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Geotechnical Evaluation
Village of Carmacks and Little Salmon First Nation
Proposed Joint Residential Development Project
Carmacks, Yukon – 2017-2018

Prepared For: **Yukon Government**

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1.0 INTRODUCTION

This report is meant to supplement our January 26th, 2018 Geotechnical Evaluation of the Village of Carmacks and Little Salmon First Nation Proposed Joint Residential Development Project which is to be located in Carmacks, Yukon as noted in Figure 1. Specifically, it provides geotechnical recommendations pertaining to residential building foundations as well as surface and (shallow) subsurface utility installations at the proposed development, based upon the soil types and conditions which were encountered during our recent test-pit excavation program. This phase of our field work was conducted on June 1st, 2018 as it was not possible to excavate the test pits during the course of the winter.

While details regarding our scope-of-work, the general site conditions and our preliminary findings can be found in our January 26th, 2018 Geotechnical Evaluation Report, we have provided a description of our methodology which was employed during our test pit and corresponding laboratory work programs along with a description of the sub-surface conditions which were encountered. In addition, we have provided corresponding discussions, recommendations and conclusions which should allow for subdivision development as outlined herein and our January 26th, 2018 Geotechnical Evaluation Report.

2.0 METHODOLOGY

The methodology we employed during our test pit and laboratory work programs have been described below.

2.1 Field Work Program

The field work program was comprised of utility locates and a test pit excavation program.

Utility Locates

Utility locates were conducted prior to test pit excavation in order to confirm that the proposed test pit locations were clear of potential underground hazards. This involved contacting *Northwestel* and *ATCO Electric Yukon*.

Test Pit Program

A test pit program was conducted on June 1st, 2018 to assess the sub-surface conditions at select locations within the study area. This component of work was conducted by our Sr.Soils Technician Mr.G.Keitel.

The work consisted of excavating seven (7) test pits utilizing a *Bobcat E50* tracked excavator equipped with a digging bucket. The test pits were excavated to an average depth of 3.0 meters (but varied between 2.8 and 3.3 meters) below the existing ground surface at the approximate locations noted in Figure 4.


TP 1-18 – Facing North

The excavator was supplied and operated by *Yellow Truck Excavating Inc.* of Whitehorse, Yukon.

Site Reconnaissance

A brief reconnaissance of the culverts which cross River Road (Figure 2 – Area B) was conducted as the culverts could not be directly observed during our previous work in the winter. In brief, the primary culvert was comprised of a 600 mm diameter CSP culvert. Drainage through this culvert was noted to be considerable at the time of our observations. A 900 mm diameter CSP overflow culvert was noted at a higher elevation immediately adjacent to the primary culvert.


Culvert Inlets facing North

Survey

The test pit locations were surveyed during the work utilizing a hand-held GPS unit. Although there were minor variations in elevation, the test pit soil logs were each given arbitrary elevations of 100.0 meters due to the nature of the study.

Test Pit Soil Logs

During the test pit excavations, field soil logs were maintained by our Sr.Soils Technician to record the stratigraphy of the soils that were encountered.

In brief, the following information was recorded;

- Soil description
  (depths, color, relative moisture content and density, gradation/plasticity, inclusions, oxidation, transition zones)
- Sample depths and types
- Comments regarding excavation effort
- Other local observations

This information was utilized along with visual observations and results of the laboratory analysis in order to compile the Test Pit 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 '*NRC'* permafrost classification systems which were utilized in creating the soil logs.

Sampling Program

A total of thirty-five (35) soil samples were retained at regular intervals during the test pit excavations to allow for laboratory analysis (as described in Section 3.3, below).

Typically, samples located within the upper meter of each test pit were retained by hand from the excavation sidewalls. The remainder of the samples were retained from the leading edge of the excavator bucket.

Once the soil samples were retained, they were described on the field soil logs, sealed in air-tight plastic bags and numbered consecutively to allow for subsequent laboratory analysis.

Test Pit Termination

The test pits were terminated at an average depth of 3 meters, but varied between 2.8 meters (TP 7-18) and 3.3 meters (TP 2-18). Each of the test pits were terminated within alluvial deposits.

Refusal was not encountered in any of the test pits.

The test pit excavations were each left open for approximately 10 minutes following excavation in order to assess the excavation sidewall stability over the course of time. In addition, this time allowed for observations of groundwater seepage to be made.

In brief, with the exception of test pits TP 4-18 and TP 6-18 where groundwater was encountered, sidewall slough did not occur. TP 4-18 and TP 6-18 each collapsed to the approximate depth of what was deemed to be the level of the water-table at depths of 2.3 and 1.9 meters, respectively. Oxidized soils were noted at most test pit locations indicating the presence of seasonally/intermittent groundwater flow.

Seasonally frozen soils were encountered in four (4) of the seven (7) test pits.

Following our individual test pit observations, the excavations were backfilled with the excavation spoils. The test pits locations were subsequently marked utilizing survey lathe to allow for subsequent field location if required.

Photographic Documentation

Photos were taken during the course of the evaluation to document the field work, soil samples and site conditions.

2.2 Laboratory Work Program

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

The analysis was comprised of the following analysis;

Description of Analysis	***ASTM Analysis***	***Quantity***	***Laboratory***
Moisture Content	D 2216-92	35	Chilkoot Engineers
Grain Size Distribution	D 422-633	15	Chilkoot Engineers
Hydrometer and Atterberg Limit	D 422-633/D 4318-10	1	Golder Associates

The grain size distribution and Atterberg limit analysis was conducted in order to assist in soil classification utilizing the *Unified Soils 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 moisture content analysis have been denoted as 'MC' (◉ - Symbol) on the Test Pit Soil Logs enclosed in Appendix A.

The results of the hydrometer and limit analysis (TP 7-18 Sample # 35) has been attached in Appendix B.

3.0 SITE CONDITIONS

While the site conditions have been described in our January 26th, 2018 Geotechnical Evaluation Report (dated January 26th, 2018), we have summarized the sub-surface conditions which were encountered during our test pit program as follows;

3.1 Soil Stratigraphy

While alluvial soils were encountered within each of the test pits which were excavated within the study area, the corresponding soil stratigraphy within each of these test pits varied. In general, test pits TP 1-18 to TP 6-18, which were excavated along the upper bench (Figure 2 – Area E) each encountered similar soil conditions whereby fine grained alluvial deposits overlay granular alluvial deposits. The exception to this was test pit TP 7-18, which was encountered in the lower bench (Figure 2 – Area D), where fine grained alluvial deposits were encountered to the depth of test pit termination.

Fine Grained Alluvial Deposits

These deposits were comprised of surficial organics and fine grained silts and silty sands which contained varying amounts of organics and clay.

On average, these deposits were 1.3 meters thick (but measured up to 1.6 meters thick at TP 4-18 & TP 5-18). The surficial organic mat encountered at the ground surface measured on average 250 mm thick (but varied between 150 to 300 mm).

Test pit TP 7-18 encountered predominately wet fine grained sandy silts to the depth of test pit termination (2.8 meters). These soils were overlain with a 300 mm thick organic mat. The *Golder Associates Ltd.* hydrometer analysis of Sample No.35 retained from TP 7-18 indicated that the soils were comprised of;

Moisture	***Gravel***	***Sand***	***Silt***	***Clay***	***Description***	***USCS***
34.9	0.0	14.9	76.9	8.2	Silt some Sand trace Clay	ML

Granular Alluvial Deposits

These soils were predominately comprised of poorly graded sandy gravels. However, sandy silty gravels were encountered at test pits TP 4-18 & TP 5-18 and silty sands were encountered at test pit TP 6-18. With the exception of test pit TP 7-18, these soils were encountered to the depth of test pit termination.

The results of the laboratory analysis suggested that these siltier granular deposits contained up to 21% fines content (by weight).

3.2 Groundwater

Groundwater was encountered in test pits TP 4-18 and TP 6-18 at depths of 2.3 and 1.9 meters below the ground surface, respectively. While there was no sign of free-flowing groundwater in the other test pits, the presence of oxidation seams suggests that groundwater may be seasonally present throughout most of the study area.

TP 4-18

TP 6-18

3.3 Bedrock

There was no indication of bedrock during our test-pit program.

3.4 Permafrost

While seasonally frozen soils were encountered at the time of our test pit program, there was no indication permafrost is present within the study area.

