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March 14, 2012 [VIA EMAIL]

Dear Mr. Nasogaluak:

Re: Inuvik to Tuktoyaktuk Highway - Terrain Evaluation Report

On behalf of the Government of Northwest Territories – Department of Transportation, Town of Inuvik and Hamlet of Tuktoyaktuk, KAVIK-STANTEC Inc. is pleased to submit the following report in two parts, to the Environmental Impact Review Board during its consideration of the Inuvik to Tuktoyaktuk Highway Project:

Inuvik to Tuktoyaktuk Highway - Baseline Data Acquisition Program: Terrain Evaluation Report
Surficial Geology and Terrain Constraints Inuvik – Tuktoyaktuk Highway: Mapbook

We are providing this report and mapbook as low-resolution files suitable for upload to the registry. A CD-ROM containing the report and high-resolution mapbook has been sent to you via mail. Additional copies of the CD-ROM report and mapbook can be obtained by contacting Erica Bonhomme by email at erica.bonhomme@stantec.com.

Sincerely,

Erica Bonhomme
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for KAVIK-STANTEC Inc.
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cc. Jim Stevens, DOT

Inuvik to Tuktoyaktuk Highway - Baseline Data Acquisition Program Terrain Evaluation

KAVIK-STANTEC

Final Report

March 12 2012

Prepared for:
Government of the Northwest Territories – Department of Transportation
Yellowknife, NT

Prepared by:
KAVIK-STANTEC INC.

Inuvik, NT Project Number: 123510689

Executive Summary

KAVIK-STANTEC undertook a terrain assessment program in support of the Government of the Northwest Territories, Department of Transportation (DOT), Town of Inuvik and Hamlet of Tuktoyaktuk's Inuvik to Tuktoyaktuk Highway Project (the Project). This report summarizes the findings of the terrain assessment.

The study included detailed airphoto interpretation of the surficial geology, geologic processes, drainage and permafrost features along route alternatives 1 and 3, as well as the identification of problematic terrain along the pre-identified alignments and borrows sources. Poor weather and unsafe flying conditions resulted in the cancellation of the scheduled 5-day field program aimed at gathering site-specific information on the terrain conditions along the proposed highway alignments. A brief overview flight permitted the viewing of 4 of the 10 borrow sources proposed for the Project.

Detailed airphoto interpretation using digital 3D imagery was conducted along a 1km wide corridor centered on proposed alignments 1 and 3. The imagery used consisted of 1:30,000 colored photographs acquired in August of 2004 and 2005. Mapping occurred at scales varying from 1:2,500 to 1:7,500. The map atlas accompanying this report is presented at a 1:10,000 scale.

The surficial geology along the proposed alignments consists mainly of glacial till. Lacustrine deposits are extensive in the northern portion of the study area near Husky Lakes. Glaciofluvial outwash and ice-contact deposits are found locally. Other surface materials include fluvial, colluvial and organic deposits. The vast majority of the alignments occur on flat to gently undulating terrain. Short steep slopes in excess of 25% are found locally.

Permafrost and periglacial processes are prevalent throughout the study area. Ice-rich terrain features are common along both alignments and are considered as the primary hazard to the stability of the proposed highway. Detailed terrain mapping suggests that up to 17.4 km of Alternative 1, and up to 19 km of Alternative 3 are characterized by ice-wedge polygons. Additional areas of ice-wedge polygons are expected but were not identified at the scale of mapping. Suspected ice-rich terrain units are extensive along the alignments, especially in the northern part where dissected topography related to thermokarst activity is extensive. Several examples of recent thermokarst activity are found along the proposed highway alignments. Retrogressive thaw slumps are common in fine-grained till and lacustrine deposits and generally occur along the edge of lakes and small ponds. Other active geoprocesses includes active layer failures, solifluction, creep and excessive surface water seepage.

The analysis of the two alignments indicates that the proposed highway traverses several areas characterized by sensitive terrain conditions (e.g. peatlands, ice-wedge polygons, poorly drained materials, etc.). Although some construction and mitigation techniques can be applied to minimize the disturbance of these sensitive areas, there may be opportunities to further optimize route geometry and alignment within the proposed 1 km wide assessment corridor to avoid these sensitive areas.

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Abbreviations

AANDC	Aboriginal Affairs and Northern Development Canada
asl	Above sea level
DEM	Digital elevation model
DOT	Department of Transportation
EIS	Environmental Impact Statement
EISC	Environmental Impact Screening Committee
ESS	Earth Sciences Sector
ISR	Inuvialuit Settlement Region
GNWT	Government of the Northwest Territories
HD-MAPP	High Definition Mapping and APPlications
ka	Thousand years
KP	Kilometre post
NRCan	Natural Resources Canada

1 INTRODUCTION

The Government of the Northwest Territories (GNWT), Department of Transportation (DOT), the Town of Inuvik and the Hamlet of Tuktoyaktuk are proposing to construct a 140 km all-season highway to connect the Town of Inuvik with the Hamlet of Tuktoyaktuk (the project). The project is wholly within the Inuvialuit Settlement Region, with portions of the highway crossing Inuvialuit 7(1)(a), 7(1)(b) and Crown lands.

1.1 PROJECT BACKGROUND

After issuance of a Terms of Reference by the EIRB, an Environmental Impact Statement (EIS) was submitted in May 2011. The EIS has undergone a conformity review by the EIRB and reviewers, where a number of deficiencies have been identified. The goal of the present report is to provide additional information related to the general terrain conditions, surficial geology and potential constraints located within the project's study area.

1.2 STUDY OBJECTIVES

The scope of the terrain assessment included the following tasks:

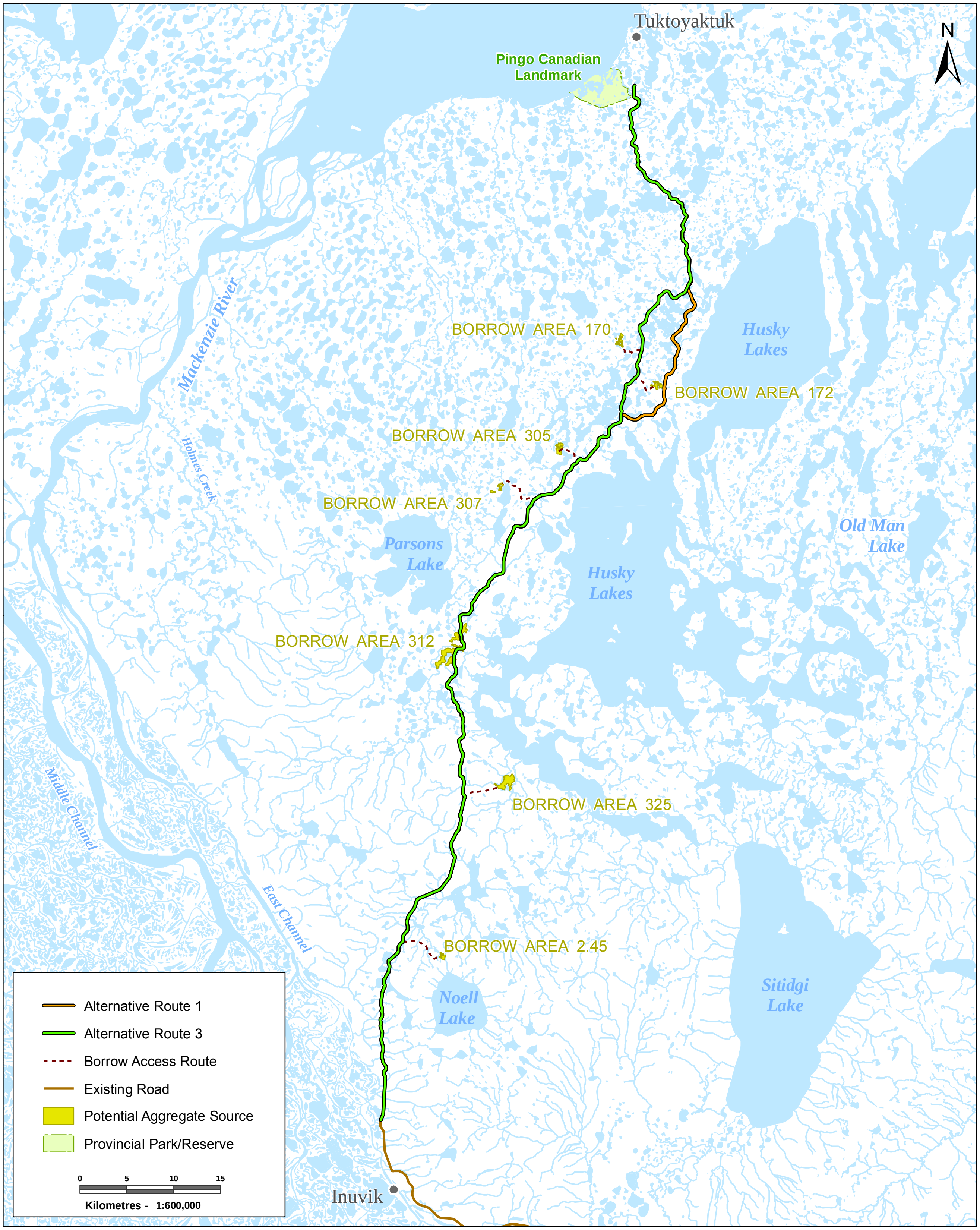
- Detailed airphoto interpretation of the surficial geology, geologic processes and drainage conditions found along route alternatives 1 and 3,
- The identification of potential terrain constraints and areas exhibiting accelerated erosion along the identified alignments and at the proposed borrow sources,
- A reconnaissance field survey of the proposed alignments and borrow sources, and
- Map and report production.

1.3 PROJECT LOCATION AND SPATIAL BOUNDARY

Several studies have been carried out in relation with the selections of the routing alternatives. The alignments considered as part of the current assessment include:

- **Alternative 1** – The 2009 Minor Realignment of the Primary 2009 Route to fully achieve the Husky Lakes 1 km setback requirements; and
- **Alternative 3** – the 2010 Minor Realignment, recommended by Inuvialuit interests to modify Alternative 1 and to provide a more direct route.

Route Alternate 2 (Upland Route; previously discussed in Section 2.1.2.4 of the EIS) was eliminated from further analysis due to greater potential risk to public safety, the considerably higher estimated cost of project construction, the greater constructability challenges, and the greater project operation and maintenance cost.



Inuvik – Tuktoyaktuk Highway, Baseline Data Acquisition Program

Proposed Highway Alignments, Borrow Sources and Access Roads

Base Data provided by Government of the Northwest Territories; Surficial Data: Stantec

PREPARED BY

KAVIK-STANTEC

PREPARED FOR

Northwest Territories Transportation

FIGURE NO.

1-1

Last Modified: March 1 2012 By: lfeschuk

2 METHODOLOGY

The following section describes the methodology relative to the terrain baseline program.

2.1 REVIEW OF EXISTING INFORMATION

2.1.1 Surficial Geology, Landforms and Geomorphic Processes

Extensive data and literature are available on terrain and permafrost-related conditions in the Mackenzie Delta region. The following four references represent the main sources of information on the surficial geology of the area between Inuvik and Tuktoyaktuk. These cartographic products are presented at scales ranging from 1:25,000 to 1:500,000.

- Heginbottom, J.A. 1985. Medium scale maps of permafrost and ground ice conditions Tuktoyaktuk and Illisarvik, Western Arctic Coast, Canada: in Workshop of Permafrost Geophysics, Golden, Colorado 23-24 December, 1984, J. Brown, M.C. Metz, P. Hoekstra (ed.), U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Special Report 85-5, pp. 15-18.
- Rampton, V.N. 1981. Surficial Geology, Mackenzie Delta, District of Mackenzie. Geological Survey of Canada, Preliminary Map 32-1979 1:250,000 scale.
- Rampton, V.N. 1988. Surficial Geology of Tuktoyaktuk, District of Mackenzie. Geological Survey of Canada, Surficial Geology Map 1647a 1:500,000 scale.
- Rampton, V.N. and M. Bouchard. 1974. Surficial Geology Tuktoyaktuk Area, District of Mackenzie. Geological Survey of Canada, Surficial Geology Map 5-1974, Paper 74-53, 1:25,000 scale.

