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**Geotechnical Evaluation
Proposed Industrial Subdivision
km 353.7 RHS Klondike Highway #2
Carmacks, Yukon – 2019**



Prepared For: Yukon Government

Date : October 11th, 2019

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1.0 INTRODUCTION

Our firm was retained by *Yukon Government - Department of Community Services, Rural Land Development - Land Development Branch (YG)* under a Standing Offer Agreement (No.2017/2018-2753) to conduct a geotechnical evaluation of a proposed industrial subdivision which is to be located in Carmacks, Yukon.

The purpose of our evaluation was to assess the development potential of the study area through subsurface investigation and laboratory analysis in order to formulate geotechnical recommendations to assist in site development and preliminary foundation design where development was deemed feasible. It should be noted that our evaluation was limited as access to the site was restricted to peripheral areas and existing trails which did not allow for subsurface exploration of the central realms of the study area.

Our evaluation was meant to supplement our December 27th, 2018 Geotechnical Feasibility Assessment which identified the overall development potential of the proposed subdivision location based upon a literature review and site reconnaissance.

The *Village of Carmacks*, located ~ 180 km north of Whitehorse along the North Klondike Highway, is one of number of Yukon communities where there is an increasing demand for overall lot development. 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.

As our recent evaluation was more comprehensive in nature than our Geotechnical Feasibility Assessment, our findings and recommendations contained herein supersede those of our previous report where conflicts may exist.

Authorization to proceed with the evaluation was granted by *YG – Community Services - Senior Program Manager, Mr.K.Fisher* on August 2nd, 2019. Our field work was subsequently conducted on August 10th and 11th in accordance with our July 29th, 2019 proposal.

Our findings have been presented herein along with a description of our methodology.



2.0 METHODOLOGY

Our work methodology was comprised of the following components.

2.1 Literature Review

Our firm reviewed our December 27th, 2018 Geotechnical Feasibility Assessment report to re-familiarize ourselves with the regional conditions and detail the field work programs. During this time, we collated the information relative to a newly compiled topographical map (which was forwarded to us by *Inukshuk Planning & Development Ltd.*) in order to detail the field work program by identifying potential test-pit locations.

The new topographical survey, which was based upon third party data retained in 2014, has been attached as Figure 2. While the (1.0-meter) contours intervals denoted local fluctuations in the ground surface, considering the age of the survey, it appears it may not necessarily reflect the existing site conditions. Specifically, we noted that the access road which traverses the sites eastern periphery, was not identified.

2.2 Field Work Program

The field work program was comprised of the following components;

Utility Locates

Northwestel, *ATCO Electric Yukon* and the *Village of Carmacks* were contacted prior to conducting the test pit program to ensure the subsurface investigation would not impact local infrastructure.

In brief, the service providers indicated they did not have any utilities located within the limits of the study area. However, *ATCO Electric Yukon* identified the presence of an overhead power transmission line which is located just beyond the northern edge of the study area. In addition, *Northwestel* indicated they had subsurface utilities located within the highway right-of-way, just beyond the western edge of the study area.

Site Reconnaissance

A site reconnaissance was conducted by the undersigned on August 10th, 2019 to mark anticipated test pit locations and delineate equipment access routes such that the potential for disturbance to vegetation and delays during the subsurface investigation was minimized. In addition, during this time we assessed the site conditions further to observations which were made during our geotechnical feasibility assessment.

Test Pit Program

A test pit program was conducted on August 11th, 2019 to assess the sub-surface conditions at select locations within the study area utilizing a *Bobcat E60* tracked excavator which was equipped with a digging bucket. The excavator was supplied and operated by *Yellow Truck Excavating Inc.* of Whitehorse, Yukon and was employed under the direction of our firm.

The work consisted of excavating three (3) test pits (TP 1-19 through TP 3-19) which were excavated at the approximate locations noted in Figure 3.

Test Pit Termination

The depth of test pit excavation varied. Test pits TP 1-19 and TP 2-19 were limited to depths of 0.7 and 0.5 meters, respectively, due to the presence of permafrost. Test pit TP 3-19, which encountered thawed soils, was excavated to a depth of 3.1 meters. While test pit TP 3-19 was terminated within glaciofluvial plain deposits, it appears test pits TP 1-19 and TP 2-19 were terminated within glaciofluvial ice stagnation complex deposits which may have washed onto the site through erosion processes.

The test pits were backfilled with the excavation spoils approximately fifteen (15) minutes following completion of excavation to allow for a period of time to assess sidewall stability and potential groundwater seepage/recharge rates. The surficial organic cover, which was stockpiled separately from the excavation spoils, was subsequently utilized to cap the backfill to reduce the potential for soil erosion and promote re-vegetation.



Site conditions traversing to test pit TP 2-19.



Survey Program

The locations of the test pits were recorded in the field utilizing a hand-held GPS unit.

Each location was subsequently marked utilizing wooden survey lathe such that if required, they could be more accurately surveyed by a YG retained surveyor. Given the regional perspective of our evaluation, the test-pits were each given arbitrary elevations of 100.00 meters.

Soil Logs

During the test pit excavation, field soil logs were maintained by the undersigned to record the stratigraphy of the soils that were encountered. This information was utilized along with visual observations and the results of the laboratory analysis in order to compile the Soil Logs which have been enclosed in Appendix A. This appendix also includes '*Notes on Soil Classification*' and a description of the '*Unified Soil Classification System*' and '*National Research Council*' permafrost classification systems which were utilized to describe the soils.

Sampling Program

Soil samples were retained at regular intervals during the subsurface investigation to allow for additional observations to be made under field and laboratory settings.

A total of eight (8) samples were obtained during the test pit program. While the near surface samples were retained by hand directly from the excavation sidewalls, the deeper samples in test pit TP 3-19 were retained from the leading edge of the excavator bucket during the course of test pit excavation.

An additional sample was retained from the *Yukon Government* gravel quarry located at km 354.3 RHS of the North Klondike Highway #2 (Disposition No.900101) to characterize potential fill materials which may be utilized during site development.

Once the soil samples were retained, they were described on the field soil logs and subsequently sealed in air-tight plastic bags. The samples were numbered sequentially in order to allow for laboratory analysis as described in Section 2.3, below.



2.3 Laboratory Work Program

The laboratory work program was comprised of both physical and analytical analysis.

Physical Laboratory Analysis

The physical laboratory work program was conducted at our Whitehorse laboratory facilities and those of our sub-consultant, *Golder Associates Ltd.* (located in Burnaby, British Columbia), in order to characterize the index properties and conditions of the retained soil samples.

The analysis was conducted between August 14th and September 6th, 2019 and was comprised of the following;

<i>Description of Analysis</i>	<i>ASTM Analysis</i>	<i>Quantity</i>	<i>Laboratory</i>
Moisture Content	D 2216-92	8	<i>Chilkoot</i>
Grain Size Distribution	D 422-633	4	<i>Chilkoot</i>
Hydrometer	D 422-633	1	<i>Golder Associates</i>
Atterberg Limit	D 4318-10	1	<i>Golder Associates</i>

In brief, each sample underwent moisture content analysis to determine the weight of the water within the sample relative to its dry weight. The results of the analysis have been denoted as ‘MC’ (☉ - Symbol) on the Soil Logs enclosed in Appendix A.

The grain size distribution and Atterberg limit analysis was conducted on a selection of samples in order to assist in soil classification utilizing the *Unified Soil Classification System*. The results of the grain size distribution analysis have been noted on the Soil Logs with the percent composition of fines (silt & clay), sand and gravel denoted with ▲, ● & ■ the –symbols, respectively.

The results of the Atterberg limit analysis have been attached in Appendix B.

The hydrometer analysis was conducted in order to determine the percentage of sand, silt and clay which was contained within the sample which was tested. These percentages were subsequently plotted on the *Soil Textural Triangle* to provide a relative assessment of the soils suitability for use as accepting soils relative to septic system design as described in Section 4.4, below.

The results of the hydrometer analysis have been attached in Appendix B.



Analytical Laboratory Analysis

The total sulphate ion content of two (2) soil samples was determined by our laboratory sub-consultant *Golder Associates Ltd.* in accordance with *CSA Standard A23.1 – 3C*. The purpose of the analysis was to assess the aggressiveness of the native and potentially imported soils relative cast-in-place concrete.