4.0 DISCUSSIONS

4.1 General

Based upon the information retained during our field and laboratory work programs, the sub-surface conditions which were encountered support our initial assessment as noted in our January 26th, 2018 Geotechnical Evaluation Report. Specifically, the residential development will need to be limited to the regions of the upper bench (delineated as Area E in Figure 2) and as noted in Figure 3. Development on the lower bench (delineated as Area D in Figure 2) should be limited to light commercial and public use areas given the presence of wet fine grained soils which have a weaker bearing capacity and region which is more susceptible to potential flooding.

Additional consideration will need to be considered given relative to the construction of buildings, surface works and sub-surface utilities given;

- the presence of weak compressible fine grained alluvial deposits (which were encountered up to a depth of 1.6 meters in Figure 2 - Area E),
- the presence of groundwater (which was encountered as shallow as 1.9 meters), and
- the presence of granular alluvial deposits which contain >15% fines (as these soils will be susceptible to undesirable volume changes if frozen).

As such, some adjustment to the individual building and infrastructure designs may be required to accommodate site-specific conditions as the soil types, local terrain and subsurface conditions will vary across the study area. These conditions should be verified through site specific geotechnical evaluations at the locations of any proposed building structures or deep utilities.

4.2 Building Foundations

Buildings should generally be constructed utilizing monolithic slab types of concrete foundation systems. Additional caution will need to be exercised in regions where footings and slab-on-grade types of foundations are utilized as the need to provide adequate frost protection through (1.8 m) soil cover may place the underside of footing close to the groundwater table which was encountered in some regions of the study area. This close proximity (< 1 meter) will be undesirable as the allowable soil bearing capacity will be lower than noted and construction difficulties may be encountered. Consideration could be given to placing the footing components upon approved granular alluvial deposits at shallower depths and importing approved fills to attain the required amount of soil cover, however, the additional costs to import the additional materials may become prohibitive.

The presence of the shallow groundwater will not allow for full basements to be incorporated into the design of any building structures.

Residential buildings which are constructed utilizing monolithic slab types of concrete foundation systems should be founded upon a structural granular pad which extends to the underlying clean granular alluvial deposits or else upon a minimum 1.8 meter thick structural granular pad which is founded upon silty granular alluvial deposits. As such, the overlying fine grained deposits and granular alluvial deposits (which contain >15% fines) will need to be removed during foundation preparation and replaced with an approved clean structural fill to allow for monolithic slab construction.

While residential foundations which utilize footings and slab-on-grade components could be considered in regions of Area E (Figure 2) where higher elevations prevail, the presence of groundwater may become a liability where it is encountered at shallow depths relative to the underside of the footing components. In addition, given the compressible nature of the fine grained alluvial deposits, these materials will need to be removed from below the slab components to the depth of the underlying granular alluvial deposits to allow for placement of structural fills.

Building sub-structures which are prepared for light commercial and public use in the region of Area D will require the construction of structural granular pads which measure no less than 1.8 meters thick as described herein.

4.3 Surface Works

The surficial organics and organic silts will need to be removed from within the regions of the road load envelope (given the compressible nature of these soils) prior to placement of the proposed road structure. If organic or weak fine grained soils are encountered below the surficial organics and organic silts then depending upon the design elevations, these materials may need to be sub-excavated in order to allow for placement of the road structure which has adequate thickness to carry the anticipated traffic loads.

Additional consideration should be given to upgrading the culverts which cross River Road such that the drainage of Areas B & C (Figure 2) is improved. This may help assist in reducing groundwater levels in the region of the proposed development.

4.4 Subsurface Utilities

The granular alluvial soils (which were encountered at depths up to 1.6 meters) should be suitable to allow for the installation of shallow utilities. However, the surficial organic deposits and wet to saturated fine grained soils will not be suitable for use as trench backfill materials and so these materials will need to be wasted. In addition, if large cobbles and/or boulders are encountered, they too will not be suitable for use in trench backfill and so should also be removed from the site (or wasted in designated areas). In addition, organic rich soils which may be encountered at the trench sub-grade elevations may not be suitable for use given their compressible nature.

Additional consideration will be required during the design and construction phases where subsurface utilities extend to depths beyond the groundwater table (approximately 2 meters below the ground surface). The extent of construction dewatering operations and side slope stability will be directly related to the depth of pipe embedment below the ground surface. A geotechnical evaluation should be conducted if the site is to be serviced utilizing deep utilities.

5.0 RECOMMENDATIONS

5.1 General

The following recommendations have been provided to outline the geotechnical requirements for subdivision development. In general, residential development should be restricted to regions above the 1 in 200 year flood elevation(s) as noted in Figure 3. Building construction in the region of the lower bench (denoted as Area D in Figure 2) should be restricted to light commercial and public use structures once suitable substructures have been prepared.

The presence of weak compressible soils (which were encountered to depths of 1.6 meters) and shallow groundwater (which was encountered as shallow as 1.9 meters) will require additional consideration during the design and construction phases.

5.2 Monolithic Footing/Slab-On-Grade (Monolithic Slab)

Building structures can be supported by a monolithic slab foundation system founded upon an approved granular base constructed in accordance with recommendations provided below.

Founding Strata

The founding soils should be comprised of approved undisturbed granular alluvial deposits. The exception to this is in the lower bench (Figure 2 – Area D) where the founding soils will be comprised of fine grained alluvial deposits.

Allowable Bearing Pressure

The net allowable bearing pressure has been estimated to range between 125-140 kilopascals for monolithic slabs constructed on a granular base founded upon approved undisturbed granular alluvial deposits as described herein. The lower bearing values should be utilized in regions where the underlying granular alluvial deposits contain >15% fines content (by weight) or where sandy soils are encountered. This allowable bearing pressure should be reduced to 115 kilopascals for monolithic slabs constructed on a granular base founded upon approved undisturbed fine grained alluvial deposits.

These figures include the total of all live and dead loads.

Differential Movements

Foundations installed in accordance with the recommendations contained herein can expect to experience differential movements in the order of (+/-) 25 mm.

Structural Fill

The monolithic slab should be founded upon a structural granular pad comprised of an approved, clean, inorganic, well graded sand and gravel mixture.

The structural granular pads should be comprised of the following;

THICKNESS [A]	**COMPACTION** [B]	**COMPOSITION** [C]
200 mm [D]	100 %	20 mm minus crushed granular aggregate, Overlying
400 mm	100 %	80 mm minus sub-base course aggregate, Overlying
1200 mm[E]	98 %	200 mm minus pit run [F], Overlying
NA	NA	[G] filter fabric, overlying
NA	95 % (or as directed)	approved sub-grade

Notes;

[A] – The thickness of the granular pad should be uniform throughout its entirety. All materials should be placed in uniform, level lifts that do not exceed 150 mm in thickness, as measured following compaction. The exception to this would be the 200 mm thick layer of 20 mm minus granular aggregate which can be placed in a single lift so long as adequate compaction is attained. Total pad thickness to be 1.8 meters unless otherwise approved by qualified geotechnical personnel.

[B] – Indicates percent compaction relative to the materials Proctor maximum dry density at (or near, ± 2%) its optimum moisture content.

[C] – The imported fills should be comprised of a well graded sand and gravel mixture and should conform to the grain size distributions specified in Appendix C – Imported Fill Specifications

[D] – This thickness should be maintained below both the central slab and thickened peripheral slab components.

[E] – Thickness should be adjusted to attain underlying approved clean (<15% fines) granular alluvial deposits and design elevations or else measure no less than 1200 mm.

[F] – Material should be comprised of an approved (cobble) drain rock for structural pads prepared in the lower bench region (Figure 2 – Area D).

[G] – A geotextile filter fabric may be required at the sub-grade elevation to allow for additional structural support in regions where the composition and conditions of the founding soils are considered to be poor as determined by qualified geotechnical personnel (such as in the region of Area D – Figure 2).

5.3 Footings

Proposed residential structures may be supported by continuous or spread footings and slab-on-grade foundation systems constructed in accordance with the recommendations contained herein.

Allowable Bearing Pressure

The net allowable bearing pressure will range between 90-115 kilopascals for conventional strip footings and 105-130 kilopascals for spread footing types of foundation systems founded upon undisturbed granular alluvial deposits. The lower bearing values should be utilized in regions where the underlying granular alluvial deposits contain >15% fines content (by weight) or are comprised of sandy soils.

These figures include the total of all live and dead loads.

Differential Movements

Foundations installed in accordance with the recommendations contained herein can expect to experience differential movements in the order of (+/-) 20 mm.

Frost Protection

As a minimum, the underside of the footings should be placed at a depth of no less than 1.8 meters below the top of the prevailing adjacent exterior grade to allow for adequate frost protection.

