FINAL
REPORT ON

BASELINE SOIL AND TERRAIN RESOURCES FOR THE PROPOSED NICO PROJECT

Submitted to:

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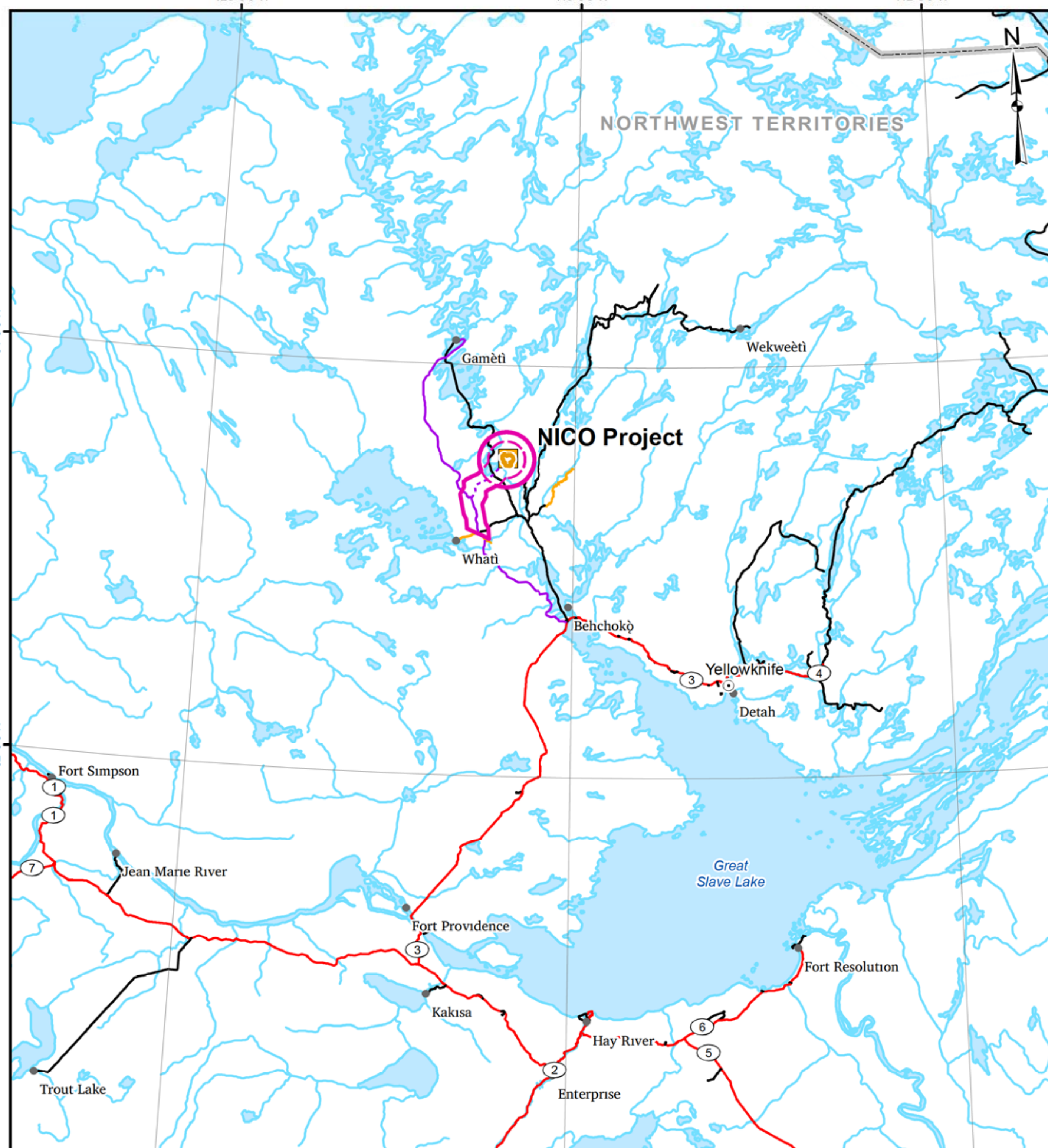
1 INTRODUCTION

1.1 BACKGROUND AND SCOPE

Fortune Minerals Limited (Fortune) is proposing to develop the NICO Cobalt-Gold-Bismuth-Copper Project (Project) approximately 160 kilometres (km) northwest of Yellowknife in the Northwest Territories (NWT). The terrain and soil baseline is one component of a comprehensive environmental and socio-economic baseline program to collect information about the natural and socio-economic environment in the vicinity of the Project. The Project is located within the Marian River drainage basin, approximately 10 km east of Hislop Lake at a latitude of 63°33' North and a longitude of 116°45' West (Figure 1.1-1).

The soil and terrain baseline report focuses on describing existing baseline conditions that may be affected by the Project facilities and the 27 km Proposed NICO Project Access Road (NPAR). At the time of the baseline studies, the NPAR was 50 km in length, and although has since been reduced to 27 km, the original 50 km NPAR was evaluated during baseline studies. This baseline report focuses on conditions within the Project regional study areas (RSAs) and local study area (LSA). Terrain data, specifically landforms and surficial materials, are needed for effects analysis with respect to resource extraction, infrastructure, and aggregate use. Soil data are required to provide an assessment of reclamation suitability, permafrost potential, and landscape susceptibility to erosion. Soil data and information are also used to assess the sensitivity of soils to acid deposition (e.g., from sulphur dioxide [SO_2] and oxides of nitrogen [NO_x] emissions), and to describe vegetation and habitat productivity.



100 0 100

SCALE 1:3,000,000 KILOMETRES

LEGEND

- NICO PROJECT
- TERRITORIAL CAPITAL
- POPULATED PLACE
- HIGHWAY
- EXISTING ALL-WEATHER ROAD
- EXISTING WINTER ROAD
- PROPOSED ALL-LAND WINTER ROAD ROUTE
- PROPOSED NICO PROJECT ACCESS ROAD
- TERRITORIAL/PROVINCIAL BOUNDARY
- WATERCOURSE
- WATERBODY
- LOCAL STUDY AREA
- REGIONAL STUDY AREA (2003-2006)
- REGIONAL STUDY AREA (2007-PRESENT)

REFERENCE

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

PROJECT
FORTUNE MINERALS LIMITED
NICO DEVELOPERS ASSESSMENT REPORT

TITLE
LOCATION OF THE NICO PROJECT

Golder Associates
Edmonton, Alberta

FILE No. B-Veg-001-GIS				
PROJECT No. 08-1373-0017		SCALE AS SHOWN		REV. 0
DESIGN	JK	04 Dec. 2008	FIGURE: 1.1-1	
GIS	CW	06 May 2010		
CHECK	LY	17 Nov. 2010		
REVIEW	GA	17 Nov. 2010		

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1.2 OBJECTIVES

Specific objectives of this study include the following:

- mapping and describing soil and terrain (surficial parent material and landform) units in the RSAs and LSA;
- assessing permafrost potential in the RSAs and LSA;
- assessing the reclamation suitability of each soil unit in the LSA to aid in reclamation planning;
- assessing erosion sensitivity of soils in the LSA; and
- collecting soil samples and completing laboratory analysis for acidification sensitivity (buffering capacity), texture, organic content, and other properties relevant to permafrost potential, reclamation, and nutrient status of soils in the LSA.

By addressing the above components in terms of their characteristics, and the abundance and spatial extent across the RSAs and LSA, a baseline was created for assessing the potential effects of the Project on soil and terrain resources. This baseline also provides supporting information for other components of the environmental assessment, such as vegetation, wildlife, and traditional and non-traditional land use. To meet these objectives, the soil and terrain baseline summary report has been organized into the following sections described below.

Section 1.3 provides a description of overall soil quality indicators.

Section 1.4 provides a detailed description of the RSAs and LSA spatial boundaries, which were delineated based on the predicted spatial extent of the potential Project-related effects and life history attributes of wildlife species potentially occupying the area. Spatial boundaries included a RSA and LSA for the proposed mine site and a RSA for the NPAR.

Section 2 provides detailed descriptions of the sampling methods for collecting soil data including soil samples for nutrient analyses, soil classification and mapping processes, and determining soil sensitivities, such as permafrost and erosion potential.

Section 3 provides qualitative and quantitative information on general soil and terrain conditions in the RSAs and LSA, as well as a discussion on the extent of permafrost. A discussion on soil erosion sensitivity, soil productivity, and soil salvage recommendations for reclamation planning in the LSA is provided.

Section 4 provides a detailed summary of the methods and results that describe soil and terrain conditions in the Project RSAs and LSA.

1.3 SELECTION OF VALUED COMPONENTS

Valued components (VCs) represent physical, biological, cultural, social, and economic properties of the environment that are considered important to society. Valued components are not specifically identified for soil and terrain resources, as all soil and terrain types are assessed. However, a number of indicators (measurement endpoints) of overall soil quality have been selected to provide a basis for an impact evaluation. These include the following:

- soil capability and productivity;
- soil and terrain type diversity;
- uncommon soil types; and
- permafrost potential.

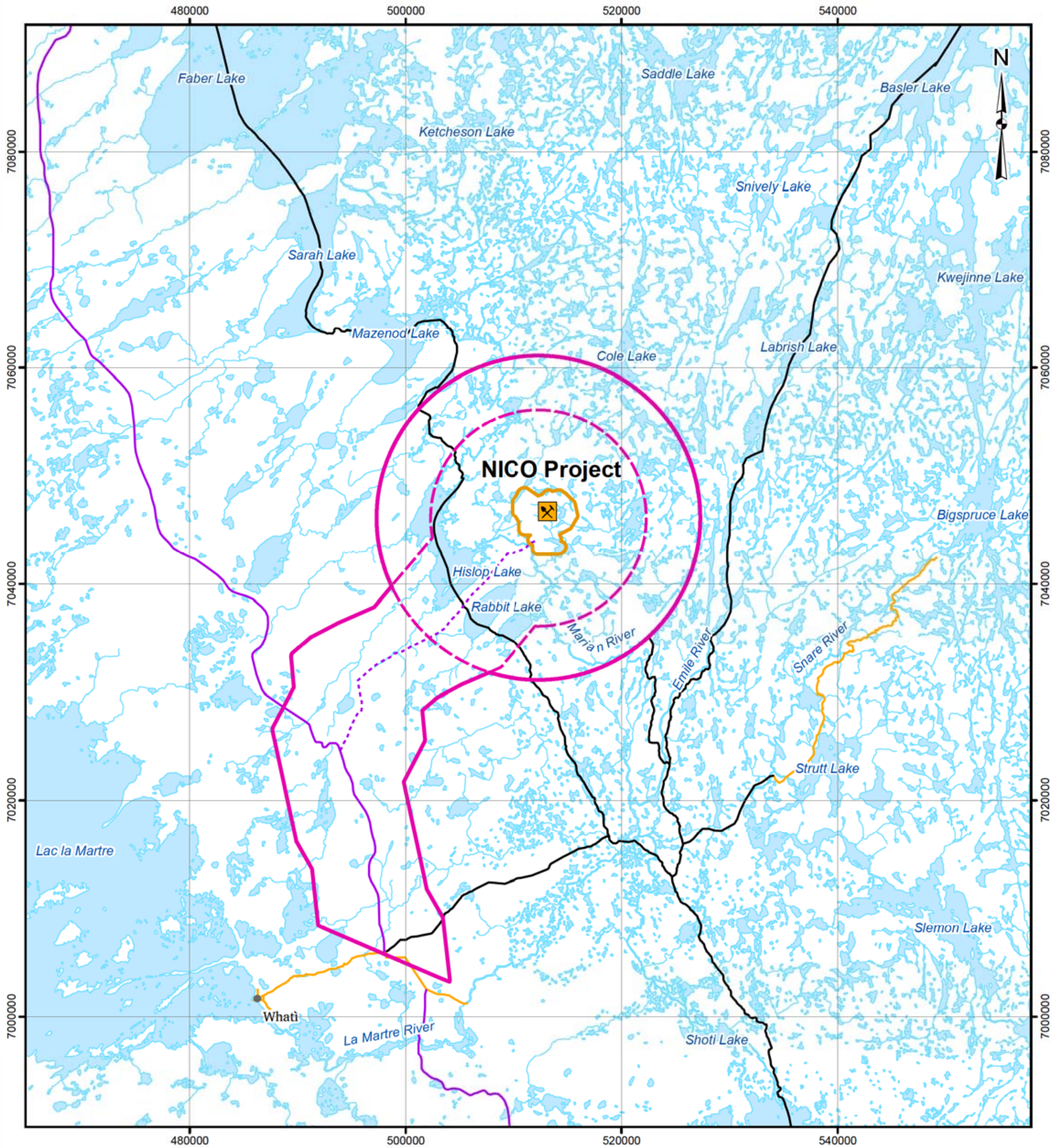
These soil and terrain indicators have been selected on the basis of their importance to sustaining natural vegetation communities and ecological processes.

1.4 SPATIAL BOUNDARIES

The Project is within the Marian River drainage basin and is located within the Taiga Shield and Taiga Plains Level II Ecoregions (Ecosystem Classification Working Group 2007, 2008). To facilitate the assessment and interpretation of potential effects associated with the Project, it is necessary to define appropriate spatial boundaries. Spatial boundaries were developed with consideration of all terrestrial components (i.e., soil and terrain, terrestrial vegetation and wetlands, wildlife, and biodiversity).

At the time of the baseline studies, the proposed NICO Project Access Road (NPAR) was a 50 km predicted alignment that joined the NICO site to the existing all-weather access road east of Whatì. The NPAR length has since been reduced to 27 km; however, the original 50 km NPAR was evaluated during baseline analyses. Soil and terrain baseline studies were completed in 2005 and 2008 within the following spatial boundaries:

- RSA for the proposed mine site (i.e., mine RSA);
- RSA for the Proposed NICO Project Access Road (NPAR RSA); and



LEGEND

- NICO PROJECT
- POPULATED PLACE
- EXISTING ALL-WEATHER ROAD
- EXISTING WINTER ROAD
- PROPOSED ALL-LAND WINTER ROAD ROUTE
- PROPOSED NICO PROJECT ACCESS ROAD
- WATERCOURSE
- WATERBODY
- LOCAL STUDY AREA
- REGIONAL STUDY AREA (2003-2006)
- REGIONAL STUDY AREA (2007-PRESENT)

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

PROJECT

FORTUNE MINERALS LIMITED
NICO DEVELOPERS ASSESSMENT REPORT

TITLE

SOIL AND TERRAIN REGIONAL AND LOCAL STUDY AREAS

Golder Associates
Edmonton, Alberta

FILE NO. B-Soil-013-GIS			
PROJECT No. 08-1373-0017		SCALE AS SHOWN	REV. 0
DESIGN	LV	04 Dec. 2008	
GIS	CW	06 May 2010	
CHECK	LY	17 Nov. 2010	
REVIEW	GA	17 Nov. 2010	

FIGURE: 1.4-1

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- LSA for the proposed mine site (i.e., LSA).

The RSAs (Figure 1.4-1) were selected to capture any effects that may extend beyond 1 km from the Project and subsequently to assess potential soil and terrain cumulative effects in the broader regional area. The LSA (Figure 1.4-1) was selected to assess the immediate direct and indirect effects of the proposed mine on soil and terrain resources. Survey intensity varied within each spatial boundary depending on the baseline study objectives. Broader baseline studies were completed within the RSAs to assess general soil and terrain conditions, while more detailed studies were completed in the LSA to obtain specific information on soil and terrain conditions that would be used to develop reclamation plans and facilitate construction and operational planning.

The methods for defining the proposed mine and NPAR portions of the RSAs and LSA are described below. For soil and terrain resources, the combined RSAs is 109 016 hectares (ha) and includes the proposed mine RSA (70 686 ha) and NPAR RSA (38 330 ha), and the LSA is 2644 ha.

1.4.1 Regional Study Area (Proposed Mine)

The proposed mine RSA was defined to capture the large scale direct and indirect effects of the Project on soil and terrain conditions (Figure 1.4-1). In 2007, the RSA was increased from 314 square kilometres (km^2) to 706 km^2 for terrestrial components (i.e., the radius was increased from 10 km to 15 km, centered on the proposed mine site) because of increased knowledge about the effects from disturbance on barren-ground and woodland caribou (Golder 2010a). 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). Based on this information, it is anticipated that the boundary of the RSA around the proposed mine and road should be large enough to contain exposure and reference areas to predict and monitor potential effects on terrestrial resources in this region.

The proposed mine 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 Working Group 2008), while the Taiga Plains Ecoregion covers the southwest portion of the RSA (Ecosystem Classification Working Group 2007).

The Taiga Shield Level II Ecoregion includes 4 Level III Ecoregions (Ecosystem Classification Working Group 2008). The northeast portion of the proposed mine

RSA occurs within the Taiga Shield High Boreal Level III Ecoregion. Elevations within this Ecoregion range from approximately 200 m above sea level (mASL) along the west boundary to greater than 500 mASL in the southeast corner. 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. Brunisols, organic soils, and organic and mineral Cryosolic (permafrost) soils are the most common soils in the Taiga Shield High Boreal Ecoregion. There is no soil development on the bare bedrock exposures. Brunisols are typically found on variable textured glacial deposits between bedrock exposures. Organic soils and Cryosols typically occur within peat plateaus. Shore fens and floating fens are characterized by Organic soils with Gleysols occurring in wet depressions.

The Taiga Plains Level II Ecoregion includes 4 Level III Ecoregions (Ecosystem Classification Working Group 2007). The southwest portion of the proposed mine RSA occurs within the Central Great Bear Plains Low Subarctic Level III Ecoregion. The Central Great Bear Plains Low Subarctic 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 cm of the organic surface. Polygonal peat plateaus are locally common in the Keller Plain area. Soils are dominantly mineral and Organic Cryosols and are typically Turbic Cryosols. Organic Cryosols occur within peat plateaus and runnels. Brunisols are commonly found on well-drained upland areas. Gleysolic soils occur in shrubby channels between spruce-lichen uplands.

1.4.2 Proposed NICO Project Access Road Study Area

The NPAR RSA was defined by the expected limit of direct and indirect effects from the NPAR on surrounding soil, vegetation, and wildlife. The proposed NPAR at the time of the baseline studies was a 50 km road that joins the Project to the existing winter road between Behchokǫ̀ and Gamètì. The NPAR has been since reduced to 27 km; however, the original 50 km NPAR was evaluated during the baseline studies. The NPAR RSA was defined by a 6.5 km buffer surrounding the proposed 50 km road alignment (Figure 1.4 1).

The RSA for the NPAR contain soil and terrain typical of regional conditions. The NPAR RSA is located within the Taiga Plains Level II Ecoregion primarily within the Central Great Plains Low Subarctic Level III Ecoregion.

The southern most portion of the NPAR RSA is within the Great Slave Uplands High Boreal Level III Ecoregion. The Great Slave Uplands High Boreal Ecoregion includes hill systems ranging in elevation from 300 to 700 mASL. These areas are surrounded by gently sloping to undulating plains. Imperfect to poorly drained glacial till is common throughout this Ecoregion, where Organic and Gleysolic soils occur or Organic Cryosols have developed. Gleysolic soils are typically found adjacent to ponds. Brunisols and Luvisols typically occur on hummocky or ridged till or on well-drained fluvial and glaciofluvial materials.

1.4.3 Local Study Area

The LSA boundary was defined by the expected spatial extent of the immediate direct (e.g., Project footprint) and indirect effects (e.g., dust deposition) from the proposed mine on surrounding soil, vegetation, and wildlife (Figure 1.4-1). The LSA for the proposed mine site was defined as a 500 metre (m) buffer around the Project lease boundary, and had previously included the proposed alignment for the 50 km NPAR.

The LSA habitat is characteristic of regional habitat conditions and vegetation within the Taiga Shield Level II Ecoregion and occurs entirely within the Taiga Shield High Boreal Level III Ecoregion. The LSA is characterized by undulating to rolling terrain with exposed bedrock outcrops overlain by Regosolic, Brunisolic, Gleysolic, Organic and Cryosolic soils. Elevations typically range from approximately 190 to 360 mASL, with low-lying areas dominated by shallow and deep water lakes or peatlands.

2 METHODS

The soil and terrain baseline report presents a review and interpretation of qualitative and quantitative information from the literature, and data collected during the 2005 and 2008 field programs. Sources of information and data incorporated into the soil and terrain baseline report include the following:

- soil data from the 2005 field survey collected along the proposed NICO Project Access Road (NPAR RSA) and proposed mine site (LSA) (Golder Associates Ltd. [Golder] 2006);
- soil data collected from the 2008 field survey of the LSA and from various locations in the proposed mine RSA and NPAR RSA;
- background information and data from Golder (2006) and EBA Engineering Consultants Ltd. (EBA) soil survey results (EBA 2005); and
- Ecological Land Classification (ELC) units for the RSAs and LSA derived from the 2005 and 2008 vegetation surveys completed by Golder.