In addition, several studies on the proposed Inuvik to Tuktoyaktuk Highway contain sections specific to the surficial geology and overall terrain conditions along the proposed alignment (e.g. Kiggiak EBA 2011; Rescan Environmental Services Ltd. 1999). Although the alignment has evolved over the last few decades, most studies have used the references presented above as a base for the descriptions of the terrain units.

2.1.2 Previous Aggregate Investigations

Granular resources in the Mackenzie Delta region are relatively scarce. A considerable number of documents have been published regarding the aggregate resources along the proposed Inuvik to Tuktoyaktuk Highway (AGRA Earth & Environmental. 1997, EBA Engineering Consultants Ltd., 1983, 1987a, 1987b; Hardy BBT Ltd. 1987, 1990a, 1990b, 1991; PWC 1981; R.M. Hardy and associates Ltd. 1977).

2.1.3 Seismic Shothole Data

Extensive seismic surveys have been conducted within the Mackenzie Delta region over the last few decades in relation to exploration by the petroleum industry. Seismic shothole log records are recorded by drill operators during geotechnical seismic operations when they auger/air-rotary drill holes to set explosive charges. Holes were drilled to varying depths, averaging 12 – 16 m (Smith 2010). As the compilation of drillers log records is largely new, they have yet to be extensively field verified. Users of the shothole drillers' log data are thus cautioned to employ the adage that "if a record indicates a particular unit as being present, then it might well be there, but if it is not identified as being there, it does not necessarily mean that it is not there" - the driller may simply have not reported it. That said, the use of these driller's logs in support of surficial geology mapping activities in the Mackenzie Delta region and other parts of northern British Columbia over the past five years have demonstrated them to be a reliable, albeit simplified, lithostratigraphic archive (Levson et. al. 2004; Smith and Lesk-Winfield 2009; Smith et al. 2011).

2.2 MAPPING METHODOLOGY

2.2.1 Terrain Mapping

Surface material, surface expression, drainage, slopes and geomorphic processes have been mapped using a combination of recently acquired stereo digital imagery and KAVIK-STANTEC's High Definition Mapping and APPlications (HD-MAPP) system. HD-MAPP incorporates PurVIEW^{TM} and ArcGIS applications, making it possible to view medium 1:30,000 scale aerial photographs in a digital environment at scales as large as 1:1,000. The ability to view stereo-imagery at such detailed scales allows for better identification, delineation and classification of surficial geology, potentially ice-rich terrain features such as polygonal peat plateaus and terrain-related constraints (e.g. steep slopes, thaw slumps and seepage areas).

The aerial photography used for the mapping exercise consists of digital 1:30,000 scale color photographs acquired in August of 2004 and 2005 as part of the Mackenzie Valley Airphoto Project (GNWT 2011). Elevation information comes from the national and provincial digital elevation model (DEM) as well as from 1:50,000 scale digital base data available on the web portal of the Earth Sciences Sector (ESS) of Natural Resources Canada (NRCan).

Mapping was completed along the entire length of the two alternate highway alignments as well as along the proposed access to the borrow sources. A 1 km corridor was placed on the alignments to define a mapping corridor (resulting in a 500 m buffer on either side of the alignment). Mapping occurred at a representative scale ranging from 1:2,500 to 1:7,500. A total of 2,095 terrain polygons were delineated, resulting in an average polygon size of approximately 9 ha. Several polygons smaller than 1 ha in size were delineated, and most of these consist of critical landscape features such as water bodies, areas of ice-wedge polygons or areas characterized by active mass movements (e.g., thaw slumps).

2.2.2 Borrow Source Identification and Mapping

Probable borrow sources along the proposed highway have been identified through numerous desktop-based mapping studies, geotechnical and geophysical field investigations and by visual observations (See Section 2.1.2 Previous Aggregate Investigations). A total of ten (10) separate borrow locations were provide by DOT at the beginning of the study. The locations and extent of these probable borrow sources was further refined using KAVI-STANTEC's HD-MAPP mapping technology. More specifically, these probable aggregate deposits were further subdivided based on a visual assessment (i.e. using air photo interpretation), to identify areas of good quality glaciofluvial, free-draining aggregate deposits with little observable vegetation cover and to identify areas of lower quality glaciofluvial aggregate deposits with poorer drainage and higher vegetation cover.

Special emphasis was placed on identifying upland units rather than low-lying areas as low-lying areas tend to be more problematic for development (e.g. poor drainage, etc.). Terrain polygons (or units) were primarily delineated on the basis of landform coupled with the available background data. For example, borrow area 325 has been mapped by Rampton

(1988) as being comprised of [glaciofluvial] outwash; plains and valley trains with deposits to 20m thick. Similarly, shothole and borehole data indicate general parent material textures based on exploration drilling. For example, some shotholes were described as “sand and gravel”, others as “gravel” and others as “clay, sand, shale”. In addition to the above background data, a reconnaissance field trip occurred on September 18, 2011 (see Section 2.3).

Based on the size and location of these areas in relation to the proposed highway alternatives, seven (7) borrow source locations were subsequently selected by DOT for further geotechnical investigation in a winter 2012 Borrow Source Investigations Program. The general location of these borrow sources is provided in Figure 1-1. A description of the terrain conditions, including an evaluation of the erosion potential, is provided in the results section (see Section 3.6.3). Detailed location information is provided in the map atlas in Appendix B.

2.3 FIELD RECONNAISSANCE

In September 2011, KAVIK-STANTEC terrain scientists and geotechnical engineers planned to conduct a reconnaissance field investigation along the proposed Inuvik to Tuktoyaktuk Highway. The goal of the field survey was two-fold:

- To collect site-specific information on the terrain conditions, surficial geology and permafrost along the proposed alignments;
- To visit 10 potential borrow sources previously identified by the client and to confirm the presence of aggregate material.

Due to poor weather conditions during the scheduled week of reconnaissance and resulting limited flying time, field investigations were limited to geotechnical reconnaissance of the borrow sources, with only minimum observations to the terrain conditions along the proposed right-of-way. Despite the very short field visit (4hr), four out of ten borrow sources were visited (2.45, 27B, 325 and 172). Data and observations gathered during the field reconnaissance are included in the results section of this report. Photographs taken during the field visit are located in Appendix A.

3 RESULTS

The following section provides a description of the physiography, geology, surficial geology, landforms and geoprocesses within the study area.

3.1 PHYSIOGRAPHY

The project lies entirely within the Mackenzie Delta Division of the Arctic Coastal Plains (Bostock 1970). The Mackenzie Delta region is described as a flat to hummocky deltaic plain comprising a large number of lakes and channels. The area comprises a mixture of unconsolidated Pleistocene and recent deposits; the former consisting of deltaic sediment of the Mackenzie River as well as recent fluvial, lacustrine, marine, colluvial and organic deposits. The Pleistocene deposits include till or morainal deposits, glaciofluvial and lacustrine sediments.

Rampton (1988) further divided the area into the Mackenzie Delta (to the west) and the adjacent Tuktoyaktuk Coastlands (to the east) in order to differentiate the recent (Holocene) sediments of the modern Mackenzie River from the older (Quaternary) deposits. The vast majority of the study area is located within the Tuktoyaktuk Coastlands, with only the first few kilometres being part of the actual Mackenzie Delta division.

3.2 PERMAFROST

The Tuktoyaktuk Coastlands and adjacent area are located within the continuous permafrost zone (Heginbottom et al. 1992). Geothermal data from Taylor and Judge (1977) indicates that much of the Tuktoyaktuk Peninsula is underlain by up to 600 m of permafrost. Thawed zones, or taliks, exist under large lakes and major river channels (Rampton 1988). The depth of the active layer (i.e. the portion of soil that thaws seasonally) varies greatly in relation with factors such as the soils texture, the vegetation type and the water content of the soil. Active layer thicknesses of vegetated soils in the Inuvik to Tuktoyaktuk area typically range from 0.6 and 0.8 m, but can vary from less than 0.5 to greater than 2 m on elevated, organic-free slopes (Tarnocai et al. 2004; KIGGIAK-EBA 2010).

3.3 GEOLOGY

The Tuktoyaktuk Coastlands and Mackenzie Delta are underlain by a thick sequence of Mesozoic and Cenozoic rocks which were deposited in the Beaufort-Mackenzie Basin (Norris 1981). Shale and siltstone were deposited in basin during major transgression, while sandstone was deposited along marine shoreline and deltaic areas.

Bedrock is generally deeply buried (from 30 to 150 m) beneath the pre-glacial, glacial and post glacial deposits along most of the proposed highway alignment (Hardy BBT Limited, 1991). Silty shales of the Horton River Formation (Rampton 1988) are exposed at the Navy Pit borrow source, just a few kilometres north of Inuvik and south of the beginning of the proposed alignment. Cretaceous shale underlying shallow surface deposits are also found in the Caribou Hills area north of Inuvik. Although close to the surface in the area between kilometre post (KP) 30 and 40 of the proposed highway alignment, the shale bedrock is relatively soft and not considered as a suitable construction material (Hardy BBT Limited, 1991).

3.4 LANDFORMS AND SURFICIAL GEOLOGY

Surficial geology information along the proposed highway corridor is available from a few maps with scales ranging from 1:25,000 to 1:500,000 (See Section 2.1 Review of Existing Information). The following description is based on a review of these documents, as well as from the interpretation of aerial photographs. Detailed terrain maps depicting the surficial geology, surface expression, geoprocesses, slope and drainages are found in Appendix B. A statistical summary of the material crossed by the two proposed alignments are presented in Section 3.5, Summary of Terrain Conditions.

Surficial deposits found within the project area consist of till (morainal deposits), glaciofluvial, lacustrine, colluvial, alluvial, eolian and organic deposits.

3.4.1 Till (morainal deposits)

By definition, till consists of material deposited directly by glacier ice without modification by any other agent of transportation (Howes and Kenk 1988). In general, till consists of massive (i.e. non-stratified), well-compacted material and contains a heterogeneous mixture of sand, silt and clay.

The textural, mineralogy and topographic characteristics of till deposits found along the Tuktoyaktuk Coastlands have been well described by Rampton (1988). Morainal deposits of both the Sitidgi Member (Late Wisconsinan age; found in the southern portion of the alignment) and Toker Point Member (Early Wisconsinan age; found in the northern portion of the alignment) are found along the proposed alignment. Both deposits consist primarily of a stony clayey diamicton. The till matrix generally consists of 10 to 30% sand, 25 to 45% silt, and 30 to 50% clay. Clast content is generally low and ranges from 3 to 25%.

Typically, till material is found overlying bedrock. The thickness of the till is variable and ranges from veneers (i.e. less than a metre thick) up to several metres thick (i.e. 20 to 30 m) (Rampton 1988). Thin till deposits tend to follow the underlying bedrock topography (e.g. morainal veneers and blankets) while some of the thicker deposits mask the underlying bedrock and present a gently undulating to hummocky surface expression. Relatively thin till deposits (i.e. till veneers and blankets) were identified in the area immediately south of Trail Valley Creek (KP 30 to 40).

Slopes in areas of undulating till deposits generally range between 2 and 10%, with local relief (i.e. the differences between topographic highs and lows) between 10 and 30 m. Hummocky till deposits such as the ones found in the northern portion of the alignments (e.g. KP 130) are characterized by shorter (e.g. 10 to 100 m), steeper slopes, sometimes reaching up to 30 or 40%. Photo interpretation indicates that these slopes are generally located in areas that have been modified by thermokarst activity.

