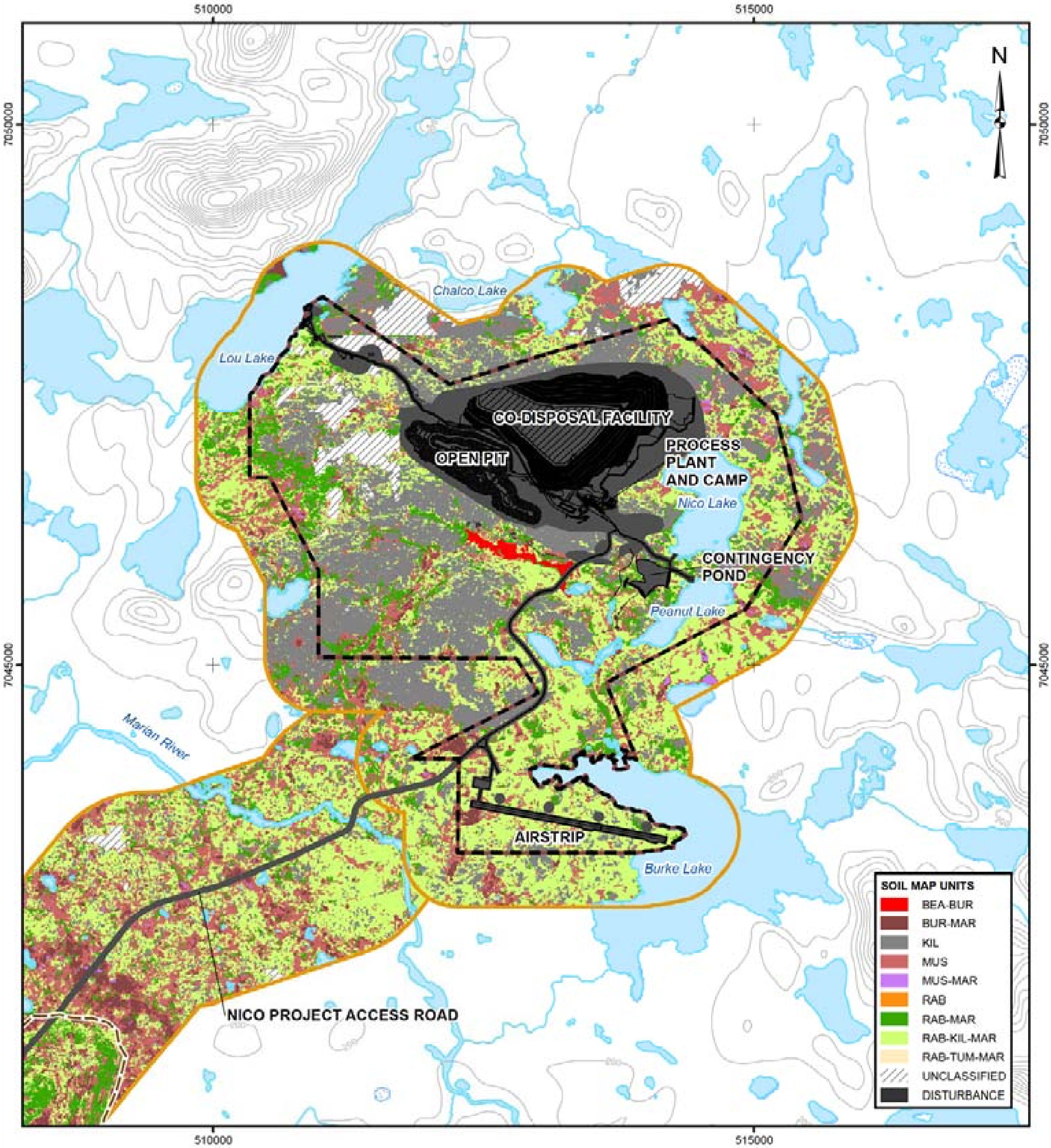
Note: Numbers are rounded for presentation purposes; therefore, it may appear that the totals do not equal the sum of the individual values.

[a] BEA-BUR = Bea-Burke; BUR-MAR = Burke-Marian; KIL = Killam; MUS = Muskeg; MUS-MAR = Muskeg-Marian; RAB = Rabbit; RAB-KIL-MAR = Rabbit-Killam-Marian; RAB-MAR = Rabbit-Marian; RAB-TUM-MAR = Rabbit-Tumi-Marian; Disturbance = anthropogenic disturbance; Unclassified = unclassified due to cloud, haze, and shadow

[b] maximum amount of disturbance during the NICO Project

[c] areas of residual disturbance are those areas that will not be reclaimed

LSA = Local Study Area; NPAR = NICO Project Access Road; na = not applicable; ha = hectare; % = percent; < = less than.



LEGEND

- PROJECT LEASE BOUNDARY
- PROPOSED NICO MINE SITE
- CONTOUR (10 METRE INTERVAL)
- WATERCOURSE
- WATERBODY
- WETLAND
- LOCAL STUDY AREA
- POTENTIAL BORROW AREA
- AREA OF MAXIMUM DISTURBANCE FOR NICO PROJECT

NOTE: Soil map unit descriptions can be found in Table 13.2-4 of the report. Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference.

