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**Geotechnical Feasibility Assessment
Proposed Industrial Lot
km 353.7 RHS North Klondike Highway #2
Carmacks, Yukon – 2018**



Prepared For: Yukon Government

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Proposed Industrial Lot
km 353.7 RHS North Klondike Highway #2
Carmacks, Yukon – 2018**

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1.0 INTRODUCTION

Our firm was retained by *Yukon Government (YG), Department of Community Services – Land Development Branch* under a Standing Offer Agreement (No.2017/2018-2753) to conduct a geotechnical feasibility assessment of an area located in Carmacks, Yukon.

The study area, which measures 3 ha in size, is located at km 353.7 right-hand-side (RHS) North Klondike Highway #2 as noted in Figure 1. The *Village of Carmacks* is located ~ 180 km north of Whitehorse along the Highway # 2.

Authorization to proceed with the geotechnical assessment was granted by *YG – Community Services - Project Manager, Mr.K.Fisher* on September 24th, 2018. The work was subsequently conducted in accordance with our September 7th, 2018 proposal.

Our findings, which were based upon information retained during a literature review, site reconnaissance and laboratory work program, have been presented herein along with a description of our methodology.

2.0 SCOPE-OF-WORK

The purpose of our feasibility assessment was to characterize the terrain and potential sub-surface conditions of the lots through a literature review, site reconnaissance and laboratory such that the development potential of the proposed area could be assessed from a geotechnical perspective relative to industrial lot development.

Specifically, the intent was to delineate regions within the proposed area which may be suitable for development and provide general geotechnical recommendations regarding infrastructure development where development is deemed feasible.

As our assessment was preliminary in nature, it was understood that a more comprehensive geotechnical evaluation would be conducted through drilling/test pit methodologies to verify site specific geotechnical parameters if the development potential was to be assessed in greater detail.



3.0 METHODOLOGY

Our methodology was comprised of a literature review, field work program and laboratory work program as described below.

3.1 Literature Review

A literature review was conducted to evaluate satellite imagery, a selection of aerial photos, topographical data and other technical resources which were readily available. This information was utilized to evaluate the regional conditions and detail the field work program by establishing GPS waypoints such that geotechnical points of interest could be better assessed during the site reconnaissance.

The following sources of information were reviewed;

Topographical Information

The regional topography was assessed by viewing a 1:50,000 scale topographical map (NTS – 115I01 Carmacks) and information available on the *YG- Water Placer Atlas* and *Yukon Geology* websites.

A selection of the *Yukon Geology* website showing the local contours (in 100 foot intervals) has been presented in Section 4.1, below.

Surficial Geology Map

A 1:100,000 surficial geology map (Map 1879A) entitled Surficial Geology, Tantalus Butte, Yukon Territory compiled by L.E.Jackson - *Geological Survey of Canada* provided a description of the anticipated surficial soil deposits.

A portion of this map and the corresponding limits of the study area has been provided in Section 4.5, below.

Bedrock Geology Map

A bedrock geology map, available through the *Yukon Geological Survey*, identified the regional bedrock types and characteristics within the study area. The map was entitled Yukon Bedrock Geology Map – Yukon Geological Survey – Open File 2016-1 - 1:1,000,000 scale compiled by M.Colpron, S.Israel, D.Murphy, L.Pigage, and D.Moynihan.



A more detailed delineation of these contacts was found on the *Yukon Geological Survey* website as noted in Section 4.6, below.

Aerial Photographs

A selection of aerial photographs was obtained from *YG – Energy, Mines and Resources* to allow for a more detailed assessment through airphoto terrain analysis. The following airphotos were available;

<i>Flight Line</i>	<i>Photo No.</i>	<i>Date</i>	<i>Comments</i>
A27477	235-236	June 22 nd , 1989	25,500' altitude
A25565	22-24	1980	None

A selection of these aerial photographs has been attached in Appendix A.

Satellite Imagery

A review of satellite imagery from *Google Earth* allowed for an assessment of the site conditions relative to the more recent imagery. The imagery which was available on the website was dated September 24th, 2008 and August 14th, 2012.

Village of Carmacks – Official Community Plan (OCP) – 2013

The OCP was partially based upon;

- a 1977 soil study which was conducted by the *Saskatoon Institute of Pedology*,
- a 1989 landscape management plan conducted by *UMA Engineering*, and
- a June 2001 flood-risk assessment conducted by *Norwest Hydraulic Consultants*.

This information was utilized by *Inukshuk Planning & Development Ltd.* to compile a development suitability map of the community which was originally included as part of the 2005 OCP. The Floodplain and Landscape Analysis Map included in Schedule C of the OCP classified the terrain in Carmacks as having either 'poor, fair or good development capability'. The poor rating was generally given to regions located within the limits of a 1 in 200 year (Yukon River) flood event or else in regions where steep slopes and/or shallow bedrock was likely. The development capability of the study area as classified in Schedule C of the OCP has been denoted in Section 4.7, below.