The native soil sample (No.6), retained from test pit TP 3-19, was comprised of a sandy silt.

The sample of material which would potentially be imported was retained from the *YG* gravel quarry (Disposition No.900101) located at km 354.3 RHS of North Klondike Highway #2.

The results of the sulphate ion content analysis have been attached in Appendix B.



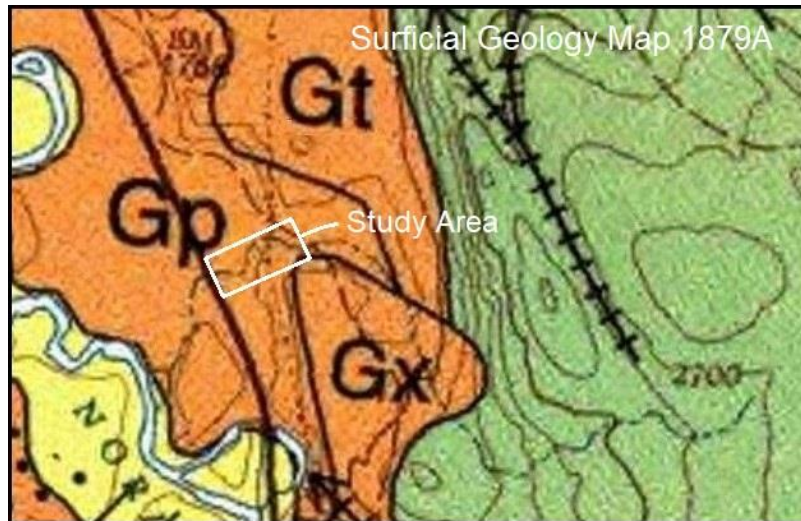
3.0 SITE CONDITIONS

Details regarding the physiographic and geomorphic settings can be found in our December 27th, 2018 Geotechnical Feasibility Assessment report along with a description of the site.

The sub-surface conditions which were encountered during our evaluation have been summarized as follows;

3.1 Soil Stratigraphy

The soil deposits located within the study area are comprised of glaciofluvial plain deposits. The approximate regional distribution of these soil deposits as identified in the surficial geology map (*GSC Map 1879A*) was delineated as illustrated, below;



Glaciofluvial Plain Deposits (Gp) - (TP 3-19)

In general, the surficial geology map (*GSC Map 1879A*) described these deposits as being comprised of pebble to cobble gravels which are 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. This sequence of fine-grained sands and silt which overlay cobbly gravels were encountered in test pit TP 3-19.

Test Pit TP 3-19

The soils which were encountered in test pit TP 3-19 were comprised of fine-grained soil deposits which overlay a granular (sandy silty gravel) deposit which was encountered at a depth of 2.9 meters below the ground surface.

The composition of the fine-grained soil deposits varied with depth. In general, non-plastic sandy silts extended to depths of approximately 1.8 meters below the prevailing ground surface. The relative moisture content of these soils was noted to be damp (11.9%) becoming moist (18.4%) beyond a depth of 1.3 meters. Silty clays to clayey silts, which were characterized through Atterberg limit analysis as being slight plasticity, were encountered at a depth of 1.8 meters. The moisture content of these plastic soil deposits was noted to be 28.4%, indicating wet soil conditions. The hydrometer analysis indicated the silty clay to clayey silt contained 11.9% clay, 51.1% silt and 37.0% sand (by weight). The consistency of these plastic soil deposits was noted to be soft beyond a depth of 2.4 meters, suggesting the presence of a nearby groundwater table.

The underlying gravel deposit was characterized as a being a sandy silty gravel which contained 18.5% fines and the odd cobble in size to 140 mm. These soils had a moisture content of 12.8 %, indicating wet/saturated soil conditions. In a confined state, the relative density of the granular deposits would be compact. However, given their saturated condition, they were noted to be loose upon excavation.



Site conditions at test pit TP 3-19.



Test pit TP 3-19 soil conditions.

The above noted soils were overlain with 150 mm of organic silt and moss, 150 mm of sandy silt and 200 mm of volcanic ash.

Test Pits TP 1-19 & TP 2-19

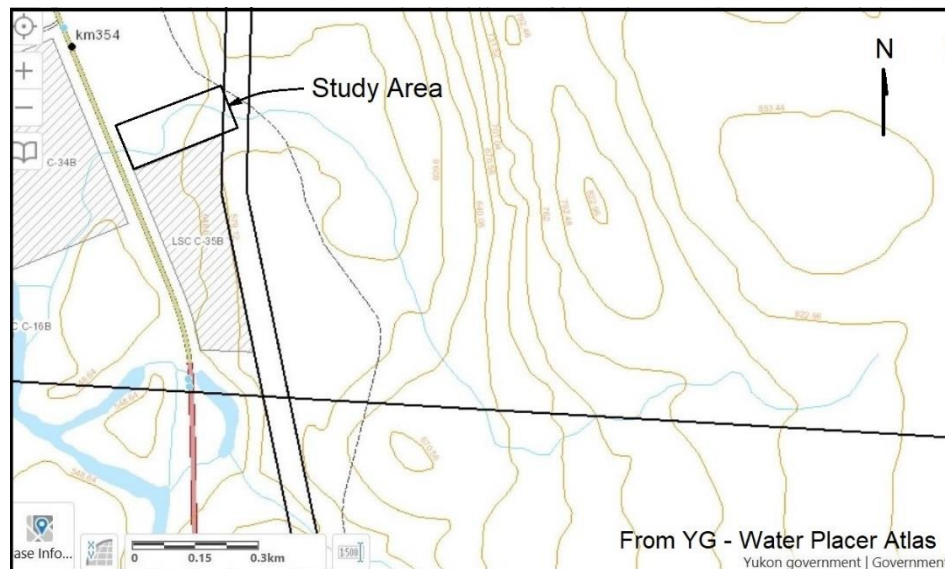
Similar soil and subsurface conditions were encountered in test pits TP 1-19 and TP 2-19. In brief, each test pit encountered permafrost comprised of black

organic silts which were overlain with approximately 100 mm of volcanic ash and approximately 250 mm of moss and rootlets. The permafrost conditions have been described in detail in Section 3.4, below. The depth of excavation in these test pits was limited to 0.7 and 0.5 meters, respectively, due to the frozen nature of the deposits.



Backfilling test pit TP 1-19.

The organic silt deposits (encountered in test pit TP 1-19 and TP 2-19) and the surficial sandy silts (encountered above the volcanic ash in test pit TP 3-19), are like flood/over-bank deposits which originated from the tributary which meandered through the site as identified in the *YG – Water Placer Atlas*, as illustrated, below;



Stripping & Grubbing Piles

A series of stripping/grubbing piles, which are remnants from construction of Klondike Highway #2, are located along the western periphery of the site (as illustrated in Figure 3).

3.2 Groundwater

While not directly observed, groundwater is likely present in the region of test pit TP 3-19 at a depth of ~2.0 meters as evidenced through wet/saturated soil conditions and sidewall slough. Some oxidation (which suggests that the subsurface may have

intermittently harbored groundwater) was noted beyond a depth of 1.3 meters in TP 3-19.

Considering the granular nature of the underlying deposits, the groundwater elevations are likely directly related to the elevations of the Nordenskiold River which is located approximately 300 meters west of the study area.

3.3 Bedrock

There was no indication of bedrock in any of the test pits which were excavated.

3.4 Permafrost

Carmacks is located in a zone where extensive discontinuous permafrost may be present (as identified in the Permafrost Map of Canada - Heginbottom et al, 1995).

Permafrost was encountered in test pits TP 1-19 and TP 2-19 immediately below a 250 mm thick layer of moss and rootlets. The frozen soils in test pits TP 1-19 and TP 2-19 were classified as being well bonded with no excess ice (Nbn – moisture content = 210%) and as having visible ice crystals in size to 2 mm (Vx - moisture content = 390%), respectively, in accordance with the *National Research Council* classification of frozen soils.

A digital thermo-coupler type of thermometer which was utilized during the field work program indicated the soil temperature of the frozen soils were minus 0.1° Celsius, which is typical for permafrost encountered in the Yukon.