REFERENCE

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

1 0 1
SCALE 1:50,000 KILOMETRES

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

SOIL MAP UNIT DISTRIBUTION AT MAXIMUM DISTURBANCE

FILE No. E-Soil-015-GIS			
PROJECT No. 09-1373-1004		SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	
GIS	AB	03 Apr. 2011	
CHECK	GRA	03 Apr. 2011	FIGURE: 13.4-3a
REVIEW	GRA	03 Apr. 2011	

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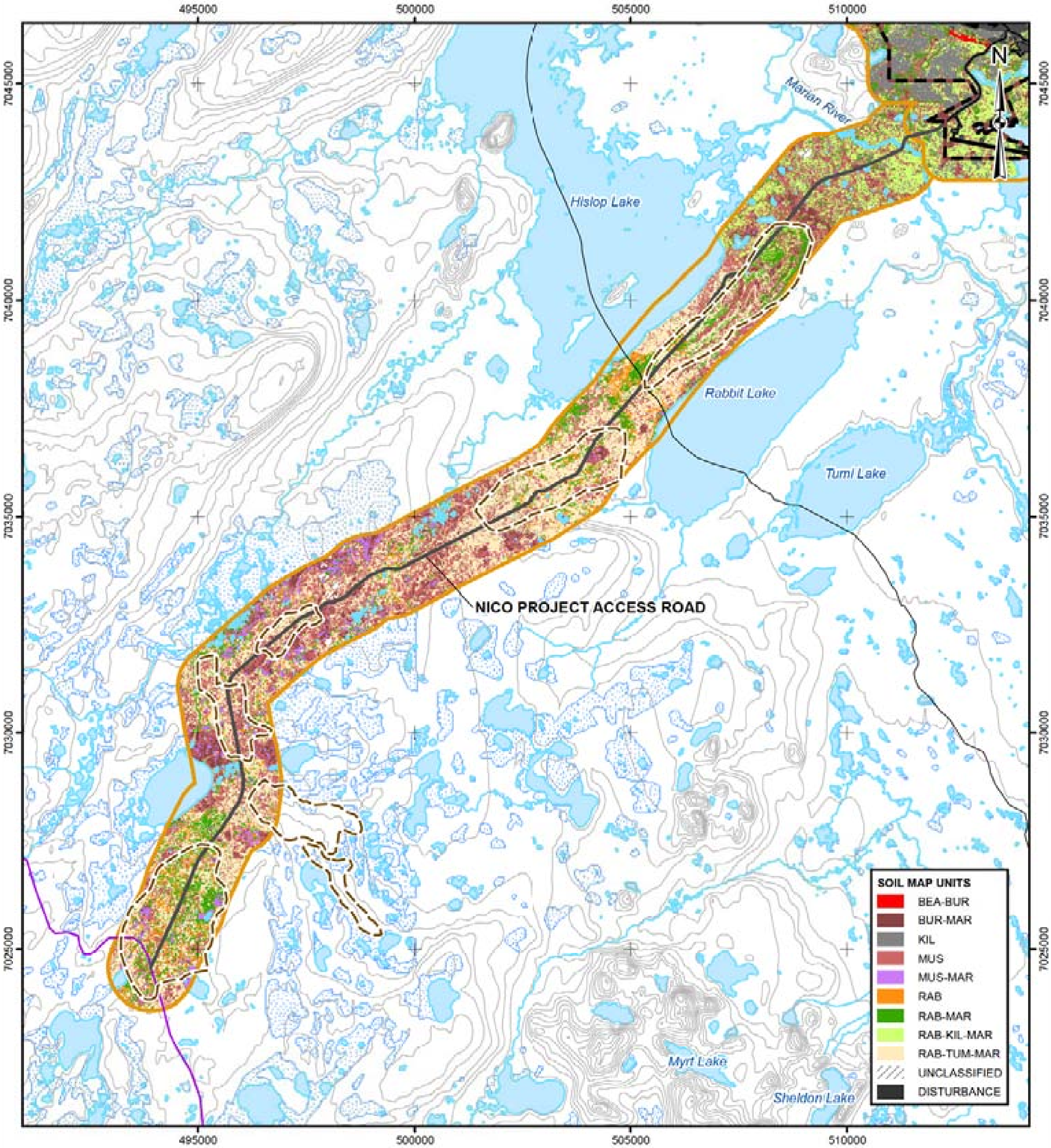

3 0 3
SCALE 1:125,000 KILOMETRES

LEGEND

- PROJECT LEASE BOUNDARY
- PROPOSED NICO MINE SITE
- CONTOUR (10 METRE INTERVAL)
- EXISTING WINTER ROAD
- PROPOSED TLICHO ROAD ROUTE
- WATERCOURSE
- WATERBODY
- WETLAND
- LOCAL STUDY AREA
- POTENTIAL BORROW AREA
- AREA OF MAXIMUM DISTURBANCE FOR NICO PROJECT

NOTE: Terrain map unit descriptions can be found in Table 13.2-4 of the report. Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference.

REFERENCE

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

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

SOIL MAP UNIT DISTRIBUTION AT MAXIMUM DISTURBANCE

Golder Associates
Edmonton, Alberta

FILE No. E-Soil-021-GIS			
PROJECT No. 09-1373-1004		SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	
GIS	AB	03 Apr. 2011	
CHECK	GRA	03 Apr. 2011	
REVIEW	GRA	03 Apr. 2011	