The OCP indicated that the study area lies within a zone denoted as ‘industrial’.

Other Resources

The *Yukon Government – Water Placer Atlas* website was reviewed as it denoted the boundaries of various land dispositions, drainage regimes and other similar types of information. The corresponding boundaries of the study area have been illustrated on the *Water Placer Atlas* map attached in Section 4.1, below.

3.2 Field Work Program

The field work program was comprised of a site reconnaissance and hand sampling program. Specifically, our Sr.Soils Technician, Mr.G.Keitel conducted a foot traverse of the site on October 3rd, 2018 to note the field conditions and geological features within the study area.

During the course of the traverse, three (3) near surface soil samples were retained by utilizing a hand shovel to allow for subsequent laboratory analysis as described in Section 3.3, below. These samples (#1-#3) were retained from the locations noted in Figure 2.

A supplemental site reconnaissance was conducted on October 8th by a combination of Mr.Keitel and the undersigned to allow for senior engineering assessment.

Fair weather was encountered at the time of the reconnaissance. Although daytime highs were in the order of + 7° C, given the time of season, frozen ground conditions prevailed.

Our observations during the field work program were documented through a combination of field notes, GPS waypoints and photographs. These observations have been summarized in Section 4.0 – Site Conditions.



3.3 Laboratory Work Program

A laboratory work program was conducted on October 8th, 2018 at our Whitehorse laboratory facilities in order to characterize the index properties and conditions of the retained soil samples.

In brief, each of the retained samples underwent moisture content analysis (ASTM D2216-92) to determine their natural moisture content. In addition, sample #1 underwent grain size distribution analysis (ASTM D422-633) to allow for characterization in accordance with the *Unified Soil Classification System*.

The results of the analysis were as follows;

<i>Sample</i>	<i>Moisture (%)</i>	<i>Silt (%)</i>	<i>Sand (%)</i>	<i>Gravel (%)</i>	<i>USCS</i>	<i>Description</i>
1	7.8	41.3	58.7	0.0	SM	Silty Sand
2	16.3	NA	NA	NA	NA	NA
3	35.2	NA	NA	NA	NA	NA

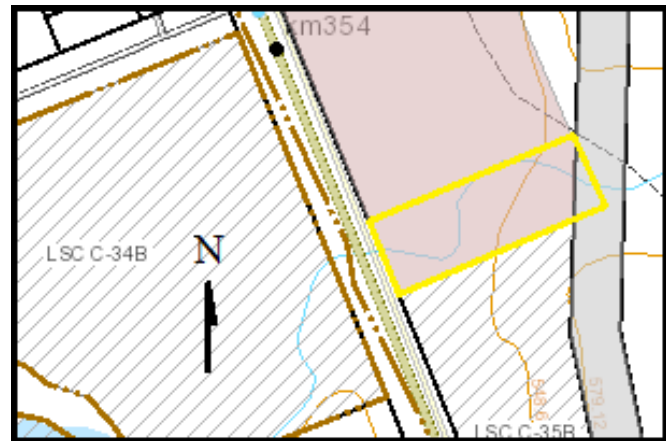


4.0 SITE CONDITIONS

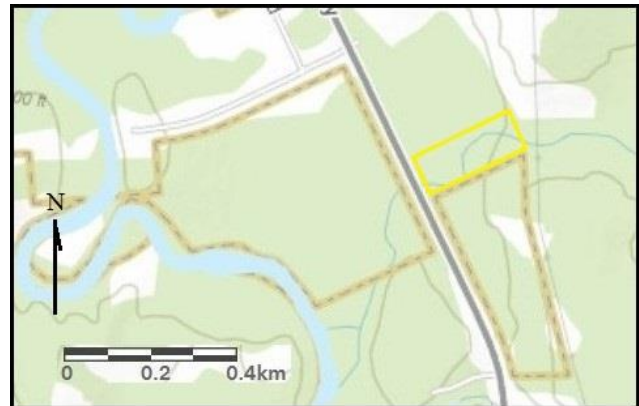
4.1 Study Area

The study area measures 3 ha in size and is located within a gravel reserve land disposition (No.900101) comprised as noted in Figure 1.

The map retained from the *YG - Water Placer Atlas* website noted that the north-eastern periphery of the study area is bound by (and lies partially within) a powerline right-of-way. The south-western edge of the study area borders the North Klondike Highway #2 right-of-way. The south-eastern side of the study area borders *Little Salmon Carmacks First Nation* land selection C-35B.