The drainage of the till deposits is variable and directly related to the topographic position and texture of the material. In general, these deposits tend to be moderately well drained. Small hilltops and sloping terrain tend to be well to moderately well drained, with the exception of seepage areas characterized by imperfect to poor drainage. Flat, low-lying terrain and depressional areas tend to be imperfectly to poorly drained. Throughout the area, the proposed alignment crosses several poorly defined channels characterized by imperfect to poor drainage. The channels generally average 100 m in width and are characterized by important surface seepage. Good examples of such features are found between KP 2 and 6 as well as between KP 22 to 28.

Reworking of surface till material by geoprocesses such as thermokarst, retrogressive thaw flow slides, solifluction and creep is common. Rampton (1988) notes that much of the clayey diamicton, found at the surface of the morainal deposits has been reworked into colluvial and lacustrine deposits. Till deposits that show high degrees of reworking (e.g. the presence of solifluction lobes) have been labeled as colluvial material (materials deposited downslope by gravity). Literature reviews as well as photo interpretation indicate that massive ice is common within till deposits of the Tuktoyaktuk Coastlands (Mackay 1971, 1989; Rampton 1988; Rampton and Mackay 1971; Dallimore et al. 1996; Murton et al. 2005).

3.4.2 Glaciofluvial

Glaciofluvial deposits consist of sediment deposited by glacial meltwater streams (outwash deposits) or material deposited in proglacial streams at the margins of glaciers or at the contact with glacier ice (ice-contact deposits) (Howes and Kenk 1988). The texture of the glaciofluvial materials in the project area varies considerably but generally consists of silty to medium-coarse textured sand with variable amounts of gravel and pebbles (Rampton 1988, R.M. Hardy and Associates Ltd. 1977; Hardy BBT Limited 1990a, 1990b; Smith et al. 2011). The coarse fragments are generally sub-rounded to round, with only a minor fraction of sub-angular clasts. Glaciofluvial sediments are often bedded.

The majority of the glaciofluvial deposits mapped within the project occur as hummocky deposits. Other surface expressions of glaciofluvial material include terraces as well as undulating to rolling outwash plains. The deposits containing higher concentrations of gravel are often irregular and hummocky in shape. Several of these isolated hills and clusters of hills are considered to be kame and kettle complexes (Rampton 1988). The thickness of these deposits is variable and typically range from 3 to 30 m. Hummocky glaciofluvial deposits have been identified at several locations in the northern half of the project area and some are considered as potential borrow areas for this project (see Section 3.7.2 Borrow Sources).

Slopes of glaciofluvial deposits range from level to approximately 30% but short steep slopes up to 70% have been observed in the field. The drainage of the glaciofluvial material is generally well to rapid, with the exception of the depressions that can be imperfectly to poorly drained.

Several gently undulating areas mapped as outwash deposits by Rampton (1981, 1988) have been mapped as till as part of this study[1]. Most of these deposits are located in the areas east and northeast of Parsons Lake. Some of these deposits could be incorrectly identified as ice-contact deposits due to mapping scale (i.e. Rampton's 1476 Map is presented at a 1:500,000) A review of the mapping could be conducted if additional field data are made available.

Although coarse textured materials generally contain less ice than fine textured material, a review of available borehole data (PWC 1981, Dallimore and Wolfe 1988; Gowan and Dallimore 1991) indicates that bodies of massive ice are commonly associated with deposits of granular materials in the Mackenzie Delta.

3.4.3 Lacustrine

Lacustrine sediments consist of material deposited from suspension, and occasionally by underwater gravity flows in or along the margins of water bodies (Howes and Kenk 1988). These sediments also include material deposited in glacial and ice-damned lakes. Lacustrine deposits found within the mapping corridor can be divided into two categories: sediment deposited in recent lake basins, and sediment deposited during high water phase of Husky Lakes (Eskimo Lakes Member, Rampton 1988). Lacustrine deposits are present in localized depressions throughout the project, many of which

[1] Mapping presented as part of this assessment as not yet been field verified.

are due to thermokarst action. Extensive lacustrine deposits are present in the northern portion of the project, along the shoreline of Husky Lake.

The texture of the lacustrine deposits is generally fine but can vary in function of the depositional settings and nature of the source materials. The texture of the lacustrine deposits mapped over the Tuktoyaktuk Coastlands (Rampton 1988) range from clay, silt, clayey silt, sand and gravel. The deposits are generally bedded and can sometime include layers of organic materials.

Several drained lake basins were identified during the aerial photograph interpretation of the project. Raised lake shorelines are clearly visible on the aerial photography around Husky Lakes and indicate former water levels. The formation of pingos in some of these drained lake basins was observed in several locations throughout the Mackenzie Delta and Tuktoyaktuk Coastlands (Mackay 1998). A series of small lakes are showing signs of recent, rapid drainage (e.g. Alternative 3, KP 81, KP 111 and KP 127).

3.4.4 Colluvium

Colluvium consist of materials that have reached their present positions as a result of direct, gravity-induced movement involving no agent of transportation such as water or ice, although the moving material may have contained water and/or ice (Howes and Kenk 1988). The texture of colluvial deposits is directly related to the nature of the parent material. Photo interpretation indicates that colluvium, issued from reworking of glacial and post glacial sediments, is found at several locations along the proposed alignments. Colluvial materials are generally found along the mid to lower portions of slopes characterized by rapid or slow mass movements. The surface expression of these deposits is variable and directly related to the morphology of the underlying material as well as the type of mass movement process which has or is occurring (e.g. solifluction, creep, retrogressive thaw slump). Drainage of colluvial material is variable and directly related to the texture of its parent material. Many of the colluvial materials are linked to periglacial related processes characterized by the downslope movement of water-saturated material, therefore most colluvial material within the project area is imperfectly to poorly drained.

Recently deposited colluvial material are found along the steep, actively eroding slopes immediately east of KP 34 to 37, as well as along the side slopes of Trail Valley Creek (KP 40) and Hans Creek (KP 55). Several other colluvial deposits are found on moderately steep to steep slopes of till and glaciofluvial deposits. These deposits are generally thin and discontinuous. Additional information on colluvial material is provided in Section 3.5 Geoprocesses.

3.4.5 Fluvial (alluvial)

Fluvial materials consist of particles transported and deposited by modern streams and rivers (Howes and Kenk 1988). Most fluvial materials occur as fans, deltas and floodplains. Several of the fluvial deposits mapped throughout the project area consist of thin veneers and are found within undefined flow paths. These features are mostly located in the southern portion of the project where surface seepage is common (e.g. KP 21 to 28).

The texture of the fluvial material is variable within the project area and is related to the type of stream (e.g. rivers, creeks, undefined flow paths, etc.), the flow regimes and the sedimentary characteristics of the local terrain. Streams such as Hans Creek and Zed Creek are flowing through relatively large floodplains which are generally medium to coarse textured, while the small poorly defined, intermittent and ephemeral channels flowing over till are characterized by fine sand and silt.

3.4.6 Organic

Most of the organic accumulations mapped within the proposed highway corridor are peatlands. Organic accumulations occur mostly in thermokarst basins, drained lakes and in poorly drained seepage channels. Most of the deposits are characterized by patterned ground, with the most common pattern being high-center peat polygons (see Section 3.5.3 Ice Wedge Polygons). String fens have been identified in a few areas (e.g. KP 113 of Alternative 3) but these tend to be rare.

No recent site specific data was used as part of this assessment but a review of available data pertinent to the project area indicates that the thickness of the organic deposits usually ranges from less than a metre (<50 cm) to as much as two metres thick (Rampton 1988).

3.4.7 Eolian (loess)

Eolian deposits consist of materials transported and deposited by wind action (Howes and Kenk 1988). Most deposits are related to the reworking of fine grained outwash deposits and recently drained lake basins (Rampton 1988). The texture of the material is fine to very fine and consists of silt and very fine sand. The thickness and surface expression of eolian deposits can range from thin discontinuous veneers to undulating blankets several metres thick. Although no eolian deposits were mapped as part of this assessment due to a lack of site-specific data, extensive eolian deposits have been documented throughout the Tuktoyaktuk Coastlands (Fyles 1966, 1967; Mackay 1963; Rampton 1988).

3.5 GEOPROCESSES

Geological processes or geoprocesses are natural mechanisms of weathering, erosion and deposition that result in the modification of the surficial materials and landforms at the earth's surface (Howes and Kenk 1988). The terrain crossed by the project is characterized by several geoprocesses, many of which are directly related to the presence of continuous permafrost. Some of the geoprocesses are more active than others, and have potentially greater impacts on the construction of the proposed highway.

3.5.1 Thermokarst

Thermokarst terrain consists of an irregular topography resulting from the melting of excess ground ice and subsequent thaw-settlement (ACGR 1988). The term refers to both the process of "slump and fall of ground because of thawing of underground ice" as well as the resulting "karst like" topography (Dylik 1968). Recent studies on thermokarst in the Tuktoyaktuk Coastlands have been published by Murton (1993, 1996, 2001). Murton reports that many of the thermokarst sediments and sedimentary structures found in the area formed as a result of rapid climate warming during the last glacial-interglacial transition (i.e. 10,000 years before present). According to Rampton (1988), thermokarst activity was extremely intense between 10 and 9 thousand years (ka) before present. Although the major thermokarst landforms result from [relatively] old thermokarst activity, local thermokarst still occurs under present-day conditions (Murton 2001).

Thermokarst activity can result in the thawing of material that has uniform ice-content, the thawing of ice-rich sediment found within other sediments which have lower ice content, as well as the thawing of large bodies of massive ice (Rampton 1988). Material composed of peat and fine grained sediments such as silt and clay commonly have moderate to high ice content, while materials composed of coarse sand and gravel generally have low ice content, but can still contain massive ice. Massive ice is abundant throughout the Tuktoyaktuk Coastland and occurs in several forms such as pingo ice, ice-wedges, buried surface ice (e.g. glacier ice) as well as intrasedimental ice formed in place by freezing of groundwater.

The nature and magnitude of thermokarst is directly related to the nature of the material as well as the thermal stability of the upper part of the permafrost including the depth of the active layer and ground-ice content (Lantuit and Pollard 2008). Higher than average ice-content is common just below the base of the active layer. Disturbance of the ground surface (e.g. removal of vegetation) can lead to an increase in the active layer depth, resulting in thermokarst subsidence.

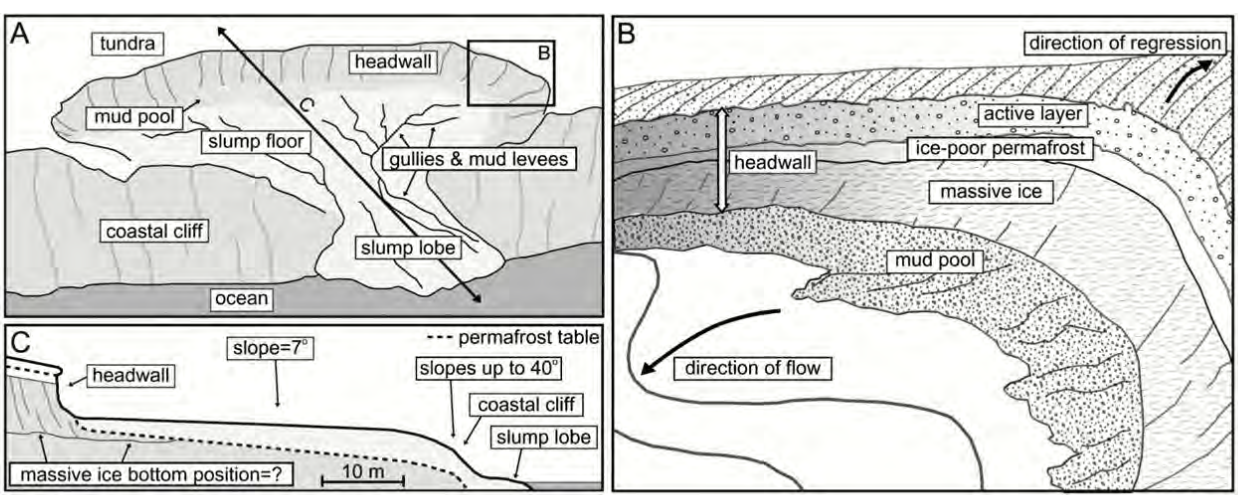
Resulting landforms include the development of irregular hummocky topography, thermokarst-lake basins and retrogressive thaw slumps. Thermokarst lake basins are present throughout the project, especially north of KP 50. These features are so extensive in the northern half of the alignment that it is not possible to avoid crossing some thermokarst basins.