FIGURE: 13.4-3b

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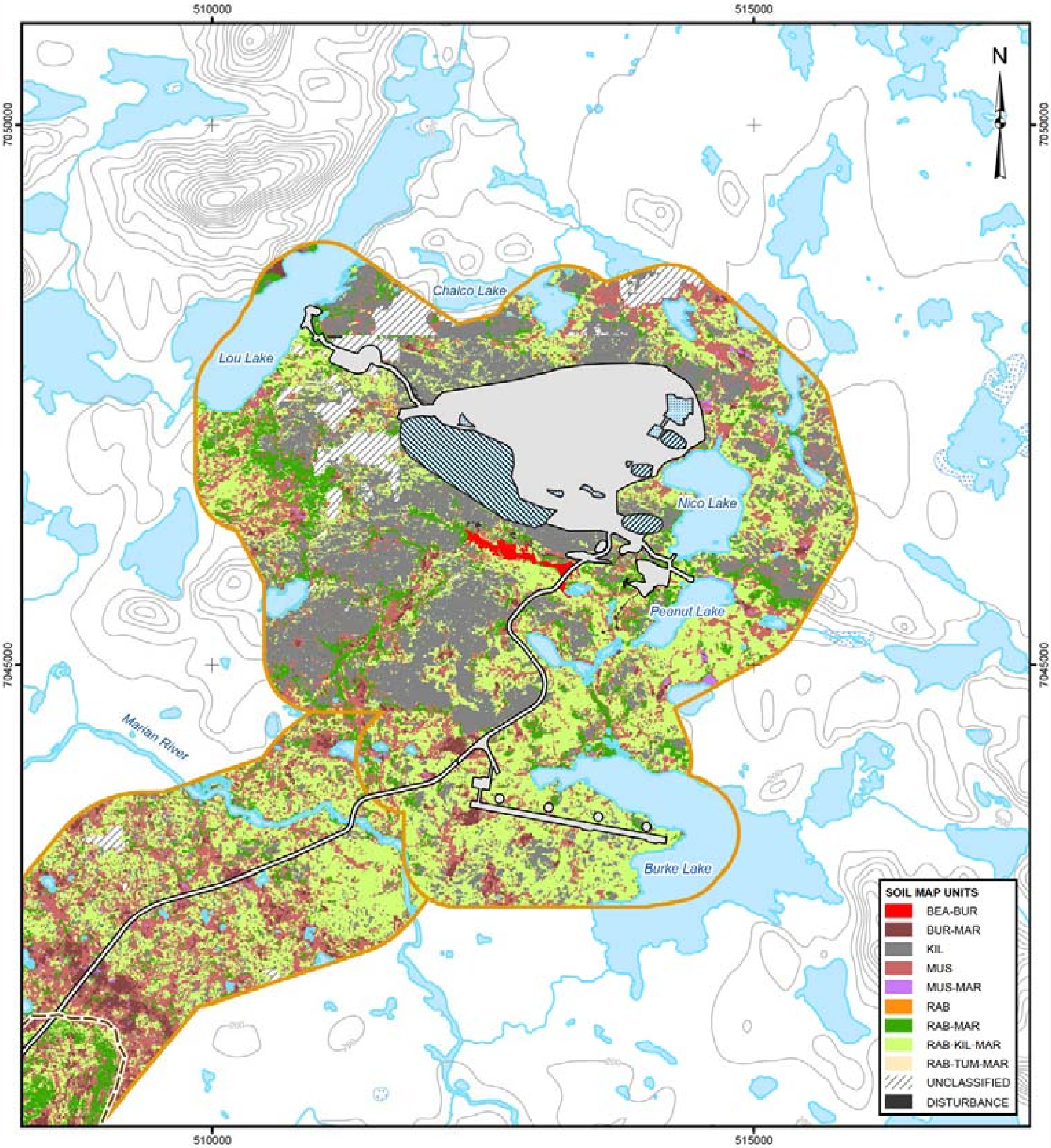


LEGEND

- CONTOUR (10 METRE INTERVAL)
- WATERCOURSE
- WATERBODY
- WETLAND
- LOCAL STUDY AREA
- POTENTIAL BORROW AREA
- RECLAIMED AREA
- NON-RECLAIMED AREA
- CONSTRUCTED WETLANDS
- FLOODED OPEN PIT
- SEEPAGE COLLECTION/SURGE PONDS AND EXCAVATED DITCH

1 0 1

SCALE 1:50,000 KILOMETRES

NOTE: Soil map unit descriptions can be found in Table 13.2-4 of the report. Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference.