The topography of the study area is best described as generally level ground which gradually increases in elevation towards the north-east. The lower elevations of the study area are in the order of 530 meters along the North Klondike Highway #2. The higher elevations located on the north-eastern portions of the study area near the powerline approach elevations in the order of 565 meters. As such, the elevation gain across the study area measures in the order of 35 meters.



4.2 Physiographic Region

Carmacks is located in the Yukon Plateau-Central Ecoregion at the confluence of the Yukon and Nordenskiöld Rivers. It lies at the southern fringe of the Dawson Range where mountains rise to elevations in the order of 1800 meters.



The prevailing elevations in the region of the study area range between 530 meters to 565 meters. The Yukon River lies at elevations near 517-518 meters. Regionally, elevations between the Yukon River and adjacent valley terraces vary by up to 300 meters.



Orthogonal view from Google Earth facing north-east.

The regional terrain can be described as rolling, glaciated terrain, which is incised by broad, U-shaped valleys.

4.3 Site Description

Relative to the site plan attached as Figure 2, uniform terrain and spruce forest conditions were generally encountered throughout the study area. However, some variations were noted as the site had once been disturbed by a series of bulldozer trails which have since become overgrown to varying degrees (photo right).



These bull-dozer trails can be noted on the airphoto which has been attached as Appendix A.

Steeper terrain is encountered as one traverses to the east. The eastern realms of the site lie within a powerline right-of-way which harbors overhead power transmission lines.



View of Powerline ROW facing north-west.



View of Powerline ROW facing south-east.



A willow bush understory is present throughout most of the site. A series of old grubbing piles, which were likely remnants from (Klondike) highway clearing operations, were located within the south-western limits of the site as noted in Figure 2.



View of North Klondike Highway facing north-west.



View of south-eastern lot pin facing north-east.

4.4 Geomorphology

Glaciation

The terrain in this region of the Yukon was last glaciated during the McConnell Glaciation which occurred approximately 17,000 years ago. The glacial deposits which were deposited during the glacial recession which occurred during this time were subsequently incised by the Yukon River which deposited alluvial soils in predominately floodplain deposits along the adjacent shorelines.

Permafrost

The vegetation did not reveal any signs of permafrost. However, as Carmacks lies in a region of extensive discontinuous to sporadic permafrost, it could be encountered within the limits of the study area depending upon the local conditions.



Watercourses

While signs of a drainage course were not observed during the site reconnaissance, the *YG – Water Placer Atlas* suggests that a historical drainage course meanders through the study area from the north-east to the south-west. This drainage course is shown to terminate in the Nordenskiold River, which is located ~320 meters south-west of the site.

Surface Drainage

There were no signs of erosion within the study area which would be attributed to surface drainage. However, the *YG – Water Placer Atlas* suggests that a local drainage course meanders through the study area from the north-east to the south-west. This drainage course was likely a historical channel which was plotted on the *Water Placer Atlas*.

A 400 mm Ø CSP culvert which crosses the North Klondike Highway #2 approximately 60 meters (north of the site) is located as noted in Figure 2.

Groundwater

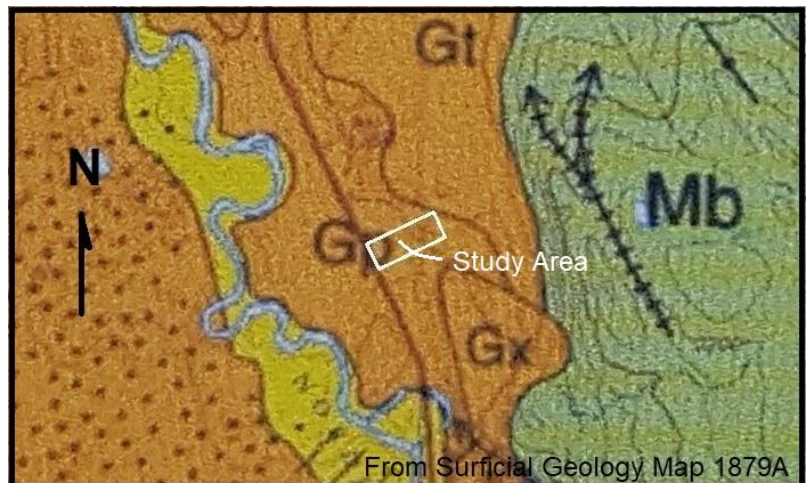
Given the study areas proximity to the Nordenskiold River, groundwater likely underlies the site at elevations which parallel those of the river.

Bedrock

There was no indication of near surface bedrock during our literature review or site reconnaissance.