2.1 SOIL AND TERRAIN MAPPING AND CLASSIFICATION

2.1.1 Approach

Soil and terrain conditions in the RSAs and LSA were classified and mapped using the principles and methods outlined by the Expert Committee on Soil Survey (1983) 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). Terrain mapping was completed for the RSAs and LSA through a review of available information and collected field data to derive a correlation between mapped soil types and subsequent terrain units. Recorded attributes obtained from field data included surficial material, landform, slope, and drainage characteristics. Surficial material descriptions were obtained during soil surveys and are limited to the materials encountered within a 1 m depth of the surface. Abbreviations used in defining soil and terrain map units and soil characteristics can be found in Appendix I.

2.1.2 Survey Intensity Level

Within the RSAs, soil surveys and subsequent soil and terrain mapping were undertaken at a reconnaissance level, which involved a general examination of soil features. The mapping process for the RSAs included a review of the preliminary soil map developed by Golder (2006), examination of updated ELC mapping based on Landsat imagery (Golder 2010b), aerial reconnaissance by helicopter, and limited field verification of soil and terrain units. Soil survey inspection sites were mainly located along the NPAR, proposed mine site, and at selected locations in the proposed mine RSA. As there are no published soil surveys for the RSAs, soil series names were derived from the names of waterbodies in the region.

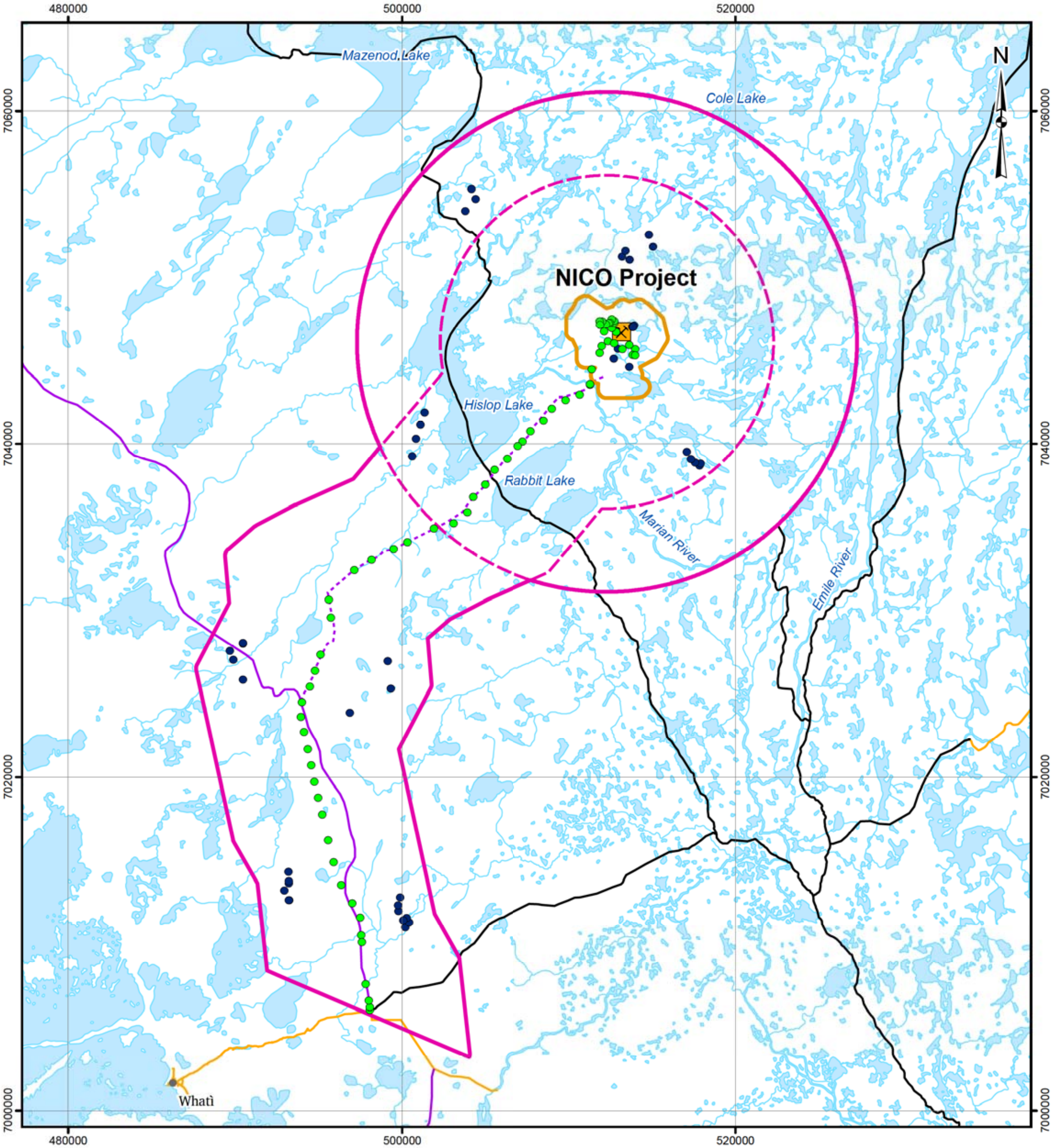
The soil survey intensity level within the LSA was higher than that for the RSAs, corresponding to an intermediate to reconnaissance level (i.e., Levels 4 to 5, which typically have a soil inspection intensity of one site for every 200 ha) (Agriculture Canada 1981). Soil and terrain map unit boundaries within the LSA were primarily derived from a correlation between ELC vegetation units and soil types. These soil map unit delineations are 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 possible soil distribution. The information should not be applied for predicting site specific characteristics without collecting additional field information.

2.1.3 Field Surveys

A review of existing soil survey information for the RSAs and LSA was undertaken in both the pre-planning and interpretation stages. Sources of information used included the following:

- summer 2005 baseline field data (Golder 2006);
- preliminary soil classification map from Golder (2006); and
- ELC classification results.

Reconnaissance level surveys were required to verify and ground truth the mapped soil polygons in the RSAs, as these map units were solely derived based on the vegetation polygons. The objective of the 2008 field inspection program was to further characterize and verify the soil map units delineated during the preliminary mapping process undertaken by Golder in 2005 (Golder 2006). Although soil sites had been surveyed within the LSA in 2005, plots were not well distributed in the LSA (Figure 2.1-1). Thus, sampling in 2008 focused on collecting information from soil map units not previously surveyed within the LSA.



LEGEND

- NICO PROJECT
- POPULATED PLACE
- EXISTING ALL-WEATHER ROAD
- EXISTING WINTER ROAD
- PROPOSED ALL-LAND WINTER ROAD ROUTE
- PROPOSED NICO PROJECT ACCESS ROAD
- WATERCOURSE
- WATERBODY
- LOCAL STUDY AREA
- REGIONAL STUDY AREA (2003-2006)
- REGIONAL STUDY AREA (2007-PRESENT)
- 2005 SOIL PLOT
- 2008 SOIL PLOT

7.5 0 7.5

SCALE 1:325,000 KILOMETRES

REFERENCE

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

PROJECT

FORTUNE MINERALS LIMITED
NICO DEVELOPERS ASSESSMENT REPORT

TITLE

SOIL INSPECTION SITES IN THE LOCAL AND REGIONAL STUDY AREAS

Golder Associates
Edmonton, Alberta

FILE NO. B-Soil-014-GIS

PROJECT No. 08-1373-0017		SCALE AS SHOWN	REV. 0
DESIGN	LV	04 Dec. 2008	
GIS	CW	06 May 2010	
CHECK	LY	17 Nov. 2010	
REVIEW	GA	17 Nov. 2010	

FIGURE: 2.1-1

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The 2005 field sampling program was primarily focused on the LSA and field inspections were selected on the basis of the following:

- access;
- landform and vegetation distribution;
- sampling as many different map units as possible; and
- sampling the proposed facility locations and road alignment within the NPAR RSA.

For the 2008 field mapping program, sampling sites were pre-selected based on landform and preliminary soil map unit distributions, and the necessity to field verify as many different soil map units as possible. Sample sites were modified in the field as required.

Field inspections were completed from 15 to 19 August 2008 using helicopter access. Mineral soils were examined using a shovel and Dutch auger up 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. Final selection of inspection sites in the field was based on the preliminary soil map units and perceived changes in drainage and vegetation that reflected soil conditions. Terrain and soil profile characteristics were recorded using the criteria outlined in the CanSIS manual (Expert Committee on Soil Survey 1983) and are summarized in Table 2.1-1. Locations of sampling sites were determined with a global positioning system (GPS) unit.

Table 2.1-1 Site and Soil Profile Attributes Collected and Described in the Field

Data Type	Attributes Described
Soil Profile	horizonation and depth
	horizon texture
	mottles
	coarse fragments
	depth of peat/LFH
	depth to ground water
	depth to frozen
Site Characteristics	landform
	surface expression
	slope position
	slope class
	drainage
	moisture and nutrient regime

LFH = organic horizon developed primarily from the accumulation of leaves, twigs, and woody materials with or without a minor component of mosses where: L – organic matter in which the original structures are easily recognizable; F – accumulation of partially decomposed organic matter; and H – accumulations of decomposed organic matter in which the original structures are indiscernible.

A Quality Assurance/Quality Control (QA/QC) program was implemented to maintain confidence with data collection, data entry, and data analysis. Each datasheet was checked in the field to make certain that all data fields were completed. Data entry was evaluated for errors or omissions by reviewing all the datasheets to confirm that the electronic database accurately reflected field observations. All completed calculations were checked to make sure that the correct formulas, procedures, or data sources were used. All components of the QA/QC process were completed by individuals who were not involved in that stage of the Project.

2.1.4 Soil Mapping and Classification

The approach to soil and terrain classification and mapping involved reviewing existing information, field surveys, soil sampling and analysis, and development of soil and terrain maps. All soil types encountered during the field surveys were classified into soil series based on similarities in soil characteristics. 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 RSAs, soil series names were taken from the names of waterbodies in the region. Appendix II provides a summary of the soil series identified for the Project.

Soil mapping involved the correlation of field observations to mapped ELC vegetation units to determine general relationships between vegetation and soils. Ikonos Imagery classification and Landsat Thematic Mapper satellite imagery were used to delineate vegetation units for the ELC map for the LSA and RSAs, (Golder 2010b). These vegetation units were then used as part of the soil mapping process to derive correlations between soil series and terrain features, and the ELC vegetation types in both the LSA and RSAs (Appendix III). Soil inspection information was extrapolated to other map units using the principles of geomorphology and surficial geology, in combination with ground-truthed vegetation patterns.

Due to the resolution of the ELC data (i.e., 30 m x 30 m pixel size), many soil map units are presented as complex units to capture the range of soil types on the landscape. Not all soil series were mapped if they represented minor inclusions that could not be separated at the scale of mapping. Soil map unit complexes are defined as dominant, co-dominant, or sub-dominant based on the proportion of soil series present in the unit. Dominant soil series represented the most common soil series and typically occupied between 60 to 100 percent (%) of the map unit. Co-dominant soil series were defined as soils that occurred in near equal proportion to the dominant soil series, whereas sub-dominant soils represented a minor proportion of the map unit (typically 20 to 30%). Soil series that represented less then 20% of the map unit were not mapped.

2.2 PERMAFROST POTENTIAL

Permafrost potential was attributed to each soil map unit in the LSA and RSAs based on soil series, drainage, general topography, and the presence or absence of permafrost observed during field surveys (Table 2.2-1). In general, poorly to imperfectly drained soils were rated as having a moderate permafrost potential, whereas 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. Cryosolic soils were rated as having a high potential, as data from selected soil inspection sites verified the presence of permafrost in these areas.

Table 2.2-1 Permafrost Potential of Soil Types in the Regional and Local Study Areas

Soil Order	Soil Texture	Soil Drainage Class	Permafrost Potential
Cryosols	Variable (permafrost present at depth)	Poorly to Very Poorly	High
Gleysols and Organic	Fine to medium textured materials and organics	Imperfectly to Poorly	Moderate
Brunisols	Coarse textured sands and gravels	Moderately-well to Imperfectly	Low
Regosols	Coarse textured sands and gravels or eroding bedrock	Rapidly	Negligible

2.3 SOIL SENSITIVITY AND QUALITY IN THE LOCAL STUDY AREA

2.3.1 Soil Erosion Risk

The risk of soil erosion from water and/or wind is influenced by many factors including soil particle size, organic matter content, water content, permeability, topography, slope gradient, vegetation cover, natural events (e.g., freeze-thaw), as well as human activities that cause soil disturbance (Cruse et al. 2001; Campbell et al. 2002; Transportation Association of Canada [TAC] 2005). Erosion from water and wind differ by the processes that move detached soil particles, and each process of erosion affects soil differently. The outcome of soil erosion is important because of potential off-site effects (Kuhn and Bryan 2004). These effects include the sedimentation of adjacent waterbodies, and the release of chemicals from the soil into surface water, which may alter water quality.

Soil erosion risk from water is generally determined by applying the modified Universal Soil Loss Equation (USLE) 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).

The potential for soil erosion by water is affected by soil texture, organic matter content, water content, permeability, topography, slope gradient, and vegetation cover. Finer textured soils (clay) tend to be more prone to erosion by water than coarser textured soils (sand) (TAC 2005), especially when the soil structure has been disturbed by freeze-thaw or human activity (Cruse et al. 2001). The higher permeability of sandy textured soils also contributes to a lower potential for over-land flow of water, thus increasing the potential for soil erosion. In areas where slope gradient and slope length increases, so does the potential for soil erosion regardless of soil texture.

The potential for erosion of soil by wind is affected by vegetation cover, wind velocity, soil water content, and soil texture. In general, coarse (sandy) textured soils are more prone to wind erosion than finer (clay) textured soils (Coote and Pettapiece 1989). Sandy textured soils typically do not have a well developed soil structure. The lack of soil structure is due to limited soil aggregation or adhesion of the soil particles, which does not allow for the formation of larger and more stable soil aggregates that are less likely to be moved by wind. Organic soils are typically less prone to wind erosion, unless they have dried out, or are disturbed (Campbell et al. 2002) and is a function of the degree of peat decomposition. Thus, the more highly decomposed, or humic, the organic soil is, the greater the risk for wind erosion.

For the Project, soil erosion risk was 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 developed based on the most limiting erosion factor (wind or water) and modified based on natural factors specific to the LSA, such as organic or shallow soils and permafrost, using professional judgement.

2.3.2 Sensitivity to Acidification

The sensitivity of mineral soils to acid deposition was evaluated using the chemical criteria described by Holowaychuk and Fessenden (1987). Soils are categorized as having high, medium, or low sensitivity ratings with respect to sensitivity of base loss (i.e., loss of base cations; primarily calcium, magnesium, and potassium), sensitivity to acidification, and sensitivity to solubilization of aluminium. An overall soil sensitivity is derived for each soil type according to the most limiting result of the 3 categories. These ratings are related to the pH and cation exchange capacity (CEC) values of the surface horizons (0 to 20 centimetres [cm]) of the soil.

In general, acidic soils (pH values lower than 6) and alkaline soils (pH values greater than 7.5) have a lower sensitivity to acidification, as these soils have an increased buffering capacity (Holowaychuk and Fessenden 1987). In addition, soils that are high in clay and/or organic matter typically have a higher CEC, and therefore a low sensitivity to acidification. Soils that tend to be the most sensitive to acidification have a low CEC and are associated with neutral pH values in the range of 6.5 to 7.5.

The sensitivity of organic soils to acid deposition was also based on criteria suggested by Holowaychik and Fessenden (1987). The sensitivity rating for organic soil is based on the type of peatland system (i.e., bog, poor fen, moderate rich fen, and extreme rich fen) that is present. In particular, it is based on the pH, CEC, and percent base saturation of the surface layer of organic soil, as well as the pH and base cation content of the associated pore water. In general, extremely poor or rich nutrient 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.

Acidification sensitivity of mineral and organic soils of each soil type in the LSA was classified as high, moderate, or low based on the system presented in Holowaychuk and Fessenden (1987) and interpretations of the soil data. Within the LSA, soil map units were assigned a sensitivity rating such that, where a single soil association represents 80% or more of the map unit, only the sensitivity rating for that soil association is shown. Where a single 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.

2.3.3 Soil Chemical and Nutrient Parameters

Soil samples of representative soil profiles of each of the major soil series in the LSA were collected from a total of 11 sites during the field programs of 2005 and 2008 for chemical analysis of soil productivity. Once collected, soil samples were sealed in labelled Ziploc bags and frozen until submission to Alberta Research Council (ARC) (2005 samples) and the ALS Laboratory Group in Edmonton, Alberta (2008 samples). Soil samples were air dried and analyzed for all or some of the following parameters depending on depth and organic matter content:

- texture (particle size analysis);
- organic matter content - organic horizons only;
- pH and electrical conductivity;
- available nitrate-N;
- available phosphate and potassium; and
- available sulphur (2005 samples).

Details on soil nutrient analysis methods are presented in Appendix IV. Soil samples were also collected in 2005 and 2008 for metals analysis to measure background metal concentrations in soils in the LSA. Metals analysed included aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, chromium, cobalt, copper, lead, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, uranium, vanadium, and zinc. Soil sample collection methods for baseline metal concentrations and corresponding results can be found in the soil and vegetation chemistry baseline report (Golder 2010c).

2.3.4 Reclamation Suitability

The reclamation suitability of soils in the LSA was evaluated to support salvage and reclamation planning, as construction activities will include the removal and salvaging of topsoil and subsoil for use in subsequent reclamation activities. Soil reclamation suitability ratings were determined by evaluating soil properties including texture, coarse fragment content, and selective soil chemistry parameters (Alberta Soils Advisory Committee 1987). Although the criteria were originally developed for the prairie and forest regions of Alberta, they reflect generic soil suitability for plant growth and soil handling characteristics, and were considered generally applicable to the LSA.

According to the criteria for forest soils, the topsoil layer should consist of a mixture of the organic (LFH) and A-horizon soil layers, and a portion of the B-horizon to a depth of approximately 20 cm, depending on site-specific conditions. Salvage of the upper layer separately from the lower layers is important because the upper layers contain a higher concentration of organic matter, and macro- and micro-organisms that maintains growth support capability, and can potentially serve as a seed source for revegetation. Salvage of subsoil is also recommended to provide an adequate soil depth for rooting of vegetation. Thus, the reclamation suitability ratings for both the topsoil and the subsoil are included here, and require consideration of several soil chemical properties. These properties are summarized in Table 2.3-1 for topsoil and in Table 2.3-2 for subsoils. The pH values presented are most appropriate for trees, primarily conifers. In addition, salinity, sodicity, and saturation limits may vary depending on the plant species used for re-vegetation.

Individual soil series within the LSA were rated according to the suitability criteria outlined by the Alberta Soils Advisory Committee (1987). Soils of the LSA were rated as G (good), F (fair), P (poor), or U (unsuitable) for the topsoil and the subsoil components of their profiles. These soil quality criteria do not include organic soils; therefore, the rating ‘O’ was used to designate these soils. Organic soils can be excellent materials for use in topsoil replacement during reclamation when mixed with mineral materials.

The reclamation suitability of each soil map unit in the LSA was determined by considering the proportions of the dominant and sub-dominant soil associations, where complex units occurred. The proportions of the soil associations within these map units were examined, and a suitability rating, recognizing a dominant and a sub-dominant component, was derived.

Table 2.3-1 Criteria for Evaluating Suitability of Topsoil for Reclamation in the Northern Forest Region[a]

Soil Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
pH	5.0 to 6.5	4.0 to 5.0 and 6.5 to 7.5	3.5 to 4.0 and 7.5 to 9.0	<3.5 and >9.0
Salinity (EC) dS/m	<2	2 to 4	4 to 8	>8
Sodicity (SAR)	<4	4 to 8	8 to 12	>12
$CaCO_3$ equivalent (%)	<2	2 to 20	20 to 70	>70
Saturation (%)	30 to 60	20 to 30 or 60 to 80	15 to 20 or 80 to 120	<15 and >120
Texture	FSL, VFSL, L, SiL, SL	CL, SCL, SiCL	LS, SiC, C, HC, S	NA
Moist consistency	very friable to friable	loose to firm	very firm	extremely firm
Stoniness (% of area)	<30	30 to 50	50 to 80	>80
Rockiness (% of area)	<20	20 to 40	40 to 70	>70

[a] Adapted from Alberta Soils Advisory Committee (1987).

EC = electrical conductivity; dS/m = deciSiemens per metre; SAR = sodium adsorption ratio; S = sand; LS = loamy sand; SL = sandy loam; FSL = fine sandy loam; L = loam; SiL = silt loam; CL = clay loam; VFSL = very fine sandy loam; SCL=sandy clay loam; SiCL = silty clay loam; C = clay; HC = heavy clay; $CaCO_3$ = calcium carbonate.