REFERENCE

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

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

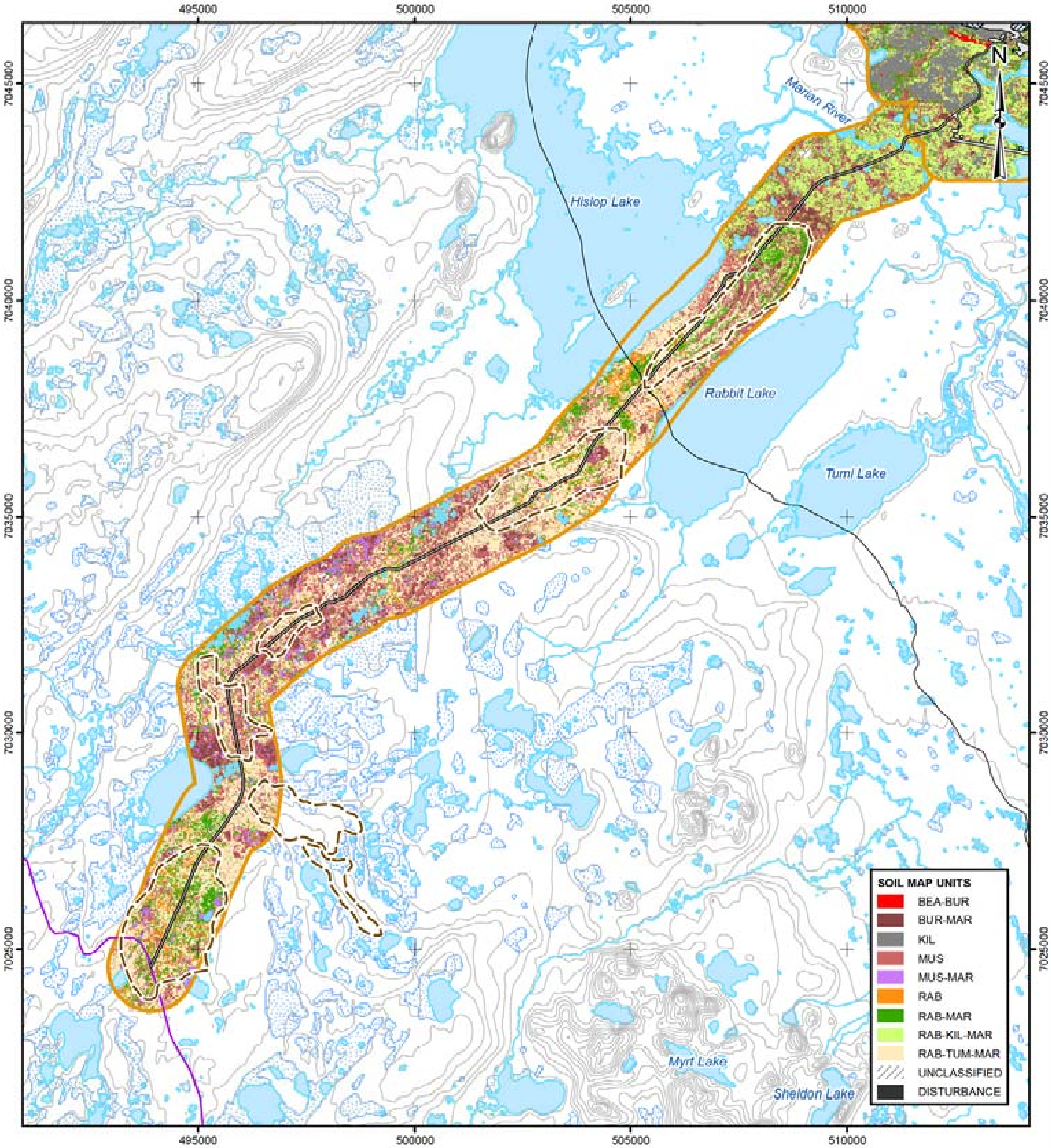
TITLE

SOIL MAP UNIT DISTRIBUTION FOLLOWING MINE CLOSURE

FILE NO. E-Soil-017-GIS

PROJECT No. 09-1373-1004		SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	
GIS	AB	03 Apr. 2011	
CHECK	GRA	03 Apr. 2011	**FIGURE: 13.4-4a**
REVIEW	GRA	03 Apr. 2011	

Golder Associates
Edmonton, Alberta



LEGEND

- CONTOUR (10 METRE INTERVAL)
- EXISTING WINTER ROAD
- PROPOSED TŁICHO ROAD ROUTE
- WATERCOURSE
- WATERBODY
- WETLAND
- LOCAL STUDY AREA
- POTENTIAL BORROW AREA
- RECLAIMED AREA

NON-RECLAIMED AREA

- CONSTRUCTED WETLANDS
- FLOODED OPEN PIT

NOTE: Soil map unit descriptions can be found in Table 13.2-4 of the report. Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference.

REFERENCE

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

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

SOIL MAP UNIT DISTRIBUTION FOLLOWING MINE CLOSURE

FILE NO. E-Soil-022-GIS

PROJECT No. 09-1373-1004		SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	
GIS	AB	03 Apr. 2011	
CHECK	GRA	03 Apr. 2011	
REVIEW	GRA	03 Apr. 2011	

Golder Associates
Edmonton, Alberta

FIGURE: 13.4-4b

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13.4.2 Effects to Soil Quality

Site clearing and construction for the NICO Project, particularly through the processes of soil stripping and storage, may result in changes to soil quality. Changes to soil quality may influence the ability of soil to support natural plant communities. Soil removal will occur mainly during the construction phase of the NICO Project, and to a lesser extent during operation (i.e., as Open Pit blasting activities are occurring). During decommissioning and reclamation, the soil (i.e., growth media) will be re-constructed as outlined in the KLOI Closure and Reclamation (Section 9). With appropriate soil salvage and reclamation techniques, soils can be returned to the landscape and support natural plant communities.

Soil quality can be altered during salvage and construction operations through the following processes:

- physical, biological, and/or chemical changes during salvage, stockpiling, and transport; and
- admixing and compaction of soil through site clearing, contouring, excavation, and decommissioning and reclamation.

13.4.2.1 Methods

The effect on soil quality is examined qualitatively and based on an evaluation using potential for soil admixing, soil compaction, erosion, and reclamation suitability ratings. Individual characteristics within each soil map unit are assessed to determine overall soil quality, and thus, the ability of a soil to sustain the capability to support natural plant communities. The effect of NICO Project activities on soil quality is determined from an analysis of each of the individual criteria and is based on studies reported in the literature and field data collected in the local and regional study areas (Section 13.2.2.3).