4.5 Surficial Geology

The distribution of surficial deposits within the study area has been illustrated in the (1:100,000 scale) surficial geology map Tantalus Butte - Yukon Territory - Map 1879A compiled by L.E.Jackson Jr., 1997. The approximate limits of the study area have been illustrated on a portion of the surficial geology map as noted right.





In brief, the map shows that the surficial deposits which are located within the study area are comprised of glaciofluvial plain deposits.

The surficial geology map legend describes these deposits as follows;

Glaciofluvial Plain Deposits (Gp)

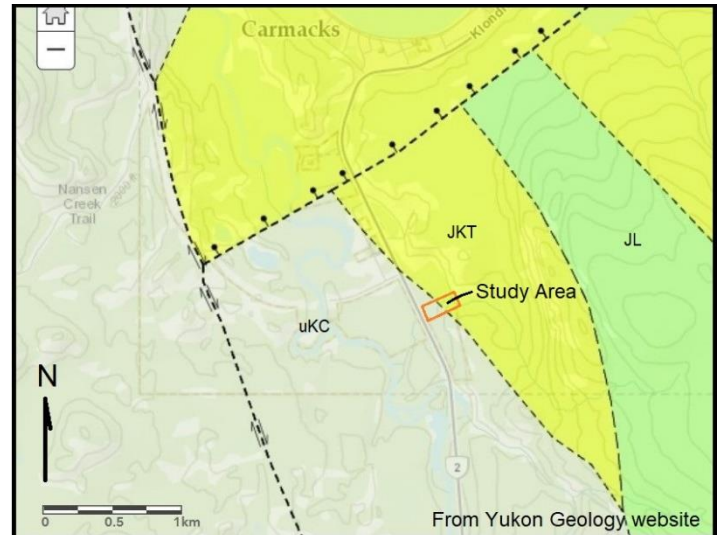
These deposits are comprised of pebble to cobble gravel, massive to thickly bedded and capped by sand and silt. They are planar in nature and measure between 1 meter to greater than 10 meters thick.

4.6 Bedrock Geology

There was no indication of any near surface bedrock during our field work program.

The geology map noted on the *Yukon Geology* website indicates that the site is underlain by two types of bedrock.

The bedrock located in the eastern side of the site is comprised of a clastic sedimentary rock (JKt) of the Tantalus Formation. This rock is described as a chert, pebble conglomerate and quartz-chert-feldspar sandstone with coal occurrences.



The bedrock located in the western side of the site is comprised of a volcanic basalt (uKC) of the Little Ridge/Casino Formation. This rock is described as an augite/olivine basalt and breccia.

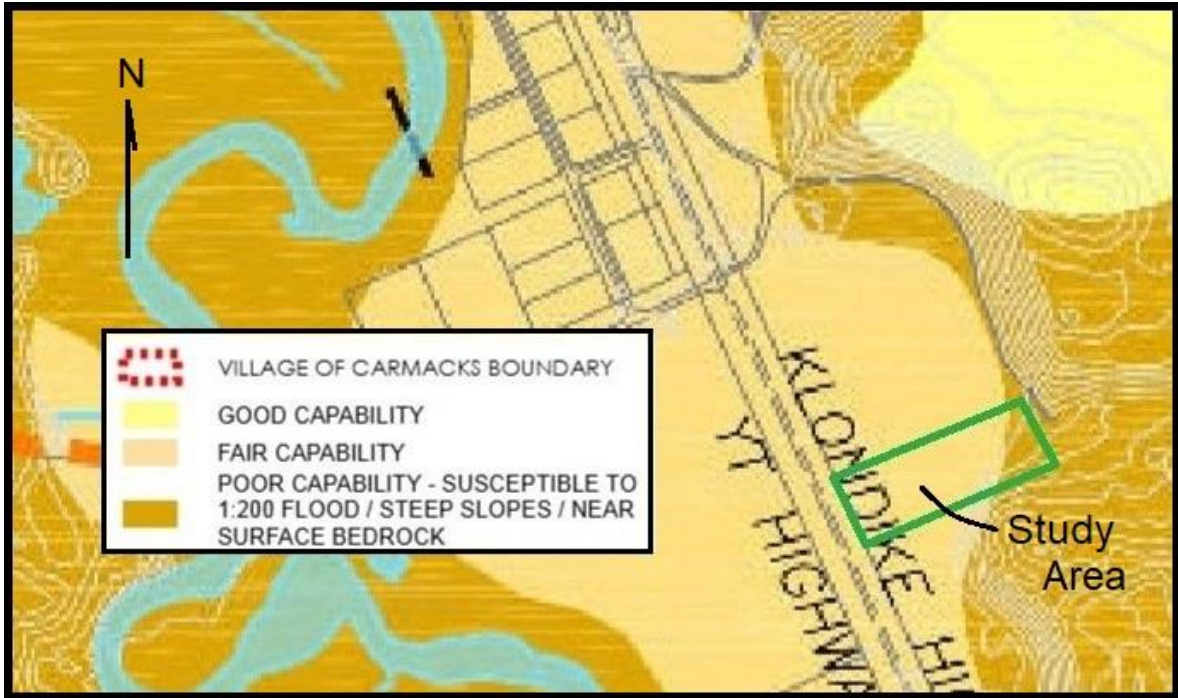
An undefined, yet probably fault separates these two types of bedrock through the central portions of the site.