If isolated spread footings are required, the footings should have a frost protection equivalent to 2.2 meters of earthen cover as measured from the underside of the footing.

The amount of earthen cover can be reduced if protective insulation is incorporated into the design.

Slab Components

The slab components should be structural separated from other components of the structure.

Structural Fill

The footing components should be founded upon a 150 mm thick layer of approved 20 mm minus crushed granular aggregate compacted to a minimum of 100 % of the materials corresponding maximum Proctor dry density at (or within ± 2% of) the materials optimum moisture content. These components should be placed upon approved granular alluvial deposits.

Interior backfill (below slab components) should be comprised of the following;

THICKNESS [A]	**COMPACTION** [B]	**COMPOSITION** [C]
100 mm	100 %	20 mm minus crushed granular aggregate, Overlying
200 mm	100 %	80 mm minus sub-base course aggregate, Overlying
As required [D]	98 %	200 mm minus pit run, Overlying
NA	NA	[E] filter fabric, overlying
NA	95 % (or as directed)	approved granular alluvial deposits

Notes;

[A] – The thickness of the granular pad should be uniform throughout its entirety. All materials should be placed in uniform, level lifts that do not exceed 150 mm in thickness, as measured following compaction. The exception to this would be the 200 mm thick layer of 80 mm minus granular aggregate which can be placed in a single lift so long as adequate compaction is attained.

[B] – Indicates percent compaction relative to the materials Proctor maximum dry density at (or near, ± 2%) its optimum moisture content.

[C] –The imported fills should be comprised of a well graded sand and gravel mixture and should conform to the grain size distributions specified in Appendix C – Imported Fill Specifications

[D] – Thickness should be uniform and adjusted to attain underlying approved granular alluvial deposits.

[E] – A geotextile filter fabric may be required at the sub-grade elevation to allow for additional structural support in regions where the composition and conditions of the founding soils are considered to be poor as determined by qualified geotechnical personnel.

Exterior backfill around footing columns (and wall components) should be comprised of non-frost susceptible granular aggregates with particle sizes less than 80 mm. This material should be compacted to a minimum of 95 % of the materials corresponding maximum Proctor dry density at (within ± 2% of) the materials optimum moisture content, unless otherwise over-ridden by recommendations provided herein.

The height of the backfill between the interior and exterior sides of wall components should not measure greater than 150 mm during construction so as not to induce undesirable lateral forces.

All backfill materials should be placed in uniform, level lifts which are 150 mm thick (as measured following compaction).

Backfill around newly placed concrete should not be conducted until a minimum of seven days has elapsed such that the concrete attains adequate strength.

Weeping Tile Systems

A weeping tile system should be incorporated into the design.

5.4 Concrete

All concrete work should conform to *Canadian Standards Association* (*CSA*) standard CAN/CSA – A23.1 and A23.2. According to the standard, the concrete should be designed to satisfy the minimum environmental durability requirements as defined by its exposure class. The exposure class is dependent upon the presence of chlorides and sulphates, freezing/thawing conditions and degree of soil saturation.

The potential for sulphate attack from soils placed in direct contact with the concrete should be assessed prior to use.

Concrete subject to frequent freeze-thaw cycles and/or deicing chemicals and should be designed in accordance with C.S.A. A23.1-94, Section 15.

Normal Portland cement (C.S.A. Type 10), should be used in all concrete work.

Residential concrete should have a minimum 28-day compressive strength of 25 MPa and be air entrained (5 to 7 percent). This assumes a maximum aggregate size of 20 mm.

5.5 Structural Breaks & Reinforcing

Structural breaks and reinforcing (rebar) should be integrated into concrete foundations to control cracking and allow for differential movements caused by soil volume changes of the underlying soil.

If heavy loads are anticipated, the monolithic slab foundation system(s) should be designed as structural slabs with thickened peripheries. Additional measures should be incorporated into the design if dynamic and/or point loads are expected. This should include thickening the areas of the slab that would be subjected to these additional forces and increasing the compressive strength of the concrete to a minimum of 32 MPa.

5.6 Vapor Barrier

A non-deteriorating vapor barrier should be placed beneath the concrete to prevent desiccation of the sub-base materials and promote concrete hydration.

5.7 Insulation

The recommendations for foundation construction have been provided assuming that the corresponding buildings are closed to the weather and heated prior to the onset of any freezing temperatures for the remainder of the buildings life-span.

As some of the alluvial deposits may be frost susceptible, frost protection in the form of perimeter insulation or thickness of soil cover is required to reduce the risk of undesirable movements due to frost action as these soils are anticipated at the sub-grade elevation. The thickness of the insulation should be increased in regions where there may be a higher loss of heat such as the corners of the structure.

The minimum frost protection requirements have been outlined in Section 5.2 & 5.3, above.

Provisions should be included to protect the subsoils from excessive desiccation in regions where there is an intense degree of concentrated heat (such as potential boiler areas). Insulation should be incorporated in these areas to limit soil volume changes to tolerable amounts.

5.8 Deleterious Materials

The organics and fine grained alluvial deposits that were encountered above the granular alluvial deposits (founding strata) are not suitable to support structural loads. As such, these materials should be removed from within the structural load envelope of building structures and (as may be required in) the roadways.

If large cobbles and/or boulders are encountered at the founding (sub-grade) elevations, then these materials should also be sub-excavated and replaced within clean structural fill as outlined herein and as directed by qualified geotechnical personnel.

If seasonal frost is encountered at the sub-grade elevations, the frozen soils should be sub-excavated and wasted until thawed soils are encountered. If permanently frozen soils are encountered, then additional consideration will be required as the use of conventional concrete foundations should not be allowed.

As the test pit locations are potential geotechnical liabilities due to the unconsolidated nature of backfill, building foundations should avoid these locations.

The resulting excavations should be backfilled utilizing non-frost-susceptible materials which are placed and compacted in accordance with Sections 5.2 & 5.3.

In general, the deleterious materials should be suitable for use as general purpose fill so long as they are frost free and are placed and compacted in accordance with the recommendations provided herein. Organic soils should be utilized as soil cover in non-structural areas. Frozen soils will not be suitable for use and so should be wasted in designated areas.

Where excavation common materials are to be utilized for fill in non-structural applications, they should be placed in 300 mm thick lifts which are compacted to 95% of the materials Proctor maximum dry density at (or near, ± 2%) its optimum moisture content. These regions should be graded so as to maintain positive drainage.

5.9 Excavations

Excavation should be conducted utilizing a heavy tracked excavator equipped with a smooth lip (clean-up) bucket, to minimize disturbance of the native sub-grade materials. While excavation difficulties are not expected under thawed conditions, large boulders may be encountered and so this should be considered as additional measures may be required to facilitate their removal.

Loose, disturbed, remolded or slough materials should not be allowed to remain in prepared excavation(s). If a suitable founding surface cannot be prepared through mechanical means, then hand cleaning may be necessary.

The sub-grade materials are subject to a loss of strength if they are disturbed and as such, equipment should not be allowed to operate directly on the sub-grade surfaces.

The base of building excavation(s) should be prepared in such a manner that the sub-grade elevation does not vary. The base of trench excavation(s) should be prepared in such a manner that the sub-grade is not undulating.

5.10 Excavation Limits

The excavation limits will be governed by the proposed design elevations and that of the founding strata.

The excavation limits should be defined by the theoretical loading footprint which can be described as a 1:1 slope which extends outwards from the perimeter of the structure (plus one meter) until suitable frost protection and founding strata has been attained. A 1:1 back-slope should be incorporated in order to provide for worker safety and maintain slope stability. This angle of repose should be reduced to 2 horizontal to 1 vertical (or less) in regions where fine grained (or saturated) deposits are encountered.

The recommended cut slopes should be verified by qualified personnel at the time of construction and (if required) modified by the construction contractor to accommodate the actual soil conditions which are encountered.

5.11 Road Construction

The road structure should be comprised of the following;

THICKNESS [A]	**COMPACTION [B]**	**COMPOSITION [C]**
200 mm	100 %	20 mm minus crushed granular aggregate, overlying
200 mm	98 %	80 mm minus sub-base course aggregate, overlying
300-600 mm [F]	95 %	200 mm minus pit run sub-base, overlying
NA	NA	[D] filter fabric, overlying
NA	95 %	[E] approved native sub-grade materials

Notes;

[A] – All materials should be placed in uniform, level lifts that do not exceed 200 mm in thickness, as measured following compaction.