13.4.2.2 Results

13.4.2.2.1 Changes to Soil Physical, Biological, and/or Chemical Properties

Stripping and stockpiling topsoil during construction can cause physical changes to soil such as disturbing soil structure. Loss of soil structure can result in a reduction in the amount of soil organic matter and soil organic carbon present within the soil (Wick et al. 2009). Soil structure influences the bulk density, pore size distribution, microbial community structure, and resistance of soil to erosion (Wick et al. 2009). The most considerable change in soil chemistry in stockpiled soil is changes in organic matter content, especially in sandy textured soil (Abdul-Kareem and McRae 1984). Soil organic matter content influences the rates of microbial decomposition and nutrient availability for plant uptake (Wick et al. 2009). Therefore, direct loss of soil organic matter and soil organic carbon can decrease the ability of soil to support vegetation. Although soil structure begins to recover following storage in stockpiles for a period of time, Wick et al. (2009) found that subsequent movement of the soil caused the structure to break apart more than the initial disturbance, resulting in more fine particles that are more susceptible to erosion.

Biological changes can also arise from stripping and stockpiling soil. There is a large decrease in soil microbial activity, microbial biomass, and mycorrhizal fungi following initial stripping of topsoil (Abdul-Kareem and McRae 1984; Stark and Redente 1987; Wick et al. 2009). Stockpiling topsoil has been known to have adverse effects on earthworm populations, microbial biomass, soil microbiological activities, and mycorrhizal fungi populations over time (Abdul-Kareem and McRae 1984). Stockpiles tend to become anaerobic over time, although the depth at which this occurs is dependent on soil texture (Abdul-Kareem and McRae 1984; Ghose 2001). For example, sandy textured soil tends to remain aerobic to a greater depth when compared to loam or clay textured soil. The pH also tends to decrease in stockpiled soil, mostly due to the build up of ammonia as a result of anaerobic conditions (Abdul-Kareem and McRae 1984). The adverse effects on soil microbiological activities and mycorrhizal fungi may result in decreased rates of nutrient cycling, and reduced nutrient availability, although this is dependent on the depth of the stockpile, length of time soil remains in the stockpile, and whether it has been revegetated (Abdul-Kareem and McRae 1984; Stark and Redente 1987; Wick et al. 2009). Vegetation maintained on stockpiles tends to maintain populations of bacteria and fungi over time at the surface of the stockpile.

Chemical changes to soil include changes to extractable nutrients in topsoil storage piles over time (Abdul-Kareem and McRae 1984). As oxygen decreases in the bulk of a topsoil stockpile, it becomes anaerobic, which inhibits the nitrogen cycle, thereby increasing ammonium-nitrogen (Williamson and Johnson 1994), which tends to increase with depth (Abdul-Kareem and McRae 1984). In some studies, extractable potassium, phosphorus, and magnesium increased in clayey stockpiles, and decreased in sandy and loamy textured stockpiles (Abdul-Kareem and McRae 1984). Other studies have found that the nutrient status of topsoil in stockpiles declined over time, which is likely a result of the loss of clays and silts to erosion (Kundu and Ghose 1997). Nitrogen, phosphorus, and potassium levels tend to decrease with increasing age of a stockpile (Ghose 2001).

The above mentioned physical, biological, and chemical changes can decrease the ability of a soil to support natural plant communities following reclamation. Effects from stripping topsoil are difficult to mitigate simply because moving soil initially causes changes to soil. However, the benefit of salvaging soils outweighs the negative effect from initially moving it. Naeth et al. (2006) reported that topsoil is the most effective way to establish vegetation cover in northern mine sites. Mitigation to reduce the adverse effects of storage of stockpiled soil include maximizing surface area of the stockpile to minimize biological and chemical changes and seeding the stockpiles as vegetation tends to:

- maintain biological activity and populations of soil bacteria and fungi;
- protect the stockpiles from wind and water erosion;
- promote soil structure formation during storage;
- reduce nutrient leaching; and
- limit weed species establishment on stockpiles.

By implementing these mitigation practices, the change in local soil quality from soil stripping and subsequent storage is anticipated to be within the range of baseline values. The residual change from soil stripping and storage on local soil quality is predicted to be reversible at the end of closure.

13.4.2.2.2 Soil Admixing

Admixing of topsoil with subsoil during soil stripping and salvage operations may cause soil profile integrity to be compromised, especially if clear distinctions are not apparent between the topsoil and subsoil. This is often the case when topsoil thickness is highly irregular over the area of the lift. The depth of the surface layer that will be salvaged from mineral soils will vary according to landscape position and soil drainage conditions.

The primary concerns of soil profile admixing are changes in texture and structure, and dilution of nutrients and organic carbon, which can directly affect soil physical, biological, and chemical characteristics. Changes in soil texture could arise from admixing, particularly in those soils with large textural differences between topsoil and subsoil horizons. However, in the LSA, differences in texture between soil horizons does not occur or textures differ by one soil texture class, but are within the same particle size class. Differences in soil texture between topsoil and subsoil only occur in some localities (i.e., subsoil becomes gravelly at depth at some locations). Consequently, the main concern regarding admixing is the dilution of nutrients and organic matter content of the topsoil. Admixing of subsoil materials into topsoil can dilute organic matter and organic carbon in the topsoil, which can negatively influence microbiological activity, and reduce rates of nutrient cycling (Wick et al. 2009). The reduction of nutrients and organic material content of the soil can decrease the ability of a soil to support natural plant communities.

Mitigation to prevent admixing includes:

- undertaking a site assessment prior to soil salvage operations to develop a site-specific soil salvage plan;
- using experienced equipment operators for topsoil salvage operations;
- supervising soil salvage operations with experienced environmental personnel to provide quality control;
- salvaging soil materials during dry conditions, where and when practical;
- salvaging mineral soil materials under non-frozen conditions, and organic materials during frozen conditions; and
- identifying and documenting surficial stripping depths to guide soil salvage and provide documentation for subsequent certification.

By implementing these mitigation practices, the change in local soil quality from admixing is anticipated to be within the range of baseline values. The residual change from admixing on local soil quality is predicted to be reversible at the end of closure.