4.7 OCP Floodplain and Landscape Analysis

The study area was identified in Schedule C – Floodplain and Landscape Analysis of the Village of Carmacks - 2013 OCP as having either a fair or else poor (development) capability. The fair rating was given to the majority of the site. The poor rating, which coincided with regions where higher elevations are encountered, was likely given due to the presence of steeper slopes and potential for shallow bedrock.



The approximate limits of the study area have been illustrated on the OCP map (below) for reference.





5.0 DISCUSSIONS

As the geotechnical development potential of the site will vary, we have for discussion purposes classified regions which exhibit similar potentials for development based upon the local types of terrain and anticipated subsurface conditions as illustrated in Figure 2. In general, the figure illustrates the relative development potential within each of the areas as being either ‘Unfavorable, Suitable or Favorable’. A description of each of these levels of classification is as follows;

Unfavorable

Development within these regions is not recommended due to the presence of either poor soil conditions, shallow groundwater/bedrock, steep slopes or combination thereof. If development within these regions is required, it should be limited to supporting infrastructure as building construction would not be recommended.

Suitable

These regions should support building/infrastructure development however, additional site preparation will generally be required relative to regions which have been deemed to be favorable.

Favorable

Development within these regions should allow for unfettered lot development utilizing conventional construction methodologies.

Some variations between these regional boundaries can be expected in the field given the scale of mapping and local geomorphology. Where development is to be conducted, additional consideration will need to be given through a subsurface geotechnical evaluation such that local geotechnical design parameters can be determined relative to the soil and terrain conditions.

Development will require careful planning and design relative to building construction, septic field placement, road alignment and surface drainage management.

5.1 Development Potential

Based upon the information retained during our assessment, the development potential of the site will vary. In general, the anticipated soil and terrain conditions will be



favorable to allow for unrestricted site development in Area A (as noted in Figure 2). However, additional consideration would be required in the unfavorable area identified as Area B, as development would be limited in regions where steeper slopes are present.

5.2 General Overview

From an overall lot development perspective and considering the intended industrial use, the safety relative to highway access would need to be considered in greater detail as there were not any acceleration/deceleration lanes in either direction of the North Klondike Highway #2 where access to the study area was envisioned. As such, while the North Klondike Highway #2 in this region is essentially flat and good sight lines are available, this aspect would need to be considered by qualified personnel from a civil engineering perspective.

5.3 Subsurface Considerations

Some adjustments to individual building foundation and septic field designs may be required to accommodate site-specific conditions as the soil types and subsurface conditions will vary across the study area.

The results of the laboratory analysis indicated that granular (silty sand), fine-grained and organic soils are located within the study area. While the presence of these soils will be beneficial in regions where site development is to occur, additional consideration will need to be given where fine-grained soils are present. Specifically, the fine-grained and organic materials will need to be removed from beneath road (and building) load envelopes during construction as these soils are weak and frost susceptible.

5.4 Terrain Considerations

The presence of steep to moderate slopes which are located within/adjacent to the north-eastern realm of the site will require careful planning and design relative to surface drainage management and building placement. Additional consideration may be required relative to the historical drainage course which was identified in the *YG – Water Placer Atlas*.



5.5 Geotechnical Evaluation

A subsurface geotechnical evaluation should be conducted through test pit/drilling methodologies to verify the local subsurface conditions and outline geotechnical design parameters regarding site development. The evaluation should assess the soils suitability for use as accepting soils relative to *Yukon Health and Social Services – Design Specifications for Sewage Disposal Systems*.

The evaluation should assess the stability of any steep slopes located within/adjacent to the north-eastern realm of the study area to determine whether or not they may pose a hazard relative to anticipated site development.

A site-specific geotechnical evaluation should be conducted utilizing standard penetration test (SPT) methodologies at any proposed building location such that the maximum net allowable bearing capacity and founding soil conditions can be determined prior to building construction.



6.0 RECOMMENDATIONS

6.1 General

The following recommendations have been provided to outline the envisioned geotechnical requirements for site development in the regions identified in Figure 2. However, as our recommendations are preliminary in nature, additional consideration may be required once the geotechnical parameters have been determined following a subsurface geotechnical evaluation (test pit/drilling and laboratory work programs).