3.5.2 Retrogressive thaw slumps

Mass movement, or mass wasting processes involve the downslope movement, due to gravity, of materials such as bedrock fragment, or snow and ice, often mixed with vegetation debris (Howes and Kenk 1988). Several different types of mass movement processes are present along the proposed highway corridor, the distinct one being retrogressive thaw slumps. This type of landslide, directly related to thermokarst activity, is typical of material characterized by ice-rich permafrost.

As mentioned above, retrogressive thaw slumps are directly related to thermokarst activity. The process involves the thermal erosion of ground ice which leads to successive failures and flow of water saturated sediments (Murton 2001). The following morphologic description is from Lantuit and Pollard (2008). Typical retrogressive thaw slumps consist of three main elements (Figure 3-2): (1) a vertical or sub-vertical headwall, (2) a headscarp whose angle varies between 20 and 50˚ and which retreats by the ablation of ice-rich material due to sensible heat fluxes and solar radiation, and (3) the slump floor, which consists of a fluid or mudflow and flow deposits that extend in a lobe pattern at the toe of the slump. Figure 3-1 from Lantuit and Pollard (2008) provides a conceptual representation of a retrogressive thaw slump.

Figure 3-1 Conceptual diagram of a retrogressive thaw slump (Lantuit and Pollard 2008)



The vast majority of the retrogressive thaw slumps found within the project area are located along the shoreline of small lakes, many of which are of thermokarst origin (photos A-1 and A-2). The parent material in which they form is mostly fine grained till and lacustrine materials. The slumps vary widely in form and size, but on average are 75 to 150 m wide. Many of the slump units are composed of the coalescence of smaller slides. The presence of vegetation on some of the slumps indicates that they are [somewhat] stable; however the reactivation of older slump units was observed (by air photo-interpretation) at several locations.

3.5.3 Ice-wedge polygons

Ice wedge polygons are a type of patterned ground that is found primarily in low-lying, moderate to poorly-drained areas. They are the result of thermal contraction and cracking of the ground surface which then forms a random or oriented polygonal pattern (ACGR 1988). The cracks that result from the thermal cracking fill with seepage water that comes primarily from the melting of snow and the water refreezes during winter as ice veins. As frost cracking reoccurs in pre-existing cracks, the accretion of ice veins with time builds up ice wedges (Fortier and Allard 2004). The volume of ice contained in tundra polygons is extensive and probably represents the most widespread and abundant form or ground ice (Washburn 1979; Harry and Gotzik 1988; Kasper and Allard 2001). Ice-wedge polygons occur in both mineral terrain and peatlands. They can be classified as low-centered and high-centered (Figure 3-2 as well as photo A-3 and A-4 of Appendix A); the contrast between the two types may be partially due to the age of the features as well as the local hydrology (Rampton 1988). Over time, low-centered polygons can evolve into high-centered polygons.

Figure 3-2 Low-centered polygons and high-centered polygons (photos from Geological Survey of Canada)

Polygons found along the alignment range considerably in size but are typically 15 to 30 m in width. They are found extensively throughout the project, but especially in low-lying areas such as peatlands, drained lake bottoms and former meltwater channels. Both proposed alignments cross several large polygonal peatlands characterized by poor drainage.

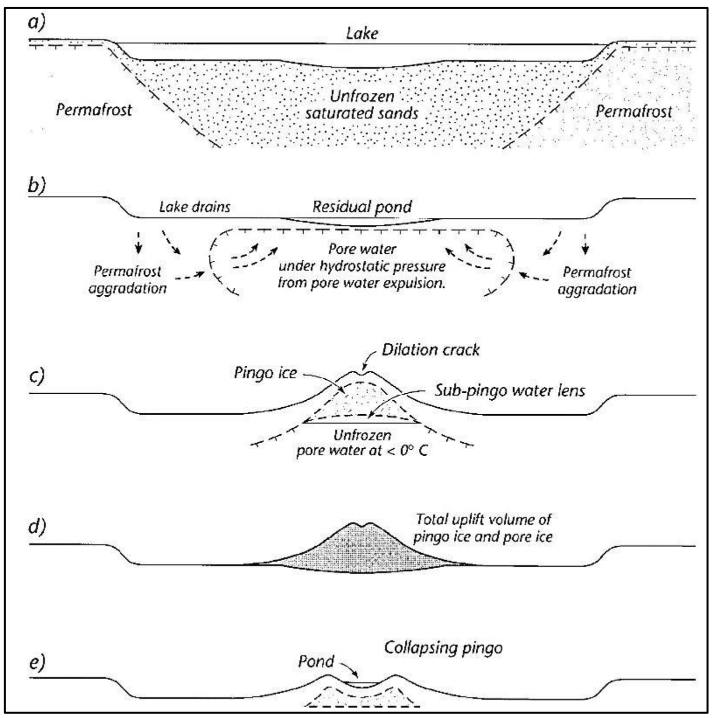
Recent degradation of some ice wedge polygons has been identified during the air photo interpretation exercise (e.g. KP 54.5, KP 83). The degradation process is generally due to thermo-erosion of the ground ice by the melting-acting of flowing water, which can further lead to rapid lake drainage (Fortier et al. 2007; Mackay 1974, 1981a, 1988a). The melting leads to the development of a gully system (or trenches) which can drastically rearrange the local topography and drainage pattern (Fortier et al. 2007).

3.5.4 Pingos

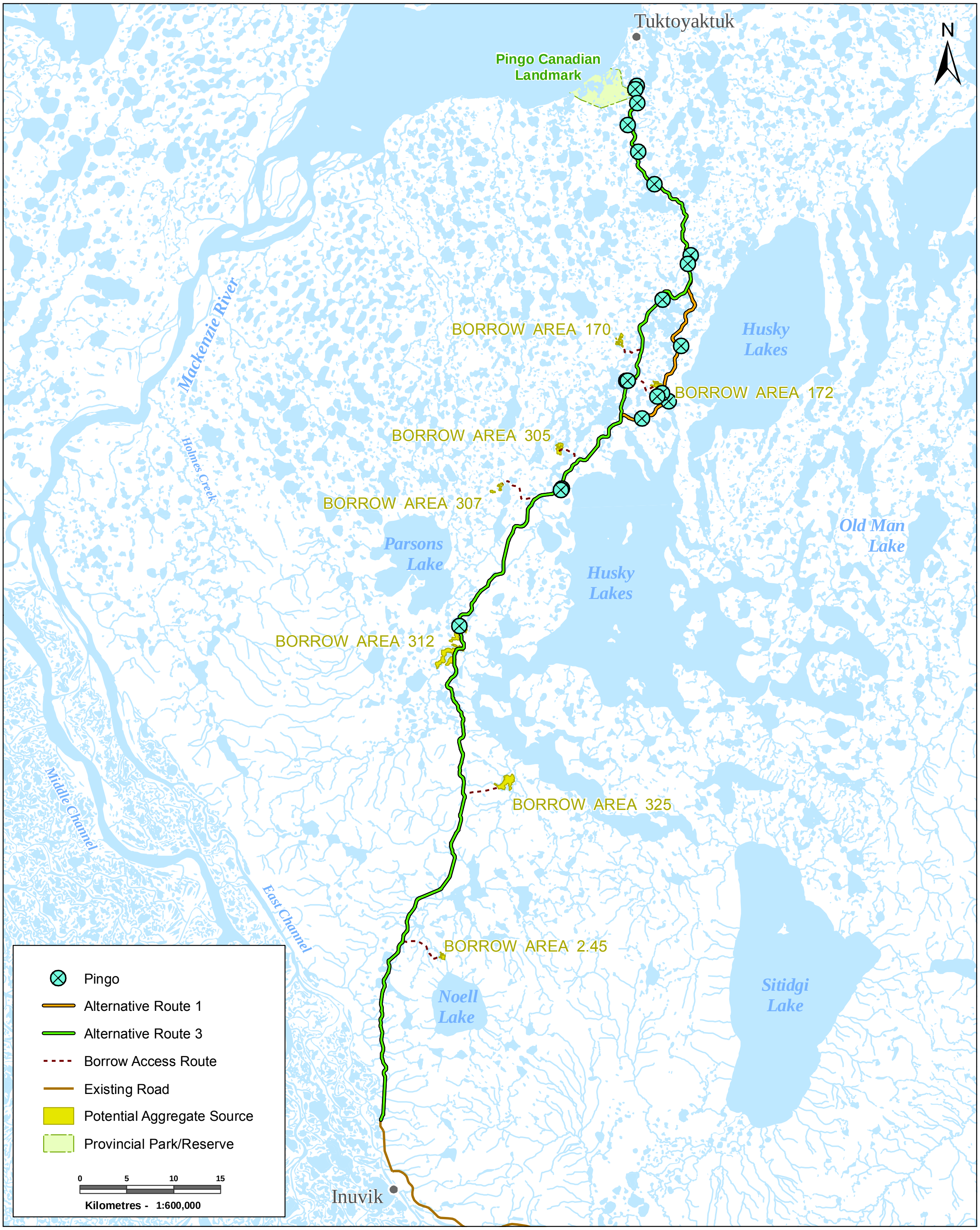
Pingos are intra-permafrost ice-core hills, typically conical in shape, that grow and persist only in a permafrost environment (Mackay 1998). Over the last few decades, J.R. Mackay has studied and continuously monitored a series of pingos along the Tuktoyaktuk Peninsula, resulting in the publication of numerous papers (1962, 1966, 1973, 1977, 1978, 1979, 1981b, 1983, 1985a, 1985b, 1986, 1987, 1988b, 1988c, 1990). The information provided below comes from literature published by Mackay.

The Tuktoyaktuk Peninsula contains the greatest concentration of pingos in the world, with approximately 1,350 pingos. Most of the pingos have grown in the bottom of drained lakes underlain by sands. Numerous theories have been proposed for the origin and growth of pingos, with the accepted theory being related to the combined effect of hydraulic pressure and freezing action in a closed system. Two basic types of pingos are found in permafrost areas of the world: hydraulic (open) system pingos and hydrostatic (closed) system pingos. Field evidence shows that nearly 100% of the pingos found along the Tuktoyaktuk Coastlands are hydrostatic (closed) system pingos. Their formation results from pore water expulsion caused by permafrost aggradation beneath the bottom of drained lakes that are underlain by saturated sands (Figure 3-3).

Figure 3-3 Conceptual diagram of the growth and collapse of a pingo (Mackay 2008)



A total of 16 pingos have been identified within the 1 km wide corridor of Alternative 1 and 13 pingos within the corridor of Alternative 3 (see Figure 3-4 as well as Photo A-17 and A-18). The pingos vary in size and shape. Some have the typical, well developed, conical shape while others are more subdued and have irregular shapes. A maximum pingo height of 14 m was measured using provincial DEM data. The minimum distance between the current proposed alignment and the edge of a pingo is approximately 100 m (KP 59).



Inuvik – Tuktoyaktuk Highway, Baseline Data Acquisition Program

Pingos Located in the 1 km Highway Corridor

Base Data provided by Government of the Northwest Territories; Surficial Data: Stantec

PREPARED BY

KAVIK-STANTEC

PREPARED FOR

Northwest Territories Transportation

FIGURE NO.

3-4

3.5.5 Solifluction

Solifluction (or gelifluction) consists of a slow downslope movement of water-saturated surface sediments caused by seasonal freeze and thaw. The movement of soil particles results from the frost heaving of the ground and the subsequent settlement upon thawing (Washburn 1979). It is considered as one of the most widespread processes of soil movement in periglacial environments (French 2007). Rates of flow vary widely from millimetres to a few centimetres a year (Ritter et al. 2002). Typical resulting landforms include aprons, sheets and lobes (e.g. KP 39; KP 71).