% = percent; > = greater than; < = less than; NA = not applicable

Table 2.3-2 Criteria for Evaluating the Suitability of Subsoil for Reclamation in the Northern Forest Region[a]

Soil Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
pH	5.0 to 7.0	4.5 to 5.0 and 7.0 to 8.0	3.5 to 4.5 and 8.0 to 9.0	<3.5 and >9.0
Salinity (EC) dS/m	<3	3 to 5	5 to 8	>8
Sodicity (SAR)	<4	4 to 8	8 to 12	>12
$CaCO_3$ equivalent (%)	<5	5 to 20	20 to 70	>70
Saturation (%)	30 to 60	20 to 30 or 60 to 80	15 to 20 or 80 to 100	<15 and >100
Texture	FS, VFSL, L, SiL, SL	CL, SiC, SiCL	S, LS, S, C, HC	bedrock
Moist consistency	very friable, friable, firm	loose, very firm	extremely firm	hard rock
Coarse fragments (% Volume)[b]	<30	30 to 50	50 to 70	>70
Coarse fragments (% Volume)[c]	<15	15 to 30	30 to 50	>50

[a] Adapted from Alberta Soils Advisory Committee (1987).

[b] Matrix texture (modal) finer than sandy loam.

[c] Matrix texture (modal) sandy loam and coarser.

EC = electrical conductivity; dS/m = deciSiemens per metre; SAR = sodium adsorption ratio; FS = fine sand; VFSL = very fine sandy loam; S = sand; L = loam; SiL = silt loam; SL = sandy loam; CL = clay loam; SiC = silty clay; SiCL = silty clay loam; LS = loamy sand; C = clay; HC = heavy clay; $CaCO_3$ = calcium carbonate

% = percent; > = greater than; < = less than

3 RESULTS

3.1 TERRAIN AND SOIL CONDITIONS IN THE REGIONAL STUDY AREAS

3.1.1 Field Programs

During summer field programs, a total of 66 soil inspection sites were examined in the NPAR RSA and LSA in 2005 and 43 field inspections were examined in the LSA and RSAs in 2008 (Table 3.1-1, Figure 2.1-1). A list of all soil inspection sites and selected soil characteristics from the 2005 and 2008 field surveys are presented in Appendix V.

Table 3.1-1 Number of Soil Inspection Sites Sampled in 2005 and 2008 Field Seasons

Study Area	Number of Soil Inspection Sites		
	2005	2008	Total
Proposed Mine RSA[a]	15	17	32
NPAR[b] RSA	29	20	49
LSA[c]	22	6	28
Total	**66**	**43**	**109**

[a] RSA = regional study area
[b] NPAR = Proposed NICO Poject Access Road
[c] LSA = local study area

3.1.2 Terrain

Eight terrain units have been defined and mapped for the RSAs based on surficial parent material and landform patterns. Descriptions of terrain unit characteristics are provided in Table 3.1-2, while the geographical distribution within the RSAs is summarized in Table 3.1-3 and Figure 3.1-1.

Table 3.1-2 Description of Terrain Units in the Regional Study Areas

Terrain Unit	Terrain Unit Description	Surficial Parent Material	Landform
Fg1	glaciofluvial	glaciofluvial	level to undulating, with minor hummocky and steep areas
Fg1-O	glaciofluvial and organic (frozen, potential permafrost)	glaciofluvial (gravels), and shallow to deep organic (frozen, potential permafrost)	undulating to rolling with level areas and minor inclusions of steep areas
Fg1-M-O	glaciofluvial, morainal/till and organic	glaciofluvial (gravels), morainal/till and shallow organic veneers	undulating with level areas and minor inclusions of steep areas
Fg2(M)-O	glaciofluvial (morainal/till) and organic	glaciofluvial (sands) and shallow organic veneers, with minor morainal/till inclusions	undulating with level areas
N	fen	fen	level to depressional
B	bog	bog	level to depressional
R	bedrock	bedrock	high relief bedrock ourtcrops, with steep scarps and ridges
Water	water	water	depressional

Table 3.1-3 Geographic Extent of Terrain Units in the Regional Study Areas

Terrain Unit	Description	Proposed Mine RSA		NPAR RSA		Total RSA	
		Area (ha)	%	Area (ha)	%	Area (ha)	%
Fg1	glaciofluvial	1 864	3	3 918	10	5 782	5
Fg1-O	glaciofluvial and organic (frozen, potential permafrost)	19 719	28	0	0	19 719	18
Fg1-M-O	glaciofluvial, morainal/till and organic	15 496	22	13 396	35	28 893	27
Fg2(M)-O	glaciofluvial (morainal/till) and organic	5 044	7	11 713	31	16 757	15
N	fen	1 487	2	3 827	10	5 314	5
B	bog	4 129	6	3 271	9	7 399	7
R	bedrock	9 492	13	119	<1	9 611	9
Water	water	13 455	19	2 086	5	15 541	14
Total		**70 686**	**100**	**38 330**	**100**	**109 016**	**100**

Note: Some numbers are rounded for presentation purposes. Therefore; it may appear that the totals do not equal the sum of the individual values.

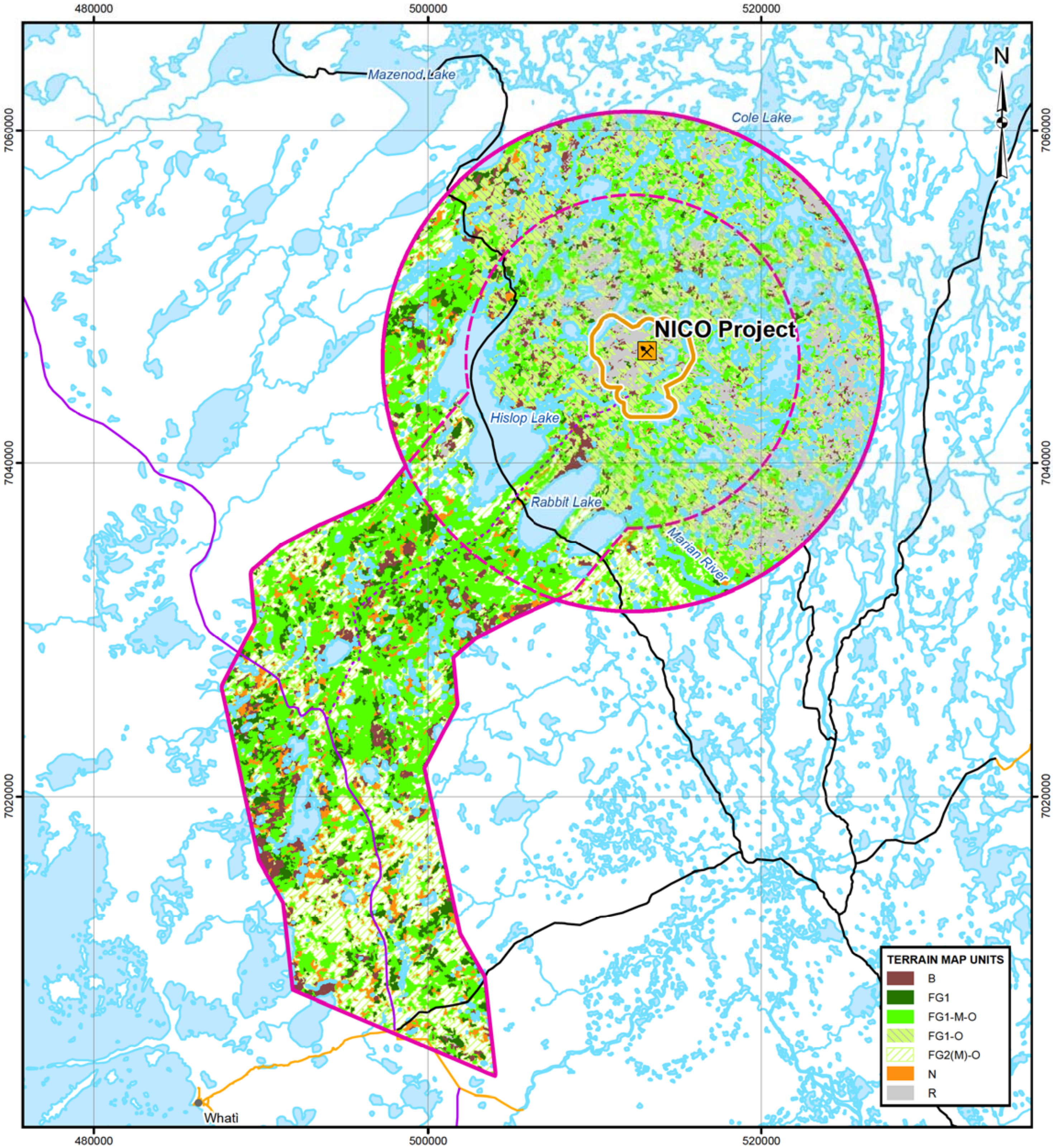
% = percent; ha = hectare; NPAR = Proposed NICO Project Access Road; RSA = regional study area

The most common terrain unit within the NPAR RSA is the glaciofluvial, morainal/till, and organic (Fg1-M-O) complex, which covers 13 396 (35%) of the NPAR RSA (Figure 3.1-1). This terrain unit is also the most common within the total RSA and covers 28 893 ha (27%) of the total area. Glaciofluvial gravels and morainal/till overlying level to undulating low relief landscapes predominate, with shallow organic veneers occurring on level to depressional areas.

The most common terrain unit encountered in the proposed mine RSA is the glaciofluvial and organic (frozen) (Fg1-O) map unit, which covers 19 719 ha (28%) of the proposed mine RSA and does not occur within the NPAR RSA (Figure 3.1-1). It is found exclusively within the proposed mine RSA, northeast of Rabbit and Hislop Lakes. This terrain unit is primarily comprised of coarse textured materials overlying undulating to rolling topography, with frozen mineral and organic deposits occurring in level or depressional areas.

The glaciofluvial (morainal/till) and organic (Fg2(M)-O) complex covers 11 713 ha (31%) of the NPAR RSA and 16 757 ha (15%) of the total RSA (Figure 3.1-1). This terrain unit is characterized by sandy and coarse textured gravely glaciofluvial deposits over undulating low relief topography and shallow organic veneers deposited in poorly drained, level areas. This terrain unit is most prevalent in the southern portion of the NPAR RSA.

Water comprises a considerable portion of the total RSA at 15 541 ha (14%) with 13 455 ha occurring within the proposed mine RSA. Hislop, Rabbit, Tumi and Betty Ray lakes represent the largest waterbodies in the region, with the Marian River representing the dominant watercourse. The remaining terrain units include bedrock (R), bog (B), fen (F), and glaciofluvial (Fg1) features and cover 9%, 7%, 5%, and 5% of the total RSA, respectively.



LEGEND

- NICO PROJECT
- POPULATED PLACE
- EXISTING ALL-WEATHER ROAD
- EXISTING WINTER ROAD
- PROPOSED ALL-LAND WINTER ROAD ROUTE
- PROPOSED NICO PROJECT ACCESS ROAD
- WATERCOURSE
- WATERBODY
- LOCAL STUDY AREA
- REGIONAL STUDY AREA (2003-2006)
- REGIONAL STUDY AREA (2007-PRESENT)

7.5 0 7.5

SCALE 1:325,000 KILOMETRES

NOTE: Terrain map unit descriptions can be found in Table 3.1-1 of the report.

REFERENCE

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

PROJECT
FORTUNE MINERALS LIMITED
NICO DEVELOPERS ASSESSMENT REPORT

TITLE
TERRAIN MAP UNITS IN THE REGIONAL STUDY AREA

Golder Associates
Edmonton, Alberta

FILE NO. B-SOIL-001-GIS				
PROJECT No. 08-1373-0017			SCALE AS SHOWN	REV. 0
DESIGN	LV	08 Dec. 2008	FIGURE: 3.1-1	
GIS	CW	06 May 2010		
CHECK	LY	17 Nov. 2010		
REVIEW	GA	17 Nov. 2010		

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3.1.3 Soil Classification and Mapping

Nine soil map units, including water, have been defined and mapped for the RSAs based on correlations with the Ecological Land Cover Classification (ELC) vegetation classes, soil characteristics and terrain features. Most of these units were defined as complex units to capture the range of variability in soil types present on the landscape. The distribution and extent of each soil map unit within the proposed mine and NPAR RSAs is provided in Table 3.1-4 and illustrated in Figure 3.1-2.

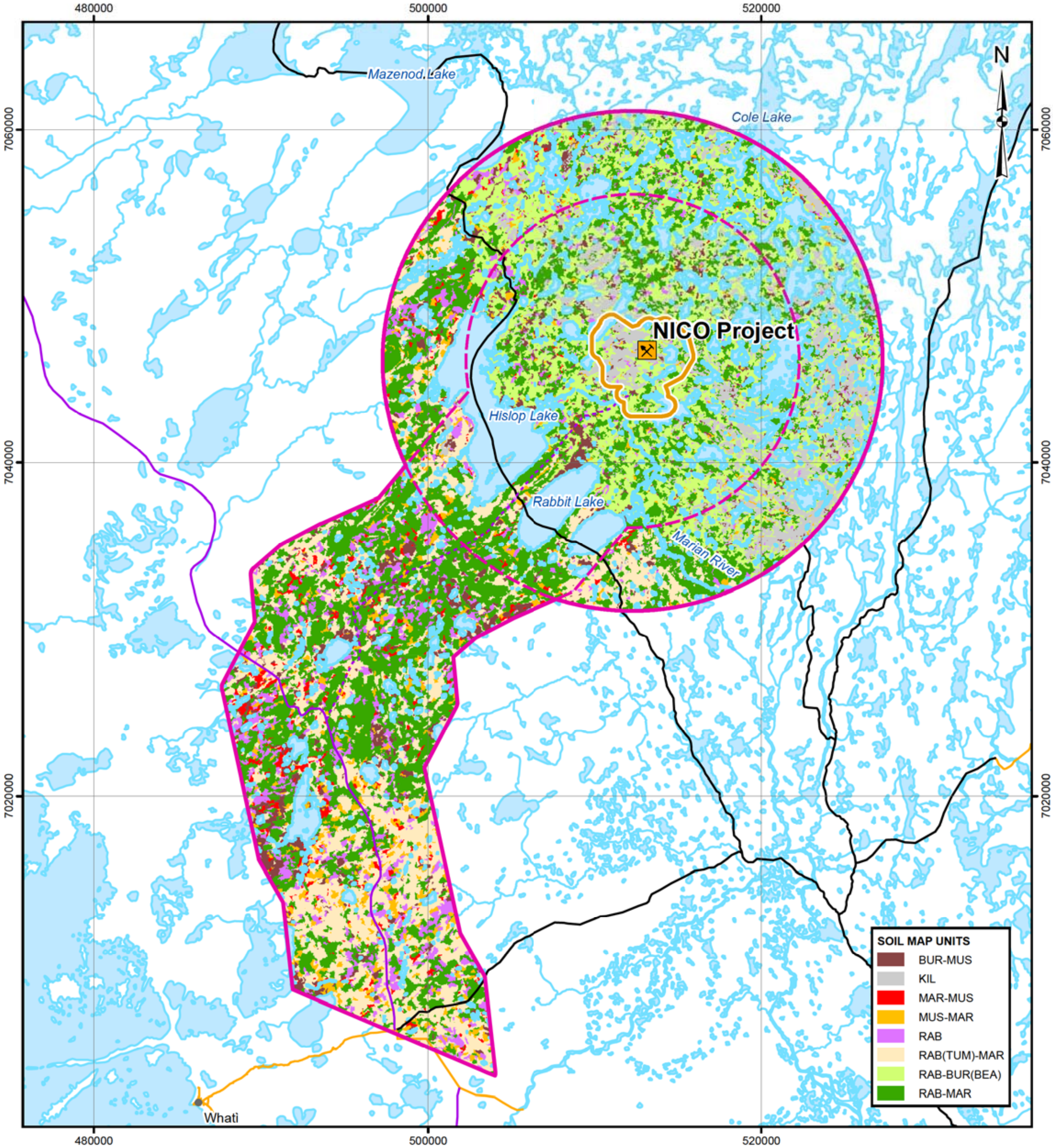
Table 3.1-4 Geographic Extent of Soils in the Regional Study Area

Soil Map Unit	Map Unit Name	Soil Patterns[a]	Proposed Mine RSA		NPAR RSA		Total RSA	
			Area (ha)	%	Area (ha)	%	Area (ha)	%
BUR-MUS	Burke	D: Cryosolic organics (BUR)	3113	4	2631	7	5744	5
	Muskeg	S: Wetlands-organic (MUS)						
KIL	Killam	D: Thin veneers over Bedrock (KIL)	9492	13	119	<1	9611	9
MAR-MUS	Marian	D: Wetlands-gleysolic (MAR)	652	1	1808	5	2460	2
	Muskeg	S: Wetlands-organic (MUS)						
MUS-MAR	Muskeg	D: Wetlands-organic (MUS)	1851	3	2658	7	4510	4
	Marian	S: Wetlands-gleysolic (MAR)						
RAB	Rabbit	D: Brunisolic (RAB)	1864	3	3918	10	5782	5
RAB(TUM)-MAR	Rabbit	D: Brunisolic (RAB)	5044	7	11 713	31	16 757	15
	Tumi	C: Wetlands-gleysolic (MAR)						
	Marian	S: Brunisolic (TUM)						
RAB-BUR(BEA)	Rabbit	D: Brunisolic (RAB)	19 719	28	0	0	19 718	18
	Burke	C: Cryosolic organics (BUR)						
	Bea	C: Wetlands-cryosolic (BEA)						
RAB-MAR	Rabbit	D: Brunisolic (RAB)	15 496	22	13 397	35	28 893	27
	Marian	C: Wetlands-gleysolic (MAR)						
Water	NA	NA	13 455	19	2086	5	15 541	14
Total			**70 686**	**100**	**38 330**	**100**	**109 016**	**100**

Note: Some 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 Section 2.1.4 for more details).

% = percent; ha = hectare; NPAR = Proposed NICO Project Access Road; RSA = regional study area; NA = not applicable



LEGEND

- NICO PROJECT
- POPULATED PLACE
- EXISTING ALL-WEATHER ROAD
- EXISTING WINTER ROAD
- PROPOSED ALL-LAND WINTER ROAD ROUTE
- PROPOSED NICO PROJECT ACCESS ROAD
- WATERCOURSE
- WATERBODY
- LOCAL STUDY AREA
- REGIONAL STUDY AREA (2003-2006)
- REGIONAL STUDY AREA (2007-PRESENT)

7.5 0 7.5

SCALE 1:325,000 KILOMETRES

NOTE: Soil map unit descriptions can be found in Table 3.1-3 of the report.

REFERENCE

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

PROJECT

FORTUNE MINERALS LIMITED
NICO DEVELOPERS ASSESSMENT REPORT

TITLE

DOMINANT SOIL MAP UNITS IN THE REGIONAL STUDY AREA

Golder Associates
Edmonton, Alberta

FILE NO. B-Soil-002-GIS				
PROJECT No. 08-1373-0017			SCALE AS SHOWN	REV. 0
DESIGN	LV	08 Dec. 2008	FIGURE: 3.1-2	
GIS	CW	06 May 2010		
CHECK	LY	17 Nov. 2010		
REVIEW	GA	17 Nov. 2010		

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The most common soil map unit in the NPAR RSA is RAB-MAR, which covers 13 397 ha of the NPAR RSA (Figure 3.1-2). This soil map unit is also the most common within the total RSA and covers 28 893 ha or 27% of the total RSA. The dominant soil type in this map unit is coarse textured Brunisolic soils of the Rabbit series (Figure 3.1-2), which is associated with upland areas. Marian soils represent minor inclusions in this unit and are described as shallow, peaty Rego Gleysols that occur in transition areas between wetlands and uplands.

The RAB-BUR(BEA) soil map unit is the second most abundant unit in the total RSA at 19 718 ha (18%) and occurs only in the proposed mine RSA. It is comprised of coarse textured Brunisolic Rabbit soils that are predominant in upland areas, with Cryosolic organic and wetland soils occurring in low-lying areas.

The RAB(TUM)-MAR soil map unit accounts for 16 757 ha (15%) of the total RSA and primarily occurs within the NPAR RSA (11 713 ha) (Figure 3.1-2). Coarse textured Brunisolic Rabbit soils are the dominant soil type, with Tumi soils occurring as co-dominant. Marian soils are minor inclusions in this map unit and are represented by shallow peaty Rego Gleysols occurring in transitional areas between wetlands and uplands.

The KIL soil map unit represents 9611 ha (9%) of the total RSA and occurs predominantly in the northern and eastern parts of the proposed mine RSA (Figure 3.1-2). Killam soils are represented by thin, discontinuous Orthic Regosolic soils and exposed bedrock outcrops. In contrast, the RAB soil map unit occurs primarily within the NPAR RSA on upland areas and accounts for 5782 ha (5%) of the total RSA.

Wetland soil map units are defined by the BUR-MUS, MAR-MUS and MUS-MAR units, which collectively represent approximately 11% of the total RSA (Table 3.1-4). The BUR-MUS map unit is a mixture of dominant Cryosolic Organic and sub-dominant wetland Organic soils that occur in depressional boggy/wetland areas. This map unit is closely associated with treed bogs, which have well developed peat layers that may be frozen at depth. In contrast, the MUS-MAR and MAR-MUS map units represent wetland soils that are associated with treed fens, graminoid fens and marshes that are not frozen.