The presence of permafrost in Area C (Figure 3) is likely due to the proximity to the steep slope which is located within the sites eastern realms which limits the available amount of sunlight. The extent to which the shade may have promoted permafrost formation in Area B is unknown however portions of this region exhibits hummocky terrain and areas of thick organic moss cover which are an indication of permafrost.



Area B site conditions.

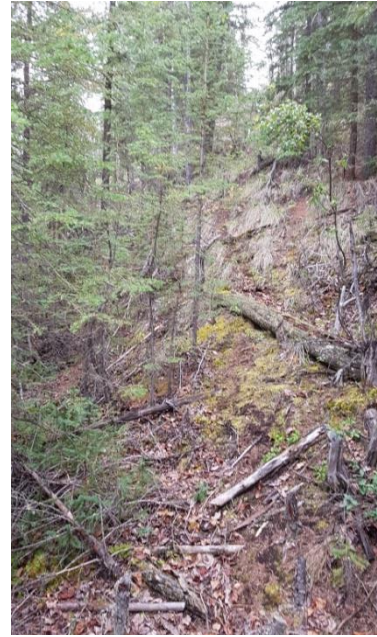


3.5 Slope Conditions

There are two slopes located immediately east and southeast of the study area.

The eastern slope measures in the order of 30 meters in height and is bisected by a trail which cuts into the side-slope to allow for access to the power transmission line. The slope is likely comprised of glaciofluvial terrace deposits. These deposits are comprised of pebble to cobble gravel, massive to thick bedded. They are often incised into flights of terraces by glacial streams and measure between 1 meter to greater than 10 meters thick.

The southeastern slope measures in the order of 20 meters in height and is likely comprised of glaciofluvial ice stagnation complex deposits. The surficial geology map (*GSC Map 1879A*) classified these deposits as being



Southeastern slope conditions.

commonly comprised of a poorly to moderately sorted sand and gravel diamicton which was deposited during equilibrium phases of glacial retreat. They can contain cobble to boulder sized materials and minor amounts of silt and clay.

By visual estimate, it appeared that approximately 50% of these respective slopes were covered in vegetation. Large trees were established on the southeastern slope.

In brief, while there were minor indications of creep along the southeastern slope as evidenced by intermittent tree trunk and willow stalk deformation, neither of the slope exhibited any indication of slope movement which would be cause for concern.

4.0 DISCUSSIONS

4.1 Development Potential

The development potential of the site is limited. At this stage, based upon the soil conditions which were encountered in test pit TP 3-19, it appears the western region of the site could be developed in Area A (Figure 3). However, further geotechnical evaluation would be required to determine the degree to which these thawed soil deposits extend towards the east as permafrost (which would preclude development) was encountered in Area C. The presence of the steep slopes located within the sites eastern and southeastern realms limits the amount of sunlight available to the central regions (Area B) of the study area and so the permafrost may extend into this region.

The presence of shallow groundwater and fine-grained soil deposits (which exhibited slight plasticity) in Area A would make building construction and septic field installation in this region challenging if development occurs.

Based upon our observations, it appears clearing and grubbing operations utilizing conventional construction methodologies should be feasible in the western regions of study area where subdivision development may occur. During this time, timber would need to be salvaged as outlined by the land use permit(s).

If development is deemed feasible, clearing and grubbing operations should not encroach any closer than 30 meters relative to the base of steep slopes or where permafrost is located in the eastern regions of the site.

4.2 Building Foundations

If development of the western realms of the study area is deemed feasible, based upon the subsurface conditions which were encountered test pit TP 3-19, it's likely buildings could be constructed utilizing conventional footing or monolithic-slab types of concrete foundation systems which are founded upon the underlying granular glaciofluvial plain deposits.

Additional consideration will be required during design and construction relative to shallow groundwater which is anticipated within the study area.



4.3 Sulphate Ion Analysis

The total sulphate ion content of two (2) soil samples was determined by our laboratory sub-consultant *Golder Associates Ltd.* in accordance with *CSA Standard A23.1 – 3C*. The purpose of the analysis was to assess the aggressiveness of the native and potentially imported soils relative to cast-in-place concrete.

The native soil sample (TP 3-19 - No.6) was comprised of a sandy silt which was retained from the glaciofluvial plain deposits. The total sulphate ion content analysis of this sample was determined to be 0.07 %.

The potentially imported material sample was comprised of sandy gravel which was retained from the *YG* gravel quarry (Disposition No.900101) located at km 354.3 RHS of North Klondike Highway #2. The sulphate ion analysis of this sample revealed the total sulfate ion content was 0.06 %.

As these values are lower than 0.10 % threshold set forth by the *American Concrete Institute – Building Code Requirements for Structural Concrete* (ACI 318-05 – Table 4.3.1), the potential for sulphate exposure is expected to be negligible. As such, it is anticipated that standard concrete which is designed as described herein can be utilized during the foundation work. Consideration should be given to testing the imported fills which will be utilized during foundation construction/backfill to verify their suitability once their source has been determined.

The results of the sulphate ion content analysis have been attached in Appendix B.

4.4 Septic Field Suitability

The results of the hydrometer analysis were utilized to determine the amount of clay sized particles (<0.002 mm) contained within a sample retained from test pit TP 3-19. This allowed for the respective percentages of sand, silt and clay to be plotted on the *Soil Texture Classification Triangle* such that the materials overall suitability for use as accepting (septic field) soils could be determined as is typical in provincial jurisdictions where regional assessments are conducted.

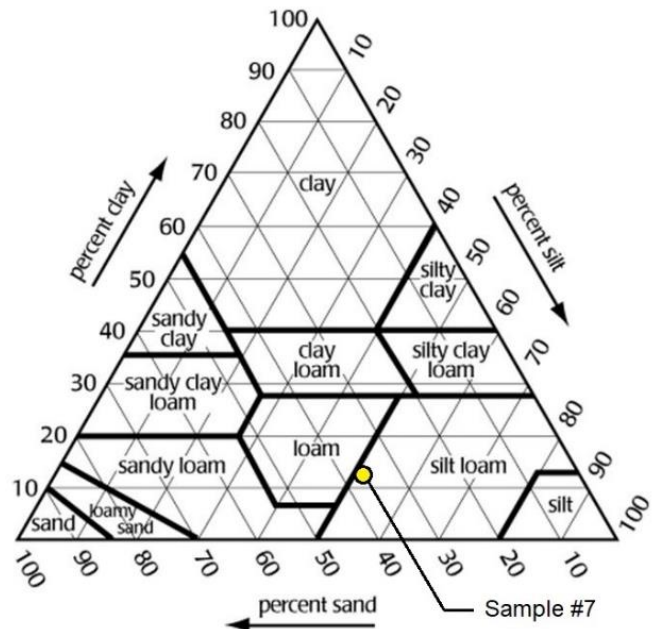
The percentages of sand, silt and clay for the sample was determined as follows;



<i>Test Pit</i>	<i>Sample No.</i>	<i>Sand %</i>	<i>Silt %</i>	<i>Clay %</i>	<i>Textural Soil Classification</i>
TP 3-19	7	37.0	51.1	11.9	silt loam

The sample was subsequently plotted on the *Soil Texture Classification Triangle* as noted in the figure, right;

Relative to the *Province of Manitoba – Onsite Wastewater Management Systems Program*, the soil sample was classified as being suitable for traditional subsurface systems. However, as the Atterberg limit analysis of the sample indicated that it exhibits slight plasticity, these soils will not likely allow for adequate percolation rates. In addition, as the presence of shallow groundwater was identified, the conditions in the study area may not be suitable to allow for septic field installation as the groundwater would be considered a nearby underlying confining layer.



Given the variability in the soils which were encountered and as required by *Yukon Health and Social Services*, site-specific assessments would need to be conducted at the time of individual lot development through percolation testing to verify the suitability of the anticipated accepting soils relative to *YG – Design Specifications for Sewage Disposal Systems*.

As the soil types and subsurface conditions will likely prevent traditional septic field construction, the use of insulated holding tanks or else raised septic fields may be required if lot/subdivision development is deemed feasible.