3.5.6 Frost Heave

Frost heave consists of upward (or outward) movement of the ground surface caused by the formation of ice in the soil (ACGR 1988). The process is a function of the movement and freezing of pore water contained in the unfrozen sediments found below the aggrading permafrost table (Mackay 1979; Rampton 1988). Significant heave of the ground surface can occur in areas characterized by recent lake drainage (subaerial exposure of taliks; Rampton 1988). Frost heave can also occur in areas characterized by poor drainage and excessive surface water seepage, as the expansion caused by the freezing of the water-saturated soil leads to heaving of the ground surface.

3.5.7 Debris slide

Debris slide refers to a rapid downslope movement of loose surface material (Howes and Kenk 1988). This type of mass movement process is controlled by gravity and it is often triggered by factors such as heavy rainfall.

Although rare due to the relatively flat topography, an area characterized by several debris slides is located along the steep, bedrock controlled, colluvial slopes a few hundred metres east of the proposed highway alignment between KP 34 to 37 (see the terrain map atlas). A few other small debris slides were identified along some exposed riverbanks, along the short steep slopes bordering glaciofluvial terraces (e.g. at borrow source 325) and glaciofluvial hummocks. The short steep banks of creeks such as Trail Valley Creek (KP 40) are also at risk of small debris slides during or following a sudden increase in water discharge, where river undercutting can trigger some slides.

3.5.8 Flooding

Flooding risks are present along most streams floodplains, fluvial fans, small creeks, poorly defined flow paths and low-lying areas surrounding lake basins. Flooding is generally caused by unusually high precipitation, spring snowmelt runoff or ice jam during spring break up.

Some areas along the coast, such as Kittigazuit Bay near Tuktoyaktuk, are periodically flooded during the annual high tides. The presence of driftwood above the present shoreline position is a very good indicator of past flood events. Other areas near the shoreline, such as the bottoms of drained thermokarst lakes, can be flooded during storm tides (Rampton 1988).

3.5.9 Stream erosion

Natural riverbank erosion occurs on a few streams crossed by the proposed highway alignments. Factors controlling fluvial erosion can be complex and include elements such as local climatic conditions, stream run-off, the nature of the surface materials as well as the vegetation type and extent. The riverbank erosion process can be divided in two main types: bank scours and mass failures. Bank scours occur as a progressive removal of bank material by flowing water, while mass failure corresponds to the collapsing and toppling of relatively large sections of the riverbank into the river. Both erosion processes contribute to channel migration.

3.5.10 Gullying

Gullies are relatively uncommon along the proposed highway corridor. The incision of some of the larger gullies (e.g. the gullies found along the edge of the East Channel Mackenzie River) probably originated during the late Pleistocene uplift, while smaller and more recent gullies result from water erosion and degradation of ice wedge polygons by the melting action of surface water. Although uncommon, gullies are found in a range of materials and landforms, from till blankets and veneers to glaciofluvial, glaciolacustrine and colluvial material. Small mass movement processes such as debris slides are common within gullies.

3.5.11 Surface Seepage

Accelerated groundwater seepage and slope wash processes have been identified on several slopes throughout the study area. These processes occur on various types of surface materials, but tend to be mostly active on gentle to moderately steep slopes characterized by till and colluvial blankets. Seepage processes are more intense during spring melt and following storms or heavy rainfalls. In many cases, the seepage process is accentuated by the presence of permafrost which causes the surface water to flow over the surface of the impermeable permafrost table. Fine grained sediment is gradually transported downslope. A series of directional arrows have been placed along the mapping corridor in an effort to characterize the movements of surface water (see the terrain map atlas).

3.5.12 Human Disturbance

Human disturbance to the tundra and forest tundra environment, in the form of old seismic lines, winter trails and drilling sumps, are visible on aerial photographs and have been identified along the study area. A feature believed to be an old sump is located at the very edge of the mapping corridor at KP 69. Airphoto interpretation shows that the area appears to be stable (i.e. well drained area, no active geoprocess).

3.6 SUMMARY OF TERRAIN CONDITIONS

The following sections provide a summary and description of the surficial geology, landforms and terrain constraints found along the proposed alignments, borrow sources and access roads. The statistics presented below were generated from terrain mapping at scales ranging from 1:2,500 to 1:7,500.

3.6.1 Surficial Geology along the Proposed Highway Alignments

Terrain conditions have been evaluated using aerial photographs from 2004 and 2005 along two proposed highway alignments (Alternative 1 and Alternative 3). Alternative 1 and Alternative 3 share the same route for the first 91 km (from

Inuvik) and the last 26 km towards Tuktoyaktuk. Table 3-1 provides a summary of the surficial geology crossed by both alignments (values are rounded).

Table 3-1 Surficial Geology along the Proposed Highway Alternatives

Parent Material Type	Alternate 1		Alternate 3	
	Length (km)	% of Route	Length (km)	% of Route
Till	87.8	64.2	91.2	67.2
Glaciofluvial	6.1	4.5	5.2	3.9
Lacustrine	14.4	10.5	8.5	6.3
Fluvial	7.2	5.3	7.3	5.4
Colluvial	4.4	3.2	4.7	3.5
Organic	17.0	12.3	18.6	13.7
Total	136.9	100	135.6	100

Alternative 1 is 136.9 km in length, while alternative 3 is slightly shorter at 135.6 km. The dominant surface material consists of till for both alignments, for a total of 64.2% of Alternative 1 and 67.2 % of Alternative 3. Rampton (1988) describes the till as a stony clayey diamicton, generally composed of 10 to 30% sand, 25 to 45% silt, and 30 to 50% clay. Clast content is generally low and ranges from 3 to 25%. The surface expression of the till deposits is generally undulating, with slope inferior to 10%. Minor areas of hummocky till deposits are found in the northern portion of the study area near KP 120 to 130. It appears from the airphoto interpretation that some of the hummocky till within the northern portion of the corridor (e.g. KP 127 of Alternative 3) share morphologic similarities with well documented ice-cored hill referred as “Involuted Hill” (Dallimore et al. 1996), which would involve the presence of massive bodies of ice within the till material.

Organic accumulations are present along 12.3% or 17.0 km of Alternative 1, and 13.7 % or 18.6 km of Alternative 3. Although frequently not mapped on medium to small scale maps, the quality of the aerial photographs and the precision of the mapping technology (i.e. HD-MAPP) allowed delineation of areas characterized by thick (>50cm) organic matter. Significant organic accumulation occur in thermokarst-related depressions, fully to partially drained lakes basins, poorly drained seepage channels as well as localized topographic depressions. The locations of the organic deposits are closely related to the presence of ice-rich features such as ice-wedge polygons.

Lacustrine material is found along 10.5% of Alternative 1, versus only 6.3% of Alternative 3. This material includes both recent deposits as well as sediment deposited during high water phase of Husky Lakes (i.e. KP 90 to 115 of Alternative 1). The lacustrine deposits consist of variable amount of clay, silt, and fines sand, which proportions are closely related to the texture of the surrounding terrain (Rampton 1988).

Approximately 5% of fluvial materials were mapped along the two proposed alternatives. The material is found along the various rivers and creek crossed by the alignment but as well within seepage channels, undefined flow path and other low-lying area characterized by higher-than-normal surface run-off.

Glaciofluvial deposits are relatively rare and comprise 3.9 to 4.5% of the ground surface over which the two routes pass. The glaciofluvial material corresponds to undulating outwash deposits as well as hummocky ice contact deposits. A review of available literature, historic borehole and shothole data suggest that the texture of the undulating outwash deposits is highly variable and composed of more fine materials than the hummocky ice contact. It appears that the route traverses considerably less glaciofluvial material than suggested by Rampton's surficial geology map of the Tuktoyaktuk Coastlands (1988); this is attributed to significant differences in mapping scale (i.e. 1:500,000 scale versus 1:10,000).

The amount of colluvial material is relatively low (3.2% of Alternative 1 and 3.5% of Alternative 3) in relation with the generally flat terrain that characterize the area. A larger proportion of colluvial material is found along Alternative 3 in relation with the short steep slopes found at the edge of the till deposits between KP 98 to 101.

3.6.2 Special Terrain Types

As stated earlier, the mapping of the terrain features along the study area ranged from scale varying from 1:2,500 to 1:7,500. A total of 2,095 terrain polygons were mapped, for an average polygon size of 9 ha. Polygons were delineated on the base of surface material, surface expression, material drainage and the presence of geoprocesses. A total of 556 water bodies have been delineated throughout the 1 km corridor, which encompasses the route alternatives, access roads, and borrow areas. Water bodies include any lakes and ponds, as well as flooded areas of wetlands large enough to be delineated. The vast majority of the lakes appear to be of thermokarst origin. The proposed alignments are located at very close proximity to a series of water bodies and specific locations are provided in Table 3-2.

Special attention was given to identify areas characterized by ice-wedge polygons. Although developing in all sorts of surface material, including generally well drained glaciofluvial deposits, the majority of the ice wedge polygons have developed in low-lying area and depressional terrain. The portion of each alternative route characterized by ice-wedge polygons is 17.4 km for Alternative 1 (12.7 %) and 19 km for Alternative 3 (14%). The higher proportion of ice-wedge polygons along Alternative 3 is due to the crossing of an extensive area of ice-wedge polygon between KP 104 and 108. These areas of ice-wedge polygons only represent a minimum value as considerably more are suspected to be present although are not visible on the aerial photographs. For example, fluvial or colluvial sedimentation is occurring on some low-lying areas characterized by polygons, potentially hiding the polygonal pattern of ice-wedges.

In addition to the presence of ice-wedge polygons, several other features indicate the presence of ice-rich material along both proposed alignments. A total of 30 active retrogressive thaw slumps have been identified within the 1 km wide corridor containing both alignments. The slumps vary considerably in shape and size and not all display the typical shape presented in figure 3-1; however, airphoto interpretation indicates that all of the identified areas are showing signs of recent activity. It is important to mention that none of the slumps intersect the proposed alignments (as displayed on the 2004-2005 imagery) but several are located at close proximity (see Table 3-2). In addition, several stabilized or inactive (e.g. vegetated) slumps have been identified throughout the area. The presence of retrogressive thaw slumps or active layer failures in a specific terrain unit should be interpreted as a strong indicator of ice-rich deposit.

Massive ice in the form of pingo was located at 18 different locations within the 1 km wide mapping corridor for both route alternatives. The minimum distance between the edge of a pingo and the proposed alignment is of 100 m (KP 59).

Table 3-2 summarizes the major terrain constraints and sensitive areas found along both proposed alignments based on airphoto interpretation and very limited field investigations (refer to the map atlas (Appendix B) and full GIS dataset for the complete data). Note that several of these areas can be avoided by applying minor modification to the geometry of the highway centerline within the 1km corridor. Where possible, a series of short re-routes are proposed in order to locate the highway in more suitable terrain. Sensitive areas characterized by ice-wedge polygons are extensive and are excluded from the list; refer to the map atlas for a detailed location of ice-wedge polygons throughout the mapping corridor.

Table 3-2 Summary of terrain constraints and sensitive areas found along the proposed alignments.