3.2 TERRAIN AND SOIL CONDITIONS IN THE LOCAL STUDY AREA

3.2.1 Terrain

Ten terrain units have been defined and mapped for the LSA based on surficial parent material and landform patterns, including water, disturbed, and unclassified areas. Disturbed areas represent existing anthropogenic features, such as exploration roads and facilities within the LSA. Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference. Because the mapping process for terrain are largely inferred from the interpretation of landscape features (i.e., elevation contours and landform), ELC vegetation classes, and correlated to survey results, areas without an ELC vegetation class could not be assigned a terrain map unit. Descriptions of terrain unit characteristics are provided in Table 3.2-1, and the geographical distribution within the LSA is summarized in Table 3.2-2 and Figure 3.2-1.

The most common terrain unit encountered in the LSA is the glaciofluvial, bedrock, and organic (Fg(R)-O) terrain unit, and covers 882 ha (33%) of the LSA (Figure 3.2-1). This terrain unit is characterized by sandy and coarse textured gravely glaciofluvial deposits over undulating to rolling topography. High relief bedrock outcrops and ridges with thin sandy veneers are also common occurrences. Shallow to deep organic veneers are less common, but occur in poorly drained low-lying to level areas.

The bedrock (R) terrain unit covers 697 ha (26%) of the LSA (Figure 3.2-1). Coarse textured glaciofluvial gravels predominate on undulating low relief landscapes, with shallow organic veneers occurring in level areas.

Fen (N) and bog (B) terrain units are widespread through the LSA and comprise 206 ha (8%) and 189 ha (7%), respectively (Table 3.2-2). These terrain units are found in scattered pockets throughout the LSA. Water makes up 347 ha (13%) of the LSA. Portions of Burke and Lou lakes represent the largest lakes in the LSA, with the Marian River representing the dominant watercourse. The remaining terrain units comprise less than 12% of the LSA (Table 3.2-2).

Table 3.2-1 Description of Terrain Units in the Local Study Area

Terrain Unit	Terrain Unit Description	Surficial Parent Material	Landform
Fg	glaciofluvial	glaciofluvial (gravels)	level to undulating, with minor steep areas
Fg-O	glaciofluvial and organic	glaciofluvial (gravels) and organic	undulating and level, with minor hummocky and steep areas
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
O	shallow organic veneers and shallow to deep bogs (frozen, potential permafrost)	frozen shallow organic veneers and shallow to deep frozen bogs (potential permafrost)	level to depressional
N	fen	fen	level to depressional
B	bog	bog	level to depressional
R	bedrock	bedrock	high relief bedrock outcrops, with steep scarps and ridges
Water	water	water	depressional
Disturbance	disturbance	NA	NA
Unclassified	unclassified	NA	NA

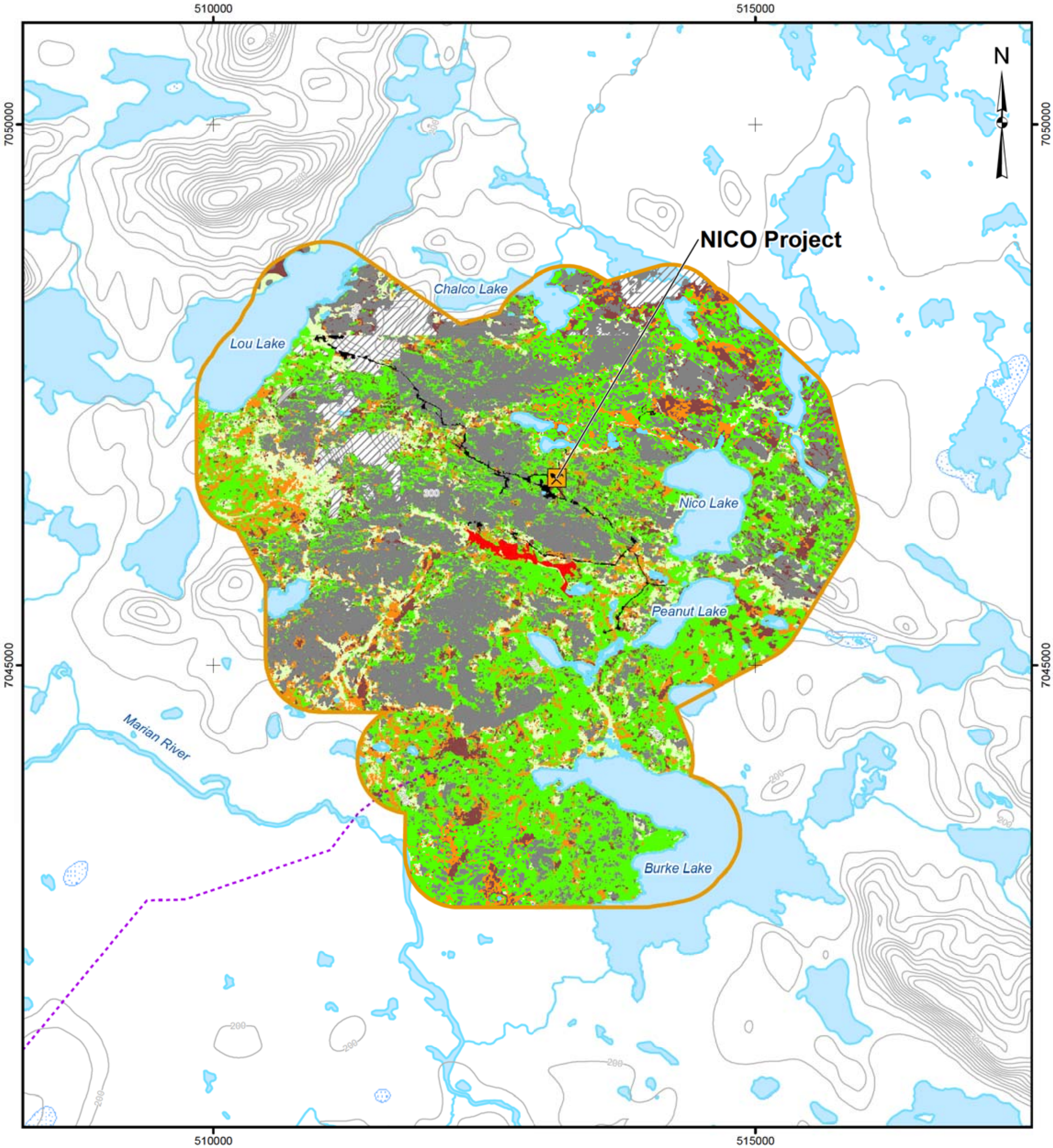
NA = not applicable

Table 3.2-2 Geographic Extent of Terrain Units in the Local Study Area

Terrain Unit	Terrain Unit Description	LSA	
		Area (ha)	%
Fg	glaciofluvial	1	<1
Fg-O	glaciofluvial and organic	219	8
Fg(R)-O	glaciofluvial, bedrock, and organic	882	33
O	shallow organic veneers and shallow to deep bogs (frozen, potential permafrost)	9	<1
N	fen	206	8
B	bog	189	7
R	bedrock	697	26
Water	water	347	13
Disturbance	disturbance	11	<1
Unclassified	unclassified	83	3
Total		**2644**	**100**

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

% = percent; < = less than; ha = hectare; LSA = local study area



1 0 1

SCALE 1:50,000 KILOMETRES

LEGEND

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

TERRAIN MAP UNITS

- Fg
- Fg-O
- Fg(R)-O
- B
- N
- O
- R
- UNCLASSIFIED
- DISTURBANCE

NOTE: Terrain map unit descriptions can be found in Table 3.2-1 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

PROJECT
FORTUNE MINERALS LIMITED
NICO DEVELOPERS ASSESSMENT REPORT

TITLE
TERRAIN MAP UNITS IN THE LOCAL STUDY AREA

Golder Associates
Edmonton, Alberta

FILE NO. B-Soil-005-GIS				
PROJECT No. 08-1373-0017			SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	FIGURE: 3.2-1	
GIS	CW	06 May 2010		
CHECK	LY	17 Nov. 2010		
REVIEW	GA	17 Nov. 2010		

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Soil Classification and Mapping

Eleven soil map units, including water, disturbance, and unclassified areas have been defined and mapped for the LSA based on correlations with the ELC vegetation classes, soil, and landscape characteristics. Most of these units were mapped as complexes to capture the range of variability in soil types present on the landscape. Disturbed areas represent existing anthropogenic features, such as exploration roads and facilities within the LSA. Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference. Because the 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 soil map unit. The distribution and extent of each soil map unit within the LSA is provided in Table 3.2-3 and illustrated in Figures 3.2-2.

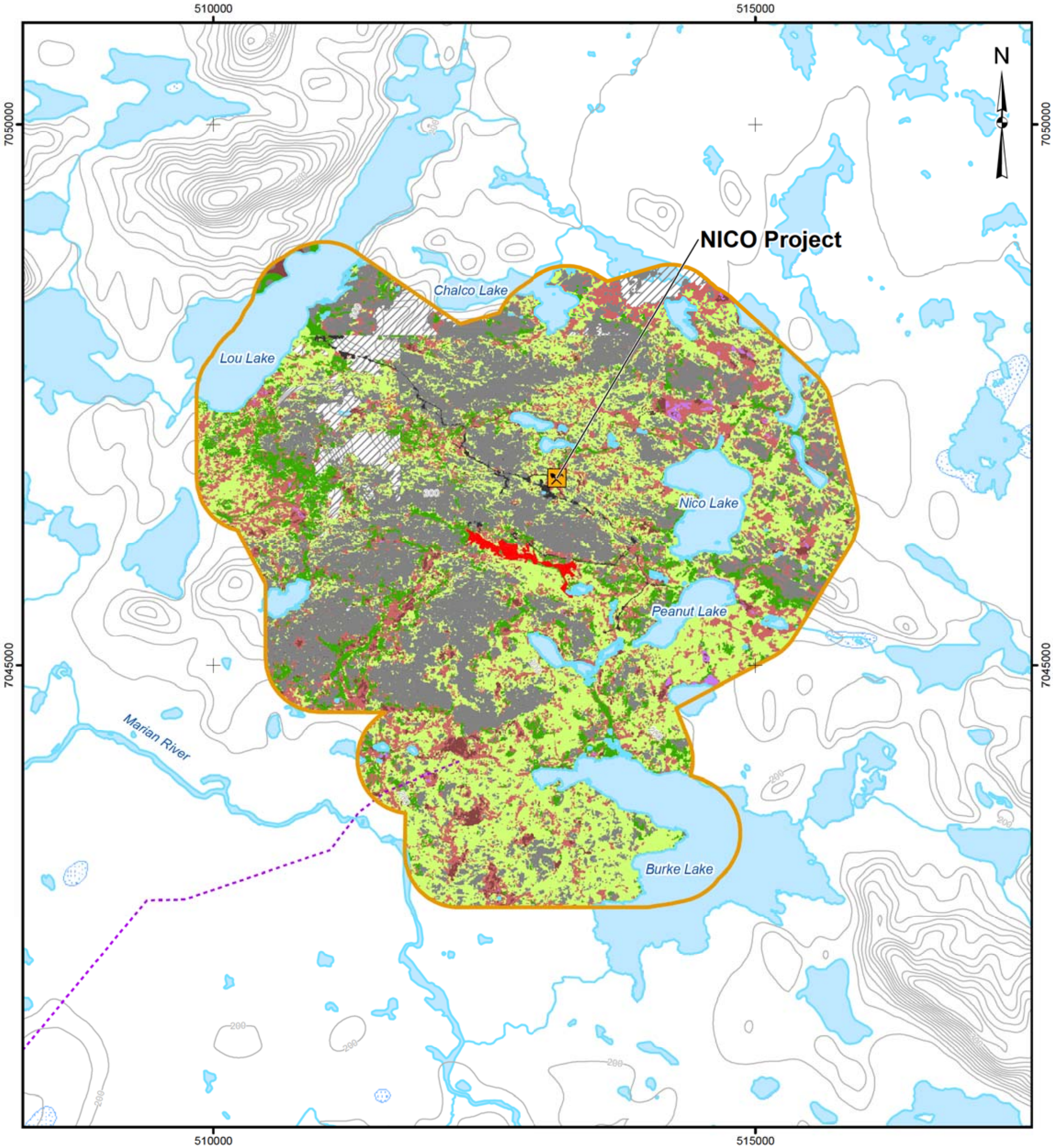
Table 3.2-3 Geographic Extent of Soils in the Local Study Area

Soil Map Unit	Map Unit Name	Soil Patterns[a]	LSA	
			Area (ha)	%
BEA-BUR	Bea Burke	D: Wetlands-Cryosolic (BEA) C: Cryosolic Organics (BUR)	9	<1
BUR-MAR	Burke Marian	D: Cryosolic Organics (BUR) C: Wetlands-Gleysolic (MAR)	55	2
KIL	Killam	D: thin veneers over Bedrock (KIL)	697	26
MUS	Muskeg	D: Wetlands-Organic (MUS)	331	13
MUS-MAR	Muskeg Marian	D: Wetlands-Organic (MUS) C: Wetlands-Gleysolic (MAR)	9	<1
RAB	Rabbit	D: Brunisolic (RAB)	1	<1
RAB-MAR	Rabbit Marian	D: Brunisolic (RAB) C: Wetlands-Gleysolic (MAR)	219	8
RAB-KIL-MAR	Rabbit Killam Marian	D: Brunisolic (RAB) C: thin veneers over Bedrock (KIL) S: Wetlands-Gleysolic (MAR)	882	33
Water	NA	NA	347	13
Disturbance	NA	NA	11	<1
Unclassified	NA	NA	83	3
Total			**2644**	**100**

Note: Some 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 Section 2.1.4 for more details).

% = percent; < = less than; ha = hectare; LSA = local study area; NA = not applicable



LEGEND

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

SOIL MAP UNITS

- BEA-BUR
- BUR-MAR
- KIL
- MUS
- MUS-MAR
- RAB
- RAB-MAR
- RAB-KIL-MAR
- RAB-TUM-MAR
- UNCLASSIFIED
- DISTURBANCE

NOTE: Soil map unit descriptions can be found in Table 3.2-3 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

PROJECT
FORTUNE MINERALS LIMITED
NICO DEVELOPERS ASSESSMENT REPORT

TITLE
DOMINANT SOIL MAP UNITS IN THE LOCAL STUDY AREA

Golder Associates
Edmonton, Alberta

FILE NO. B-Soil-007-GIS

PROJECT No. 08-1373-0017		SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	FIGURE: 3.2-2
GIS	CW	26 Oct. 2010	
CHECK	LY	17 Nov. 2010	
REVIEW	GA	17 Nov. 2010	

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The most common soil map unit in the LSA is RAB-KIL-MAR, which accounts for 882 ha (33%) of the LSA (Table 3.2-3). It occurs most extensively west of Burke Lake (Figure 3.2-2). Rabbit soils are the predomiant soil type, with Killam soils occurring as a co-dominant unit. Rabbit soils are characterized by coarse textured Orthic, Eutric, and Dystric Brunisols with high amounts of coarse fragments. Killam soils are characterized by exposed bedrock outcrops with thin, discontinuous soils that have a high proportion of coarse fragments. Marian soils are minor inclusions in this map unit and are represented by shallow peaty Rego Gleysols occurring in transitional areas between wetlands and uplands.

The KIL soil map unit is the second most common soil map unit within the LSA and covers 697 ha (26%) (Table 3.2-3, Figure 3.2-2). Killam soils are typically Orthic Regosols formed from the degradation and weathering of exposed bedrock, including some water-deposited veneers over bedrock. Exposed bedrock outcrops are common and the soils that do occur in this map unit are thin, discontinuous, and can have a high proportion of coarse fragments.

The RAB-MAR soil map unit covers 219 ha (8%) of the LSA (Table 3.2-3, Figure 3.2-2). The dominant soil type in this map unit is the Rabbit soil series, which is associated with upland areas. Rabbit soils are characterized by coarse textured Orthic, Eutric, and Dystric Brunisols with high amounts of coarse fragments. Marian soils represent the co-dominant soil in this map unit and are described as shallow peaty Rego Gleysols overlying various textures that occur in transition areas between wetlands and uplands.

The MUS map unit is also prevalent within the LSA, and it covers 331 ha (13%) of the LSA (Table 3.2-3). Muskeg soils are characterized by moderately deep organic Terric Mesisols that occur on level to depressional areas. These soils are not frozen at depth and are often associated with treed fens and are found in scattered pockets 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 5% of the LSA (Table 3.2-3). The BEA-BUR map unit is a unique unit defined by mineral soils that were frozen (potential permafrost), with minor inclusions of organic soils that were frozen (potential permafrost). It is only found in the central portion of the LSA in a low-lying area between 2 major bedrock ridges (Figure 3.2-2). Bea soils are usually located in transition areas along the edges of peatlands, whereas Burke soils are more common in depressional areas, where peat bogs develop. The BUR-MAR map unit is closely associated with treed bogs, which have well developed peat layers that may be frozen at depth. In contrast, the MUS-MAR map unit represent wetland soils that are associated with graminoid fens and marshes that are not frozen. Water covers 347 ha (13%) of the LSA. Disturbance and unclassified areas comprise the remainder of the soil map units in the LSA (Table 3.2-3). Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference. Because the 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 soil map unit.

3.3 PERMAFROST POTENTIAL

3.3.1 Overview

Permafrost is generally referred to as permanently frozen soil or rock and incorporated ice and organic material that remains at or below 0°C for a minimum of 2 years due to natural climatic factors (van Everdingen 1998). The distribution and thickness of permafrost is influenced by various factors including climate, topography, peat thickness, winter snow accumulation, hydrology, and subsurface geology, as well as ground disturbance characteristics (texture). Peat thickness, vegetation cover, micro-topography (i.e., presence of hummocks), and moisture content at 50 cm are critical variables in predicting the presence of permafrost (Williams and Burn 1996).

Permafrost soils are sensitive to ground disturbances as changes to surface materials can alter the soil thermal regime and result in warming of the soil to a greater depth, and cause persistent ice to melt (Hayhoe and Tarnocai 1993). This can result in differential thaw settling, slumping, and increased soil erosion (Burgess and Harry 1990; Hayhoe and Tarnocai 1993). The potential effects of disturbance on permafrost soils depend on ice content, soil type, drainage, and vegetative cover. Peat soils are particularly sensitive to disturbance, and the subsequent melting of ice in the discontinuous permafrost zone (Magnusson and Stewart 1987). However, depressional topography, high moisture content at 50 cm, dense vegetation cover, thickness of snow cover, and thickness of surface organic matter can have an insulating effect on permafrost (Tarnocai 1984; Zoltai 1995; Williams and Burn 1996). In addition, the ice content of a disturbed area potentially can be controlled through the maintenance of snow cover, if warming at depth has not already occurred (Judge 1973).

3.3.2 Permafrost in the Regional Study Areas

In general, the distribution and thickness of permafrost increases with latitude (Zoltai 1995). As such, the occurrence of permafrost in the RSAs is characterized as discontinuous and widespread, which indicates that permafrost underlies approximately 10% to 50% of the area (Wolfe 1998). Though most peatlands typically contain permafrost, many fens are free of permafrost (Zoltai 1995). Within the RSAs, permafrost occurs in both poorly-drained organic areas and low-lying mineral soils. The distribution of permafrost is highly variable, with changes in ice content occurring over small scales (i.e., within several metres). The permafrost potential was determined for each soil series in the RSAs as described in Section 2.2. A summary of permafrost potential across the RSAs is provided in Table 3.3-1 and Figure 3.3-1.