4.5 Potential Hazards

Our observations of the slopes located within and adjacent to the eastern region of the study area did not reveal any signs of slope movement which would be cause for concern.



As the eastern region (Area C) of the study area harbored ice-rich permafrost, the proximity of development relative to this sensitive thermal regime will need to be considered such that potential thaw does not pose a hazard to regions located down-gradient to the west.

Final design elevations will need to be carefully considered relative to the 1:200-year flood event outlined in the *Village of Carmacks - Official Community Plan (OCP)*.

4.6 Geotechnical Setbacks

Assuming the site conditions will allow for subdivision development in the western and potentially central regions of the study area, geotechnical setbacks should be observed relative to the permafrost and steep slopes which are located in the eastern and southeastern regions of the study area. Typically, 30-meter setbacks from the limit of the permafrost and the base of steep slopes would be utilized. The purpose of the setback(s) would be to minimize potential disturbance to the permafrost regime and create a buffer relative to increased surface water runoff and potential slope movements.

4.7 Seismic Site Response

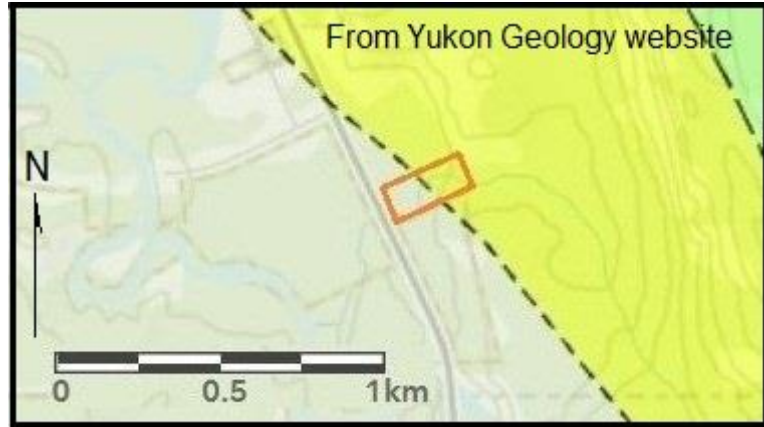
The study area was classified for seismic site response in accordance with the *National Building Code of Canada*, based upon the information obtained during the field work program. In general, the classification is based upon the type of soils that are located below the intended structure(s) as follows:

CLASS	SOIL TYPE
A	hard rock
B	rock
C	dense soil or soft rock
D	stiff soil
E	>3 m of 'soft soil'
F	Others (liquefiable, peat, etc.)

Based upon the presence of the granular glaciofluvial plain deposits, the soils within the study area would be classified as a Class D site.



Additional consideration may be required relative the presence of an unclassified fault which bisects the central regions of the study area. The approximate location of this fault was identified in the *Yukon Geology* website as noted right;



4.8 Geotechnical Evaluations

Further geotechnical evaluation would be required to better assess the study area to verify whether or not the western and central regions will be suitable to allow for subdivision/lot development. The intent should be to delineate the approximate limits/distribution of the permafrost which was encountered and further characterize the depositional setting relative to the ancient/historical drainage course which appears to have flowed through the study area.

New *Google Earth* satellite imagery dated August 21st, 2019 suggest that nearby test pits (in *YG* - Disposition No.900101), which may have been recently excavated by *YG* – *Department of Highways and Public Works*, are located north of the site as illustrated in the imagery noted, right.



These test pit soil logs should be reviewed to further characterize the regional soil conditions.

As access to the site is restricted due to the presence of a forest, access trails would need to be prepared to allow for additional subsurface investigation. We’ve noted the



locations of potential exploration trails originating from the newly identified *YG* test pit trails as illustrated in the figure above.

If subdivision development is deemed feasible, geotechnical evaluations should be conducted at any location where buildings and subsurface infrastructure is proposed to verify site-specific geotechnical parameters.

4.9 Hydrogeological Assessment

A hydrogeological study would be required to assess the feasibility of installing water wells within the study area.



5.0 RECOMMENDATIONS

The following recommendations have been provided as a guideline assuming development of the western realms of the study area will be feasible. Additional consideration will be required following completion of a supplemental geotechnical evaluation considering the presence of permafrost which was encountered in the eastern regions of the study area.

5.1 Deleterious Materials

The surficial organics, volcanic ash, remnant stripping/grubbing piles and fine-grained soil deposits which overlie the granular glaciofluvial plain deposits are deleterious and so would need to be removed from beneath building load envelopes. In addition, the deleterious surficial organics, volcanic ash and remnant stripping/grubbing materials would need to be removed from below roads and parking areas to allow for sub-base and base construction in these areas. As the fine-grained soil deposits are susceptible to a loss of strength if they become disturbed, wet or desiccated, caution will need to be exercised during construction. Temporary roads and laydown areas may need to be prepared in order to facilitate subdivision/lot development and building construction.

Surficial organics which are removed during site preparation should be stockpiled separately and either utilized for landscaping or else removed from the site.

The non-plastic fine-grained soil deposits can be utilized as general purpose (non-structural) fill so long as the materials are compacted to approximately 95% of the materials corresponding maximum proctor density at (or near) the materials optimum moisture content.

Soils which exhibit any degree of plasticity or which are wet to saturated will need to be removed from the site and wasted.

The ice-rich permafrost which was encountered in the eastern regions of the site (Area C) would also be considered deleterious and so the vegetation and organic mat in (and within 30 meters of) this region should not be disturbed. Disturbance would result in thaw which at this stage is undesirable.

5.2 Building Foundations

Buildings in thawed regions can be constructed utilizing conventional footing or monolithic-slab types of concrete foundation systems which are founded upon the underlying granular glaciofluvial plain deposits.

Additional consideration will be required during design and construction relative to shallow groundwater which is anticipated within the study area.

5.3 Roads & Parking Areas

The soils which were encountered in the western regions of the study area would allow for the construction of roads and parking areas where thawed soil deposits are present. Considering the anticipated industrial nature of lot development, we anticipate that the thickness of the road structure would measure in the order of 1.0 meters. The thickness of the road would ultimately be dependent the anticipated traffic loads, loading frequency and subgrade conditions.

5.4 Geotechnical Setbacks

Assuming the site conditions will allow for subdivision development in the western and potentially central regions of the study area, (30 meter) geotechnical development setbacks should be observed relative to the permafrost and steep slopes which are located in the eastern and southeastern regions of the study area. The purpose of the setback(s) would be to minimize potential disturbance to the permafrost regime and create a buffer relative to increased surface water runoff and potential slope movements.

5.5 Geotechnical Evaluation

Further geotechnical evaluation would be required to better assess the study area to verify whether or not the western and central regions (Figure 3 – Areas A & B) will be suitable to allow for subdivision/lot development. The intent should be to delineate the approximate limits/distribution of the permafrost which was encountered and further characterize the depositional setting relative to the ancient/historical drainage course which appears to have flowed through the study area. Detailed foundation recommendation would need to be formulated based upon these soil and subsurface conditions. The results of the test pits, which may have been recently excavated by YG



– *Department of Highways and Public Works* just north of the site, should be reviewed to better assess the regional soil conditions at this time.

As access to the site is restricted due to the presence of a forest, access trails would need to be prepared to allow for additional subsurface investigation (as illustrated in Section 4.8, above).

If subdivision development is deemed feasible, geotechnical evaluations should be conducted at any location where buildings and subsurface infrastructure is proposed to verify site-specific geotechnical parameters.

5.6 Site Survey

Although topographical survey data of the site is available from 2014, a more recent survey should be undertaken by qualified personnel to assist the design team in establishing site grading profiles relative to the current site conditions.

6.0 CONCLUSIONS

6.1 Site Suitability

The development potential of the site is limited. At this stage, based upon the soil conditions which were encountered in test pit TP 3-19, it appears the western region of the site could be developed in Area A (Figure 3). However, further geotechnical evaluation would be required to determine the degree to which these thawed soil deposits extend towards the east as permafrost (which would preclude development) was encountered in Area C. The presence of the steep slope located within the sites eastern and southeastern realms limits the amount of sunlight available to the central regions (Area B) of the study area and so the permafrost may extend into this region.