Alternate 1 and Alternate 3 (KP 0 to KP 90)	
Location (KP)	**Comments**
2 to 6	Visible surface seepage in a series of undefined flow paths. Will require proper management of surface water along the upper side slope
4	Slumping along the shoreline of a thermokarst lake (approximately 400 m west of the alignment)
11	Recent lake drainage on the east side of the alignment; slumping along the creek exiting the lake (250 m downstream from the creek crossing)
15 to 15.5	Alignment running along a narrow ridge separating two lakes; route geometry could be improved
16	Recently drained lake basin; active thermokarst
16.5	Geometry could be improved to stay away from small creek
17 to 17.3	Low lying, very poorly drained area; presence of ice wedge polygons and signs of recent thermokarst activity
18.1	Alignment sitting less than 30 m from a receding shoreline affected by thermokarst and slumping
19 to 19.3	Geometry could be improved to stay away from small creek
19 to 21	Signs of solifluction on several mid to lower slopes in the area
21 to 25	Alignment crosses a series of seven (7) undefined flow paths characterized by seepage, ice wedge polygons and organic accumulations
31 to 32.5	Alignment runs along a side slope characterized by extensive seepage
35 to 36	Alignment is located approximately 100 m west of a steep escarpment characterized by several gullies and active mass movement
39	Active mass movement in the area; several solifluction lobes in till material approximately 400 m west of the alignment
39.8	Alignment crosses a small colluvial fan; potential debris flow following spring melt or heavy rainfall
40.4 to 41	Alignment crosses a 15 to 25% side slope characterized by creep and solifluction
44	Geometry could be improved to stay further away from a moderately steep slope
47.2 to 47.6	Geometry could be improved as the alignment crosses a depression (thermokarst) which has side slopes characterized by creep and solifluction
48.6	Geometry could be improved to stay further away from the short steep slopes of a recently drained lake
48.8 to 49.4	Poorly drained area; recently drained lake 70 m east; presence of ice wedge polygons and signs of recent thermokarst activity

49.8	Poorly drained area; recently drained lake 65 m west of the alignment; presence of ice wedge polygons; possible pingo adjacent to the alignment
50.2 to 50.6	Several small retrogressive thaw slumps; the alignment runs along the headscarp of an old slide and is 80 m upslope from an active slide to the east
51.4	Alignment runs along the edge of a steep slope characterized by active mass movement; geometry could be improved to stay away from the slope
53.6 to 54.1	Area characterized by a recently (and partially) drained lake as well as an extensive polygonal peatland; possible re-route to the west of the lake
55.4	Alignment crosses a polygonal peat plateau that is characterized by recent thermokarst of ice-wedge polygons due to rapid drainage of a lake
56	Alignment crosses an active colluvial fan (located at the edge of Hans Creek floodplain) characterized by a recent debris flow; the fan is located on top of a fluvial terrace; Hans Creek crossing could be relocated
57	Alignment crosses a 170 m thermokarst depression characterized by seepage and ice wedge polygons
58.5	Alignment located only a few metres (<10 m) from the headscarp of a stabilized retrogressive thaw slump
59.2	Alignment located 100 m from the edge of a small pingo
60.6 to 62	Alignment crosses a low-lying are modified by thermokarst; presence of ice wedge polygons
62.6 to 64	Alignment crosses the headscarp of four (4) stabilized retrogressive thaw slumps; geometry could be improved to avoid the slumps
67	Alignment crosses a polygonal peat plateau that is characterized by recent thermokarst of ice-wedge polygons
68.5 to 72	Area characterized by extensive surface seepage, creep and solifluction
76	Alignment located along a narrow ridge (approx. 120 m wide) separating 2 lakes; there is a 10 m elevation change between the two lakes; possibility of rapid lake drainage if thermokarst occurs along the ridge
78.8	Alignment is located on top of a narrow ridge (80 m wide) separating a lake (upslope from the alignment) and a moderately steep downslope
81 to 81.5	Complex area characterized by poorly drained thermokarst lake basin and recently drained lake; with a recent retrogressive thaw slump (200m west from the alignment); possibility for catastrophic lake drainage at KP 81; field assessment is strongly recommended
81.8 to 82	Alignment crosses 2 solifluction lobes
82.2 to 82.8	Alignments crosses a thermokarst lake basin and a polygonal peatland
83 to 83.7	Alignment crosses a complex area characterized by thermokarst lake basins and ice wedge polygon networks; the area is characterized by recent thermokarst of massive ice (possibly a collapsed pingo) and ice wedge polygons

84 to 85	Alignment crosses two (2) fluvial fans formed from the recent drainage of two small lakes; potential for high seepage
87	Alignment crosses a narrow section (125 m wide) between two (2) lakes; signs of surface seepage
88.3	Alignment crosses the flow path of an old stabilized slump
89 to 89.2	Alignment crosses a very narrow section (50 m wide) between two lakes; the area is very poorly drained organic and lacustrine deposits and is characterized by the presence of ice-wedge polygons; possible thermokarst of some ice-wedge polygons
88.8 to 90.5	Alignment crosses a large polygonal peatland characterized by recent thermokarst of ice-wedge polygons due to rapid drainage of a lake
Route Alternative 1	
91.3 to 92.1	Alignment is located less than 60 m away from the edge of a thermokarst lake characterized by retrogressive thaw slumps; geometry could be improved
93 to 96	Ice-rich deposits; several retrogressive thaw slumps (slumps located 75 to 250 m away from the alignment)
97.3	Alignment is located at edge of a thermokarst pond characterized by ice wedge polygons, approximately 120 m from the edge of a small pingo
97.7 to 98	Alignment is located less than 20 m from the edge of a thermokarst lake; geometry could be improved
98.4	Alignment is located less than 10 m from the edge of a thermokarst lake; geometry could be improved
100.3 to 101.2	Alignment is located less than 60 m in average (and as close as 20 m) from the edge of a thermokarst lake; geometry could be improved
105.2 to 105.4	Alignment is located less than 20 m from the edge of a thermokarst lake; geometry could be improved
106.4	Alignment is located less than 30 m from the edge of a thermokarst lake; geometry could be improved
107.3	Alignment is located less than 40 m from the edge of a thermokarst lake; geometry could be improved
107.7 to 108	Alignment is located less than 40 m from the edge of a thermokarst lake; geometry could be improved
108.8	Alignment passes a narrow (60 m wide) low lying area separating two lakes; small creek crossing; ice-wedge polygons and signs of recent thermokarst
Route Alternative 3	
93.2 to 93.4	Vast low lying area characterized by polygonal peatlands and poor to very poor drainage
95.3	Alignment located on top of a narrow ridge characterized by retrogressive thaw slumps (approximately 20 m from the alignment)
96.2 to 96.7	Alignment crosses a poorly drained thermokarst lake basin characterized by ice wedge polygons
97	Alignment passes close (20 m) to the headwalls of two (2) successive thermokarst depressions
98.4	Alignment follows the edge of a recently drained lake basin (less than 40 m from the water); geometry could be improved
102.2	Alignment passes 65 m from the edge of a thermokarst lake; geometry could be improved

103	Alignment passes 40 m from the edge of two thermokarst lakes; area is characterized by ice-wedge polygons; geometry could be improved
103.7	Alignment passes 35 m from the edge of two thermokarst lakes; area is characterized by ice-wedge polygons; geometry could be improved
104 to 108	Centerline crosses an extensive thermokarst lake basin characterized by ice-wedge polygons
107 to 108	Complex area characterized by several thermokarst lakes, organic accumulation and ice-wedge polygons; alignment is located less than 30 m from the edge of a recently drained area; stream crossing at KP 108
	The route alternatives join at KP 109.5
110.5	Alignment passes at the edge of a recently drained lake; geometry could be improved
111.5	Alignment follows the edge of a flooded wetland characterized by thermokarst; geometry could be improved
112.5 to 113	The alignment crosses a very poorly drained string fen; presence of a pingo approximately 350 m east from the alignment; a re-route could be considered to avoid the fen
114	Alignment passes 30 m from the edge of a thermokarst lake; geometry could be improved
114.1	Alignment passes along the edge of a moderately steep slope characterized by mass movements (debris slide and active layer failures); geometry could be improved
114.5 to 115.5	Alignment passes a complex area characterized by small thermokarst topography, small lakes and moderately steep slopes with susceptible to mass movements; a small re-route could be considered
116 to 117	Alignment runs along the edge of a steep slope (10 to 20 m away) characterized by active mass movements (small debris slides)
119 to 119.7	Alignment runs along the edge of a steep slope (35 to 50 m away) characterized by active mass movements (small debris slides)
123	Alignment passes along the edge of a recently drained lake characterized by ice-wedge polygons and a pingo (200 m away); area is very poorly drained and shows signs of thermokarst; geometry could be improved
123.6	Alignment passes a narrow (60 m wide) low lying area separating two lakes; small creek crossing; signs of recent thermokarst
124.1	Alignment passes 40 m above the headwall of a stabilized retrogressive thaw slump; geometry could be improved
131.6	Retrogressive thaw slump 35 m west of the alignment

Table 3-3 summarizes the susceptibility of various surface materials to thermokarst, frost heave and mass wasting (modified from Rampton 1988). Notes on surface drainage are also provided.

Table 3-3 Susceptibility of the various surficial materials found along the alignments to thermokarst, frost heave and mass wasting (Modified from Rampton 1988)

Surface material	Thermokarst and frost heave	Mass wasting	Drainage
Undulating (rolling) and hummocky till	Moderate to major[1] subsidence possible under most hills and ridges, especially in the areas already characterized by thermokarst topography and in the areas underlain by massive ice; significant frost heave upon freezing of the poorly drained areas	Susceptible to both slow and rapid mass movements; solifluction, creep and active layer detachments occur on some slopes; retrogressive thaw slumps occur in areas underlain by massive ice	Generally moderately well to well drained, however several areas are characterized by intense surface seepage; a series of undefined flow paths cross the alignments at several locations
Undulating outwash deposits	Major subsidence possible along the shore of Husky Lakes where massive ice underlies the outwash deposits	Retrogressive thaw slumps possible in areas underlain by massive ice	Moderate to well drained; possibility of water ponding in localized depressions
Hummocky glaciofluvial deposits	Low to moderate subsidence possible under most hills and ridges; especially in the areas already characterized by thermokarst topography and in the areas underlain by massive ice	No retrogressive thaw slumps were identified within the hummocky glaciofluvial deposits and borrow areas; small active layer detachments and debris slides were identified along some of the steep slopes	Material is generally well to rapidly drained, with the exception of the depressions and low lying areas located between the hills
Lacustrine	Moderate to major subsidence possible especially in the areas already characterized by thermokarst topography and in the areas underlain by massive ice (e.g. Husky Lakes area); moderate subsidence in Holocene lake basins; significant to major frost heave upon freezing of recently drained lake basins	Several retrogressive thaw slumps identified in the ice-rich lacustrine deposits near Husky Lakes (especially along Alternate 1); reactivation of older slumps can be expected	Imperfect to poorly drained due to the texture of the material and topographic position of the deposits, poor drainage in recently drained area

Fluvial plains and fans, including thin fluvial deposits found along undefined flow paths	Variable subsidence and thermokarst in relation to the ice content and texture of the fluvial sediments; significant frost heave upon freezing	Excessive ground seepage on moderate slopes can lead to solifluction and active layer detachments	Moderate to well drained along the major floodplains; imperfect to poorly drained along the small creeks and flow path; possibility of flooding following snow melt and heavy rainfall
Colluvial	Moderate to major thermokarst possible at the bottom of some slopes if the material is thick	Significant solifluction and creep in some specific areas; reactivation of older slumps to be expected, gullying and small debris slides present along steep bedrock controlled slopes (e.g. KP 34 to 37)	Generally moderately well to well drained due to topographic position, however drainage may be poorer on lower slope areas and where seepage is found
Organic deposits	Major thermokarst and thaw subsidence possible in areas characterized by ice wedge polygons	Very low susceptibility due to the topographic position	Generally very poorly drained; excessive surface runoff following snow melt, storms, or lake drainage can lead to the melting of ice-wedges

[1] Example of major subsidence could be the melting of ice-rich permafrost in the first metre below the active layer as the amount of thaw settlement would be directly related to the ice content of the material.

3.6.3 Borrow Sources and Access Roads

Although a total of ten (10) potential borrow sources were initially identified and delineated along the corridor, only seven (7) of the potential borrow sources are being delineated and sampled for suitability at this time; these are listed in Table 3-4. Three (3) of the seven (7) borrow sources are found on 7(1),(b) Private Lands near Tuktoyaktuk, three (3) borrow sources occur on Crown lands, and one (1) straddles both Private and Crown lands. No investigations are being conducted within 1,000 m of Husky Lakes.