Table 3.3-1 Permafrost Potential Class Distribution in the Regional Study Areas

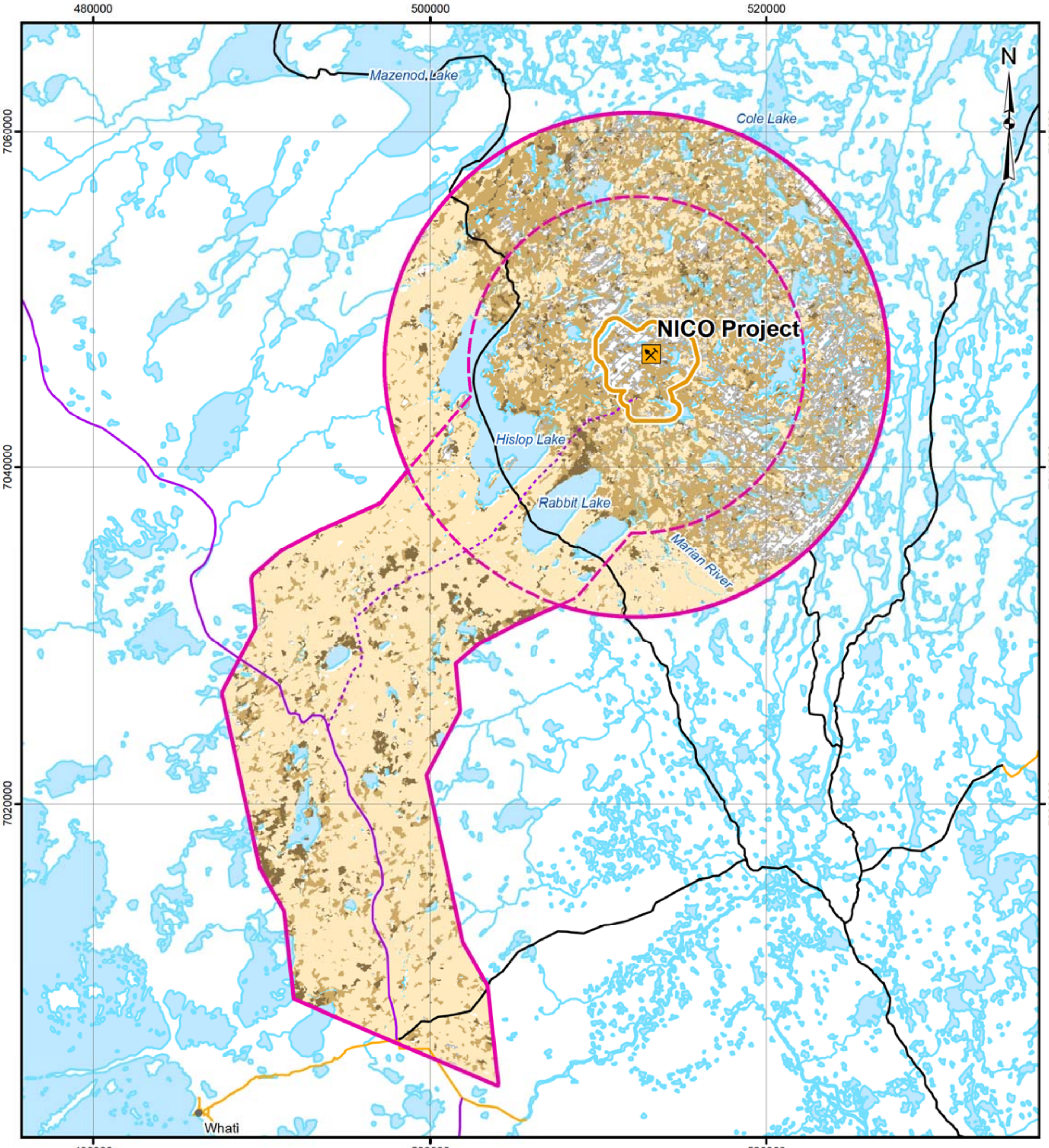
Permafrost Potential	Proposed Mine RSA		NPAR RSA		Total RSA	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
High	3113	4	2631	7	5744	5
Moderate	22 223	31	4466	12	26 689	24
Low	22 403	32	29 028	76	51 431	47
Negligible	9492	13	119	<1	9611	9
Water	13 455	19	2086	5	15 541	14
Total	**70 686**	**100**	**38 330**	**100**	**109 016**	**100**

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

% = percent; < = less than; ha = hectare; NPAR = Proposed NICO Project Access Road; RSA = regional study area

The majority of the proposed mine RSA has been characterized as having low and moderate potential for permafrost occurrence, and represents 32% and 31% of the proposed mine RSA respectively (Table 3.3-1). 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 soils). Frozen ground 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 3113 ha (4%) of the proposed mine RSA.

The majority of the NPAR RSA has been characterized as having a low permafrost potential and represents 29 028 ha (76%) of the NPAR RSA. Similar to the proposed mine RSA, areas rated as having a high permafrost potential tend to be scattered in isolated pockets throughout the NPAR RSA and make up 2631 ha (7%) of the NPAR RSA. Areas rated as having a moderate potential for permafrost in the NPAR RSA represent 4466 ha (12%).



LEGEND

- NICO PROJECT
- POPULATED PLACE
- EXISTING ALL-WEATHER ROAD
- EXISTING WINTER ROAD
- PROPOSED ALL-LAND WINTER ROAD ROUTE
- PROPOSED NICO PROJECT ACCESS ROAD
- WATERCOURSE
- WATERBODY
- LOCAL STUDY AREA
- REGIONAL STUDY AREA (2003-2006)
- REGIONAL STUDY AREA (2007-PRESENT)

PERMAFROST POTENTIAL

- HIGH
- MODERATE
- LOW
- NEGLIGIBLE

7.5 0 7.5

SCALE 1:325,000 KILOMETRES

REFERENCE

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

PROJECT
FORTUNE MINERALS LIMITED
NICO DEVELOPERS ASSESSMENT REPORT

TITLE
DISTRIBUTION OF PERMAFROST POTENTIAL IN THE REGIONAL STUDY AREA

Golder Associates
Edmonton, Alberta

FILE NO. B-Soil-003-GIS

PROJECT No. 08-1373-0017		SCALE AS SHOWN	REV. 0
DESIGN	LV	08 Dec. 2008	
GIS	CW	06 May 2010	
CHECK	LY	17 Nov. 2010	FIGURE: 3.3-1
REVIEW	GA	17 Nov. 2010	

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3.3.3 Permafrost in the Local Study Area

Permafrost in the LSA is also associated with poorly-drained organic areas and low-lying mineral soils. The BEA-BUR map unit is a unique unit defined by mineral soils that were frozen (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 3.2-2). The BUR-MAR map unit is closely associated with treed bogs, which have well developed peat layers that may be frozen. Frozen ground (potential permafrost) was observed at depths between 22 to 45 cm within the LSA, with an average thaw depth of 34 cm. Frozen ground 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 (Fortune 2007).

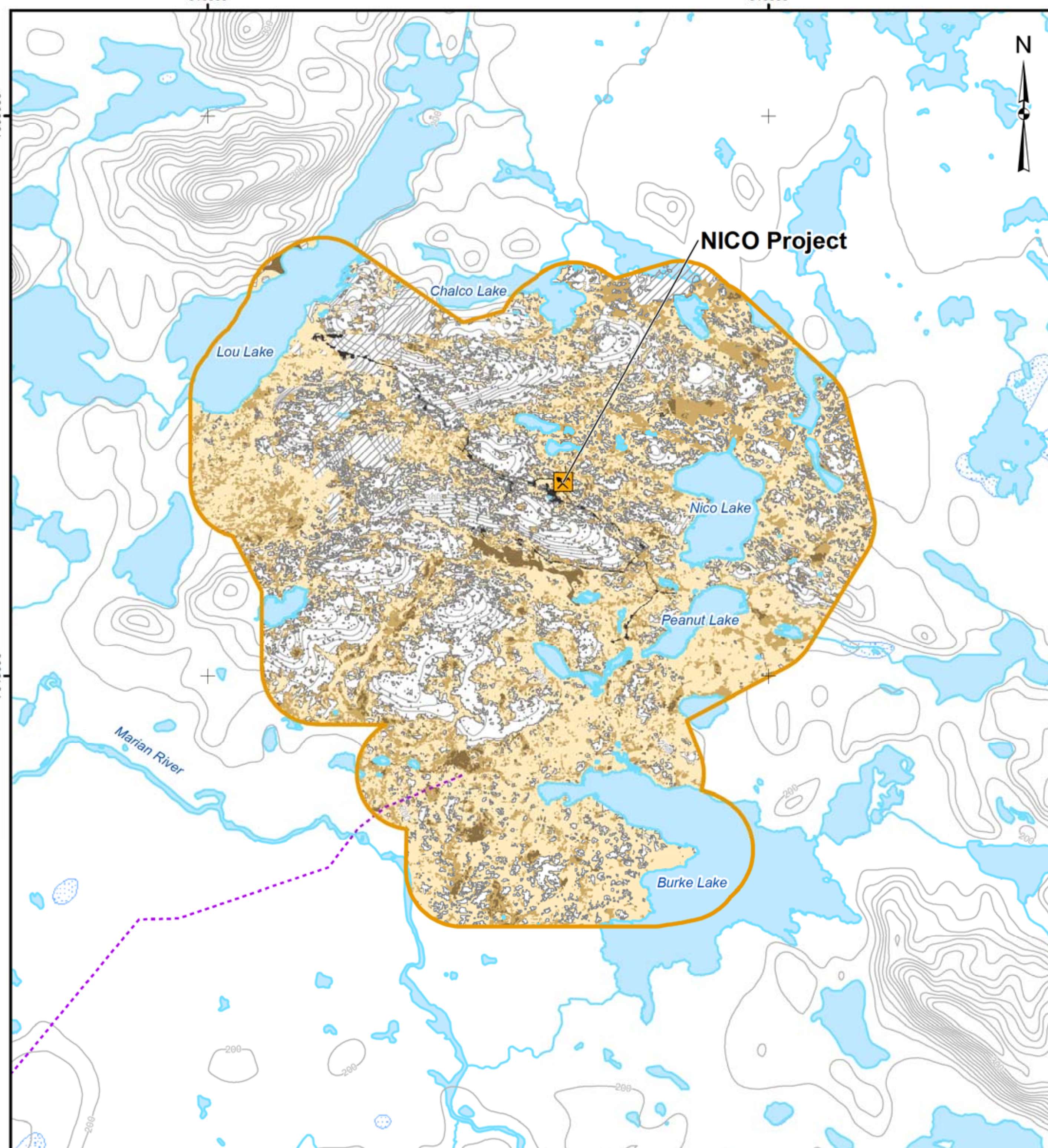
Similar to the RSA, permafrost potential was determined for each soil series in the LSA as described in Section 2.2. A summary of permafrost potential across the LSA is provided in Table 3.3-2 and illustrated in Figure 3.3-2. Within the LSA, the majority of the area (42%) is classified as having a moderate potential for permafrost. Only 64 ha (2%) of the LSA is classified as high permafrost potential, and occur in isolated pockets associated with poorly-drained organic areas and low-lying mineral soils. Disturbances and unclassified areas that cover approximately 3% of the LSA area were not assigned a permafrost potential class. Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference. Because the 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 permafrost potential.

Table 3.3-2 Permafrost Potential Class Distribution in the Local Study Area

Permafrost Potential	LSA	
	Area (ha)	%
High	64	2
Moderate	1102	42
Low	340	13
Negligible	697	26
Water	347	13
Disturbance	11	<1
Unclassified	83	3
Total	**2644**	**100**

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

% = percent; < = less than; ha = hectare; LSA = local study area



LEGEND

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

PERMAFROST POTENTIAL

- HIGH
- MODERATE
- LOW
- NEGLIGIBLE
- UNCLASSIFIED
- DISTURBANCE

1 0 1

SCALE 1:50,000 KILOMETRES

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

PROJECT
FORTUNE MINERALS LIMITED
NICO DEVELOPERS ASSESSMENT REPORT

TITLE
DISTRIBUTION OF PERMAFROST POTENTIAL IN THE LOCAL STUDY AREA

Golder Associates
Edmonton, Alberta

FILE NO. B-Soil-009-GIS				
PROJECT No. 08-1373-0017			SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	FIGURE: 3.3-2	
GIS	CW	26 Oct. 2010		
CHECK	LY	17 Nov. 2010		
REVIEW	GA	17 Nov. 2010		

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3.4 SOIL SENSITIVITY AND QUALITY IN THE LOCAL STUDY AREA

3.4.1 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 soil and terrain characteristics, resulting in loss of topsoil and subsequent soil quality. To understand soil erosion sensitivities in the LSA, all soil map units were assigned a soil erosion risk rating based on 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. Soil erosion risk ratings were not assigned to water, disturbances, and unclassified map units, as these units are not considered soil types. A summary of soil characteristics and the overall erosion sensitivity for each soil map unit is presented in Table 3.4-1.

Table 3.4-1 Erosion Sensitivity of Soil Map Units in the Local Study Area

Soil Map Unit	Map Unit Name	Soil Patterns[a]	Parent Material	Soil Erosion Risk
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 Section 2.1.4 for more details).

[b] Primarily precipitation (water) erosion sensitivities.

[c] Primarily wind erosion sensitivities.

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 soils with a presence of 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 Killam soils was also raised to moderate because any loss of this thin soil may have implications for plant growth. Soil erosion risk was assigned to complex map units based on the relative proportion of dominant and sub-dominant soils and their associated erosion sensitivities. Thus, the rating of Low (Moderate) indicates that there are some areas of soil complexes in which one of the soil components has a rating higher than Low.

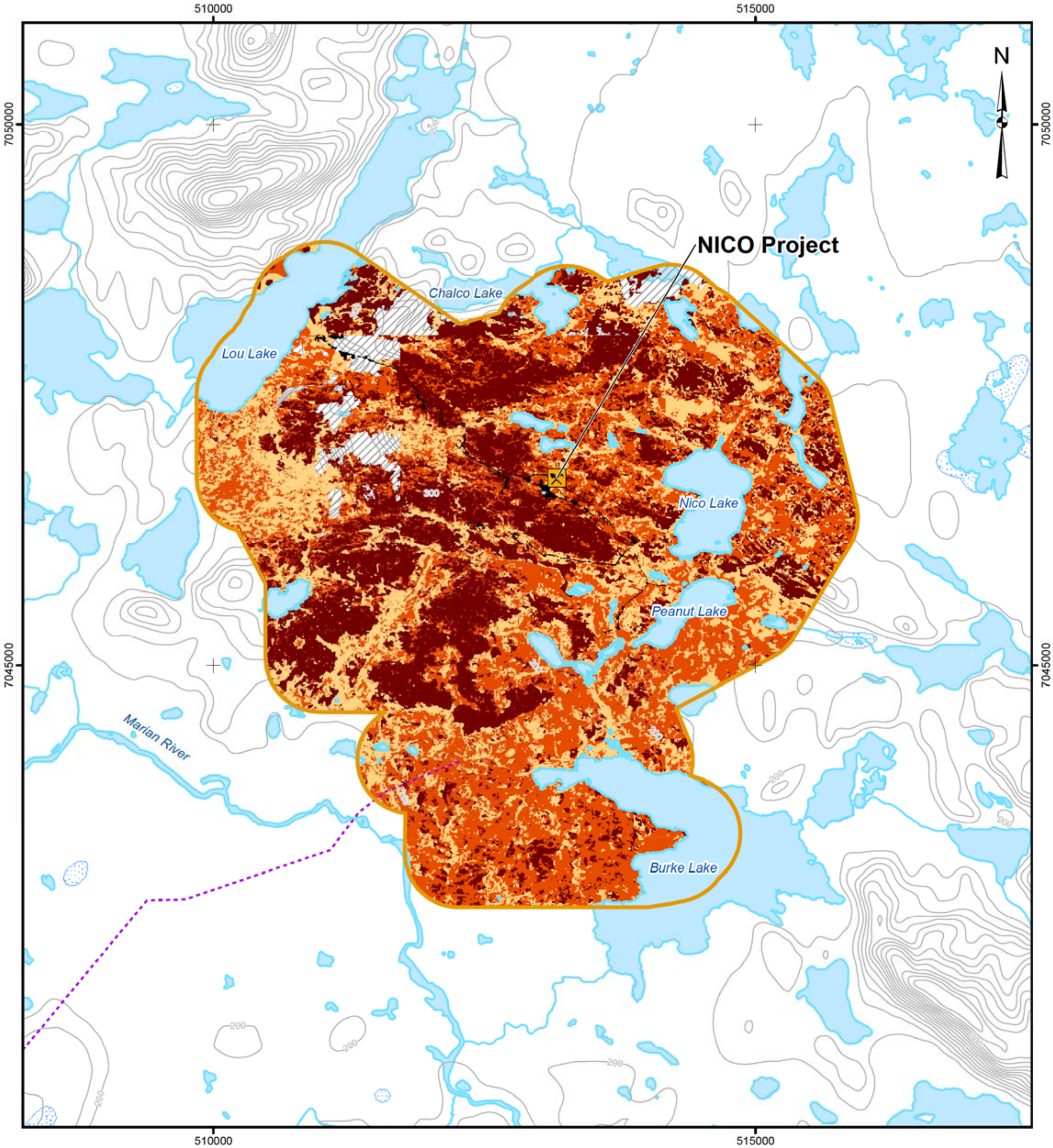
A summary of soil erosion ratings in the LSA is presented in Table 3.4-2 and Figure 3.4-1. No areas in the LSA were identified as having high soil erosion risk and 706 ha (27%) of the LSA was identified as having a moderate erosion risk. Areas of moderate risk are found primarily in the central part of the LSA and are typically associated with Cryosolic soils and thin soil veneers that are more sensitive to disturbance. The remainder of the LSA is classified as Low (Moderate) or Low erosion risk at 937 ha (35%) and 560 ha (21%), respectively (Figure 3.4-1).

Table 3.4-2 Soil Erosion Risk Distribution in the Local Study Area

Soil Erosion Risk	LSA	
	Area (ha)	%
High	0	0
Moderate	706	27
Low(Moderate)	937	35
Low	560	21
Water	347	13
Disturbance	11	<1
Unclassified	83	3
Total	**2644**	**100**

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

% = percent; < = less than; ha = hectare; LSA = local study



LEGEND

- NICO PROJECT
- PROPOSED ALL-LAND WINTER ROAD ROUTE
- PROPOSED NICO PROJECT ACCESS ROAD
- CONTOUR (10 METRE INTERVAL)
- WATERCOURSE
- WATERBODY
- WETLAND
- LOCAL STUDY AREA

SOIL EROSION RISK

- MODERATE
- LOW (MODERATE)
- LOW
- UNCLASSIFIED
- DISTURBANCE

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

PROJECT
FORTUNE MINERALS LIMITED
NICO DEVELOPERS ASSESSMENT REPORT

TITLE
DISTRIBUTION OF SOIL EROSION RISK IN THE LOCAL STUDY AREA

Golder Associates
Edmonton, Alberta

FILE NO. B-Soil-011-GIS			
PROJECT No. 08-1373-0017		SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	FIGURE: 3.4-1
GIS	CW	26 Oct. 2010	
CHECK	LY	17 Nov. 2010	
REVIEW	GA	17 Nov. 2010	

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3.4.2 Soil Sensitivity to Acidification

The areas and percentages of the different sensitivity acidification categories and associated map units for the LSA are shown in Table 3.4-3. Soil acidification sensitivity ratings were not assigned to water, disturbances, and unclassified map units, as these units are not considered soil types.

The majority (68%) of soil map units in the LSA were categorized as being Sensitive or Moderate to acidification. Soils classified as Sensitive to acidification include the Killam and Rabbit map units, which account for 697 ha (26%) of the LSA. Soils in these map units are characterized by a low clay content and low organic matter content, which result in a low buffering capacity. Wetland organic and peaty Gleysolic soils (e.g., BEA-BUR, BUR-MAR, MUS, and MUS-MAR) were categorized as having a Low to Moderate sensitivity to acidification, as some of these map units may contain nutrient poor bogs or nutrient rich fens that have higher buffering capacities and thus are more resistant to acidification.

Table 3.4-3 Acidification Sensitivity of Soils in the Local Study Area

Soil Map Unit	Acidification Sensitivity	LSA Area (ha)	Proportion of LSA (%)
KIL; RAB	Sensitive	697	26
RAB-MAR; RAB-KIL-MAR	Sensitive (Moderate)	1101	42
BEA-BUR; BUR-MAR; MUS[a]; MUS[a]-MAR	Low to Moderate	404	15
Water	NA	347	13
Disturbance	NA	11	<1
Unclassified	NA	83	3
Total		**2644**	**100**

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

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

% = percent; < = less than; LSA = local study area; NA = not applicable

3.4.3 Soil Chemical and Nutrient Parameters

Soil chemical and nutrient parameters selected for analyses included pH, electrical conductivity (i.e., salinity), available nitrate-N, phosphorus, and potassium, which are all considered to be potential limiting factors to plant growth. Table 3.4-4 provides a summary of the soil chemical and nutrient parameters for selected soil series sampled from within the NPAR RSA along the proposed 50 km NPAR at the time of the field programs and within the LSA.