The presence of shallow groundwater and fine-grained soil deposits (which exhibited slight plasticity) in Area A would make building construction and septic field installation in this region challenging if development occurs.

6.2 Deleterious Materials

The surficial organics, volcanic ash, remnant stripping/grubbing piles and fine-grained soil deposits which overlie the granular glaciofluvial plain deposits are deleterious and so would need to be removed from beneath building load envelopes. In addition, the deleterious surficial organics, volcanic ash and remnant stripping/grubbing materials would need to be removed from below roads and parking areas to allow for sub-base and base construction in these areas.

Caution will need to be exercised if construction occurs as the fine-grained soil deposits located in the study area are susceptible to a loss of strength if they become disturbed, wet or desiccated. As such, temporary roads and laydown areas may need to be prepared in order to facilitate subdivision/lot development and building construction.

Surficial organics which are removed during site preparation should be stockpiled separately and either utilized for landscaping or else removed from the site.

The non-plastic glaciofluvial plain deposits can be utilized as general purpose (non-structural) fill so long as the materials are compacted to approximately 95% of the materials corresponding maximum proctor density at (or near) the materials optimum moisture content.



Soils which exhibit any degree of plasticity or which are wet to saturated will need to be removed from the site and wasted.

The ice-rich permafrost which was encountered in the eastern regions of the site (Area C) would also be considered deleterious and so the vegetation and organic mat in (and within 30 meters of) this region should not be disturbed. Disturbance would result in thaw which at this stage is undesirable.

6.3 Surface Utilities

The construction of roads and ditches utilizing conventional cut/fill construction methodologies will be feasible in the study area following adequate site preparation. In general, this will require the removal of the surficial organics and volcanic ash following clearing and grubbing operations. While the granular components of the road structure would measure in the order of 1.0 meters thick, the constructed thickness would need to be based upon the subgrade conditions which are encountered at the time of construction, the anticipated traffic loads/frequency and the design elevations.

The drainage in the region of building sites, septic fields and roadways should be carefully controlled to direct surface water away from the infrastructure. Additional consideration may be required relative to the drainage course which was identified in the *YG – Water Placer Atlas* as described in Section 3.1, above.

6.4 Building Foundations/Construction

Buildings can be founded upon conventional footing or monolithic-slab types of concrete foundation systems which are founded upon approved granular glaciofluvial plain deposits. However, as these deposits are predominately frost susceptible, the foundations will need to be designed and constructed as determined through subsequent geotechnical evaluations. Additional consideration may be required relative to the shallow groundwater which was encountered. As such, site-specific geotechnical evaluations should be conducted to verify the foundation design parameters.

6.5 Sulphate Attack Potential

The sulphate ion content analysis revealed the potential for sulphate exposure is expected to be negligible. As such, standard concrete which is designed as described herein can be utilized during foundation work if subdivision/lot development is deemed feasible.

6.6 Septic Field Suitability

The soil sample which was analyzed suggests that the fine-grained glaciofluvial plain deposits may not be suitable to allow for installation of traditional septic fields as some of these soils exhibited slight plasticity. As such, these soils may not be sufficiently free draining to allow for adequate percolation rates. In addition, as the presence of shallow groundwater was identified, additional consideration would be required as the groundwater would constitute a confining layer which may preclude septic field construction. As such, the use of insulated holding tanks or else raised septic fields may be required if lot/subdivision development is deemed feasible.

Site-specific percolation tests will need to be conducted as required by *Yukon Health and Social Services* at the time of individual lot development to verify the suitability of the anticipated accepting soils at the proposed septic field locations relative to *YG – Design Specifications for Sewage Disposal Systems*.

6.7 Subsurface Utilities

New subsurface utility lines should be installed at a depth equivalent to 3 meters of soil cover for frost protection. Critical infrastructure should be well protected from frost through the use of insulated pipes, heat tape, re-circulation lines, overlying rigid insulation and other similar types of protective measures.

As shallow groundwater is anticipated in the thawed regions of the study area, subsurface utility installations will be challenging.

6.8 Seismic Site Classification

Based upon the information obtained during the field work program the study area was classified as a Class D site for seismic site response in accordance with the *National Building Code of Canada*.

Additional consideration may be required relative the presence of an unclassified fault which bisects the central regions of the study area (as discussed in Section 4.7, above).

6.9 Potential Hazards & Geotechnical Setbacks

While our observations of the slopes located within and adjacent to the study area did not reveal any signs of slope movement which would be cause for concern (30 meter)



geotechnical development setbacks should be observed relative to the base of the slopes due to the potential for increased surface water run-off and slope movements.

As the permafrost encountered in the eastern realms of the site may pose a potential hazard relative to thermal degradation, similar (30 meter) geotechnical development setbacks should be observed relative to this area.

Final design elevations will need to be carefully considered relative to the 1:200-year flood event outlined in the *Village of Carmacks - Official Community Plan (OCP)*.

6.10 Geotechnical Evaluations

Further geotechnical evaluation would be required to better assess the study area to verify whether or not the western and central regions (Figure 3 – Areas A & B) will be suitable to allow for subdivision/lot development.

6.11 Hydrogeological Assessment

A hydrogeological study would be required to assess the feasibility of installing water wells within the study area.



7.0 LIMITATIONS

This report is intended for the sole use of the *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 recommendations provided herein are based upon the subsurface conditions encountered at the time of our investigation, current construction techniques and generally accepted engineering practices. The content within this report reflects our best judgment in light of the information available to our firm at the time of report preparation.

The anticipated construction conditions have been discussed, but only to the extent that they may influence design decisions. Any references to construction methods contained herein, express our opinion and are not intended to direct contractors on how to carry out construction. Prospective contractors should be aware that the information presented herein and our corresponding discussions may not be sufficient to assess all factors that may have an effect upon construction. The elevations noted herein are for discussion purposes only.

It is important to emphasize that the geotechnical investigation component of any evaluation is, in fact, a random sampling of the site and that subsequent discussions and assessments of the retained information are based upon the results obtained at the sample locations. Due to the geomorphological nature of the deposits which were encountered, interpolations of the subsurface conditions between the test locations have not been made or been implied.

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

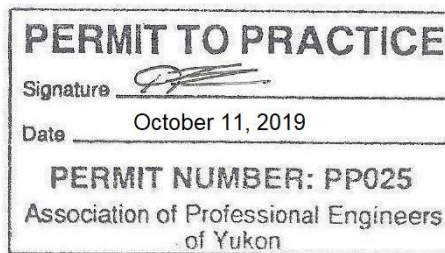
8.0 CLOSURE

Thank you for providing our firm with the opportunity to conduct the above noted geotechnical evaluation.

We trust that the information we have provided will be suitable for your purposes, 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