6.2 Building Foundations

Buildings should be constructed utilizing footing and monolithic (slab-on-grade) types of concrete foundation systems. Some adjustments to the individual designs may be required to accommodate site-specific conditions as the soil types, local terrain and subsurface conditions will vary across the study area.

Given the proximity to the Nordenskiöld River, further evaluation would be required if basements are to be considered as shallow groundwater may be present in the region.

Although permafrost is not anticipated, additional consideration could be given if encountered as the use of conventional building foundations should not be allowed in these circumstances.

6.3 Surface Works

The construction of roads and surface utilities should be feasible throughout the study area. While the road structure would need to be determined based upon the subgrade conditions and expected traffic loads, we anticipate the granular components of the road structure would measure in the order of 0.7-1.0 meters thick. Thicker road/parking area structures may be required depending upon the subgrade conditions and design traffic loads.

6.4 Subsurface Utilities

The anticipated soils should allow for subsurface utility installation. However, additional consideration may be required during the design and construction phases if groundwater, large boulders and/or bedrock is encountered.



While the soils would need to be assessed during future geotechnical evaluations to determine their suitability for use as accepting soils relative to *Yukon Health and Social Services – Design Specifications for Sewage Disposal Systems* based upon the information retained during our assessment we anticipate that the soils should prove to be suitable for use.

6.5 Additional Assessments & Evaluations

Additional assessments and evaluations should be conducted to verify site-specific design parameters as follows;

Geotechnical Evaluations

A subsurface geotechnical evaluation should be conducted through test pit and/or drilling methodologies to verify the local subsurface conditions and outline geotechnical design parameters regarding site development.

Site-specific geotechnical evaluations should be conducted utilizing standard penetration test (SPT) auger drilling methodologies at all proposed building locations such that the maximum net allowable bearing capacity and founding soil conditions can be determined prior to building design and construction.

Site Grading, Surface Drainage and Erosion Control Plan

Site grading, surface drainage and erosion control plans should be formulated once conceptual designs have been established to ensure surface waters are adequately controlled.

CSP culverts should be utilized to ensure drainage is unimpeded where access roads/driveways are constructed.

Drainage in steep areas should be controlled utilizing silt fencing, straw bales and/or other similar types of erosion control measures if deemed necessary.

Site Survey

A detailed site survey (minimum 2-meter contour intervals) should be conducted to allow for additional geotechnical evaluation as the scale of mapping available at the time of our assessment was not sufficient to note site-specific variations in the topography.



Environmental Site Assessment(s)

Considering the presence of the highway alignment, old grubbing piles and former bulldozer trails, a Phase I Environmental Site Assessment (ESA) should be conducted to determine whether or not there may be any environmental liabilities associated with the study area.

Natural Hazard Assessment

A natural hazard assessment should be conducted by qualified personnel to assess the forest fire potential if development is to proceed.

Hydrogeological Assessment

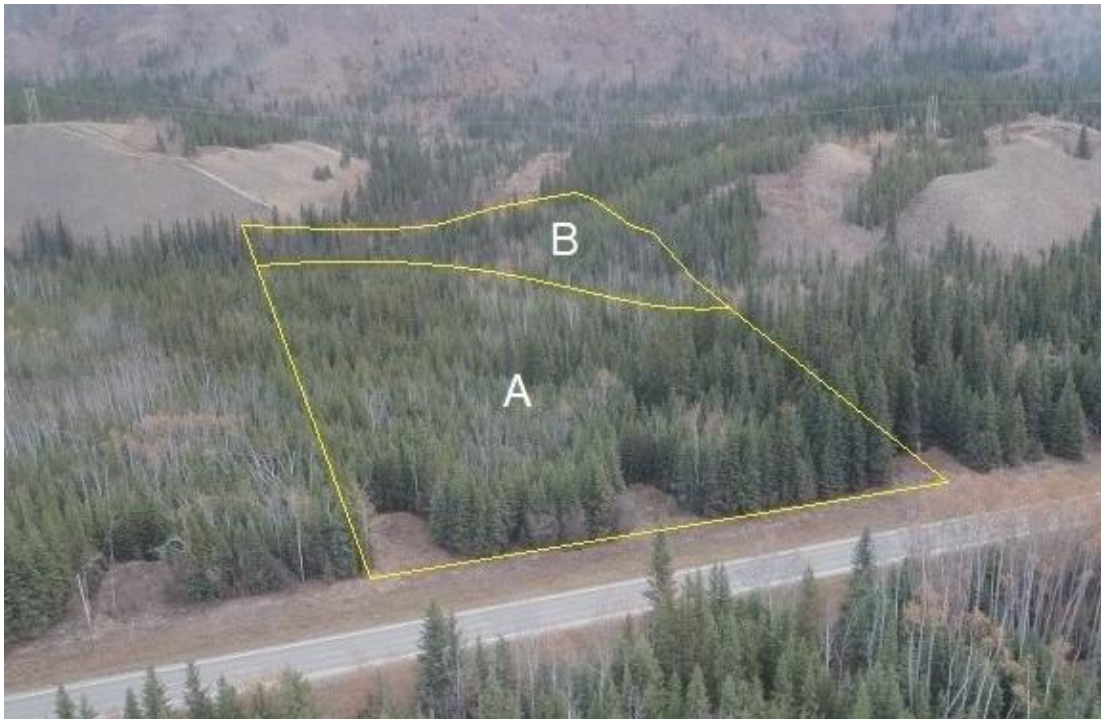
A hydrogeological study should be conducted if water wells are to be installed within the study area. The intent of the study should be to assess the impacts a well (or wells) would have upon the underlying aquifer and delineate any potential liabilities.