Table 3.4-4 Soil Chemical and Nutrient Parameters of Selected Map Units within the Proposed NICO Project Access Road Regional Study Area and Local Study Area

Study Area	Soil Series	Plot	Horizon[a]	Depth (cm)	pH[b]	Electrical Conductivity[b] (dS/m)	Available Nitrate-N (mg/kg)	Available Phosphorus (mg/kg)	Available Potassium (mg/kg)	Available Sulfate-S (mg/kg)
NPAR RSA	RAB	NAS001	LFH	8-0	7.3	0.21	--	--	--	--
			Ah	0-4	7.3	0.22	--	--	--	--
			Bm	4-30	7.7	0.27	6	<5	50	5
	MAR	NAS002	Of	0-16	7.4	0.17	--	--	--	--
	TUM	NAS004	LFH	5-0	7.1	0.37	--	--	--	--
			Bm	2-29	7.9	0.09	<1	<5	70	3
			C	29-40+	8.1	0.09	--	--	--	--
	HIS	NAS020	LFH	0-5	6.8	0.16	--	--	--	--
			Bm	5-30	7.9	0.19	2	<5	60	8
			Cg	30-40+	8.2	0.16	1	<5	40	2
LSA	MAR	NCS042	Of	35-0	6.0	0.80	--	--	--	--
			Cg	0-65	6.1	0.91	1.0	1	125	--
	MUS	NAS063	Of	0-20	5.0	0.45	--	--	--	--
	RAB	NAS058	LFH	2-0	5.5	0.15	--	--	--	--
			Bf	0-1	5.1	0.04	<1	<5	90	4
			C	1-20	5.1	0.07	<1	<5	90	7
	RAB	NCS040	Ae	0-6	5.2	0.12	<0.9	2	98	--
			Btj	6-20	4.7	0.12	<0.9	1	98	--
			C	20-27	5.8	0.71	<0.9	<1	37	--
	RAB	NCS041	Ae	0-5	4.4	0.14	1.4	6	192	--
			Bm	5-23	4.7	0.10	<0.9	1	134	--
	RAB	NCS044	Ahe	0-18	4.5	0.70	<0.9	3	56	--
			Bm	18-44	5.2	0.61	<0.9	<1	27	--
			C	44-50	5.4	0.72	<0.9	1	19	--
	TUM	NCS043	Ahe	0-8	5.0	0.63	<0.9	3	47	--
			Bm	8-20	4.9	0.90	<0.9	1	34	--
			C	20-40	5.2	0.63	<0.9	<1	37	--

[a] Refer to Appendix I for horizon descriptions.

[b] Calculated based on a 1:2 Soil:Water

-- = no data; <= less than; cm = centimetre; dS/m = deciSeimens per metre; mg/kg = milligrams per kilogram; NPAR = Proposed NICO Project Access Road; RSA = regional study area; LSA = local study area

There appears to be strong differences between soil pH values from plots in the LSA and plots within the NPAR RSA (Table 3.4-4). 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 depth. In contrast, soil samples from the 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 and have a low nutrient availability (Moore 1980). The soils sampled in the LSA and NPAR RSA reflect this as they also have low values for available nitrate and phosphorus in the mineral soil (Table 3.4-4). However, native plant species are adapted to these conditions, despite the low nutrient content and acidity of these soils.

Results of the metal analyses for the baseline metal chemistry of soils can be found in soil and vegetation chemistry baseline report (Golder 2010c).

3.4.4 Soil Reclamation Suitability

The reclamation suitability of soils in the LSA was evaluated to support salvage and reclamation planning, as construction activities will include the removal and salvaging of topsoil and subsoil for use in subsequent reclamation activities. Soil reclamation suitability rankings for each of the soil map units in the LSA are provided in Table 3.4-5. Soil reclamation suitability ratings were not assigned to water, disturbance, and unclassified map units, as these units are not considered soil types. A detailed overview of the reclamation suitability for each map unit is provided in Appendix VI.

Table 3.4-5 Reclamation Suitability of Soils in the Local Study Area

Soil Map Unit	Map Unit Name	Soil Patterns[a]	Reclamation Suitability[b]		LSA	
			Topsoil	Subsoil	Area (ha)	%
Mineral Soils						
KIL	Killam	D: thin veneers over Bedrock (KIL)	unsuitable	unsuitable	697	26
RAB	Rabbit	D: Brunisolic (RAB)	poor to fair	poor	1	<1
RAB-MAR	Rabbit	D: Brunisolic (RAB)	fair (organic)	poor (good)	219	8
	Marian	C: Wetlands-gleysolic (MAR)				
RAB-KIL-MAR	Rabbit	D: Brunisolic (RAB)	fair (organic); unsuitable[c]	poor (good); unsuitable[c]	882	33
	Killam	C: Thin veneers over Bedrock (KIL)				
	Marian	S: Wetlands-gleysolic (MAR)				
RAB-TUM-MAR	Rabbit	D: Brunisolic (RAB)	poor to fair (organic)	poor (good)	0	0
	Tumi	C: Brunisolic (TUM)				
	Marian	S: Wetlands-gleysolic (MAR)				
Wetland Soils						
BEA -BUR	Bea	D: Wetlands-cryosolic (BEA)	fair (organic)	fair (organic)	9	<1
	Burke	S: Wetlands-crysolic organics (BUR)				

Table 3.4-5 Reclamation Suitability of Soils in the Local Study Area (continued)

Soil Map Unit	Map Unit Name	Soil Patterns[a]	Reclamation Suitability[b]		LSA	
			Topsoil	Subsoil	Area (ha)	%
BUR-MAR	Burke	D: Wetlands-crysolic organics (BUR)	organic	organic (good)	55	2
	Marian	C: Wetlands-gleysolic (MAR)				
MUS-MAR	Muskeg	D: Wetlands-organic (MUS)	organic	organic (good)	9	<1
	Marian	C: Wetlands-gleysolic (MAR)				
MUS	Muskeg	D: Wetlands-organic (MUS)	organic	organic	331	13
Other						
Water	NA	NA	NA	NA	347	13
Disturbance	NA	NA	NA	NA	11	<1
Unclassified	NA	NA	NA	NA	83	3
Total					**2 644**	**100**

Note: Some 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 Section 2.1.4 for more details).

[b] Alberta Agriculture 1987. Topsoil = LFH plus 0-20 cm depth; Subsoil = 20-100 cm depth.

[c] Unsuitable refers to bedrock areas only.

% = percent; < = less than; ha = hectare; LSA = local study area; NA = not applicable

Topsoils in the LSA generally have Poor to Fair suitability for reclamation, with topsoils in a portion of the area (38%) being Unsuitable for reclamation, as these areas are comprised of thin soil veneers over bedrock (Table 3.4-5). The extensive Organics and Organic Cryosols in the area are not given a rating and are classified simply as an Organic category. Organic material can be valuable in reclamation because of its nutrient content and ability to improve the soil moisture holding capacity. The major limitation for topsoil suitability for reclamation is the coarse texture of most surface soils in the LSA, which is associated with low pH, low nutrient status, and low moisture holding capacity. The high stone and boulder content of the soils also limits the suitability for reclamation.

Subsoils predominantly were categorized as Poor and Unsuitable for reclamation (Table 3.4-5). This rating arises mainly from the high stone and boulder content of the glacial-fluvial and till soils, and the presence of bedrock close to the soil surface. Furthermore, many of the subsoils have coarse textures and associated low pH, nutrient status, and water holding capacity, similar to the surface soils. However, the subsoil of Marian soil was rated as good and should be stockpiled. In addition, there may be some areas in the LSA where soils have developed on glacial till that are suitable for reclamation, as they have relatively low stone contents and fine soil textures.

The results of the baseline metal chemistry can be found in the soil and vegetation chemistry baseline report (Golder 2010c). The results from the metal analyses indicate there are areas where naturally occurring arsenic concentrations are high, and this material would be unsuitable for reclamation. It is recommended that this material not be used in future reclamation efforts. If these materials are to be salvaged, they should be salvaged separately from materials that are suitable for reclamation to prevent cross-contamination of salvaged materials with soils containing naturally high arsenic concentrations.

4 SUMMARY

4.1 GENERAL SETTING

The soil and terrain baseline is one component of a comprehensive environmental and socio-economic baseline program to collect information about the natural and socio-economic environment in the vicinity of the NICO Cobalt-Gold-Bismuth-Copper Project (Project). The soil and terrain baseline report presents a review and interpretation of qualitative and quantitative information from the literature, previous baseline surveys, expert knowledge, and data collected during the 2005 and 2008 field programs. The primary objective of this baseline report is to describe and characterize the existing soil and terrain resources, and associated soil quality and sensitivities within the Project regional study areas (proposed mine and NPAR RSA) and local study area (LSA).

The proposed mine regional study area (proposed mine RSA) was developed with consideration of all terrestrial components (i.e., soil and terrain, vegetation, wildlife, and biodiversity). It was defined on the basis of the maximum predicted spatial extent of the Project-related effects on all terrestrial resources, including the life history attributes of wildlife species potentially influenced by the Project. In 2007, the proposed mine RSA was increased from 314 to 706 km^2 (i.e., the radius was increased from 10 to 15 km, centered on the proposed mine site).

The Proposed NICO Project Access Road (NPAR) RSA was defined by the expected limit of direct and indirect effects from the NPAR on surrounding soil, vegetation, and wildlife. The proposed NPAR during baseline studies was a 50 km road that joins the Project to the existing winter road between Behchokǫ̀ and Gamètì. The NPAR length has since been reduced to 27 km; however, the original 50 km NPAR was evaluated during the baseline studies. The NPAR RSA was defined by a 6.5 km buffer surrounding the proposed 50 km road alignment.

The local study area (LSA) boundary was defined by the expected spatial extent of the immediate direct (e.g., Project footprint) and indirect effects (e.g., dust deposition) from the Project on surrounding soil, vegetation, and wildlife. The LSA was defined as a 500 m buffer around the former proposed Project lease boundary.

The proposed mine and NPAR RSAs covers an area of approximately 109 016 hectares (ha) and are situated within 2 Level II Ecoregions: Taiga Shield and Taiga Plains. The northeast portion of the proposed mine RSA occurs within the Taiga Shield High Boreal Level III Ecoregion. Elevations within this Ecoregion range from approximately 200 m above sea level (mASL) along the west boundary to greater than 500 mASL in the southeast corner. 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. Brunisols, Organic soils, 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. Brunisols are typically found on variable textured glacial deposits between bedrock exposures. Organic soils and Cryosols typically occur within peat plateaus. Shore fens and floating fens are characterized by Organic soils with Gleysols occurring in wet depressions.

The southwest portion of the proposed mine RSA and the majority of the NPAR RSA are located within the Central Great Bear Plains Low Subarctic Level III Ecoregion. The Central Great Bear Plains Low Subarctic 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 cm of the organic surface. Polygonal peat plateaus are locally common in the Keller Plain area. Soils are dominantly mineral and Organic Cryosols and are typically Turbic Cryosols. Organic Cryosols occur within peat plateaus and runnels. Brunisols are commonly found on well-drained upland areas. Gleysolic soils occur in shrubby channels between spruce-lichen uplands.

The southern most portion of the NPAR RSA is within the Great Slave Uplands High Boreal Level III Ecoregion. The Great Slave Uplands High Boreal Ecoregion includes hill systems ranging in elevation from 300 to 700 mASL. These areas are surrounded by gently sloping to undulating plains. Imperfect to poorly drained glacial till is common throughout this Ecoregion, where Organic and Gleysolic soils occur or Organic Cryosols have developed. Gleysolic soils are typically found adjacent to ponds. Brunisols and Luvisols typically occur on hummocky or ridged till or on well-drained fluvial and glaciofluvial materials. The LSA habitat is characteristic of regional habitat conditions and vegetation within the Taiga Shield Level II Ecoregion and occurs entirely within the Taiga Shield High Boreal Level III Ecoregion.

4.2 TERRAIN AND SOIL CONDITIONS IN THE REGIONAL AND LOCAL STUDY AREAS

4.2.1 Methods

Detailed soil surveys in the LSA and along the proposed NPAR in the NPAR RSA were completed in August 2005. Reconnaissance level soil surveys of the proposed mine and NPAR RSAs and of 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, including parent material, landform, surface expression, and slope class.

The approach to classifying and mapping soil and terrain units involved a review of existing information, field surveys, soil sampling and analysis, and development of a soil map. Terrain mapping was completed for the RSAs and LSA through a review of available information and collected field data to derive a correlation between mapped soil types and subsequent terrain units.

Soil mapping involved the correlation of field observations to mapped vegetation units to determine general relationships between vegetation and soils. Ikonos Imagery classification and Landsat Thematic Mapper satellite imagery was used to delineate vegetation units for ELC mapping in the LSA and RSAs, respectively. These vegetation units were then used as part of the soil mapping process to derive correlations between soil series and terrain features, 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.

4.2.2 Results

4.2.2.1 Regional Study Areas

In total, 109 soil inspection sites were examined during the 2005 and 2008 field programs. In 2005, 15 soil inspection sites were completed in the proposed mine RSA, 29 along the proposed NPAR in the NPAR RSA, and 22 within the LSA. In 2008, 17 soil inspection sites were completed in the proposed mine RSA, 20 in the NPAR RSA, and 6 in the LSA.

Eight terrain units were defined and mapped for the RSAs. The most common terrain unit within the NPAR RSA is the glaciofluvial, morainal/till, and organic (Fg1-M-O) complex, which covers 13 396 (35%) of the NPAR RSA. This terrain unit is also the most common unit within the total RSA and covers 28 893 ha (27%) of the total area. The most common terrain unit encountered in the proposed mine RSA is the glaciofluvial and organic (frozen) (Fg1-O) complex, which covers 19 719 ha (28%), and does not occur within the NPAR RSA. The glaciofluvial (morainal/till) and organic (Fg2(M)-O) complex covers 11 713 ha (31%) of the NPAR RSA and 16 757 ha (15%) of the total RSA. Water comprises a considerable portion of the total RSA at approximately 15 541 ha (14%) with 13 455 ha occurring within the proposed mine RSA. The remaining terrain units include bedrock (R), bog (B), fen (F), and glaciofluvial (Fg1) features and cover 9%, 7%, 5%, and 5% of the total RSA, respectively.

A total of 9 soil map units, including water, were described and mapped for the RSAs. The most common soil map unit in the NPAR RSA is RAB-MAR, which covers 13 397 ha of the NPAR RSA and covers 28 893 ha or 27% of the total RSA. The RAB-BUR(BEA) soil map unit is the second most abundant unit in the total RSA at 19 718 ha (18%) and it occurs exclusively in the proposed mine RSA. The RAB(TUM)-MAR soil map unit accounts for 16 757 ha (15%) of the total RSA and primarily occurs within the NPAR RSA (11 713 ha). The KIL soil map unit represents 9611 ha (9%) of the total RSA and occurs predominantly in the northern and eastern parts of the proposed mine RSA. The RAB soil map unit occurs primarily within the NPAR RSA on upland areas and accounts for 5782 ha (5%) of the total RSA. Wetland soil map units are defined by the BUR-MUS, MAR-MUS, and MUS-MAR units, which collectively represent approximately 11% of the total RSA.

4.2.2.2 Local Study Area

Ten terrain units have been defined and mapped for the LSA, including the following:

- glaciofluvial (Fg);
- glaciofluvial and organic (Fg-O);
- glaciofluvial, bedrock and organic (Fg(R)-O);
- frozen shallow organic veneers and shallow to deep bogs (potential permafrost) (O);
- fen (N);
- bog (B);
- bedrock (R);
- water;
- disturbances; and

- unclassified (satellite land mapping interference).

The most common terrain unit encountered in the LSA is the glaciofluvial, bedrock, and organic (Fg(R)-O) terrain unit, and covers 882 ha (33%) of the LSA. The bedrock (R) terrain unit covers 697 ha (26% of the LSA. Fen (N) and bog (B) terrain units are widespread through the LSA and comprise 206 ha (8%) and 189 ha (7%), respectively. Water makes up 347 ha (13%) of the LSA. The remaining terrain units comprise less than 12% of the LSA.

Eleven soil map units were described and mapped for the LSA as follows:

- Bea - Burke (BEA-BUR);
- Burke - Marian (BUR-MAR);
- Killam (KIL);
- Muskeg (MUS);
- Muskeg - Marian (MUS-MAR);
- Rabbit (RAB);
- Rabbit - Marian (RAB-MAR);
- Rabbit - Killam - Marian (RAB-KIL-MAR);
- water;
- disturbances; and
- unclassified (satellite land mapping interference).

The most common soil map unit in the LSA is RAB-KIL-MAR, followed by KIL, which account for 882 ha (33%) and 697 ha (26%) of the LSA, respecitively. The RAB-MAR soil map unit covers 219 ha (8%) of the LSA. The MUS map unit is also prevalent within the LSA and it covers 331 ha (13%) 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 5% of the LSA. Water covers 347 ha (13%) of the LSA. Disturbance and unclassified areas comprise the remainder of the soil map units in the LSA.

4.3 PERMAFROST POTENTIAL IN THE REGIONAL AND LOCAL STUDY AREAS

4.3.1 Methods

Permafrost potential was assigned to each soil map unit in the LSA and RSAs based on soil type, drainage, general topography, and the presence or absence of permafrost noted during field surveys. 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.

4.3.2 Results

4.3.2.1 Regional Study Areas

The occurrence of permafrost in the RSAs is characterized as discontinuous and widespread, and permafrost is most commonly found in both poorly-drained organic areas and low-lying mineral soils. The distribution of permafrost is highly variable, with changes in ice content occurring over small scales (i.e., within several metres).

The majority of the proposed mine RSA has been characterized as having a low and moderate potential for permafrost occurrence, and represent 32% and 31% of the proposed mine RSA respectively. Areas rated as having a high permafrost potential tend to be scattered in isolated pockets throughout the proposed mine 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 soils). Permafrost was observed at depths between 30 to 75 cm within BEA soils, with an average active layer (i.e., seasonal thaw depth) of 45 cm. Permafrost was observed at depths between 22 to 100 cm within BUR soils, with an average active layer of 54 cm. Areas of high permafrost potential represent 3113 ha (4%) of the proposed mine RSA.

The majority of the NPAR RSA has been characterized as having a low permafrost potential and represents 29 028 (76%) of the NPAR RSA. Similar to the proposed mine RSA, areas rated as having a high permafrost potential tend to be scattered throughout the NPAR RSA and make up 2631 ha (7%) of the area. Areas of moderate potential represent 4466 ha (12%).

4.3.2.2 Local Study Area

Permafrost in the LSA is also 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 mineral soils that were frozen (i.e., Gleysolic Static Cryosol), with minor inclusions of organic soils that were frozen (i.e., Organic Cryosol). 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 between 22 to 45 cm within the 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.

Within the LSA, the majority of the area (42%) is classified as having a moderate potential for permafrost. Only 64 ha (2%) of the LSA is classified as high permafrost potential, and occur in isolated pockets associated with poorly-drained organic areas and low-lying mineral soils. Disturbances and unclassified areas that cover approximately 3% of the LSA area were not assigned a permafrost potential class.

4.4 SOIL SENSITIVITY AND QUALITY IN THE LOCAL STUDY AREA

4.4.1 Methods

Soil sensitivity and quality in the LSA were evaluated in terms of soil erosion risk, soil acidification susceptibility, soil productivity, and reclamation suitability.

4.4.1.1 Soil Erosion Risk

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 developed based on the most limiting erosion factor (wind or water) and modified based on natural factors specific to the LSA, such as organic or shallow soils and permafrost.

4.4.1.2 Soil Sensitivity to Acidification

Acidification sensitivity of mineral and organic soils of each soil type in the LSA was classified as high, moderate, or low based on information in Holowaychuk and Fessenden (1987) and interpretations of the soil data. In general, mineral soils that have a low clay content and organic matter content have a lower cation exchange capacity (CEC) 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 assigned a sensitivity rating such that, where a single soil association represents 80% or more of the map unit, only the sensitivity rating for that soil association is shown. Where a single 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.

4.4.1.3 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 within the NPAR RSA. Soil samples were collected from 11 sites and analysis included texture (particle size analysis), pH, electrical conductivity (i.e, salinity), available nitrate-N, phosphorus, and potassium.

4.4.1.4 Soil Reclamation Suitability

The reclamation suitability of each soil map unit in the LSA and within the NPAR RSA was determined by considering the proportions of the dominant and sub-dominant soil series associations, where complex units occurred. Individual soil series within the LSA were 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. The proportions of the soil series associations within these map units were examined, and a suitability rating, recognizing a dominant and a sub-dominant component, was derived.

4.4.2 Results

4.4.2.1 Soil Erosion Risk

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 soils with a presence of 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 Killam soils was also raised to moderate because any loss of this thin soil may have implications for plant growth.

The majority of the LSA is classified as Low (Moderate) or Low soil erosion risk at 937 ha (35%) and 560 ha (21%), respectively. No areas in the LSA were identified as having high soil erosion risk and 706 ha (27%) 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 and thin soil veneers that are more sensitive to disturbance.

4.4.2.2 Soil Sensitivity to Acidification

The majority (68%) of soil map units in the LSA were categorized as being Sensitive or Moderate to acidification. Soils classified as Sensitive to acidification include the Killam and Rabbit map units, which account for 697 ha (26%) of the 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 Low to Moderate sensitivity to acidification, as some of these map units may contain nutrient poor bogs or nutrient rich fens that have higher buffering capacities and are more resistant to acidification. These map units account for 404 ha (15%) of the LSA.

4.4.2.3 Soil Chemical and Nutrient Parameters

Soil nutrient availability within the NPAR RSA along the proposed NPAR alignment at the time of the field programs and within the LSA is generally poor. Many of these soils have a low soil nutrient availability. This is reflected by the low values for available nitrate-N and phosphorus in the mineral soils that are found in the LSA and NPAR RSA. Available nitrate-N, ranged from <1 to 1.4 mg/kg in soils in the LSA. Available nitrate-N in soils along the proposed NPAR ranged from <1 to 6 mg/kg.. Available phosphorus ranged from <5 to 6 mg/kg in soils in the LSA, and range from <1 to 6 mg/kg along the proposed NPAR.