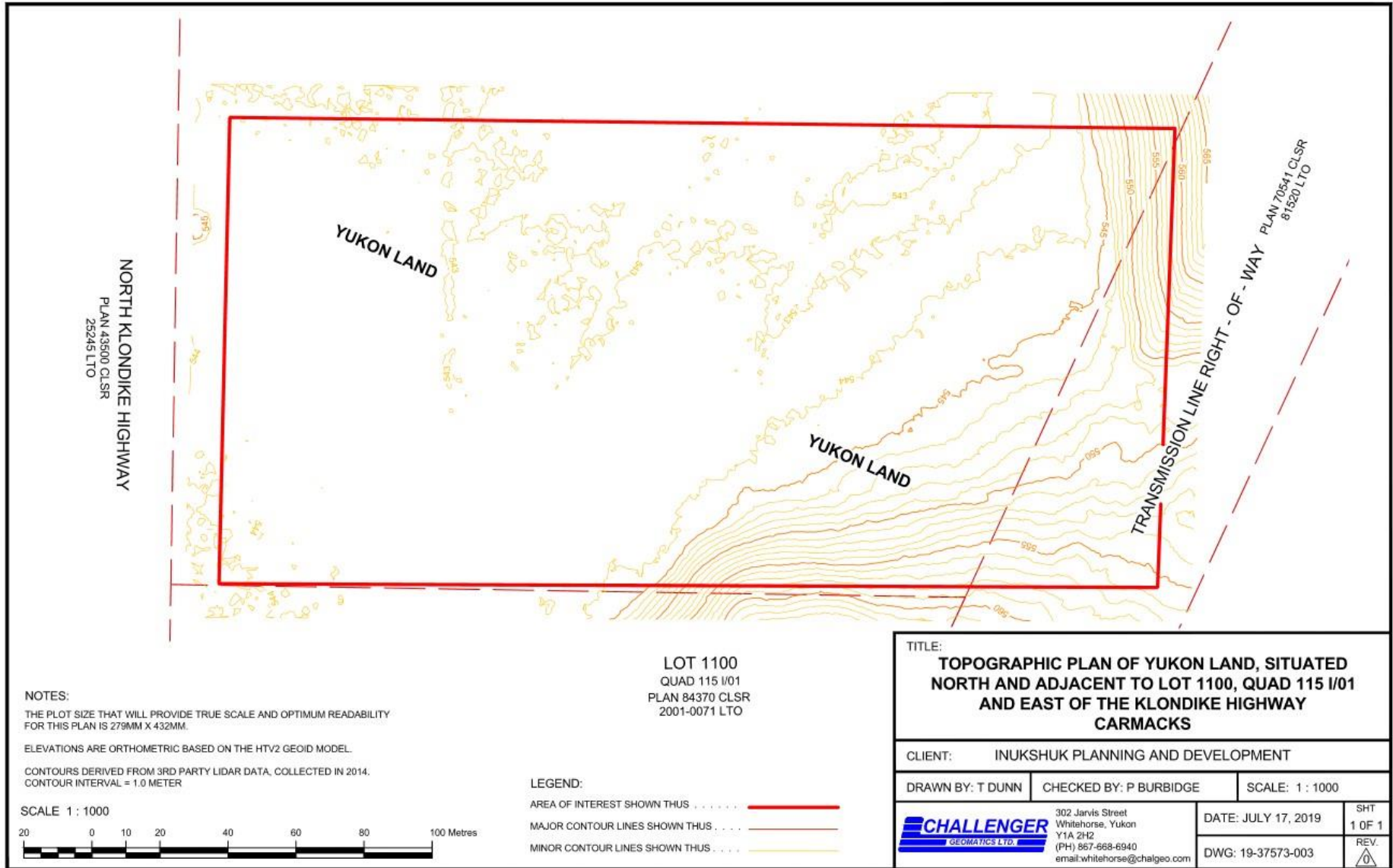


Geotechnical Evaluation
Proposed Industrial Subdivision
km 353.7 RHS – North Klondike Highway #2 - Carmacks, Yukon – 2019
Figure 1 – Location of Study Area





Geotechnical Evaluation
Proposed Industrial Subdivision
km 353.7 RHS – North Klondike Highway #2 - Carmacks, Yukon – 2019
Figure 2 – Site Topography



NOTES:
THE PLOT SIZE THAT WILL PROVIDE TRUE SCALE AND OPTIMUM READABILITY FOR THIS PLAN IS 279MM X 432MM.

ELEVATIONS ARE ORTHOMETRIC BASED ON THE HTV2 GEOID MODEL.

CONTOURS DERIVED FROM 3RD PARTY LIDAR DATA, COLLECTED IN 2014.
CONTOUR INTERVAL = 1.0 METER

SCALE 1 : 1000



LOT 1100
QUAD 115 I/01
PLAN 84370 CLSR
2001-0071 LTO

LEGEND:

- AREA OF INTEREST SHOWN THUS
- MAJOR CONTOUR LINES SHOWN THUS
- MINOR CONTOUR LINES SHOWN THUS

TITLE:
TOPOGRAPHIC PLAN OF YUKON LAND, SITUATED NORTH AND ADJACENT TO LOT 1100, QUAD 115 I/01 AND EAST OF THE KLONDIKE HIGHWAY CARMACKS

CLIENT: INUKSHUK PLANNING AND DEVELOPMENT

DRAWN BY: T DUNN CHECKED BY: P BURBIDGE SCALE: 1 : 1000

CHALLENGER
GEOMATICS LTD.
302 Jarvis Street
Whitehorse, Yukon
Y1A 2H2
(PH) 867-668-6940
email:whitehorse@chalgeo.com

DATE: JULY 17, 2019 SHT 1 OF 1
DWG: 19-37573-003 REV.



Geotechnical Evaluation
Proposed Industrial Subdivision
km 353.7 RHS – North Klondike Highway #2
Carmacks, Yukon - 2019

Figure 3 – Development Potential & Test Pit Locations



Base map from *Google Earth*- Not to Scale – Locations are approximate
Compiled by T.Dhara, P.Eng. – Sept.10th, 2019




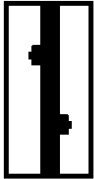
APPENDIX A

Soil Logs



NOTES ON SOIL LOGS

Soil Log - Sample Type

<u>Symbol</u>	<u>Test Pitting</u>	<u>Drilling</u>
	<p>Grab Samples Retained from excavation sidewall or base</p>	<p>Auger Sample Retained from auger flighting</p>
	<p>Bucket Sample Retained from leading edge of excavator bucket</p>	<p>Split-Spoon Sample Retained from Split-Spoon sampler tube</p>

Soil Description

The soil is named after its principal component and modified by other components as follows;

<u>Percent of Component</u>	<u>Modifier</u>
> 15 %	XXX - ey
11% to 15%	some XXX
5% to 10%	trace XXX

Examples;

<u>SILT</u>	<u>SAND</u>	<u>GRAVEL</u>	<u>Description</u>
6	32	62	Sandy Gravel trace Silt
55	6	39	Gravelly Silt trace Sand
43	36	21	Silty Gravelly Sand

Note: In the cases where the coarse fraction (sand & gravel) comprise > 50% of the sample, then the larger component of the coarse fraction becomes the principal component.



Relative Density / Consistency (Qualitative Classification)

Granular Soils (Relative Density)

- Very Loose - Considerable sidewall slough noted
- Loose - Some sidewall slough noted – Easy digging
- Compact/ Medium-Dense - Unimpeded excavation – little to no sidewall slough
- Dense - Considerable effort required during excavation – Stable vertical sidewalls
- Very Dense - Extreme difficulty in excavation

Cohesive (fine-grained) Soils (Consistency)

- Very Soft - Exudes between fingers when squeezed by hand
- Soft - Molded by light finger pressure
- Firm - Molded by strong finger pressure
- Stiff - Cannot be molded by fingers – Can be indented by thumb
- Very Stiff - Can only be indented by thumbnail
- Hard - Cannot be indented by thumbnail

At times, the consistency of non-plastic fine-grained soils are described utilizing the relative density terms.

Relative Moisture

Described as - *dry, damp, moist* or *wet* - relative to the principal soil matrix.

For example, a moisture content of 10 percent may be classified as ‘*moist to wet*’ for a coarse grained soil (sand or gravel) but ‘*damp*’ for a fine-grained cohesive soil.

The moisture content is recorded as a percentage (%) of the weight of water within the soil sample relative to the dry weight of the sample.

Recovery

Refers to the (linear) amount of sample retained after driving the Split Spoon (SPT) sampler tube 18 inches.

Recorded as a percentage (i.e. 12 inch sample/18 drive = 66 %)



N-Value

Refers to the total number of blows required to drive the Split Spoon sampler tube the final 12 inches of the 18 inch drive.