[B] – Indicates percent compaction relative to the materials Proctor maximum dry density at (or near, ± 2%) its optimum moisture content.

[C] –The imported fills should be comprised of a well graded sand and gravel mixture and should conform to the grain size distributions specified in Appendix C – Imported Fill Specifications

[D] – Geotextile fabric should be utilized if poor soil conditions/types are encountered at the sub-grade elevation.

[E] - The sub-grade surface should be proof-rolled. If excessive deflections are noted, then these regions should be sub-excavated to allow for construction as directed by qualified geotechnical personnel. This surface (and subsequent lifts of backfill) should be shaped with a 2% road crown to promote drainage.

[F] – The thickness of the pit run will vary. This granular course can measure 300 mm thick in regions where granular alluvial deposits are encountered. Otherwise the thickness should be increased to 600 mm in regions where fine grained alluvial deposits are encountered or where embankments are to be constructed. If heavy traffic loads are anticipated (eg water trucks, etc.), then consideration should be given to increasing the thickness of this granular course to 900 mm.

5.12 Subsurface Utility Installations

Any sub-surface (water) pipes or tanks should be embedded in bedding sand which conforms to the grain size specifications provided in Appendix C.

Utility pipes and subsurface tanks should be established on a base of bedding sand which measures 300 mm thick. The bedding sand should extend a minimum of 300 mm on all sides of the pipe/tank. The material should be compacted to a minimum of 95% of the materials corresponding Proctor density at (or near) the materials optimum moisture content.

If sub-grade conditions are poor, then the use of (clear stone) drain rock encased in geotextile filter fabric can be utilized in lieu of the bedding sand.

The excavation spoils will generally be suitable for use as trench backfill in non-structural areas so long as the materials are inorganic and not frozen, however, cobbles/rocks larger than 150 mm in size should not be placed within 1 meter of the pipe/tanks. The trench backfill should be comprised of an approved granular materials in regions where trenches intersect the building load envelope.

Trench (and tank) backfill materials should be placed in lifts which do not exceed 200 mm as measured following compaction. The material should be compacted to a minimum of 95% of the materials corresponding maximum Proctor dry density at (or near) the materials optimum moisture content. The compaction effort should be increased to a minimum of 98 % of the materials corresponding maximum Proctor dry density in regions where the sub-surface utilities cross roadways/parking areas or other regions where loading envelopes may be affected.

The installed utilities should be placed at depths >1.8 meters or else have equivalent insulation in order to allow for a sufficient degree of frost protection.

If subsurface holding tanks are utilized to store water, then provisions should be incorporated to counter potential uplift forces which may be induced by a shallow groundwater table. These tanks should be well insulated to prevent freezing through adequate soil (or else protective coating) cover.

5.13 Inclement Weather

The sub-grade, excavations and construction materials should be protected from drying, freezing, rain, snow, surface waters and groundwater at all times. The fine grained alluvial deposits are moisture sensitive and so construction operations may need to cease or be altered at times of precipitation until drier weather conditions prevail. Some of the alluvial deposits are frost susceptible and so it is critical that construction work is conducted during the summer months.

If construction work is scheduled in the spring or early summer months, additional consideration may be required as seasonally frozen soils may be present. Caution should be exercised to ensure frozen soils are not present within any load envelopes at the time of construction or are utilized during road construction.

5.14 Temporary Stockpiles

Stockpiled materials should be protected from segregation and the ingress of snow, frost, rain and surface waters at all times. Stockpiles should be placed no closer than 1 meter from the edge of any excavation.

5.15 Surface and Groundwater

Construction Operations

The subgrade materials may be subject to a loss of strength if they become wet, saturated or disturbed. As such, the surfaces surrounding excavations should be graded so as to direct water away from the excavation. Surface and groundwater should be removed from excavations at all times during construction.

While groundwater was not encountered during our investigation, seasonal fluctuations may occur and thus the contractor should be prepared to undertake conventional construction dewatering to ensure a dry working area.

Ditches

Ditches should be incorporated into the design and construction phases to control regional, lot and building perimeter drainage.

Site Grading

The drainage in the region of building sites and roadways should be carefully controlled.

The surrounding areas should be graded to direct surface water away from the building structure and foundation/excavations. Typically, a 2 percent slope which extends a minimum of 5 meters away from the building perimeter will be sufficient for this purpose.

Exterior backfill should be capped with a low permeability soil or surface cover which is placed around the perimeter of building foundations following concrete placement. The low permeability soil/surface cover will assist in directing surface waters away from the foundation and limits of the former excavation. The backfill should be placed to protect the sides of concrete slabs and prevent undermining of the slab during periods of heavy precipitation/run-off.

Eaves troughs

Eaves troughs should be incorporated into roof structures. The outlets from the roof drains should extend a minimum of 4.0 meters away from the building structure such that the discharge is directed away from the structure(s).

5.16 Geotechnical Setbacks

Residential building development should not be allowed within ~30 meters of Scarp # 2 as noted in Figure 3. This setback should be observed as the scarp coincides with the approximate limits of a 1 in 200 year flood event.

While residential building construction within these setback corridors should not be allowed, access roads could be constructed within these setback limits.

5.17 Temporary Excavations & Worker Safety

Worker safety is paramount.

Temporary excavations to conventional depths at this site should comply with current *Occupational Health & Safety Regulations.*

While the excavation sidewall (slope) stability will be dependent upon the material characteristics, configuration of the excavation and length of exposure, in general, one to one cut slopes should provide adequate slope stability during excavation of the anticipated excavation common materials. Slope stability will however be poor where wet/saturated, loose or fine grained materials are encountered and so more gradual cut slopes will be required in these areas to minimize the potential for slope failure.

The contractor should be prepared to adjust their construction methodology and excavation profiles as soil conditions dictate.

5.18 Construction Monitoring & Testing

During construction, qualified geotechnical personnel should inspect all subgrade surfaces prior to backfill to verify that the materials noted at the subgrade elevation are consistent with those identified herein. Side slope parameters should be verified in the field by qualified personnel during the time of construction.

Materials testing services should be provided during foundation construction to assess the suitability of the structural fills and conduct in-situ field density (compaction) and concrete testing.

5.19 Local Infrastructure Upgrades

The culverts which cross River Road should be upgraded such that the drainage of Areas B & C (Figure 2) is improved. This may help assist in reducing groundwater levels in the region of the proposed development.

5.20 Additional Assessments

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

Geotechnical Evaluations

Site specific geotechnical evaluations should be conducted at the locations of proposed buildings and deep utilities through auger drilling methodologies such that the bearing capacity and soil conditions can be verified.

Site Survey

A detailed site survey (with minimum 1 meter contour intervals) should be conducted to allow for additional evaluation from a geotechnical and civil design perspective.

Environmental Site Assessment(s)

A Phase I Environmental Site Assessment (ESA) should be conducted to identify potential environmental liabilities which may be associated with the study area and the well which is located in the study area.

Other Studies and Plans

Development plans should be compiled to identify site grading, surface drainage and erosion control requirements.

6.0 CONCLUSIONS

Based upon the information retained during our evaluation, the soil types and conditions encountered within the study area will allow for development within the study area as noted in Figure 3. However, the presence of weak compressible soils (which were encountered up to a depth of 1.6 meters in Figure 2 - Area E) and the presence of groundwater (which was encountered as shallow as 1.9 meters) will require additional consideration relative to the construction of buildings, surface works and sub-surface utilities. Standard 30-meter setbacks should be observed for residential building construction relative to the anticipated 1 in 200 year flood limit.

Building Foundations/Construction

The presence of the shallow groundwater will not allow for basements to be incorporated into the design of any building structures.

As such, buildings should be constructed utilizing monolithic slab types of concrete foundation systems founded upon structural granular pads which extend to approved granular alluvial deposits which lie at depths up to 1.6 meters below the ground surface and as described herein. Footing and slab-on-grade types of foundations can also be considered in regions where higher elevations prevail however caution will need to be exercised given the presence of the shallow groundwater and compressible fine grained alluvial deposits. Adjustments to the individual foundation designs will be required to accommodate site-specific conditions as discussed herein.

Surface Utilities

The construction of roads and ditches utilizing conventional cut/fill construction methodologies will be feasible following adequate site preparation which will require the removal of the surficial organics and near surface organic silts. While the granular components of the road structure would in general measure in the order of 0.7-1.3 meters thick, the thickness would need to be based upon the subgrade conditions which are encountered at the time of construction, the anticipated traffic loads and the design elevations.