Table 3-4 provides the locations of each of the seven (7) borrow sources as well as the length of the proposed access roads. Each potential borrow source is discussed below.

Table 3-4 Location of Borrow Sources and length of Proposed Access Roads

Borrow Source Site	Corresponding Highway KP	Access Road Length (km)	UTM Coordinates (centroid)
2.45	20	5.0	556917 / 7607670
325	40	3.8	563654 / 7626160
312	55 - 60	-	559881 / 7639562
307	77	4.9	562715 / 7657406
305	83	2.7	569176 / 7661957
172	95 (Alternate1) 98 (Alternate 3)	2.8	579803 / 7668488
170	100	2.5	575769 / 7673248

3.6.3.1 Borrow Source 2.45

Borrow source 2.45 is the most southerly of the seven (7) borrow sources being investigated. It occurs 1.5 km north of Noell Lake near KP 20 and some 4.5 km east of the proposed alignment. The proposed access route is approximately is 5 km in length.

No shothole data exists for this particular borrow source area; however, the site was quickly visited on September 18, 2011, and limited borehole data exists for the general area (PWC 1981). Rampton (1988) has mapped the area as being comprised of hummocky and rolling moraine, generally 4 to 10 m thick. Analysis of the aerial photographs indicates the presence of localized glaciofluvial outwash deposits located on either side of the creek exiting Noell Lake. Drainage at the site ranges from well to moderate, with the exception of a low-lying area at the center of the proposed borrow source which is characterized by a veneer (to a blanket) of fluvial material (photo A-5 to A-7). A small exposure along a creek that crosses the borrow area indicates the presence of coarse-grained material (photo A-8).

Erosion potential at borrow source 2.45 is considered as moderate due to the presence of a creek at proximity to the potential borrow source. A series of gullies are located on either side of the creek in the area separating the proposed borrow source and Noell lake. A small but recent active layer detachment was observed during the brief site reconnaissance on the east bank of the creek, some 800 m upstream from the borrow area (Photo A-9). Another larger slump was identified on the east side of the bank, a few hundred metre from the proposed borrow area (Photo A-10).

3.6.3.2 Borrow Source 325

Borrow source 325 occurs approximately 1.6 km from the shoreline of Husky Lakes near KP 40. It occurs some 3 - 4 km east of the proposed alignment. The proposed access route is approximately is 3.8 km in length.

No shothole data exists for this particular borrow source area. The site was quickly visited on September 18, 2011; no borehole data exists for this area. Rampton (1988) has mapped the area as being comprised of outwash materials: “plains and valley trains; generally 3 to 20 m thick; includes Portage Point Sands in Husky Lakes and Kugaluk River Outwash.”

Analysis of the aerial photographs indicates the presence of several large glaciofluvial terraces. The area selected for the proposed borrow source consist of a single terrace, approximately 2 km long by 1 km wide (Photo A-11 and A-12). The surface of the proposed borrow source is flat and sits approximately 40 m above the current Husky Lakes water level. Trail Valley Creek marks the northern limit of the terrace while another unnamed creek marks the eastern edge. Sandy to gravelly glaciofluvial material was observed along the escarpment marking the edge of one of the terraces (photo A-13)

The erosion potential at borrow source 325 is considered as low to moderate in relation with the creeks located on either side of the terrace. The edges of the terrace are steep and slopes up to 70% have been observed in the field. Small mass movement processes take place along the edge of the terrace and for are mostly related to fluvial erosion undercutting the edges of the terrace (Photo A-14).

3.6.3.3 Borrow Source 312

Borrow source 312 is found at KP 55 – 60, immediately southeast of Parsons Lake and extends approximately 3 km to the east to the shoreline of Husky Lakes. The proposed access road passes through the middle of this borrow source. Approximately 480 shotholes are found in this area and mapping by Rampton (1988) suggests a highly variable origin, with materials ranging from ice contact, to glaciofluvial outwash to alluvium. Medium to coarse textured till might also be present within the area.

The shothole data indicates the presence of highly variable material, ranging from pure “gravel”, “gravel sand”, “sand gravel”, “clay, gravel, ice”, “sandy clay, shale, mud” to “clay, rocks”. This heterogeneity of the materials supports the mapping completed by Rampton (1987). The shothole data suggests that gravel sand deposits range from 6 to 27 m with an apparent average of 18 m.

The drainage over most of the area is considered as good. The erosion potential at borrow source 325 is considered as moderate in relation with the presence of Hans Creek. Active mass movements were identified on the southern shore of the creek during the airphoto interpretation. Thermokarst of ice-wedge polygons takes place along the edge of a proposed borrow deposit a few hundred metres from KP 56. The melting of the ice-wedges appears to be related to the rapid drainage of a lake and has created a series of deep gullies.

3.6.3.4 Borrow Source 307

Borrow source 307 is found northeast of Parsons Lake and is some 2.6 to 3.5 km west of the proposed route at KP 77. The proposed access road is 4.9 km in length.

Rampton (1988) has mapped the area as consisting of ice contact deposits. The proposed borrow source consist of several hills (kame deposits) averaging a few hundred square metres in size. The area contains several small ponds and is surrounded by a series of larger lakes. Low lying areas between the aggregate deposits are displaying polygonal pattern typical of ice-rich soils. Airphoto interpretation and a review of previous aggregate investigation in the area (PWC 1981) indicate the presence of massive ice. Data from 230 shotholes suggest textures ranging from “gravel”, “sand”, to “sand, clay gravel” and “rocks gravel”. The gravel deposits in this area range from 9 to 36 m in thickness with majority in the 18 m thickness range.

The erosion potential at borrow source 307 is considered as low to moderate. No rivers or creeks cross the proposed borrow sources although the proposed access roads crosses a small stream a few hundred metres before accessing the borrow area. Minor mass movement processes can be expected along some of the short steep slopes (up to 45% grade) that characterize the edge of some hills.

3.6.3.5 Borrow Source 305

Borrow source 305 is found 2.4 km west of the proposed alignment near KP 83. The proposed access route is approximately 2.7 km in length. The area is located in an outwash plain and the surface topography ranges from hummocky to undulating. Several lakes and small ponds are located throughout the area. The drainage is generally good with the exception of the low-lying channels that intersect the potential aggregate deposits.

Rampton (1988) has mapped the area as consisting of ice contact deposits. Records from 98 shotholes suggest that the materials vary from “sand gravel” to “clay rock” and “clay” and that the gravel and sand deposits range from 6 to 37 m in thickness. The shothole data indicates a high degree of variability in thickness in these deposits with an average depth of 18 – 20 m. Previous borehole drilling in the general area of site 305 indicates the presence of massive ice ranging in thickness from 0.5 m to over 3 m (PWC 1981).

Erosion potential at borrow source 305 is considered as low. No rivers or small creeks cross the proposed borrow area.

3.6.3.6 Borrow Source 172

Borrow source 172 is located approximately 2.5 km west of Husky Lake, between the Alternative 1 (at KP 98) and Alternative 3 (at KP 95). The proposed access route is approximately 2.8 km in length and starts at KP 95.5 of Alternative 3. The area is undulating to hummocky and generally well drained (photo A-15). Several small lakes are located near the proposed borrow area. Organic accumulations and ice-wedge polygons are common around these lakes. Areas containing massive ice are to be expected as the local topography results in part from thermokarst activity.

Rampton (1988) has mapped the area as consisting of mainly ice contact deposits with lacustrine deposits to the south and east. Records from 36 shotholes suggests highly variable materials with over half of the points leading with clay (e.g., “clay, gravel”; “clay”, “clay sand”). The “sand” and ‘gravel” deposits vary in thickness from 9 to 30 m with approximately 50% being 13 m thick and the other 50% being 30 m in thickness. Only nine (9) of the 36 shotholes are leading with gravel (e.g., “gravel”; “gravel sand”; “gravel sandstone”). Several small exposures of sandy to gravely glaciofluvial material were observed during the field reconnaissance (photo A-16)

Erosion potential at borrow source 172 is considered as low. No rivers or small creeks cross the proposed access road or borrow area. Surface water seepage is present in the low-lying areas characterized by gentle slopes. Minor mass movement processes can be expected along some of the short steep slopes (up to 25% grade) that characterize the edge of some hills.

3.6.3.7 Borrow Source 170

Borrow source 170 is the most northerly of the areas reviewed. It is found approximately 2 km west of Alternative 3, between KP 99 and 101. The proposed access road is 2.5 km in length. The area is undulating to hummocky and generally well drained. Low lying areas contain small lakes and ponds, as well as organic accumulations characterized by ice-wedge polygons. Areas containing massive ice are to be expected as the local topography results in part from thermokarst activity.

Rampton (1987) has mapped the area as consisting of ice contact deposits. The records of 86 shotholes suggest that the materials range in textures from “gravel”, “sand” to “clay”, with some sites showing “rocks, gravel, sand” and “gravel sandstone”. The gravel and gravel sand deposits range in thickness from 15 to 30 m with an average of approximately 24 m.

Erosion potential at borrow source 170 is considered as low. No rivers or small creeks cross the proposed access road or borrow area. Surface water seepage is present in the low-lying areas characterized by gentle slopes. Minor mass movement processes can be expected along some of the short steep slopes (up to 45% grade) that characterize the edge of some hills.

4 CONCLUSION AND RECOMMENDATIONS

The detailed airphoto interpretation of the two proposed highway alignments reveals that the surficial geology consists mainly of till deposits (64% of Alternative 1 and 67% of Alternative 3). A total of 12.3% of Alternative 1 and 13.7% of Alternative 3 are underlain by thick organic accumulations. Lacustrine deposits corresponding to both recent deposits as well as sediment deposited during high water phase of Husky Lakes are more widespread over Alternative 1 (10.5%) than Alternative 3 (6.3%). Glaciofluvial, fluvial and colluvial material are generally scarce and represents less than 13% of each alternative.

The review of the proposed alignments at scales varying anywhere between 1:2,500 and 1:7,500 indicated the presence of considerable areas of sensitive terrain, most of which is related to the presence of ice-rich materials. Special attention was given to identify and delineate any areas characterized by ice-rich terrain and other potential terrain hazards.

One of the most common features associated with ice-rich terrain is ice-wedge polygons. A terrain assessment released in October of 2010 by the Terrain Science Unit of AANDC (formally INAC) revealed the presence of 14 km of “confirmed and suspected ice-rich terrain” along the 2009 route (Alternative 1). A summary of this mapping effort indicates that up to 17.4 km of Alternative 1, and up to 19 km of Alternative 3 are characterized by ice-wedge polygons. These statistics only include the route segments overlying visible ice-wedge polygons and do not include potentially hidden or buried features as well as any areas that include other form of massive ice.

Several examples of recent thermokarst activity are found along the proposed highway alignments. Examples include several retrogressive thaw slumps as well as the degradation and thawing of ice wedges polygons. Retrogressive thaw slumps are common in fine-grained till and lacustrine deposits and generally occur along the edge of lakes and small ponds. Such failures results from thermal erosion of ground ice which leads to successive failures and flow of water saturated sediments (Murton 2001).

In an effort to characterize the local drainage, mapping symbols (directional arrows) have been added onto the terrain maps in order to identify the direction of surface water flow and seepage. As reported by the Terrain Science Unit of AANDC (2010), some flow paths might not be visible until the after the road is built, which could lead to extensive ponding of surface water along the side of the road. Such process can cause deepening of the active layer and accentuate thaw settlement.

As summarized in Table 3-2 of Section 3.5, the proposed highway alternatives traverse several areas characterized by sensitive terrain conditions. Although some construction and mitigation techniques can be applied to minimize the disturbance of these areas, several of these areas could be avoided by applying minor modifications to the alignment during the detailed design phase. Since the location of the current proposed alignment likely reflects consideration of a number of factors (such as minimum curve radius, etc.), it is recommended that the alignment occurring in sensitive areas be reviewed in more detail by a team of geotechnical engineers, terrain and permafrost scientists prior to the finalizing the alignment and geometry.