Relative Density based upon SPT 'N' Value

Non-cohesive (Granular) Soil		Cohesive (Clayey) Soils	
Relative Density	Blows per Foot (N-value)	Consistency	Blows per Foot (N-value)
<i>Very Loose</i>	< 5	<i>Very Soft</i>	0 to 2
<i>Loose</i>	5 to 9	<i>Soft</i>	3 to 4
<i>Compact</i>	10 to 29	<i>Firm</i>	5 to 8
<i>Dense</i>	30 to 50	<i>Stiff</i>	9 to 15
<i>Very Dense</i>	> 50	<i>Very Stiff</i>	16 to 30
		<i>Hard</i>	> 30

Undrained Shear Strength of Cohesive Soils

Consistency	Undrained Shear Strength	
	p.s.f	kN/m ²
Very Soft	< 375	<20
Soft	375-750	20-40
Firm	750-1500	40-75
Stiff	1500-3000	75-150
Very Stiff	3000-6000	150-300
Hard	>6000	<300



Description & Classification of Frozen Soils – National Research Council (NRC)
















(Adapted from Linnell & Kaplar, 1966)

1. DESCRIBE SOIL INDEPENDENT OF FROZEN STATE	Classify Soil by The Unified Soil Classification System				
2. MODIFY SOIL DESCRIPTION BY DESCRIPTION OF FROZEN SOIL ^(a)	Major Group		Subgroup		
	Description (b)	Designation	Description (b)	Designation	
	Segregated ice not visible by eye	N	Poorly bonded or friable	Nf	
			Well Bonded	No excess ice	Nbn
				Excess ice	Nbe
Segregated ice visible by eye (ice less than 25 mm thick)	V	Individual ice crystals or inclusions	Vx		
		Ice coatings on particles	Vc		
		Random or irregularly oriented ice formations	Vr		
		Stratified or distinctly oriented ice formations	Vu		
3. MODIFY SOIL DESCRIPTION BY DESCRIPTION OF SUBSTANTIAL ICE STRATA ^(a)	Ice greater than 25 mm thick	ICE	Ice with soil inclusions	ICE + Soil Type	
			Ice without soil inclusions	ICE	

(a) Reference ASTM D4083.



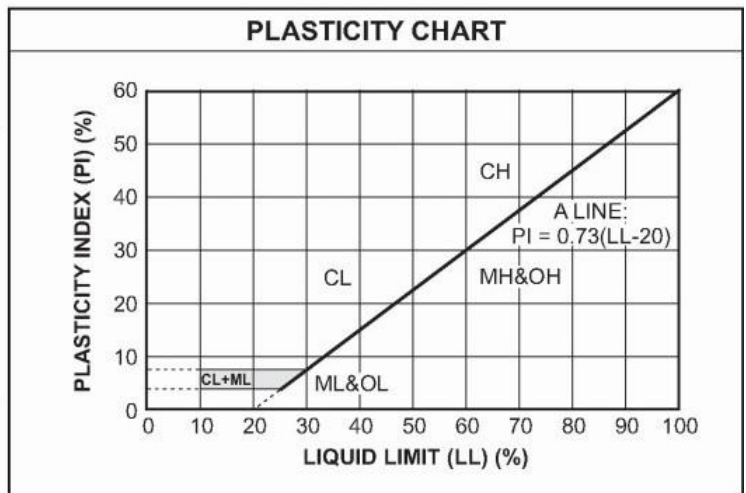
Unified Soil Classification System

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART		
COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)		
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	
	 GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	 GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	
	 GM	Silty gravels, gravel-sand-silt mixtures
	 GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	
	 SW	Well-graded sands, gravelly sands, little or no fines
	 SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	
	 SM	Silty sands, sand-silt mixtures
	 SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)		
SILTS AND CLAYS Liquid limit less than 50%	 ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
	 CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	 OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	 MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	 CH	Inorganic clays of high plasticity, fat clays
	 OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	 PT	Peat and other highly organic soils

LABORATORY CLASSIFICATION CRITERIA		
GW	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3	
GP	Not meeting all gradation requirements for GW	
GM	Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
GC	Atterberg limits above "A" line with P.I. greater than 7	
SW	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3	
SP	Not meeting all gradation requirements for GW	
SM	Atterberg limits below "A" line or P.I. less than 4	Limits plotting in shaded zone with P.I. between 4 and 7 are borderline cases requiring use of dual symbols.
SC	Atterberg limits above "A" line with P.I. greater than 7	

Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:

Less than 5 percent GW, GP, SW, SP
 More than 12 percent GM, GC, SM, SC
 5 to 12 percent Borderline cases requiring dual symbols





APPENDIX B

Golder Associates Laboratory Results

Atterberg Limit Analysis

Hydrometer Analysis

Sulphate Ion Content Analysis



DETERMINATION OF TOTAL OR WATER-SOLUBLE SULPHATE ION CONTENT OF SOIL CSA A23.2-3B

September 6, 2019

Project Number: 1780303-6000

CHILKOOT GEOLOGICAL ENGINEERS LTD.
5B Bennett Road
Whitehorse, YT
Y1A 5P7

Attention: Mr. Tares Dhara, P.Eng.

PROJECT: Carmacks, Yukon

Date sampled: August 11, 2019

Sampled by: Client - TD

Date tested: August 30, 2019

Tested by: RZ

Site Location	Sample ID	Total Sulphate Ion Content %	Water-Soluble Sulphate Ion Content %
Industrial Site #2	TP3-19, Sample #6	0.07	Not Applicable *
YG Pit - Disposition #900101	Sample #1	0.06	Not Applicable *

Notes:

- * Per Clause 9.1.4, the water-soluble sulphate ion content need not be tested when the total sulphate ion content is less than 0.20%
- Detection limit for the test is 0.005%

Reported by: R. Zhu

Reviewed by: _____

S. John, AScT



Notice: The test data given herein pertain to the samples provided. This report constitutes a testing service only. Interpretation of the data given here may be provided upon request.

Client: Chilkoot Geological Engineers Ltd.
Project: Carmacks, Yukon
Location: Whitehorse, YT
Project No.: 1780303 **Phase:** 6000

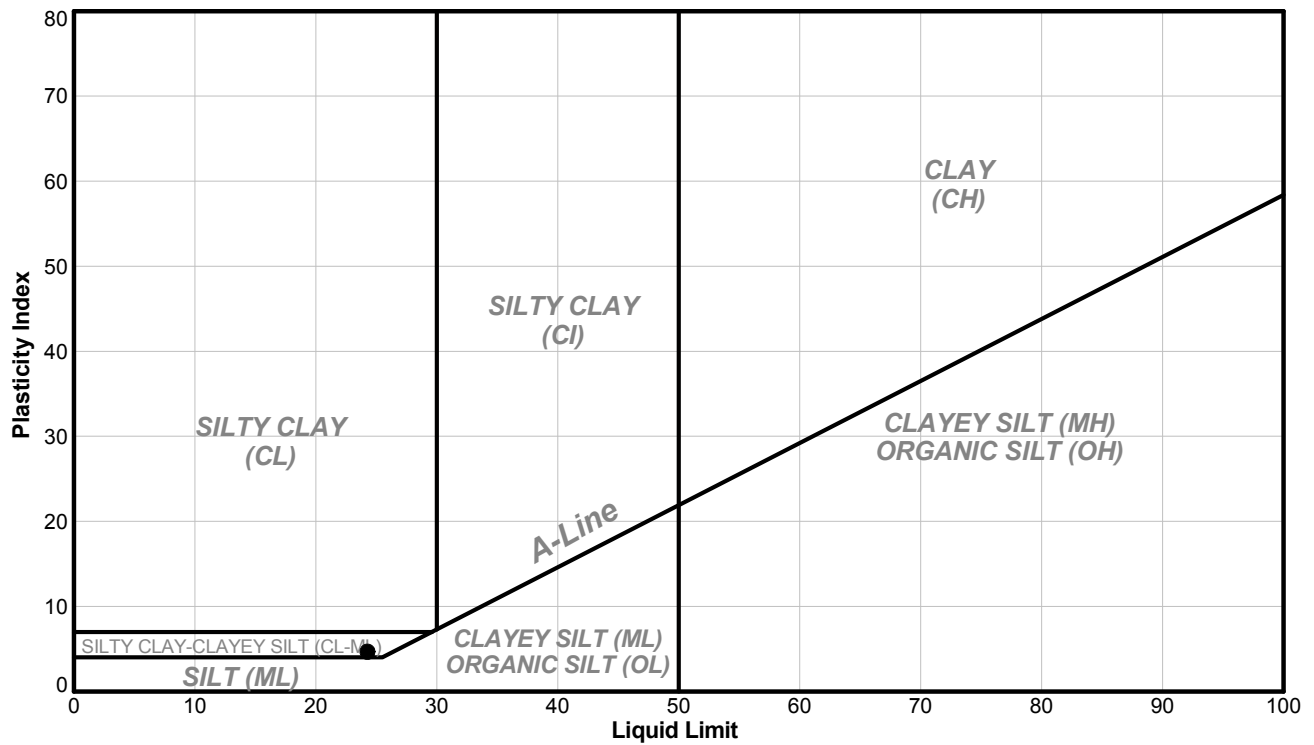
ID: Industrial Site #2
Sample No.: TP3-19 - SA7
Depth (m): 2.0
Lab Schedule No.: B19-275