Soil pH values varied considerably between soils in the LSA and soils along the proposed NPAR in the NPAR RSA. 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 depth. In contrast, soil samples from the 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.

Baseline metal chemistry of soils can be found in soil and vegetation chemistry baseline report (Golder 2010c).

4.4.2.4 Soil Reclamation Suitability

Topsoils in the LSA generally have Poor to Fair suitability for reclamation, with 38% of the area 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 and should be stockpiled wherever possible, 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.

The results of the baseline metal chemistry can be found in the soil and vegetation chemistry baseline report (Golder 2010c). The results from the metal analyses indicate there are areas where naturally occurring arsenic concentrations are high, and this material would be unsuitable for reclamation. It is recommended that this material not be used in future reclamation efforts. If these materials are to be salvaged, they should be salvaged separately from materials that are suitable for reclamation to prevent cross-contamination of salvaged materials with soils containing naturally high arsenic concentrations.

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6 GLOSSARY

6.1 GLOSSARY OF TERMS

Acidification	The process of becoming acid or being converted into an acid.
Available nutrients	Nutrients (elements and compounds) in the soil solution that can be readily absorbed into plant roots. The available nutrients are usually much less than the total amount of nutrient in soil.
Baseline	A surveyed or predicted condition that serves as a reference point to which later surveys are coordinated or correlated.
Bedrock	The body of rock that underlies gravel, soil, or other subregion material.
Bog	A peat-covered area or peat-filled wetlands. The water table is at or near the surface. The surface is often raised, or level with the surrounding wetlands, and is virtually unaffected by the nutrient-rich groundwater from the surrounding mineral soils. Hence, the groundwater of the bog is generally acid and low in nutrients. The dominant peat materials are sphagnum and forest peat underlain, at times, by fen peat. The associated soils are Fibrisols, Mesisols and Organic Cryosols. Bogs may be treed or treeless, and they are usually covered with sphagnum and feather mosses, and ericaceous shrubs.
Boreal Forest	The northern hemisphere, circumpolar, tundra forest type consisting primarily of black spruce and white spruce with balsam fir, birch, and aspen.
Buffering capacity	The ability of a soil to resist changes in pH.
Brunisolic soil	Brunisolic soils are boreal forest soils that primarily develop in sandy glacial sediments. These soils have undergone very limited soil formation. The diagnostic horizon is the Bm, which has undergone only slight chemical change from the original parent material, although it may have a bright red colour compared to the underlying C horizon.
Classification, soil	The systematic arrangement of soil types into categories (order, great group, sub-group) according to their similarity to each other. Groupings are based on criteria relative to degree of soil formation, materials present in the soil profile, and site conditions that influence soil characteristics.

Cryosolic soil	Cryosolic soils have horizons with permafrost. In some soils the frost action causes considerable mixing of soil horizons, which is termed cryoturbation. In these soils, the permafrost layer must be within 2 m of the surface. If no strong cryoturbation has occurred, the permafrost layer must be within 1 m of the surface.
Dominant	In natural resources mapping, the feature (soil type, terrain, or other feature) that constitutes the largest component of a mapping unit (generally 40% or more, and usually 50% or more).
Ecological Land Classification (ELC)	An ecological mapping process that involves the integration of site, soil, and vegetation information.
Ecoregion	Relatively homogeneous subregion within an ecozone.
Ecosystem	An integrated and stable association of living and non-living resources functioning within a defined physical location. A community of organisms and its environment functioning as an ecological unit. For the purposes of assessment, the ecosystem must be defined according to a particular unit and scale.
Ecozone	An area of the earth's surface that is representative of a broad-scale ecological unit characterized by particular abiotic (non-living) and biotic (living) factors (e.g., taiga forest, tundra).
Electrical conductivity	The ability of soil to conduct electrical current and expressed in deciSeimens per metre (dS/m). It is typically used to measure soil salinity.
Erosion	The detachment and movement of topsoil by the action of wind and water.
Fen	A fen is a peat-covered or peat-filled wetlands with a high water table, which is usually at or above the surface. The waters are mainly nutrient-rich, minerotrophic waters from mineral soils. The vegetation consists mainly of sedges, grasses, reeds and brown mosses with some shrub cover, and sometimes a sparse tree cover.
Fibric material	Materials (primarily mosses, rushes, and woody materials) that are readily identifiable as to botanical origin. A fibric horizon (Of) has 40% or more of rubbed fiber by volume.
Fluvial	Sediments that have been deposited by streams and rivers. Fluvial deposits generally consist of gravel and sand, with a minor fraction of silt and rarely clay.
Geographic information system (GIS)	A computer-based tool for analyzing, displaying, and manipulating digital spatial data.
Glaciofluvial	Sediments or landforms produced by melt waters originating from glaciers or ice sheets. Glaciofluvial deposits commonly contain

	rounded cobbles arranged in bedded layers.
Gleysolic soil	Gleysolic soils are associated with prolonged water saturation of the soil profile. Water saturation leads to depletion of oxygen and the development of soil features associated with oxygen-depleted conditions: blue-grey colours and reddish specks (called mottles) within the soil profile. These features are the diagnostic criteria for Gleysolic soils and occur within 50 cm of the soil surface.
Habitat	The physical location or type of environment in which an organism or biological population lives or occurs.
Humic material	Materials (primarily mosses, rushes, and woody materials) at an advanced stage of decomposition. It is very stable and changes little physically or chemically with time unless it is drained. The rubbed fiber content is less than 10% by volume.
Lacustrine	Sediments that have been deposited on a lake bed or nearshore materials that have been transported and deposited by wave action. Lacutrine sediments are generally stratified fine sand, silt, and clay.
Landform	A particular type of land formation.
Landscape	A heterogeneous land area with interacting ecosystems that are repeated in similar form throughout. From a wildlife perspective, a landscape is an area of land containing a mosaic of habitat patches within which a particular "focal" or "target" habitat patch is embedded.
Local study area (LSA)	Area defined for the description of vegetation types in the vicinity of the Project footprint. The area where direct effects of the Project might be expected to occur. Occurs within the regional study area.
Lowlands	Areas with ground slopes of less than 0.5% and typically poorly drained.
Luvisolic soil	Luvisolic soils are a characteristic soil of forested regions; identified by the presence of a light coloured eluvial (Ae) horizon and an illuvial (Bt) horizon where silicate clay has accumulated. They can also be characterized by the presence of a leafy, humus surface horizon.
Map unit, soil	Unit developed to represent dominant, co-dominant, and sub-dominant soil types on soil maps.
Map unit, terrain	Unit developed to represent areas with similar parent material, textures, and landforms on terrain maps.
Marsh	A mineral or a peat-filled wetland that is periodically inundated by standing or slowly moving water.

Mesic material Materials (primarily mosses, rushes, and woody materials) at a stage of decomposition intermediate between fibric and humic materials. The material is partly altered both physically and biochemically. It has a rubbed fiber content ranging from 10% to less than 40%.

Moisture regime The relative moisture supply at a site available for plant growth.

Moraine A mass of till (boulders, pebbles, sand, and mud) deposited by a glacier, often in the form of a long ridge.

Nutrient regime The supply of nutrients available for plant growth at a given site.

Nutrients Chemical elements and compounds, such as nitrogen and phosphorus, found in the environment that plants and animals need to grow and survive.

Organic matter Plant and animal materials that are in various stages of decomposition.

Organic soil Organic soils are composed of organic materials. They include most of the soils commonly known as peat, or bog/fen soils. Most Organic soils are saturated with water for prolonged periods. These soils occur widely in poorly and very poorly drained depressions and level areas and are derived from vegetation that grows in such sites. The organic layer is greater than 60 cm thick (if fibric) or 40 cm thick (if mesic or humic).

Palsa A peaty permafrost mound possessing a core of alternating layers of segregated ice and peat or mineral soil material. Palsas are typically between 1 and 7 m in height and a few metres to 100 m in diameter

Parameter A particular physical, chemical, or biological property that is being measured.

Parent material Underlying bedrock or drift deposit on which soil horizons form and are made up of consolidated or unconsolidated mineral material that has undergone some degree of physical or chemical weathering.

Peat plateau A bog composed of perennially frozen peat, rising abruptly about 1 m from the surrounding unfrozen fen. The surface is relatively flat, even, and often covers very large areas. The peat was originally deposited in a non-permafrost environment and is often associated with collapse scars or fens

Permafrost Permanently frozen soil or rock and incorporated ice and organic material that remain at or below 0°C for a minimum of 2 years due to natural climatic factors (van Everdingen 1998). The occurance of permafrost increases with latitude (i.e., more northern areas permafrost is continuous, and more southern areas patches of permafrost alternate with unfrozen ground).

Plant community A collection of plants that live together on a generally uniform area of land with a floristic composition and structure that is distinct from surrounding vegetation.

Polygon The spatial area delineated on a map to define one feature unit (e.g., one type of ecosite phase).

Polygonal peat plateau A perennially frozen bog, rising about 1 m above the surrounding fen. The surface is relatively flat, scored by a polygonal pattern of trenches that developed over ice wedges. The permafrost and ice wedges developed in peat originally deposited in a nonpermafrost environment. Polygonal peat plateaus are commonly found near the boundary between the zones of discontinuous and continuous permafrost.

Reclamation Process of creating useful landscapes that meet predetermined goals, typically creating and replacing productive ecosystems in disturbed areas. It can include material placement, stabilization, re-grading, replacing soils, and re-vegetation.

Regional study area (RSA) A broad area defined for the description of vegetation conditions generally centred on the Project and surroundings, and including areas where indirect effects of the Project might be expected to occur. Includes the local study area.

Regosolic soil Regosolic soils lack significant soil formation and occur on very young surfaces (e.g., sand dunes or river floodplains) or unstable surfaces (e.g., upper slope positions that experience high rates of soil erosion). Regosolic soils are thin and either completely lack a B horizon or have a thin B horizon less than 5 cm thick.

Riparian Refers to terrain, vegetation, or simply a position next to or associated with a stream, floodplain, or standing waterbody.

Rubbed fibre Fibre that remains after rubbing a sample of the layer a number of times between the thumb and forefinger.

Runnel A pattern of alternating flow channels and interchannel uplands perpendicular to contour. In permafrost-affected areas, light and dark-striped patterns on hill slopes are runnels; the light stripes are usually sparsely treed, lichen covered interchannel areas with permafrost close to the surface, and the dark stripes are shallow drainage channels vegetated by dwarf birch, willow and other shrubs with a thicker active layer.

Soil great group	Used in the classification of soil and is the next division of the soil order. These are differentiated on the basis of characteristics that reflect the differences in the strengths of the dominant processes or a major contribution of an additional process.
Soil order	Used in the classification of soil and include Brunisolic, Regosolic, Organic, Cryosolic, and Gleysolic Orders. At this level, soils are differentiated on the basis of characteristics of the soils that reflect the nature of the total soil environment and the effects of the dominant soil forming processes.
Soil series	Groupings of soils with similar arrangements of horizons whose color, texture, structure, consistence, thickness, reaction, and composition fall within a narrow and well defined range.
Species	A group of organisms that actually or potentially interbreed and are reproductively isolated from all other such groups. A taxonomic grouping of genetically and morphologically similar individuals.
Soil macro-organisms	Invertebrates that live in the soil and are generally visible to the naked eye. Many benefit the soil by helping to break down minerals, soil particles, and nutrients. Examples include beetles, earthworms, and some nematodes.
Soil micro-organisms	Any organism in soil which requires a microscope to observe. These organisms include bacteria, fungi, algae, and protozoa. Soil micro-organisms are responsible for the breakdown of organic matter, conversion of inorganic compounds from one form to another, and the production of humus.
Soil texture	A soil property used to describe the relative proportion of different grain sizes of mineral particles in a soil.
Subsoil	The layer of soil under the topsoil.
Terrain	A particular geographic area including the surface features of an area (i.e., topography)
Thermal regime, soil	Refers to the amount of heat available for plant growth and development during the growing period. Thermal regime also influences the presence or absence of permafrost.
Till	An unstratified, unconsolidated mass of boulders, pebbles, sand, and mud deposited by the movement or melting of a glacier
Topography	The surface features of a region, such as hills, valleys, or rivers
Topsoil	Uppermost layer of soil, usually the top 5 to 20 cm. It has the highest concentration of organic matter and micro-organisms and is where most of the biological activity occurs. Plants generally concentrate their roots in and obtain most of their nutrients from

	this layer.
Upland	Areas that have ground slopes of 1 to 3% and are typically well drained.
Vegetation	A term to describe all of the plants or plant life of a place.
Wildlife	A term to describe all undomesticated animals living in the wild.

6.2 ABBREVIATIONS AND ACRONYMS

ARC	Alberta Research Council
CEC	cation exchange capacity
EBA	EBA Engineering Consultants Ltd.
e.g.	for example
ELC	Ecological Land Cover Classification
et al.	group of authors
Fortune	Fortune Minerals Limited
GIS	geographic information system
Golder	Golder Associates Ltd.
GPS	global positioning system
i.e.	that is
LSA	local study area
NO_x	oxides of nitrogen
NPAR	NICO project access road
NWT	Northwest Territories
Project	NICO Cobalt-Gold-Bismuth-Copper Project
QA/QC	quality assurance/quality control
RSA	regional study area
SO_2	sulphur dioxide
TAC	Transportation Association of Canada
TM	Thematic Mapper (Landsat satellite image product)
USLE	universal soil loss equation

VC	valued component

6.3 UNITS OF MEASURE

%	percent
°C	degrees Celsius
<	less than
>	greater than
cm	centimetre
dS/m	deciSiemens per metre
ha	hectare
km	kilometre
km^2	square kilometre
m	metre
mg/kg	milligrams/kilogram
mm	millimetre

APPENDIX I

KEY TO ABBREVIATIONS USED IN SOIL MAP UNITS AND SOIL CHARACTERISTICS

Soil map unit and associated soil characteristic abbreviations are listed below in Tables I-1 to I-9.

Table I-1 Soil Series

Soil Series	Abbreviations
Burke	BUR
Bea	BEA
Marian	MAR
Hislop	HIS
Killam	KIL
Muskeg	MUS
Rabbit	RAB
Tumi	TUM

Table I-2 Soil Subgroup Classification

Soil Subgroup	Description
Brunisolic Order	
E.EB	Eluviated Eutric Brunisol
GL.EB	Gleyed Eluviated Eutric Brunisol
O.EBpt	Eluviated Eutric Brunisol (peaty phase)
O.EB	Orthic Eutric Brunisol
Cryosolic Order	
GL.SC	Gleysolic Static Cryosol
TFI.OC	Terric Fibric Organic Cryosol
FI.OC	Fibric Organic Cryosol
ME.OC	Mesic Organic Cryosol
TME.OC	Terric Mesic Organic Cryosol
Gleysolic Order	
O.G	Orthic Gleysol
O.Gpt	Orthic Gleysol (peaty phase)
R.G	Rego Gleysol
R.Gpt	Rego Gleysol (peaty phase)
Organic Order	
T.F	Terric Fibrisol
TY.F	Typic Fibrisol
THU.M	Terric Humic Mesisol
T.M	Terric Mesisol
Regosolic Order	
O.R	Orthic Regosol
O.Rpt	Orthic Regosoil (peaty phase)

Table I-3 Parent Materials

Parent Material Class	Description
GF	Glaciofluvial
GL	Glaciolacustrine
M	Moraine/till
R	Bedrock
O	Organic
N	Fen
B	Bog

Table I-4 Slope Class

Slope Class	Percent Slope Range	Description
1	0 to 0.5%	level
2	0.5 to 2%	nearly level
3	2 to 5%	very gentle slopes
4	5 to 10%	gentle slopes
5	10 to 15%	moderate slopes
6	15 to 30%	strong slopes
7	30 to 45%	very strong slopes
8	45 to 70%	extreme slopes

% = percent

Table I-5 Surface Landform Expression

Surface Landform Class	Description
l	level
u	undulating
h	hummocky
I	inclined
r	ridged
o	other

Table I-6 Drainage Classes

Drainage Class	Description
R	rapidly
W	well
MW	moderately well
I	imperfectly
P	poorly
VP	very poorly

Table I-7 Soil Horizon Designations

Horizon Class	Description
Of	organic horizon consisting of fibric (e.g., poorly decomposed material)
Om	organic horizon consisting of mesic material (e.g., at a state of decomposition intermediate between fibric and humic)
Oh	organic material at an advanced state of decomposition (e.g., humic)
LFH	organic materials of varying degrees of decomposition found at the surface of mineral soil profiles
Ae	surface mineral horizon characterized by the loss (eluviation) of clay, Iron (Fe), Aluminum (Al) or organic matter alone or in combination, which generally results in a lighter colour than the underlying horizons
Ah	surface mineral horizon enriched with organic matter
Bm	subsurface mineral horizon slightly altered by soil forming processes, usually accumulation, which result in development of colour and/or structure
Bt	subsurface mineral horizon that accumulates illuvial clay, which can alter texture and structure and generally forms below an eluvial Ae horizon
Bf	subsurface mineral horizon enriched with Fe and Al combined with organic matter, generally having a reddish colour
BC	transitional horizon exhibiting characteristics of both the overlying B and underlying C horizons
C	subsurface mineral horizon comparatively unaffected by soil forming processes at work in the A and B horizons, frequently called the parent material
Cg	subsurface mineral horizon distinguished by dull colours indicating reduction due to saturation for all or part of the year in C or B horizons
Ck	subsurface mineral horizon which contains carbonates as indicated by visible effervescence with dilute HCL
IC, IIC	C horizons with distinct parent materials, generally differentiated by texture
b	a buried soil horizon (e.g., Ahb)
j	a modifier indicative of an expression of, but not meeting the specified limits of the suffix it modifies and therefore juvenile (e.g., Btj – a underdeveloped [j] Bt horizon)
z	suffix indicative of a frozen horizon (e.g., Ohz – an Oh horizon with a frozen layer [z])

Table I-8 Soil Textural Classes

Soil texture Class	Description
HC	heavy clay
C	clay
CL	clay loam
SC	sandy clay
SCL	sandy clay loam
SiC	silty clay
SiCL	silty clay loam
SiL	silt loam
Si	silt
L	loam
SL	sandy loam
LS	loamy sand
S	sand
c	prefix denoting coarse (e.g., cLS)
f	prefix denoting fine (e.g., fLS)

Table I-9 Terrain Units

Terrain Unit	Description
Fg	glaciofluvial
M	moraine/till
R	bedrock
O	organic
N	fen
B	bog
W	water

APPENDIX II

SUMMARY OF SOIL SERIES IN THE REGIONAL AND LOCAL STUDY AREAS

Table II-1 Summary of Soil Series in the Regional and Local Study Areas

Soil Series		Soil Great Group	Dominant Soil Subgroups	Dominant Parent Material		Dominant Soil Texture	Notes
BUR	Burke	Cryosol	Terric Mesic Organic Cryosol; Fibric Organic Cryosol	Bog/Fen	Bog or fen peat > 40 cm	Organic	Permafrost in organic horizon
BEA	Bea		Gleyed Static Cryosol	Variable	Various mineral	Variable	Permafrost in mineral horizon
MAR	Marian	Gleysols	Peaty Rego Gleysol	Glaciofluvial	Coarse textured material deposited by water or ice	Shallow organic peat over coarse textured sand, loamy sand and gravel	Organic layer less than 40 cm
HIS	Hislop		Rego Gleysol	Fluvial; Glaciolacustrine; Lacustrine	Fine textured material deposited by water,	Clay loam to sandy clay	Typically riparian and associated with waterbodies and water courses
RAB	Rabbit	Brunisols	Orthic Brunisol; Eutric Brunisol; Dystric Brunisol	Glaciofluvial; Moraine/Till	Coarse textured material deposited by water or ice	Coarse to fine textured material with gravel	High percentage of coarse fragments
TUM	Tumi		Orthic Brunisol; Eutric Brunisol; Dystric Brunisol	Glaciofluvial	Coarse textured deposited by water or ice	Sand	
KIL	Killam	Regosols	Orthic Regosol	Bedrock; Glaciofluvial	Eroded bedrock and water deposited veneers	Loamy sand to sandy loam	Includes areas of rock outcrops
MUS	Muskeg	Organic	Terric Mesisol	Bog/Fen	Bog and fen peat	Deep organic peat over variable textured material	

> = greater than; cm = centimetre

APPENDIX III

CORRELATION OF SOIL SERIES TO MAPPED ELC VEGETATION TYPES IN THE REGIONAL AND LOCAL STUDY AREAS

Table III-1 Correlation of Soil Map Units to Mapped ELC Vegetation Types in the Regional Study Areas

ELC Vegetation Classes	RSA Soil Map Units
Bedrock open conifer	KIL
Coniferous pine	RAB
Coniferous spruce	RAB-MAR
Deciduous aspen-paper birch	RAB
Marsh/graminoid fen	MAR-MUS
Mixedwood-spruce-paper birch-aspen in Kellor Lake Plain Ecoregion	RAB(TUM)-MAR
Mixedwood-spruce-paper birch-aspen in Copper River Upland Ecoregion	RAB-BUR(BEA)
Open bog	MUS-MAR
Shrubland	BUR-MUS
Treed bog	BUR-MUS
Treed fen	MUS-MAR
Burn[a]	n/a
Water	Water

[a] Soil map units in the burn class were derived from the previous ELC vegetation classes from Golder (2006).