7.0 CONCLUSIONS

Development Potential

Based upon the information retained during our assessment, the development potential of the site will vary. In general, the anticipated soil and terrain conditions will be favorable to allow for unrestricted site development in Area A (as noted in Figure 2). However, additional consideration would be required in the unfavorable area identified as Area B, as development would be limited in regions where steeper slopes are present.



From an overall lot development perspective and considering the intended industrial use, the safety relative to highway access would need to be considered in greater detail as there were not any acceleration/deceleration lanes in either direction of the North Klondike Highway #2 where access to the study area was envisioned. As such, while the North Klondike Highway #2 in this region is essentially flat and good sight lines are available, this aspect would need to be considered by qualified personnel from a civil engineering perspective. Some adjustments to individual building foundation, road structures and septic field designs may be required to accommodate site-specific conditions as the soil types and subsurface conditions will vary across the study area.



Additional consideration will be required through a subsurface geotechnical evaluation such that the geotechnical design parameters associated with the study area can be characterized in greater detail.

Building Foundations

The anticipated glaciofluvial plain deposits should allow for building construction utilizing conventional (footing and monolithic-slab types of) foundation systems.

Surface Utilities

The construction of roads, ditches and laydown areas utilizing conventional cut/fill construction methodologies will be feasible following adequate site preparation.

Subsurface Utilities

While the soils would need to be assessed during future geotechnical evaluations to determine their suitability for use as accepting soils relative to *Yukon Health and Social Services – Design Specifications for Sewage Disposal Systems* based upon the information retained during our assessment we anticipate that the soils should prove to be suitable for use. Additional consideration may be required during the design and construction phases if groundwater, large boulders and/or bedrock is encountered.

Site Grading, Surface Drainage and Erosion Control Plan

Site grading, surface drainage and erosion control plans should be formulated once conceptual designs have been established to ensure surface waters are adequately controlled. The presence of steep to moderate slopes which are located within/adjacent to the north-eastern realm of the site will require careful planning and design relative to surface drainage management and building placement. Additional consideration may be required relative to the historical drainage course which was identified in the *YG – Water Placer Atlas*.



8.0 LIMITATIONS

This report is intended for the sole use of *Yukon Government*.

No portion of this report may be used as a separate entity; it is intended to be read in its entirety.

Any use of this report by a third party is the responsibility of such third party.

The comments contained herein reflect our best judgment in light of the information available to our firm at the time of our assessment. They are based upon our collation of available literature, observations made during our site reconnaissance, recognition of geomorphic features and generally accepted engineering practices.

Given the nature of our assessment and scale of mapping, the information contained herein will not be sufficient to assess all factors that may have an effect upon design and construction and so this should be considered from a project management perspective. As such our findings should be supplemented through subsequent geotechnical evaluations and other technical studies as may be required.

Due to the geomorphological nature of the deposits encountered, interpolations of subsurface conditions have not been made or implied other than for discussion purposes. The anticipated conditions have also been discussed, but only to the extent that they may influence design decisions. Suggestions of construction methods contained herein express our opinion and are not intended to direct contractors on how to carry out construction. Any reference to structures, roads or overall use of the study area have been made for discussion purposes only. The actual use will need to be determined during the planning and design processes.

Should unexpected subsurface conditions be encountered during future evaluations of the study area, our firm should be notified immediately in order to confirm the suitability of our recommendations and conclusions. If required, our firm may alter or modify our recommendations and conclusions at such time.



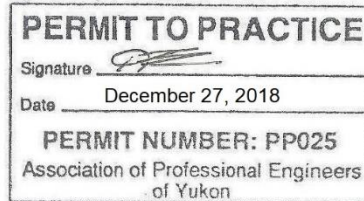
9.0 CLOSURE

Thank you for providing our firm with the opportunity to conduct this geotechnical feasibility assessment.