Other Remarks: N/A

Test Method: A-Multi Point

Preparation Method: Air Dried

PLASTICITY CHART



National IM Server:GINT_GAL_NATIONAL\IM Unique Project ID: Output Form: LAB ATTERRBERG CASAGRANDE (SINGLE) 2018 SJ.dgn 6/9/19

Sym.	Sample Location	Sample / Specimen Number	Depth (m)	Bottom (m)	Percent Passing #40 Sieve (%)	Liquid Limit	Plastic Limit	Plasticity Index	Natural Water Content (%)	Liquidity Index
●	Industrial Site #2	TP3-19 - SA7	0.00	0.00	100	24	20	4.0	16.0	-1.0

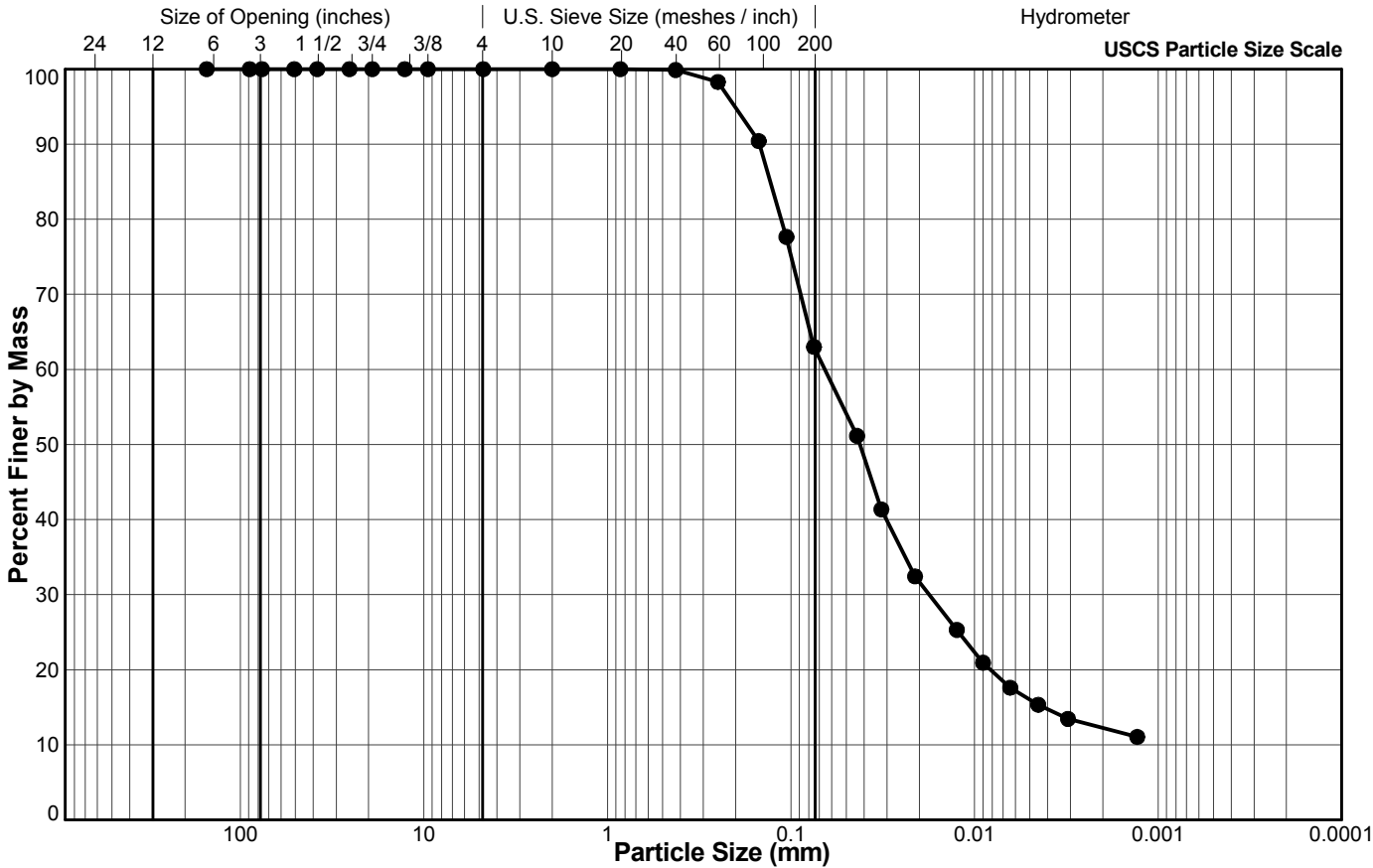
NP - NON-PLASTIC RESULT ND - NOT DETERMINED

Note: The test data given herein pertain to the sample provided only. This report constitutes a testing service only.

JH	8/30/2019	SJ	9/4/2019
Tech	Date	Checked	Date

Client: Chilkoot Geological Engineers Ltd.
Project: Carmacks, Yukon
Location: Whitehorse, YT
Project No.: 1780303 **Phase:** 6000

Sample Location: Industrial Site #2
Sample No.: TP3-19 - SA7
Depth (m): 2.0
Lab Schedule No.: B19-275



Legend

Sieve Size (USS)	Particle Size (mm)	Percent Passing
6"	152.4	100.0
3.5"	88.9	100.0
3"	76.2	100.0
2"	50.8	100.0
1 1/2"	38.1	100.0
1"	25.4	100.0
3/4"	19.1	100.0
1/2"	12.7	100.0
3/8"	9.5	100.0
#4 US MESH	4.75	100.0
#10 US MESH	2	100.0
#20 US MESH	0.85	100.0
#40 US MESH	0.425	99.9
#60 US MESH	0.25	98.3
#100 US MESH	0.15	90.4
#140 US MESH	0.106	77.7
#200 US MESH	0.075	63.0
	0.0437	51.2
	0.0322	41.3
	0.0211	32.4
	0.0125	25.3
	0.0090	20.9
	0.0064	17.6
	0.0045	15.3
	0.0031	13.4
	0.0013	11.0

BOULDER	COBBLE	GRAVEL		SAND			FINES (Silt, Clay)
		Coarse	Fine	Coarse	Medium	Fine	

DC/VN

8/28/2019

SJ

9/4/2019

Tech

Date

Checked

Date



APPENDIX C

Recommended Grain Size Distribution for Imported Fills

CHILKOOT GEOLOGICAL ENGINEERS LTD.



Appendix C

Recommended Grain Size Distribution for Imported Fill

Gran E Pit Run	
Sieve Size (mm)	% Passing By Wt
200	100
80	75-100
25	55-100
12.5	42-84
5	26-65
1.25	11-47
0.315	3-30
0.08	2-13
LA Abrasion 35 % Max Loss	

80 mm minus Sub-base	
Sieve Size (mm)	% Passing By Wt
80	100
25	60-100
12.5	40-90
5	20-65
1.25	9-35
0.315	3-15
0.08	0-8
LA Abrasion 35 % Max Loss	

Clear Stone	
Sieve Size (mm)	% Passing By Wt
28	100
20	70-100
12.5	55-100
10	30-80
5	0-40
2	0-10
NA	NA
LA Abrasion 35 % Max Loss	

Bedding Sand	
Sieve Size (mm)	% Passing By Wt
10	100
5	80-100
2	55-100
0.63	25-65
0.25	10-40
0.08	2-10

20 mm minus Base Course	
Sieve Size (mm)	% Passing By Wt
20	100
12.5	64-100
5	36-72
1.25	12-42
0.315	4-22
0.08	3-6

Class I Rip-Rap	
Sieve Size (mm)	% Passing By Wt
450	100
350	80
300	50
200	20

Class II Rip-Rap	
Sieve Size (mm)	% Passing By Wt
800	100
600	80
500	50
300	20

Class III Rip-Rap	
Sieve Size (mm)	% Passing By Wt
1200	100
900	80
800	50
500	20