Table III-2 Correlation of Soil Map Units to Mapped ELC Vegetation Types in the Local Study Areas

ELC Vegetation Classes	LSA Soil Map Units
Bedrock open conifer	KIL
Coniferous pine	RAB
Coniferous spruce in Kellor Lake Plain Ecoregion	RAB-TUM-MAR
Coniferous spruce in Copper River Upland Ecoregion	RAB-KIL-MAR
Deciduous aspen-paper birch	RAB-MAR
Marsh/graminoid fen	MUS-MAR
Mixedwood-spruce-paper birch-aspen	RAB-MAR
Open bog	BUR-MAR
Treed bog	MUS
Treed fen	MUS
Shrubland	BUR-MAR
n/a	BEA-BUR[b]
Burn[a]	n/a
Cloud/Haze	Unclassified
Disturbance	Disturbance
Water	Water

[a] Soil map units in the burn class were derived from the previous ELC vegetation classes from Golder (2006).

[b] Soil map unit not derived from ELC vegetation class.

APPENDIX IV

SOIL CHEMISTRY AND NUTRIENT ANALYTICAL METHODS

Table IV-1 Soil Chemistry Analytical Methods

Method Name	Reference	Location	Method	Date Analysis Started
Boron in general soil	McKeague	Norwest Labs Edmonton, AB	Hot Water Soluble Boron - Azomethine-H Method, 4.61	11-Oct-05
Mercury (Hot Block) in Soil	US EPA	Norwest Labs Edmonton, AB	Determination of Hg in Sediment by Cold Vapor Atomic Absorption Spec, 245.5	11-Oct-05
Metals ICP-MS (Hot Block) in soil	SW-846	Norwest Labs Edmonton, AB	Acid Digestion of Sediments, Sludges, and Soils, EPA 3050B	12-Oct-05
Nutrients in General Soil	Comm. Soil Sci. Pl. Anal.	Norwest Labs Edmonton, AB	Modified Kelowna Soil Test, Vol 26, 1995	11-Oct-05
Organic Matter by Ignition	McKeague	Norwest Labs Edmonton, AB	Loss on Ignition (LOI), 3.8	9-Oct-05
Particle Size Analysis - GS	Carter	Norwest Labs Edmonton, AB	Hydrometer Method, 47.3	11-Oct-05
pH and Conductivity in general soil 1:2	McKeague	Norwest Labs Edmonton, AB	1:2 Soil:Water Ratio, 4.12	11-Oct-05
Sulfate in General Soil	McKeague	Norwest Labs Edmonton, AB	Sulfate Extractable by 0.1M CaCl2, 4.47	11-Oct-05
Available Nitrate – N	Carter	ALS Laboratory Group, Edmonton, AB	CSSS (1993) 4.3	18-Aug-08
Available Phosphate & Potassium	Soil Science and Plant Analysis	ALS Laboratory Group, Edmonton, AB	Comm.Soil Sci. Plant Anal, 25 (5&6)	18-Aug-08
Organic Matter by LOI at 375 degree C.	McKeague	ALS Laboratory Group, Edmonton, AB	CSSS (1993) p. 160	18-Aug-08
Particle Size Analysis: hydrometer	Carter	ALS Laboratory Group, Edmonton, AB	CSSS (1993) p. 508-509	18-Aug-08
pH and EC 1:2 Soil:Water Extraction	Carter	ALS Laboratory Group, Edmonton, AB	CSSS (1993) 16.2.2, 18.3.1	18-Aug-08
Particle size – Pipette removal Om & CO3	Kalra and Maynard	ALS Laboratory Group, Edmonton, AB	Forestry Canada (1991) p. 46-53	18-Aug-08

References:

Carter, Martin. 1993. Method 4.3. Soil Sampling and Methods of Analysis. Can. Soc. Soil Science.

EPA. Acid Digestion of Sediments, Sludges, and Soils 3050B. SW-846 Test Methods for Evaluating Solid Waste.

EPA. Determination of Hg in Sediment by Cold Vapor Atomic Absorption Spec. US Environmental Protection Agency Test Methods 245.5.

Kalra, Y.P. and D.G Maynard. 1991. Methods manual for forest soil and plant analysis. Forestry Canada

McKeague, J.A. 1978. Method 4.23. Soil Sampling and Methods of Analysis. Can. Soc. Soil Science

Soil Science and Plant Analysis. 1994. Communications in Soil Science and Plant Analysis Volume 25, Nos. 5&6, pgs. 627-635.

APPENDIX V

LIST OF SOIL INSPECTION SITES

Table V-1 List of Soil Inspection Sites and Selected Site Characteristics

Site	NAD	Zone	Easting	Northing	Surface Expression	Landform	Drainage	Slope Class	Peat/LFH Depth (cm)	Soil Subgroup	Soil Series
NAS001	83	11V	498049	7006053	Undul.	Upland	W	3	7	O.EB	RAB
NAS002	83	11V	498044	7006212	Level	Fen	I	1	33	O.Rpt	MAR
NAS003	83	11V	497983	7006603	Level	Fen	P	1	42	O.Gpt	MAR
NAS004	83	11V	497809	7007594	Humm.	Upland	R	3	5	O.EB	TUM
NAS005	83	11V	497527	7010530	Undul.	Upland	W	3	4	O.EB	TUM
NAS006	83	11V	497582	7010115	Level	n/d	P	2	35	O.Rpt	KIL
NAS008	83	11V	497466	7011575	Level	Bog	P	4	35	R.Gpt	MAR
NAS009	83	11V	496993	7012448	Undul.	Fen	P	3	30	R.Gpt	MAR
NAS010	83	11V	496337	7013539	Level	Fen	VP	1	67	T.M	MUS
NAS011	83	11V	495880	7014916	Undul.	Upland	I	2	3	E.EB	RAB
NAS012	83	11V	495559	7016233	Level	Bog	P	1	20	R.Gpt	MAR
NAS013	83	11V	495200	7017786	other	Upland	I	2	10	O.EB	TUM
NAS018	83	11V	495723	7029608	Level	Fen	VP	1	30	R.Gpt	MAR
NAS020	83	11V	495585	7030672	Ridge	Upland	I	2	5	GL.EB	HIS
NAS022	83	11V	497117	7032461	Incl.	Upland	I	3	3	O.EB	TUM
NAS024	83	11V	498147	7033069	Level	Bog	VP	1	32	GL.SC	BEA
NAS026	83	11V	499475	7033718	Level	Bog	P	1	2	O.G	HIS
NAS028	83	11V	500288	7034130	Level	Fen	VP	1	23	R.Gpt	MAR
NAS030	83	11V	501884	7034947	Ridge	Upland	W	3	6	O.EB	RAB
NAS032	83	11V	507222	7040154	Ridge	Upland	n/d	1	5	O.R	KIL
NAS034	83	11V	507710	7040780	Undul.	Upland	I	2	5	O.R	RAB
NAS036	83	11V	508500	7041420	Ridge	Upland	n/d	3	4	O.EB	RAB
NAS038	83	11V	508995	7042130	Level	Bog	VP	1	100	TFI.OC	BUR
NAS040	83	11V	509819	7042650	Ridge	Upland	n/d	3	2	O.R	KIL
NAS044	83	11V	510660	7042972	Level	Other wetland	P	1	4	R.G	HIS
NAS046	83	11V	511286	7043575	Ridge	Upland	n/d	4	2	O.R	KIL
NAS048	83	11V	511849	7045475	Incl.	Upland	R	5	3	O.EB	RAB
NAS050	83	11V	511985	7045895	Incl.	Other wetland	I	2	26	O.Gpt	MAR
NAS052	83	11V	512359	7046172	Level	Fen	VR	1	28	GL.SC	BEA
NAS053	83	11V	511276	7043617	Humm.	Swamp	P	1	18	R.Gpt	MAR
NAS054	83	11V	511379	7044485	Level	Fen	P	1	30	R.Gpt	MAR
NAS055	83	11V	513981	7045697	Incl.	Swamp	VR	2	10	GL.SC	BEA
NAS056	83	11V	513841	7045358	Ridge	Upland	n/d	4	3	O.R	KIL
NAS057	83	11V	513977	7045327	Level	Other wetland	VP	1	40	T.M	MUS
NAS058	83	11V	513627	7045951	Incl.	Upland	W	3	2	O.EB	RAB
NAS059	83	11V	512838	7046736	Incl.	Upland	n/d	3	3	R	KIL
NAS060	83	11V	512713	7046051	Level	Fen	VP	1	30	GL.SC	BEA
NAS061	83	11V	513219	7045711	Level	Fen	VP	1	22	TME.OC	BUR
NAS062	83	11V	512578	7046973	Incl.	Upland	n/d	3	8	O.R	KIL
NAS063	83	11V	512719	7047280	Level	Other wetland	VP	1	45	O.Rpt	MUS
NAS064	83	11V	512731	7047397	Incl.	Upland	n/d	3	8	O.R	KIL

Table V-1 List of Soil Inspection Sites and Selected Site Characteristics (continued)

Site	NAD	Zone	Easting	Northing	Surface Expression	Landform	Drainage	Slope Class	Peat/LFH Depth (cm)	Soil Subgroup	Soil Series
NAS065	83	11V	512578	7047489	Incl.	Upland	VR	6	10	O.R	KIL
NAS066	83	11V	512470	7047298	Incl.	Upland	R	3	4	O.R	KIL
NAS067	83	11V	512386	7047272	Level	Bog	P	1	37	TME.OC	BUR
NAS068	83	11V	512226	7047185	Incl.	Upland	W	2	8	O.EB	KIL
NAS070	83	11V	512006	7047376	Incl.	Upland	R	5	2	O.R	KIL
NAS071	83	11V	511856	7047374	Incl.	Upland	R	5	2	O.EB	KIL
NAS072	83	11V	511879	7047173	Incl.	Other wetland	P	2	45	TME.OC	BUR
NAS073	83	11V	512129	7046768	n/d	Upland	W	3	8	O.EB	TUM
NBS015	83	11V	494952	7018781	Undul.	Upland	MW	2	4	O.EB	RAB
NBS017	83	11V	494726	7019737	Undul.	Upland	I	2	8	O.EB	RAB
NBS019	83	11V	494531	7020733	Undul.	Upland	I	2	32	R.Gpt	MAR
NBS021	83	11V	494332	7021700	Undul.	Bog	P	2	49	T.M	MUS
NBS023	83	11V	494106	7022727	Level	Upland	MW	1	6	O.EB	RAB
NBS025	83	11V	493925	7023649	Undul.	Upland	W	2	5	O.EB	RAB
NBS027	83	11V	493987	7024529	Level	Upland	W	1	2	O.EB	RAB
NBS029	83	11V	494452	7025451	Level	Other wetland	MW	1	10	O.EB	RAB
NBS031	83	11V	494766	7026409	Undul.	Upland	W	3	6	O.EB	RAB
NBS033	83	11V	495090	7027365	Level	Other wetland	P	1	36	R.Gpt	MAR
NBS035	83	11V	503064	7035264	Level	Bog	P	1	50	THU.M	MUS
NBS037	83	11V	503888	7035918	Undul.	Upland	W	2	16	O.R	KIL
NBS039	83	11V	504247	7036833	Undul.	Upland	MW	3	22	R.Gpt	MAR
NBS041	83	11V	504960	7037574	Level	Upland	W	1	6	O.R	RAB
NBS043	83	11V	505510	7038451	Undul.	Upland	W	2	8	O.R	RAB
NBS045	83	11V	506285	7039119	Undul.	Upland	MW	4	17	O.Ebpt	TUM
NBS047	83	11V	506935	7039880	Level	Upland	I	1	36	R.Gpt	MAR
NCS001	83	11V	500174	7011015	Humm.	Fen	VP	3	15	GL.SC	BEA
NCS002	83	11V	500402	7011305	Ridge	Upland	I	3	15	R.G	HIS
NCS003	83	11V	500254	7011565	Humm.	Fen	P	2	40	R.Gpt	MAR
NCS004	83	11V	500047	7011430	Level	Bog	VP	1	55	TME.OC	BUR
NCS005	83	11V	499763	7011967	Undul.	Bog	VP	2	55	T.M	MUS
NCS006	83	11V	499742	7012333	Undul.	Upland	W	3	20	R.Gpt	RAB
NCS007	83	11V	499869	7012803	Undul.	Upland	I	3	15	R.G	RAB
NCS008	83	11V	493222	7012634	Ridge	Upland	R	4	5	O.R	RAB
NCS008a	83	11V	493206	7012638	Undul.	Upland	W	1	25	O.R	RAB
NCS009	83	11V	492932	7013219	Undul.	Upland	W	3	10	O.EB	TUM
NCS010	83	11V	493190	7013654	Undul.	Upland	MW	3	6	O.R	RAB
NCS010A	83	11V	493201	7013763	Level	Fen	P	1	30	R.Gpt	MAR
NCS011	83	11V	493179	7014320	Undul.	Upland	W	3	12	O.EB	RAB
NCS012	83	11V	490452	7025861	Undul.	Upland	W	2	8	O.EB	RAB
NCS013	83	11V	490320	7026314	Undul.	Upland	W	3	15	O.EB	RAB

Table V-1 List of Soil Inspection Sites and Selected Site Characteristics (continued)

Site	NAD	Zone	Easting	Northing	Surface Expression	Landform	Drainage	Slope Class	Peat/LFH Depth (cm)	Soil Subgroup	Soil Series
NCS014	83	11V	489879	7027066	Level	Fen	VP	1	125	TY.F	MUS
NCS015	83	11V	489670	7027595	Level	Fen	VP	1	30	R.Gpt	MAR
NCS016	83	11V	490455	7028027	Level	Bog	VP	1	50	T.M	MUS
NCS017	83	11V	490457	7028074	Undul.	Upland	MW	3	15	O.R	RAB
NCS018	83	11V	500582	7039258	Level	Fen	P	1	20	R.G	HIS
NCS019	83	11V	500822	7040309	Undul.	Upland	R	4	2	O.EB	RAB
NCS020	83	11V	501071	7041170	Level	Bog	VP	1	125	FI.OC	BUR
NCS021	83	11V	501319	7041914	Undul.	Bog	P	3	50	FI.OC	BUR
NCS022	83	11V	503772	7053997	Level	Bog	P	2	50	FI.OC	BUR
NCS023	83	11V	504389	7054720	Undul.	other	VR	3	0	O.R	KIL
NCS024	83	11V	504137	7055319	Level	Fen	VP	1	100	FI.OC	BUR
NCS025	83	11V	517847	7038714	Ridge	Upland	R	5	5	O.R	KIL
NCS026	83	11V	517911	7038832	Level	Bog	P	2	50	FI.OC	BUR
NCS027	83	11V	517581	7038892	Ridge	other	R	5		O.R	KIL
NCS028	83	11V	517326	7039098	Undul.	other burn	P	3	10	GL.SC	BEA
NCS029	83	11V	517080	7039532	Level	Bog	P	2	30	GL.SC	BEA
NCS030	83	11V	496856	7023883	Level	Bog	P	1	125	ME.OC	BUR
NCS031	83	11V	499296	7025334	Level	Other wetland	VP	1	125	TY.F	MAR
NCS032	83	11V	499112	7026979	Level	Fen	P	1	50	T.F	MUS
NCS033	83	11V	513196	7051248	Incl.	Upland	R	6	8	O.EB	RAB
NCS036	83	11V	515062	7051853	Level	Bog	VP	1	65	FI.OC	BUR
NCS037	83	11V	514805	7052578	Incl.	Upland	VR	7	0	O.R	KIL
NCS038	83	11V	513914	7047118	Ridge	Upland	VR	2	0	O.R	KIL
NCS040	83	11V	513809	7047053	Incl.	Upland	R	3	6	O.EB	RAB
NCS041	83	11V	512695	7045123	Ridge	Upland	R	3	15	O.EB	RAB
NCS042	83	11V	513640	7044635	Undul.	Bog	P	3	35	R.Gpt	MAR
NCS043	83	11V	513848	7047038	Incl.	Upland	R	4	10	O.EB	TUM
NCS044	83	11V	512947	7045725	Incl.	Upland	MW	4	10	O.EB	RAB

n/d = no data; cm = centimetre

APPENDIX VI

SOIL RECLAMATION SUITABILITY IN THE LOCAL STUDY AREA

Table VI-1 Soil Reclamation Suitability in the Local Study Area

Map Unit	Site #	Soil Series	Horizon	Depth (cm)	pH	Texture	Moist Consistency	Overall Rating
BEA -BUR	NAS055	BEA	Of	10-0	n/d	n/d	n/d	O
			Cg	0-20	n/d	F	F	F
			Cgz	20-30	n/d	F	F	F
	NAS067	BUR	Of	0-22	n/d	n/d	n/d	O
			Om	22-27	n/d	n/d	n/d	O
			Of	27-37	n/d	n/d	n/d	O
			Omz	37+	n/d	n/d	n/d	O
BUR-MAR	NAS067	BUR	Of	0-22	n/d	n/d	n/d	O
			Om	22-27	n/d	n/d	n/d	O
			Of	27-37	n/d	n/d	n/d	O
			Omz	37+	n/d	n/d	n/d	O
	NCS042	MAR	Of	35-0	n/d	n/d	n/d	O
			Cg	0-65	G	G	G	G
KIL	NAS064	KIL	LFH	8-0	n/d	n/d	n/d	O
			Bmj	0-4	n/d	U	U	U (texture)
			R	4+	n/d	U	U	U (texture)
MUS	NAS010	MUS	Of	0-21	n/d	n/d	n/d	O
			Om	21-58	n/d	n/d	n/d	O
			Oh	58-67	n/d	n/d	n/d	O
			Cg	67+	n/d	n/d	n/d	n/d
MUS-MAR	NAS010	MUS	Of	0-21	n/d	n/d	n/d	O
			Om	21-58	n/d	n/d	n/d	O
			Oh	58-67	n/d	n/d	n/d	O
			Cg	67+	n/d	n/d	n/d	n/d
	NAS002	MAR	OF	33-17	n/d	n/d	n/d	O
			Om	17-0	n/d	n/d	n/d	O
			Cg	0-5	n/d	G	G	G
RAB	NAS001	RAB	LFH	8-0	n/d	n/d	n/d	O
			Ah	0-4	F	G	F	F (pH)
			Bm	4-30	P	F	F	P (pH)
			C	30-33	n/d	P	P	P (texture)
RAB-KIL-MAR	NCS044	RAB	LFH	10-0	n/d	n/d	n/d	O
			Ahe	0-18	F	G	G	F(pH)
			Bm	18-44	G	G	G	G
			C	44-50	G	P	G	P (texture)
	NAS064	KIL	LFH	8-0	n/d	n/d	n/d	O
			Bmj	0-4	n/d	U	U	U (texture)
			R	4+	n/d	U	U	U (texture)

Table VI-1 Soil Reclamation Suitability in the Local Study Area (continued)

Map Unit	Site #	Soil Series	Horizon	Depth (cm)	pH	Texture	Moist Consistency	Overall Rating
	NCS042	MAR	Of	35-0	n/d	n/d	n/d	O
			Cg	0-65	G	G	G	G
RAB-TUM-MAR	NAS001	RAB	LFH	8-0	n/d	n/d	n/d	O
			Ah	0-4	F	G	F	F (pH)
			Bm	4-30	P	F	F	F (texture)
			C	30-33	n/d	P	P	P (texture)
	NAS004	TUM	LFH	5-0	n/d	n/d	n/d	O
			Ah	0-2	P	G	G	P (pH)
			Bm	2-29	P	G	G	P (pH)
			C	29-40+	P	G	G	P (pH)
	NAS002	MAR	OF	33-17	n/d	n/d	n/d	O
			Om	17-0	n/d	n/d	n/d	O
			Cg	0-5	n/d	G	G	G
RAB-MAR	NCS044	RAB	LFH	10-0	n/d	n/d	n/d	O
			Ahe	0-18	F	G	G	F(pH)
			Bm	18-44	G	G	G	G
			C	44-50	G	P	G	P (texture)
	NCS042	MAR	Of	35-0	n/d	n/d	n/d	O
			Cg	0-65	G	G	G	G

Source: Alberta Agriculture 1987.

Notes: The upper lift consists of organic/LFH and A horizons and perhaps a portion of the B horizon to a depth of 20 cm. The lower lift consists of material beneath the upper lift appropriate to specific site conditions: O = Organic soil; G = Good; F = Fair; P = Poor.

n/d = no data; cm = centimetre