The culverts which cross River Road should be upgraded such that the drainage of Areas B & C (Figure 2) is improved. This may help assist in lowering groundwater levels in the region of the proposed development.

Subsurface Utilities

The alluvial soils which were encountered should be suitable to allow for the installation of shallow utilities. However, the surficial organic deposits and wet to saturated fine grained and organic rich soils will not be suitable for use as trench backfill materials and so these materials will need to be wasted. In addition, if large cobbles and/or boulders are encountered, they too will not be suitable for use in trench backfill and so should also be removed from the site (or wasted in designated areas).

Additional consideration will be required during the design and construction phases where subsurface utilities extend to depths beyond the groundwater table as construction dewatering operations will be required.

Otherwise, construction difficulties are not anticipated.

Future Assessments/Evaluations

Site-specific geotechnical evaluations should be conducted prior to individual lot development and deep utility installations through drilling methodologies to determine the soil suitability and bearing capacity of the founding strata.

A site survey should be conducted to characterize the site topography. These results should be assessed by qualified geotechnical personnel to identify potential geotechnical liabilities.

An environmental site assessment should be conducted to identify potential environmental liabilities.

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 are based upon the subsurface conditions encountered at the time of our evaluation, current construction techniques and generally accepted engineering practices. The content within this report reflects our best judgment in light of the information available to Chilkoot Geological Engineers Ltd. 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 data presented may not be sufficient to assess all factors that may have an effect upon construction.

It is important to emphasize that a geotechnical evaluation is, in fact, based upon random sampling and that the comments made are based upon the results obtained at the test pit and sample locations. Due to the geomorphological nature of the deposits encountered, interpolations of native subsurface conditions between the test locations have not been made or been implied and the conditions noted may change over time.

Should unexpected subsurface conditions or soils be encountered during construction, 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.

8.0 CLOSURE

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

#1277
TARES DHARA

PERMIT TO PRACTICE
Signature
Date July 11, 2018
PERMIT NUMBER: PP025
Association of Professional Engineers of Yukon

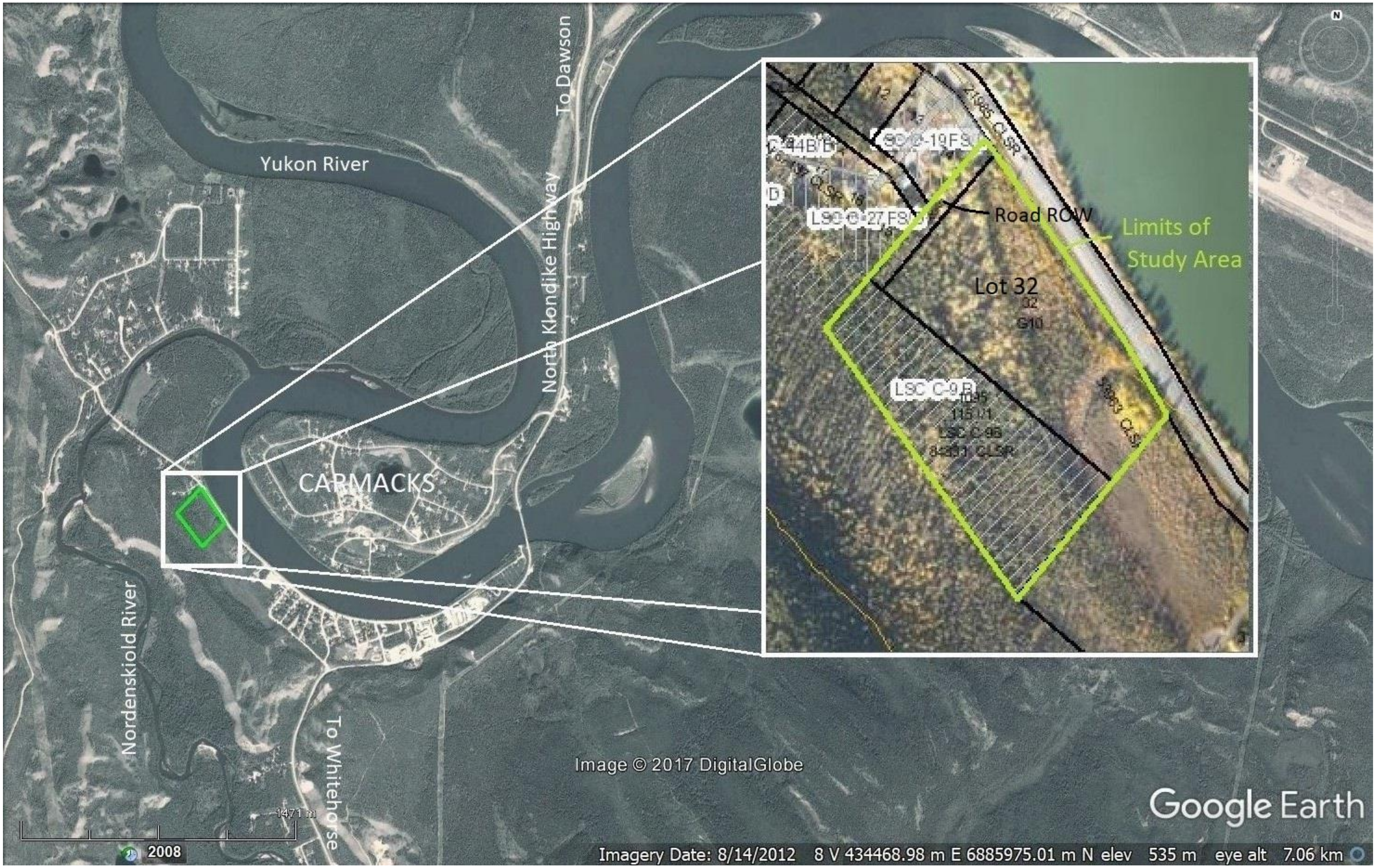
Tares Dhara, P.Eng.
Senior Geotechnical Engineer

TD/td

FIGURES 1-4

CHILKOOT GEOLOGICAL ENGINEERS LTD.

Geotechnical Evaluation – Village of Carmacks and Little Salmon First Nation
Proposed Joint Residential Development – Carmacks, Yukon – 2017-2018
Figure 1 – Location of Study Area



Based map modified from Google Earth – Not to Scale – Locations are approximate

Compiled Jan.4th, 2018 by T.Dhara

Geotechnical Evaluation – Village of Carmacks and Little Salmon First Nation
Proposed Joint Residential Development – Carmacks, Yukon – 2017-2018
Figure 2 – Site Plan

Based map modified from Google Earth – Not to Scale – Locations are approximate

Compiled Jan.4th, 2018 by T.Dhara

CHILKOOT GEOLOGICAL ENGINEERS LTD.

Geotechnical Evaluation – Village of Carmacks and Little Salmon First Nation
Proposed Joint Residential Development – Carmacks, Yukon – 2017-2018
Figure 3 – Preliminary Conceptual Development Plan

Based map modified from Google Earth – Not to Scale – Locations are approximate

Compiled Jan.19th, 2018 by T.Dhara

Geotechnical Evaluation – Village of Carmacks and Little Salmon First Nation Proposed Joint Residential Development – Carmacks, Yukon 2017-2018

Figure 4 - Test Pit Locations

Base map from Google Earth

Compiled by T.Dhara, P.Eng. - June 24th, 2018

APPENDIX A

Test Pit Soil Logs

NOTES ON SOIL LOGS

Soil Description

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

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

Examples;

SILT	SAND	GRAVEL	Description
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.