13.4.2.2.3 Compaction

Compaction of soil influences drainage, structure, porosity, aeration, permafrost, and potential susceptibility to erosion, all of which affect soil quality. Compaction from heavy equipment or repeated passes of lighter equipment can compress the soil by breaking down soil structure, thereby decreasing macro-pore volume and increasing the volume proportion of solids. Compaction can influence the depth of thaw in areas of permafrost, but not as much as where the vegetation is removed (Lawson 1986). Compaction may result in different degrees of change to thaw depth, depending on the soil properties and the ice content of permafrost in an area. Compaction will result in immediate effects on surface drainage in an area (Lawson 1986).

A soil's capability to support natural plant communities can be reduced if the soil becomes compacted. Soil compaction can also influence the success of reclamation by decreasing plant establishment and subsequent plant growth. Compaction of topsoil and subsoil can lead to a decrease in long-term productivity (Heuer et al. 2008; Blouin et al. 2008). The decrease in long-term productivity is a result of increases in soil bulk density and soil strength, reductions in soil aeration (i.e., less soil oxygen), reduced water infiltration and available soil water, restricted root growth, reductions in soil microbiological activity, and influences on nutrient uptake.

The susceptibility of soils to compaction depends on several factors including soil texture, organic matter content, and soil moisture conditions. In general, the higher the clay content, the higher the susceptibility to compaction, especially when soils are moist or wet. For example, well-drained, medium-textured soils (loams, sandy loams, silt, and silt loams) are less prone to compaction than fine-textured soils (silty clay loam, silty clay, clay loam, and clay) under the same soil moisture conditions. In addition, variability in soil particle size tends to offset compaction, such that soils with homogenous texture (i.e., clay, silt) are more prone to compaction than are soils of mixed particle size (Pritchett and Fisher 1987).

Soils developed on coarse to moderately coarse-textured glacial till and glaciofluvial deposits, commonly overlying bedrock at shallow depths (less than 1 m), characterize the NICO Project footprint. Areas prone to compaction are limited to low-lying, poorly drained areas where the clay content of soils are slightly higher than in upland soils.

Topsoil stripping while the soil is not excessively wet will reduce risk of compaction and limit damage to soil structure (Ghose 2001). Topsoil stripping under frozen conditions can also reduce the risk of compaction. If construction is completed under frozen or dry conditions, then compaction is less likely to have an influence on soil quality and suitability for reclamation.

Mitigation to reduce the risk of compaction during construction includes the following:

- a pre-construction site-specific survey to better evaluate soil sensitivity to compaction;
- construction in winter to the extent practical to reduce the potential for compaction;
- discontinue construction during excessively wet periods to the extent practical; and
- limit vehicle traffic and similar activities to designated areas.

The following mitigation may be undertaken during the reclamation of facilities:

- deep rip subsoil prior to surface soil replacement;
- do not deep rip when the soil is excessively wet; and
- crimp suitable organic materials into the subsoil after ripping.

By implementing these mitigation practices, the change in local soil quality and suitability for reclamation from compaction is anticipated to be within the range of baseline values, and reversible at the end of closure.

13.4.2.2.4 Erosion

Erosion is a concern within the NICO Project footprint during soil salvage and stockpiling due to removal of the vegetation cover. Also, stockpiles maintained through the operation phase may be susceptible to erosion due to factors such as absence of vegetation, steep slopes, and desiccation. Soil quality can be affected because erosion can remove finer particles and organic materials from bulk soil. The removal of organic particles and clays from soil can reduce the overall nutrient content and water holding capacity. Vegetation on storage stockpiles helps to protect the stockpiles from wind and water erosion (Stark and Redente 1987; Ghose 2001). Plant cover shields soils from rainfall erosion, reduces run-off velocity, disperses surface flows, and improves soil permeability, thus reducing potential effects from erosion. Plant cover will also act to physically bind soil particles, and further reduce the effects from erosion.

Overall, most soil map units in the LSA are rated as having low erosion sensitivity, with the exception of those with special management concerns (i.e., organic or shallow soils, and frozen soils [potential permafrost]).

Erosion sensitivities for Cryosolic soils (i.e., BEA and BUR) were rated as moderate to reflect the sensitivity of these soils to disturbance and the potential for changes in the thermal regime to de-stabilize soil structure and increase pore water pressures. The erosion sensitivity for KIL soils was also rated as moderate because any loss of this thin soil may have implications for plant growth. The soil erosion ratings represent the maximum effect potential based on the disturbance of the soil profile and no mitigation to control soil loss. Because erosion is a concern mainly with respect to disturbed soils, the effect will be confined to the NICO Project footprint. Environmental design features and mitigation (i.e., erosion control practices) will be applied to control wind and water erosion on topsoil and overburden stockpiles (Table 13.3-1). Mitigation will include the implementation of erosion and sedimentation control structures, creation of a stable and favourable landscape that will encourage natural colonization, and seeding or fertilizing, where required, as outlined in the KLOI: Closure and Reclamation (Section 9). Applying appropriate mitigation is expected to reduce the residual effects of local soil erosion (i.e., decreases in soil quality) to within the range of baseline values.

The following general mitigation can be applied to limit erosion:

- salvage topsoil and store on the site away from sensitive areas or areas of high potential erosion;
- construct temporary cross ditches to redirect surface run-off;
- construct roads so natural drainage patterns are not impeded and in a manner that runoff to road ditches enters natural drainage systems or contoured containment areas;
- use temporary erosion control practices such as mulches, mats, netting, or straw crimping to control erosion prior to establishment of a protective vegetative cover; and
- promptly seed exposed areas and topsoil stockpiles with a self-sustaining, erosion controlling seed mix appropriate to the region.