5 LIMITATIONS

This report contains the results of a terrain investigation and does not include geotechnical advice. The assessment was conducted using available data and digital imagery provided by the client. The imagery used for the photo-interpretation exercise consists of digital photographs at 1:30,000 scale, dating from August of 2004 and 2005. The field program aimed at collecting additional baseline information along the proposed highway alignments was cancelled due to poor weather conditions. Only a 4 hour reconnaissance flight to four (4) of the 10 borrow areas was conducted. Therefore the results of the terrain mapping should be considered as preliminary and resulting from a desktop study. Detailed field investigations should be carried out to support this effort.

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APPENDIX A

Site photographs

Photo A-1 Retrogressive thaw slumps near KP 93 of Alternative 1

Photo A-2 Retrogressive thaw slumps west of KP 50

Photo A-3 Low center polygon near Borrow Source 2.45

Photo A-4 High center polygon near KP 66

Photo A-5 Aerial oblique view of Borrow Source 2.45 (looking northeast)

Photo A-6 Aerial oblique view of Borrow Source 2.45 (looking northwest)

Photo A-7 Aerial oblique view of Borrow Source 2.45 (Noell Lake in the background)

Photo A-8 Coarse-grained glaciofluvial material at Borrow Source 2.45

Photo A-9 Small active-layer detachment failure next to a gully at Borrow Source 2.45

Photo A-10 Old stabilized slide (dashed line) along the eastern bank of a stream at Borrow Source 2.45 (looking northeast)

Photo A-11 Glaciofluvial terrace at Borrow Source 325 (looking west)

Photo A-12 Successive terraces at Borrow Source 325 (looking northwest)

Photo A-13 Texture of glaciofluvial material at Borrow Source 325

Photo A-14 Active slumping (dashed line) along the edge of a terrace at Borrow Source 325

Photo A-15 Hummocky glaciofluvial deposit at Borrow Source 172 (helicopter for scale)

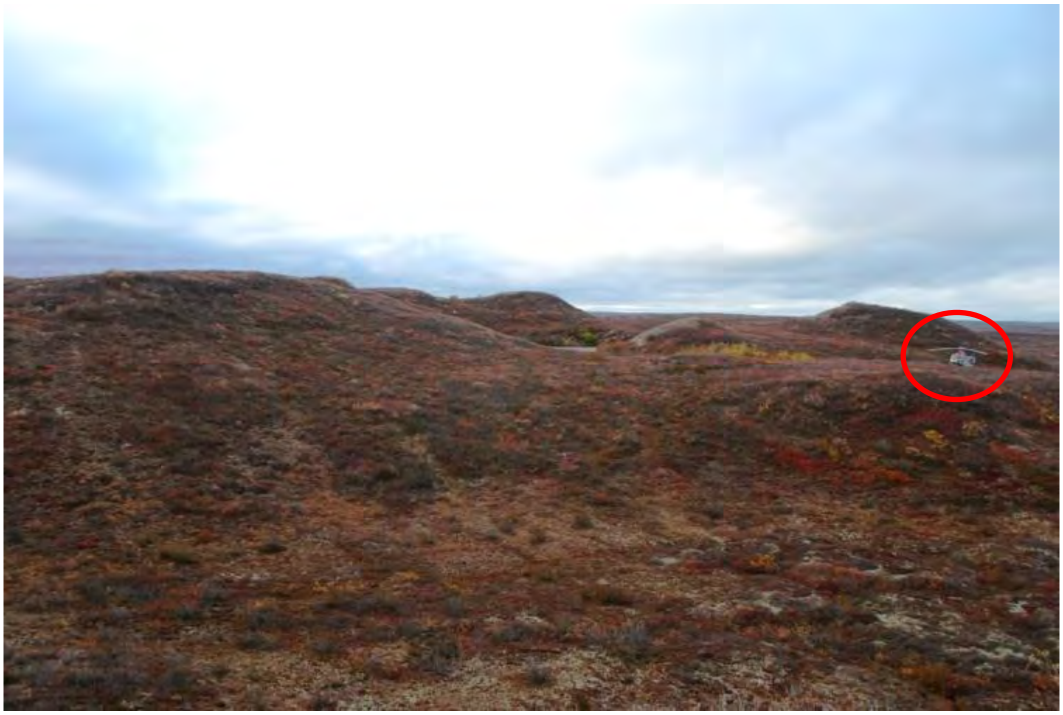
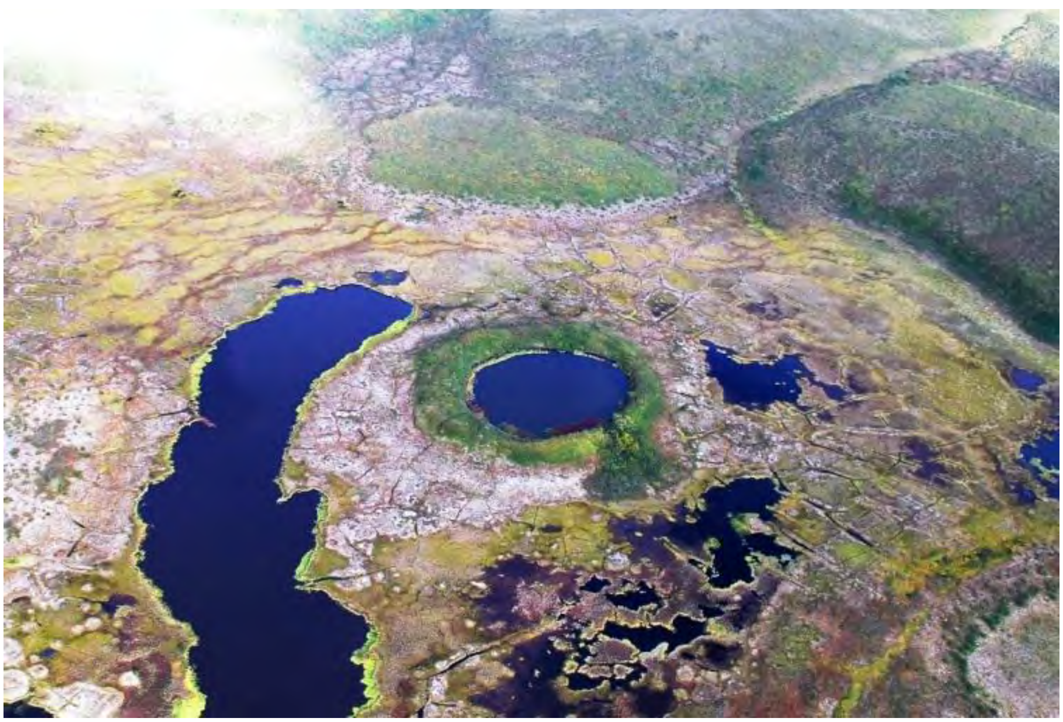


Photo A-16 Texture of glaciofluvial material at Borrow Source 172

Photo A-17 Well developed pingo approximately 1km west of Alignment 1 at KP 93

Photo A-18 Collapsed pingo



APPENDIX B

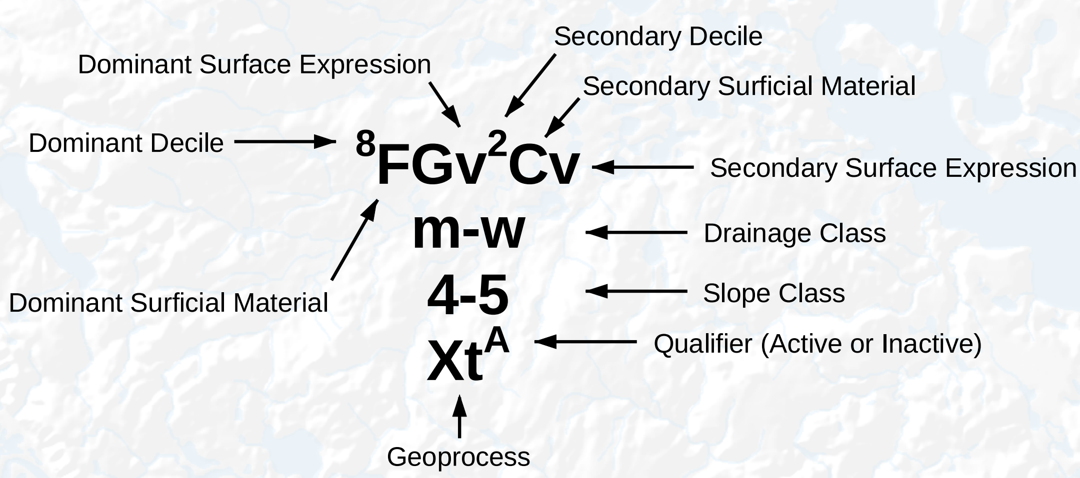
Alignment Sheets

Surficial Geology and Terrain Constraints

Inuvik to Tuktoyaktuk Highway

Surface Materials		Description
M	Till	Poorly sorted diamicton deposited directly, or without major reworking, by glacier ice; consists of heterogeneous mixture of sand, silt and clay with variable amounts of coarse fragments; commonly modified by cryoturbation and thermokarst; thicknesses range from veneers (50 cm) to several meters thick.
FG	Glaciofluvial	Mixture of sand and gravel with variable amounts of silt; includes sediments deposited along floodplains, outwash plains and hummocky ice-contact deposits; thicknesses range from veneers (50 cm) to several meters thick; commonly modified by thermokarst.
L	Lacustrine	Interbedded silt, clayey silt and sand; can include organic material and layers of peat; thicknesses range from thin veneers (50 cm) to several meters thick; includes sediment deposited in recent lake basins as well as sediment deposited during high water phase of Eskimo Lakes.
F	Fluvial/Alluvial	Well to moderately well sorted sediment deposited in modern rivers, deltas and fans; includes material deposited in small, poorly defined, intermittent and ephemerals channels; thicknesses range from thin veneers (50 cm) to several meters thick.
C	Colluvial	Poorly sorted clay, silt, sand and rubble; the texture of the material directly relates to the underlying parent material; thicknesses range from thin veneers (50 cm) to 2-3 meters thick.
O	Organic	Accumulation of organic materials in bogs, fens, swamps and peatlands; can include interbeds of silt and fine sands; thicknesses generally range from 0.5 to 3 m thick; deposited in shallow depressions and generally underlain by poorly drained fine-grained sediment.
W	Marine	Moderately well to well sorted, bedded or massive silt, sand or sand and gravels; can include minor organic materials; generally more than 1 m thick; deposited at or near present sea level, commonly found as intertidal plains and beaches.
A	Anthropogenic Materials	Disturbed materials or modified geological material whose original properties have been drastically modified: generally flat or terraced.

Polygon Label



Surface Expression		Drainage Classes		Slope Classes	
b	Blanket	v	Very poor	1	0-2 %
f	Fan	p	Poor	2	>2-5 %
h	Hummocky	i	Imperfect	3	>5-9 %
m	Rolling	m	Moderate	4	>9-15 %
p	Plain	w	Well	5	>15-30 %
r	Ridge	r	Rapid	6	>30-45 %
t	Terrace	x	Very rapid	7	>45-60 %
u	Undulating			8	>60-85 %
v	Veneer			9	>85 %
j	Gentle slope (6-26%)				
a	Moderate slope (26-50%)	-	One class grading to another		
k	Moderately steep slope (50-70%)	,	Two distinct class portions		
s	Steep slope (>70%)				

Geoprocesses	
Xw	Ice-wedge polygons
Xt	Thermokarst
Xf	Retrogressive thaw slump
Xe	Thermal erosion by water
Rs	Debris slide
S	Solifluction
V	Gullying
C	Creep
L	Surface Seepage

Base Data provided by Government of the Northwest Territories

Inuvik – Tuktoyaktuk Highway, Baseline Data Acquisition Program

Surficial Geology and Terrain Constraints Map Index

Base Data provided by Government of the Northwest Territories; Surficial Data: Stantec

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