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

Relative Density (Qualitative Classification)

Cohesive Soils

Very Soft - Exudes between fingers when squeezed by hand

Soft - Moulded by light finger pressure

Firm - Moulded by strong finger pressure

Stiff - Cannot be moulded by fingers – Can be indented by thumb

Very Stiff - Can only be indented by thumbnail

Hard - Cannot be indented by thumbnail

Granular Soils

Very Loose - Considerable sidewall sloughage noted

Loose - Some sidewall sloughage noted – Easy digging

Compact/ Medium-Dense - Unimpeded excavation – little to no sidewall sloughage

Dense - Considerable effort required during excavation – Stable vertical sidewalls

Very Dense - Extreme difficulty in excavation

Soil Log - Sample Type

Symbol	Test Pitting	Drilling
☒	**Grab Sample** Retained from excavation sidewall or base	**Auger Sample** Retained from Auger flighting
◫	**Bucket Sample** Retained from leading edge of excavator bucket	**Split-Spoon Sample** Retained from Split-Spoon Sampler tube

Relative Moisture

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

> For example, a moisture content of 10 percent may be classified as ‘*moist*’ for a coarse grained soil (sand or gravel) but ‘*damp*’ for a fine grained (silt) 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 %)

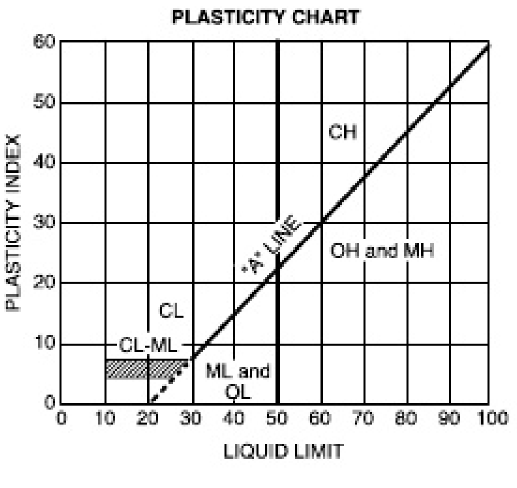
N-Value

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)**
Very Loose	< 5	*Very Soft*	0 to 2
Loose	5 to 9	*Soft*	3 to 4
Compact	10 to 29	*Firm*	5 to 8
Dense	30 to 50	*Stiff*	9 to 15
Very Dense	> 50	*Very Stiff*	16 to 30
		Hard	> 30

UNIFIED SOIL CLASSIFICATION SYSTEM (ASTM D-2487)

Major Divisions			Group Symbols		Typical Names	Laboratory Classification Criteria		
Coarse-grained soils (More than half of material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than No. 4 sieve size)	Clean gravels (Little or no fines)	GW		Well-graded gravels, gravel-sand mixtures, little or no fines	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[b]	$c_u = \frac{D_{60}}{D_{10}}$ greater than 4; $c_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP		Poorly-graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradiation requirements for GW	
		Gravels with fines (Appreciable amount of fines)	GM[a]	d	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are *borderline* cases requiring use of dual symbols
				u				
			GC		Clayey gravels, gravel-sand-clay mixtures		Atterberg limits above "A" line with PI greater than 7	
	Sands (More than half of coarse fraction is smaller than No. 4 sieve size)	Clean sands (Little or no fines)	SW		Well-graded sands, gravelly sands, little or no fines		$c_u = \frac{D_{60}}{D_{10}}$ greater than 6; $c_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP		Poorly graded sand, gravelly sands, little or no fines		Not meeting all gradiation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM[a]	d	Silty sands, sand-silt mixtures		Atterberg limits below "A" line or PI less than 4	Limits plotting in hatched zone with PI between 4 and 7 are *borderline* cases requiring use of dual symbols
				u				
			SC		Clayey sands, sand-clay mixtures		Atterberg limits above "A" line with PI greater than 7	
Fine-grained soils (More than half material is smaller than No. 200 sieve)	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 greater than 50)		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			

---

[a] Division of GM and SM groups into subdivisions of d and u are for roads and airfields only. Subdivision is based on Atterberg limits; suffix d used when LL is 28 or less and the PI is 6 or less; the suffix u used when LL is greater than 28.

[b] Borderline classification, used for soils possessing characteristics of two groups, are designated by combinations of group symbols. For example GW-GC, well-graded gravel-sand mixture with clay binder.

CHILKOOT GEOLOGICAL ENGINEERS LTD.

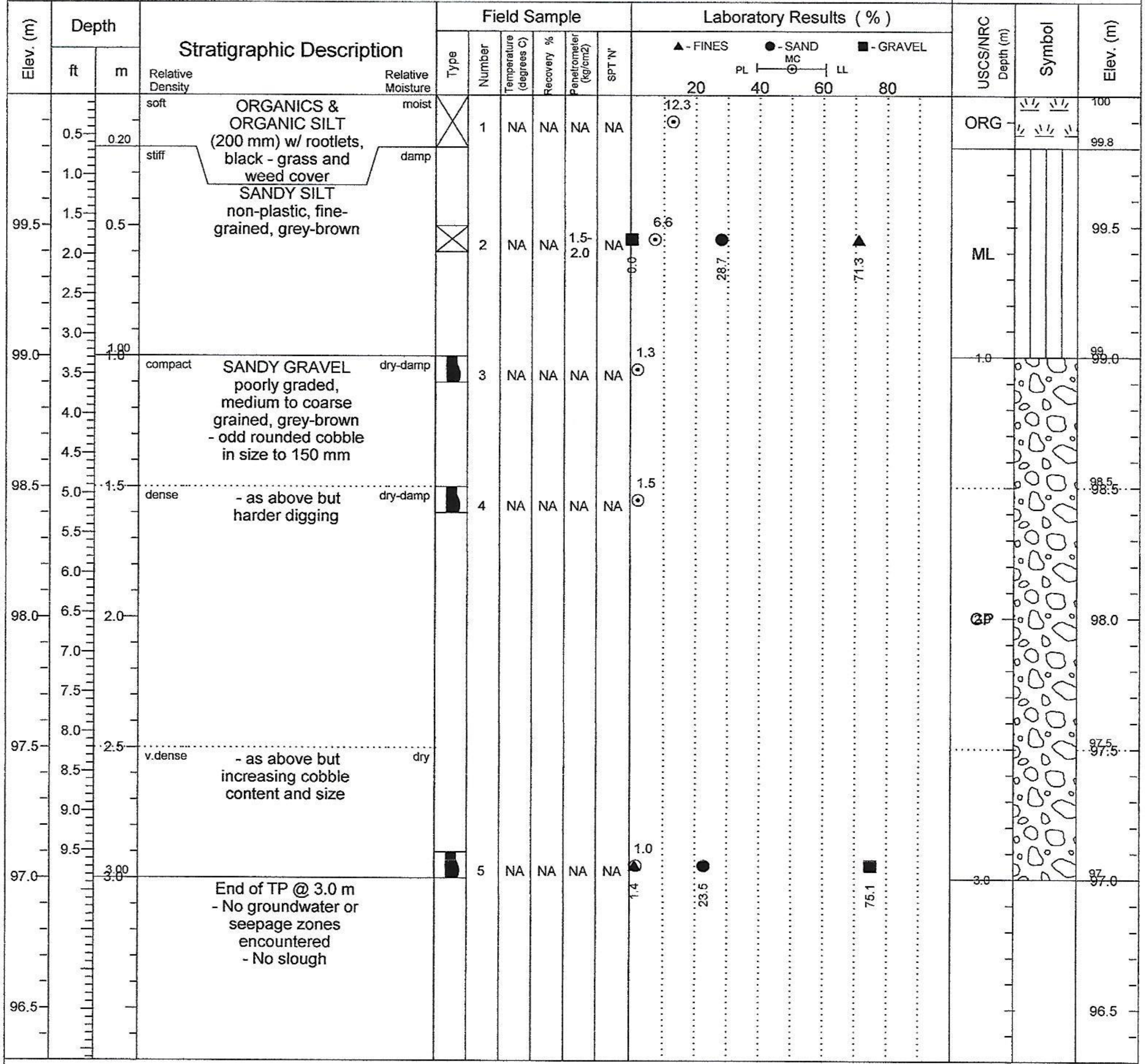
5B Bennett Road, Whitehorse, Yukon
(867) 335-5804 chilkoot.eng@gmail.com

TEST PIT SOIL LOG

Client : YG - EMR - Lands Branch
Location : Carmacks, Yukon
Project : Geotechnical Evaluation - Joint Development Sub
Date Excavated: June 1, 2018

Elevation : 100.0 meters
TP Termination Depth: 3 meters
Instrumentation: NA
Weather: Partly Cloudy +13 to +17 C

TEST PIT
1-18
Sheet 1 of 1



Depth (m)	Relative Density	Stratigraphic Description	Relative Moisture	USCS/NRC
0 - 0.20	soft	ORGANICS & ORGANIC SILT (200 mm) w/ rootlets, black - grass and weed cover	moist	ORG
0.20 - 1.00	stiff	SANDY SILT non-plastic, fine-grained, grey-brown	damp	ML
1.00 - 1.5	compact	SANDY GRAVEL poorly graded, medium to coarse grained, grey-brown - odd rounded cobble in size to 150 mm	dry-damp	GP
1.5 - 2.5	dense	- as above but harder digging	dry-damp	
2.5 - 3.00	v.dense	- as above but increasing cobble content and size	dry	