13.4.2.2.5 Reclamation Suitability

Soil reclamation suitability is discussed as an integrator of various soil quality parameters. Reclamation suitability is defined by a set of soil quality parameters that define a soil's capability to support natural plant communities. Criteria to determine reclamation suitability was based on methods developed in Alberta (Alberta Agriculture 1987) for the Northern Forest Region and were applied to the baseline soil data.

Based on the criteria for the upper lift (topsoil), the topsoils of minerals soils in the LSA have generally fair to poor reclamation suitability (Section 13.2.2.3.4). Subsoils were predominantly categorized as poor and unsuitable for reclamation. However, the subsoil of Marian soil was rated as good, along with any soils that have developed on glacial till, which may have higher soil suitability for reclamation due to low stone contents and fine soil textures. The extensive Organics and Organic Cryosols in the area are not given a rating and are classified as an organic category, because these materials are valuable in reclamation because of higher nutrient contents and soil moisture holding capacities and may be used as an amendment during reclamation.

The results from the metal analyses indicate there are areas where naturally occurring arsenic concentrations are high (i.e., above Canadian Soil Quality Guidelines [CCME 2007]). If these materials are salvaged, they will be salvaged separately from materials that are not naturally high in arsenic to prevent cross-contamination of salvaged materials. Additional sampling may be required to better evaluate the spatial extent of soils containing naturally high arsenic concentrations to prevent mixing with soils that do not contain naturally high arsenic concentrations within the NICO Project footprint.

Given the generally poor quality of soils in the LSA, the NICO Project is not predicted to diminish soil quality greatly when compared to baseline conditions. Residual effects to local soil quality from admixing, compaction, erosion, and changes during storage are predicted to be within the range of baseline values. In some cases, soil quality in terms of reclamation suitability can be improved to some extent by removing stones from lifts prior to replacement, planting vegetation on stockpiles, and by carefully lifting topsoil to reduce admixing with subsoil during construction. Effects to reclamation suitability of soils are expected to be reversible at the end of closure.

13.5 Residual Effects Summary

13.5.1 Effects to Terrain Units, Soil Quantity, and Distribution

The effect from the NICO Project on terrain and soil distribution will be confined to the NICO Project footprint. Most of this effect will occur during the construction phase, although activities through the life of the NICO Project will continue to change terrain and soil distribution across the landscape. The type and degree of change consists of the spatial extent of change and the shape of the landscape. Terrain and soils share a closely linked interaction, resulting in comparable changes from development. The changes in terrain distribution results in a small net loss in the spatial extent of some terrain types, as well as the corresponding soil map units.

The maximum area that will be disturbed during construction and operation is predicted to be approximately 486 ha (5.8% of the LSA). At closure, the extent of the effect on terrain and soil quantity will consist of 402 ha of reclaimed land and 84 ha of non-reclaimed land (i.e., residual ground disturbance). Non-reclaimed land is associated with the Open Pit, constructed wetlands, Seepage Collection Ponds, Surge Pond, and excavated ditch, and represents 1.0% of the LSA. These areas will become new soil map units as the Open Pit will eventually fill with water and the constructed wetlands, Seepage Collection Ponds, Surge Pond, and excavated ditch will also contain water. These soils include the Killam (KIL) and Rabbit-Killam-Marian (RAB-KIL-MAR) soils, where 29 ha (KIL) and 22 ha (RAB-KIL-MAR) will be permanently lost.

In addition to the residual ground disturbance areas, a decrease in soil quantity due to water and wind erosion is of concern at the time of soil salvage and stockpiling, and during storage. Environmental design features and mitigation will be applied to control soil erosion and it is expected that the loss of soil quantity due to erosion will be within the range of baseline conditions.

13.5.2 Effects to Soil Quality

Changes to soil quality are attributed to NICO Project activities that include physical, biological, and chemical changes that could occur during soil storage in stockpiles, admixing of soil materials, compaction, and soil erosion. The geographic extent of the effect from these activities will be limited to the NICO Project footprint.

Soil in storage is susceptible to changes in organic matter content, microbial community and activity, pH, and nutrient availability. Some of the adverse consequences of stockpiling soil can be reduced by maximizing surface area of the stockpiles. Vegetation on storage stockpiles can maintain populations of soil bacteria and fungi, limit noxious and invasive weed species establishment on stockpiles, reduce nutrient leaching, as well as protect the stockpiles from wind and water erosion. Residual changes to physical, biological, and chemical properties of local soils from the NICO Project are expected to be within the range of baseline values, and last from construction until the end of closure.

The primary concerns of soil profile admixing are changes in texture and structure, and dilution of nutrients and organic carbon, which can directly affect soil physical, biological, and chemical characteristics. Generally, in the LSA, differences in texture between soil horizons does not occur or textures differ by one soil texture class, but are within the same particle size class. Admixing of subsoil materials into topsoil can dilute organic matter and organic carbon in the topsoil, which can negatively influence microbiological activity, and reduce rates of nutrient cycling. Consequently, the main concern regarding admixing is the dilution of nutrients and organic matter content of the topsoil. Mitigation practices should limit the potential admixing during soil salvage, and therefore, the change in local soil quality from admixing is anticipated to be within the range of baseline values. The residual change from admixing on soil quality is predicted to be reversible at the end of closure.