We trust that the information we have provided will be suitable for your purposes at this time, however, if you should have any questions or concerns, please feel free to contact the undersigned at your convenience.

Respectfully Submitted,

CHILKOOT GEOLOGICAL ENGINEERS LTD.

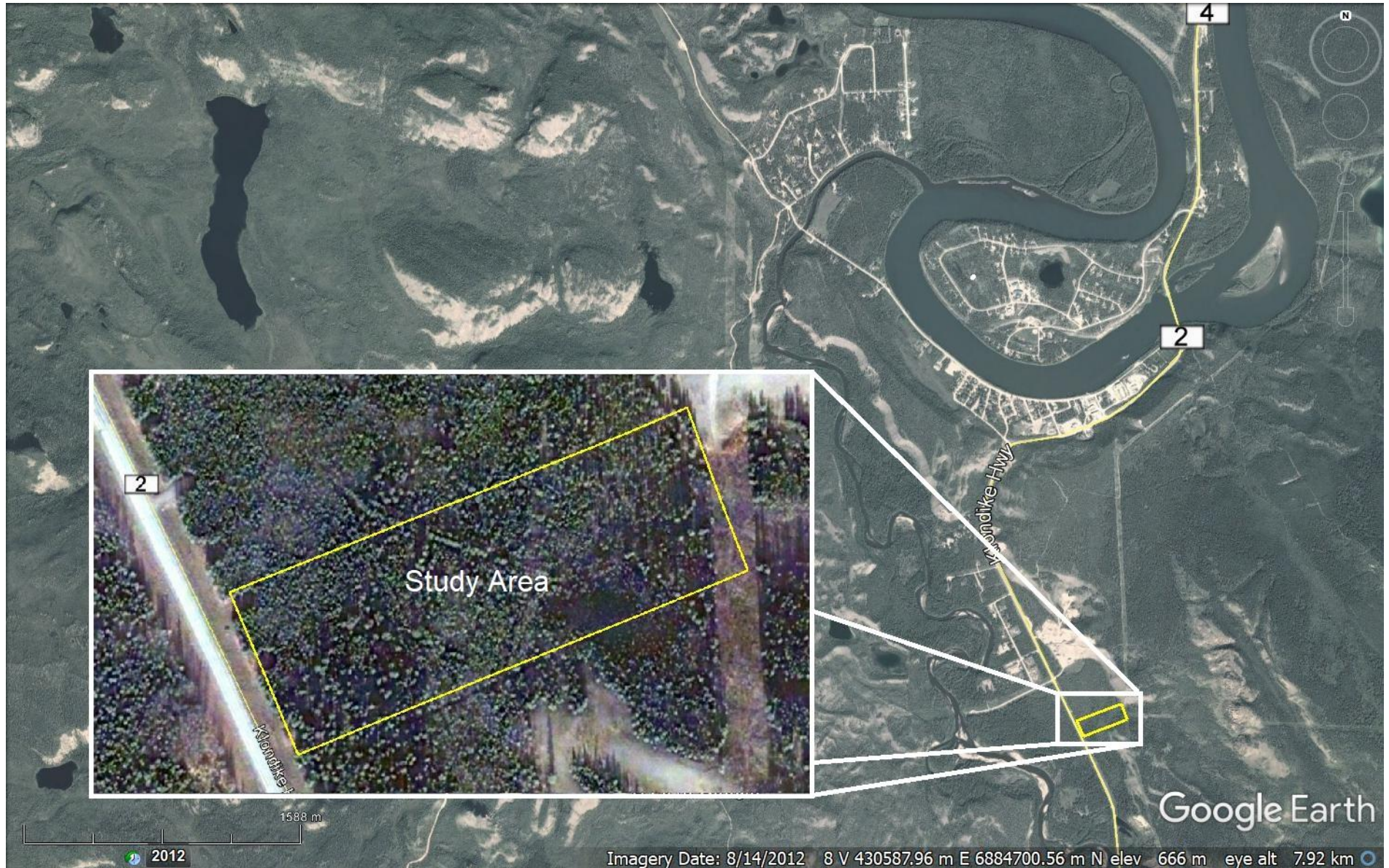


Tares Dhara, P.Eng.
Senior Geotechnical Engineer

TD/td



Geotechnical Feasibility Assessment
Proposed Industrial Lot – Carmacks, Yukon – 2018
Figure 1 – Location of Study Area





Geotechnical Feasibility Assessment
Proposed Industrial Lot – Carmacks, Yukon – 2018
Figure 2 – Development Potential





Geotechnical Feasibility Assessment
Proposed Industrial Lot – Carmacks, Yukon – 2018
Appendix A – Airphoto A25565 #23 - (1980)