End of TP @ 3.0 m
- No groundwater or seepage zones encountered
- No slough

Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	MC	Gravel	Sand	Fines
1	NA	NA	NA	NA	12.3			
2	NA	NA	1.5-2.0	NA	6.6	0.0	28.7	71.3
3	NA	NA	NA	NA	1.3			
4	NA	NA	NA	NA	1.5			
5	NA	NA	NA	NA	1.0	75.1	23.5	1.4

Excavated By : Yellow Truck Excavating Inc. Excavator Type : Bobcat E50 Bucket Type : Digging

Water Level(s)
▽ During Excavation ▼ After Excavation
▼ At End of Excavation

Logged By : G.Keitel
Date : June 1, 2018

Data Entry By : T.Dhara, P.Eng.
Date : June 15-20, 2018

Reviewed By:
Date : June 21, 2018

CHILKOOT GEOLOGICAL ENGINEERS LTD.
5B Bennett Road, Whitehorse, Yukon
(867) 335-5804 chilkoot.eng@gmail.com

TEST PIT SOIL LOG

Client : YG - EMR - Lands Branch
Location : Carmacks, Yukon
Project : Geotechnical Evaluation - Joint Development Sub
Date Excavated: June 1, 2018

Elevation : 100.0 meters
TP Termination Depth: 3.3 meters
Instrumentation: NA
Weather: Partly Cloudy +13 to +17 C

TEST PIT
2-18
Sheet 1 of 1

Laboratory Results (%): ▲ - FINES ● - SAND ■ - GRAVEL; PL ├ MC ⊙ ┤ LL; scale 20 40 60 80

Depth (m)	Relative Density	Stratigraphic Description	Relative Moisture	Type	Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	Laboratory Results (%)	USCS/NRC	Elev. (m)
0 – 0.30	soft	ORGANICS & ORGANIC SILT (300 mm) w/ rootlets, black - grass and weed cover	moist								ORG	100 – 99.7
0.30 – 0.80	dense	SILTY SANDY GRAVEL w/ORGANIC INCLUSIONS - poorly graded, fine to medium grained, brown-black - seasonally frozen	wet	☒	6	NA	NA	NA	NA	⊙ 10.1	GM	99.5 99.2
0.80 – 1.40	firm	SANDY SILT some GRAVEL - non-plastic, fine-grained, gravel in size to 30 mm, grey	damp	☒	7	NA	NA	0.75-1.0	NA	⊙ 6.6 ■ 12.4 ● 19.9 ▲ 67.7	1.0 ML	99.0 98.6
1.40 – 2.0	dense	SANDY GRAVEL some SILT - poorly graded, fine to medium grained, grey - trace oxidation - odd cobble in size to 150 mm	moist		8	NA	NA	NA	NA	⊙ 4.9 ▲ 12.0 ● 28.2 ■ 59.7	GM - GP	98.5
2.0 – 3.30	dense	- as above	damp		9	NA	NA	NA	NA	⊙ 2.3	2.0 GP	98 98.0 97.8 97.5
		- as above			10	NA	NA	NA	NA	⊙ 2.4	3.0	97.0 96.8 96.7
3.30		End of TP @ 3.3 m - No groundwater or seepage zones encountered - No sloughage										96.5

Elev (m): 99.5, 99.0, 98.5, 98.0, 97.5, 97.0, 96.5
Depth ft: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0, 10.5
Depth m: 0.30, 0.5, 0.80, 1.0, 1.40, 1.5, 2.0, 2.5, 3.0, 3.30

Excavated By : Yellow Truck Excavating Inc. Excavator Type : Bobcat E50 Bucket Type : Digging

Water Level(s)
▽ During Excavation ▼ After Excavation
▼ At End of Excavation

Logged By : G.Keitel
Date : June 1, 2018

Data Entry By : T.Dhara, P.Eng.
Date : June 15-20, 2018

Reviewed By:
Date : June 21, 2018

CHILKOOT GEOLOGICAL ENGINEERS LTD.

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TEST PIT SOIL LOG

Client : YG - EMR - Lands Branch
Location : Carmacks, Yukon
Project : Geotechnical Evaluation - Joint Development Sub
Date Excavated: June 1, 2018

Elevation : 100.0 meters
TP Termination Depth: 3 meters
Instrumentation: NA
Weather: Partly Cloudy +13 to +17 C

TEST PIT

3-18

Sheet 1 of 1

Depth (m)	Relative Density	Stratigraphic Description	Relative Moisture	USCS/NRC Depth (m)	Elev. (m)
0.15	soft	ORGANICS & ORGANIC SILT (150 mm) w/ rootlets, black - grass and weed cover	wet	ORG	100 99.85
0.80	firm	SANDY SILT some ORGANICS - non-plastic, fine grained, dark grey-brown	moist	ML	99.2
1.10	dense	SILTY SAND - poorly graded, fine grained, light brown - seasonally frozen	moist	SM 1.0	98.9
	dense	SANDY GRAVEL - poorly graded, fine to medium grained, grey-brown - trace oxidation - odd rounded cobble in size to 150 mm	damp		98.3
2.5	dense	- as above but cobbles in size to 200 mm - as above	dry-damp	2.0 GP	97.8 97.5
3.00	dense	- as above but coarser gravels - some oxidation - possibly washed	dry-damp	3.0	97.0
		End of TP @ 3.0 m - No groundwater or seepage zones - No sloughage			

Field Sample / Laboratory Results (%)

▲ - FINES ● - SAND ■ - GRAVEL PL MC LL

Type	Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	MC	▲ Fines	● Sand	■ Gravel
☒	11	0.2	NA	0.5-1.0	NA	19.1	58.6	40.2	1.2
☒	12	-0.2	NA	NA	NA	9.5			
▌	13	NA	NA	NA	NA	2.1	4.5	44.0	51.4
▌	14	NA	NA	NA	NA	1.8			
▌	15	NA	NA	NA	NA	1.7	2.8	25.7	71.5

Excavated By : Yellow Truck Excavating Inc. Excavator Type : Bobcat E50 Bucket Type : Digging

Water Level(s)
▽ During Excavation ▼ After Excavation
▼ At End of Excavation

Logged By : G.Keitel
Date : June 1, 2018

Data Entry By : T.Dhara, P.Eng.
Date : June 15-20, 2018

Reviewed By:
Date : June 21, 2018

TEST PIT SOIL LOG

Client : YG - EMR - Lands Branch
Location : Carmacks, Yukon
Project : Geotechnical Evaluation - Joint Development Sub
Date Excavated: June 1, 2018

Elevation : 100.0 meters
TP Termination Depth: 3 meters
Instrumentation: NA
Weather: Partly Cloudy +13 to +17 C

TEST PIT

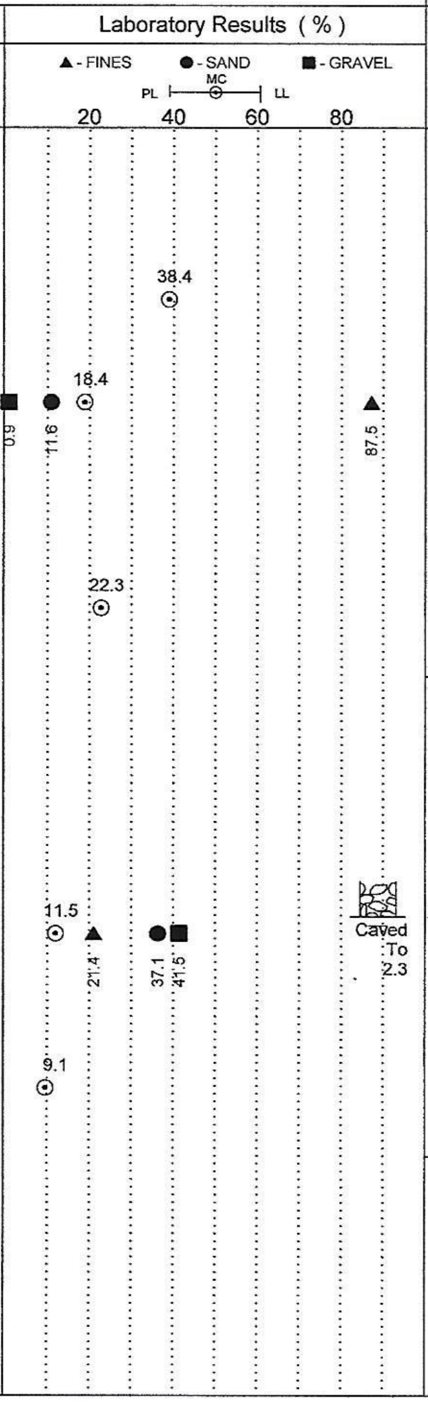
4-18

Sheet 1 of 1

Depth (m)	Relative Density	Stratigraphic Description	Relative Moisture	USCS/NRC	Elev. (m)
0.0	soft	ORGANICS & ORGANIC SILT (300 mm) w/ rootlets, black - grass and weed cover	moist	ORG	100
0.30	stiff	SILT some SAND odd GRAVEL - non-plastic, fine grained, grey - seasonally frozen	wet		99.7
	firm	- as above but not frozen	moist	ML	99.3
		- as above			98.65
1.60	dense	SANDY SILTY GRAVEL - poorly graded, fine to medium grained, grey-brown - some oxidation - odd rounded cobble in size to 150 mm	damp		98.4
	loose	- as above - groundwater encountered @ 2.3	wet	GM	97.7
		- as above			97.25
3.00		End of TP @ 3.0 m - Groundwater encountered (10 cm of water after 10 minutes) - Slough to 2.3			97.0