Compaction of soil influences drainage, structure, porosity, aeration, permafrost, and potential susceptibility to erosion, all of which affect soil quality. A soil's capability to support natural plant communities can be reduced if the soil becomes compacted. Soil compaction can also influence the success of reclamation by decreasing plant establishment and subsequent plant growth. In general, the higher the clay content, the higher the susceptibility to compaction, especially when soils are moist or wet. The majority of the soils that occur within the NICO Project footprint have developed on coarse to moderately coarse-textured glacial till and glaciofluvial deposits, commonly overlying bedrock at shallow depths (less than 1 m), and therefore a have a lower susceptibility to compaction. Areas prone to compaction are limited to low-lying, poorly drained areas where the clay content of soils are higher than in upland soils. In addition, mitigation will be applied to decrease the effect of compaction on soil quality. By implementing mitigation practices, the change in local soil quality from compaction is anticipated to be within the range of baseline values, and reversible at the end of closure.

Soil loss by water and wind erosion is of concern at the time of soil salvage and stockpiling, and during storage. Overall, most soil map units in the LSA are rated as having low erosion sensitivity, with the exception of those with special management concerns (i.e., organic or shallow soils, and frozen soils [potential permafrost]). Environmental design features and mitigation (i.e., erosion control practices) will be applied to control wind and water erosion on topsoil and overburden stockpiles. Mitigation will include the implementation of erosion and sedimentation control structures, creation of a stable and favourable landscape that will encourage natural colonization, and seeding or fertilizing, where required, as outlined in the KLOI: Closure and Reclamation (Section 9).Applying appropriate mitigation is expected to prevent soil erosion and associated effects to soil quality. The change in soil quality related to soil erosion is anticipated to be within the range of baseline values.

The topsoils of minerals soils in the LSA have generally fair to poor reclamation suitability. Subsoils have generally poor and unsuitable reclamation suitability. The subsoil of Marian soil was rated as good along with any soils that have developed on glacial till, which may have higher soil suitability for reclamation due to low stone contents and fine soil textures. The extensive Organics and Organic Cryosols in the area are valuable in reclamation because of higher nutrient contents and soil moisture holding capacities and may be used as an amendment during reclamation. In areas where naturally occurring arsenic concentrations are high (i.e., above Canadian Soil Quality Guidelines [CCME 2007]) soil will not be used in future reclamation efforts in areas where arsenic is not naturally high. If these materials are salvaged, they will be salvaged separately from materials that are not naturally high in arsenic to prevent cross-contamination of salvaged materials. Given the generally poor quality of soils in the LSA, soil quality is not predicted to diminish greatly when compared to baseline conditions. Soil quality in terms of reclamation suitability can be improved to some extent by removing stones from lifts prior to replacement, planting vegetation on stockpiles, and by carefully lifting topsoil to reduce admixing with subsoil during construction. Effects to reclamation suitability of soils are expected to be reversible at the end of closure.

13.6 Uncertainty

There is a high degree of confidence that surficial materials will be moved, excavated, and re-contoured and soil will be disturbed within the NICO Project footprint. The areas affected have been determined based on the current Mine Plan and the terrain and soil types containing the Open Pit, constructed wetlands, Seepage Collection/Surge Ponds, and excavated ditch will permanently change. There is uncertainty associated with the location of ice-rich permafrost within the NICO Project footprint, and site-specific investigations will be undertaken prior to construction to reduce this uncertainty.

Several aspects of soil quality were examined. The effects from soil removal, storage, and other NICO Project activities on soils were assessed. The main processes are biological, chemical, and physical changes during storage in stockpiles, soil admixing, compaction, erosion, and associated reclamation suitability. Minor changes in quality due to these processes are predicted with moderate certainty. Admixing, compaction, and erosion effects are expected to be localized. Storage effects are not well known for soils in northern climates. Prediction of a low effect is based on appropriate stockpile design, vegetating the stockpiles, and storage being mainly under frozen conditions; however, there is little background information in subarctic environments to support this assumption. There is uncertainty associated with the distribution of soil containing high concentrations of naturally occurring arsenic (i.e., above Canadian Soil Quality Guidelines [CCME 2007]). To reduce this uncertainty, additional soil samples would require analysis during salvaging of soils to limit or prevent mixing of materials containing high arsenic with materials that do not contain high arsenic concentrations.

Uncertainty was addressed in the assessment by incorporating information from available and applicable literature, and using past experience in similar areas. In addition, the application of environmental design features and mitigation during construction, operation, and reclamation, and the Conceptual Closure and Reclamation Plan (Section 9) will be implemented to mitigate effects to soil and the ability of soil to support plant communities. Finally, a conservative approach was used when information was limited so that effects are typically overestimated. For example, for erosion sensitivities of soils, the highest sensitivity (i.e., wind or water erosion) was applied to each soil map unit.

13.7 Monitoring and Follow-up

Monitoring programs implemented during the life of the NICO Project may be a combination of environmental monitoring to track conditions and implement further mitigation as required (e.g., monitoring for soil erosion during construction), and follow-up monitoring to verify the accuracy of effect predictions and adaptively manage and implement further mitigation as required.

Terrain stability and soil quantity and quality would be assessed during the construction and operations phases of the NICO Project, and during closure and post-closure as part of reclamation. Soil conditions may be monitored to estimate reclamation success, and on-going terrain stability monitoring is anticipated after closure. Other soil quality issues such as erosion, admixing, and compaction will be visually assessed as part of this task. Results from this program can be used to support adjustments to the reclamation and closure plan and incorporated into the ongoing reclamation activities. Mine closure requires input from regulatory agencies and communities to identify closure objectives and strategies, so the precise monitoring required is unknown at this time.

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