Field Sample

Number	Temperature (degrees C)	Recovery %	Penetrometer (Kg/cm2)	SPT 'N'	MC	GRAVEL	SAND	FINES
16	-0.2	NA	>4.5	NA	38.4			
17	0.5	NA	0.75-1.0	NA	18.4	0.9	11.6	87.5
18	NA	NA	0.5-1.0	NA	22.3			
19	NA	NA	NA	NA	11.5	41.5	37.1	21.4
20	NA	NA	NA	NA	9.1			



Excavated By : Yellow Truck Excavating Inc.
Excavator Type : Bobcat E50
Bucket Type : Digging

Water Level(s)
▽ During Excavation ▼ After Excavation
▼ At End of Excavation

Logged By : G.Keitel
Date : June 1, 2018

Data Entry By : T.Dhara, P.Eng.
Date : June 15-20, 2018

Reviewed By:
Date : June 21, 2018

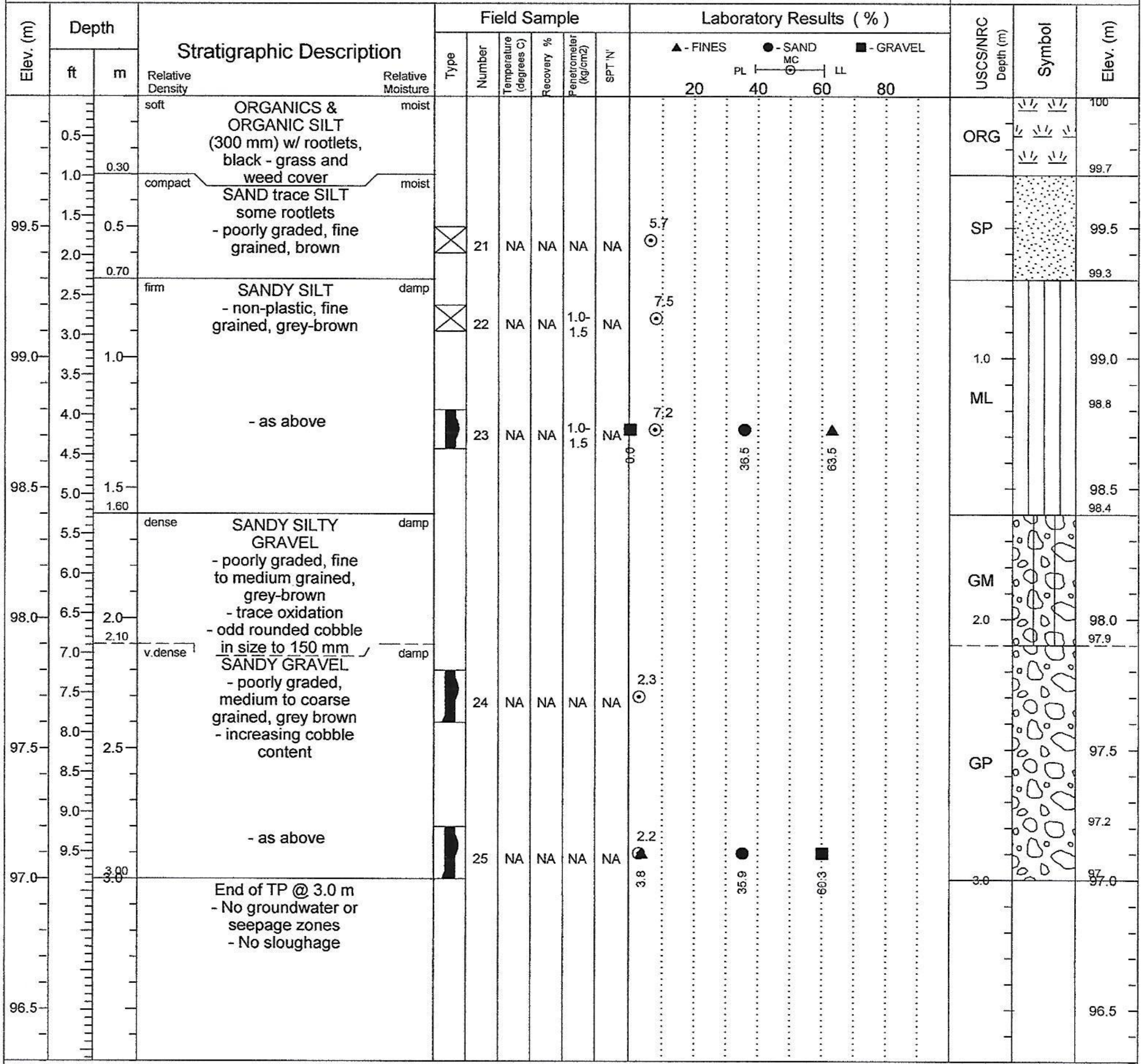
CHILKOOT GEOLOGICAL ENGINEERS LTD.
5B Bennett Road, Whitehorse, Yukon
(867) 335-5804 chilkoot.eng@gmail.com

TEST PIT SOIL LOG

Client : YG - EMR - Lands Branch
Location : Carmacks, Yukon
Project : Geotechnical Evaluation - Joint Development Sub
Date Excavated: June 1, 2018

Elevation : 100.0 meters
TP Termination Depth: 3 meters
Instrumentation: NA
Weather: Partly Cloudy +13 to +17 C

TEST PIT
5-18
Sheet 1 of 1



Depth (m)	Relative Density	Stratigraphic Description	Relative Moisture	USCS/NRC	Elev. (m)
0 – 0.30	soft	ORGANICS & ORGANIC SILT (300 mm) w/ rootlets, black - grass and weed cover	moist	ORG	100 – 99.7
0.30 – 0.70	compact	SAND trace SILT some rootlets - poorly graded, fine grained, brown	moist	SP	99.7 – 99.3
0.70 – 1.60	firm	SANDY SILT - non-plastic, fine grained, grey-brown - as above	damp	ML	99.3 – 98.4
1.60 – 2.10	dense	SANDY SILTY GRAVEL - poorly graded, fine to medium grained, grey-brown - trace oxidation - odd rounded cobble in size to 150 mm	damp	GM	98.4 – 97.9
2.10 – 3.00	v.dense	SANDY GRAVEL - poorly graded, medium to coarse grained, grey brown - increasing cobble content - as above	damp	GP	97.9 – 97

End of TP @ 3.0 m
- No groundwater or seepage zones
- No sloughage

Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	MC	Fines	Sand	Gravel
21	NA	NA	NA	NA	5.7			
22	NA	NA	1.0-1.5	NA	7.5			
23	NA	NA	1.0-1.5	NA	7.2	63.5	36.5	0.0
24	NA	NA	NA	NA	2.3			
25	NA	NA	NA	NA	2.2	3.8	35.9	60.3

Excavated By : Yellow Truck Excavating Inc. Excavator Type : Bobcat E50 Bucket Type : Digging

Water Level(s)
▽ During Excavation ▼ After Excavation
▼ At End of Excavation

Logged By : G.Keitel
Date : June 1, 2018

Data Entry By : T.Dhara, P.Eng.
Date : June 15-20, 2018

Reviewed By: TD
Date : June 21, 2018

CHILKOOT GEOLOGICAL ENGINEERS LTD.

5B Bennett Road, Whitehorse, Yukon
(867) 335-5804 chilkoot.eng@gmail.com

TEST PIT SOIL LOG

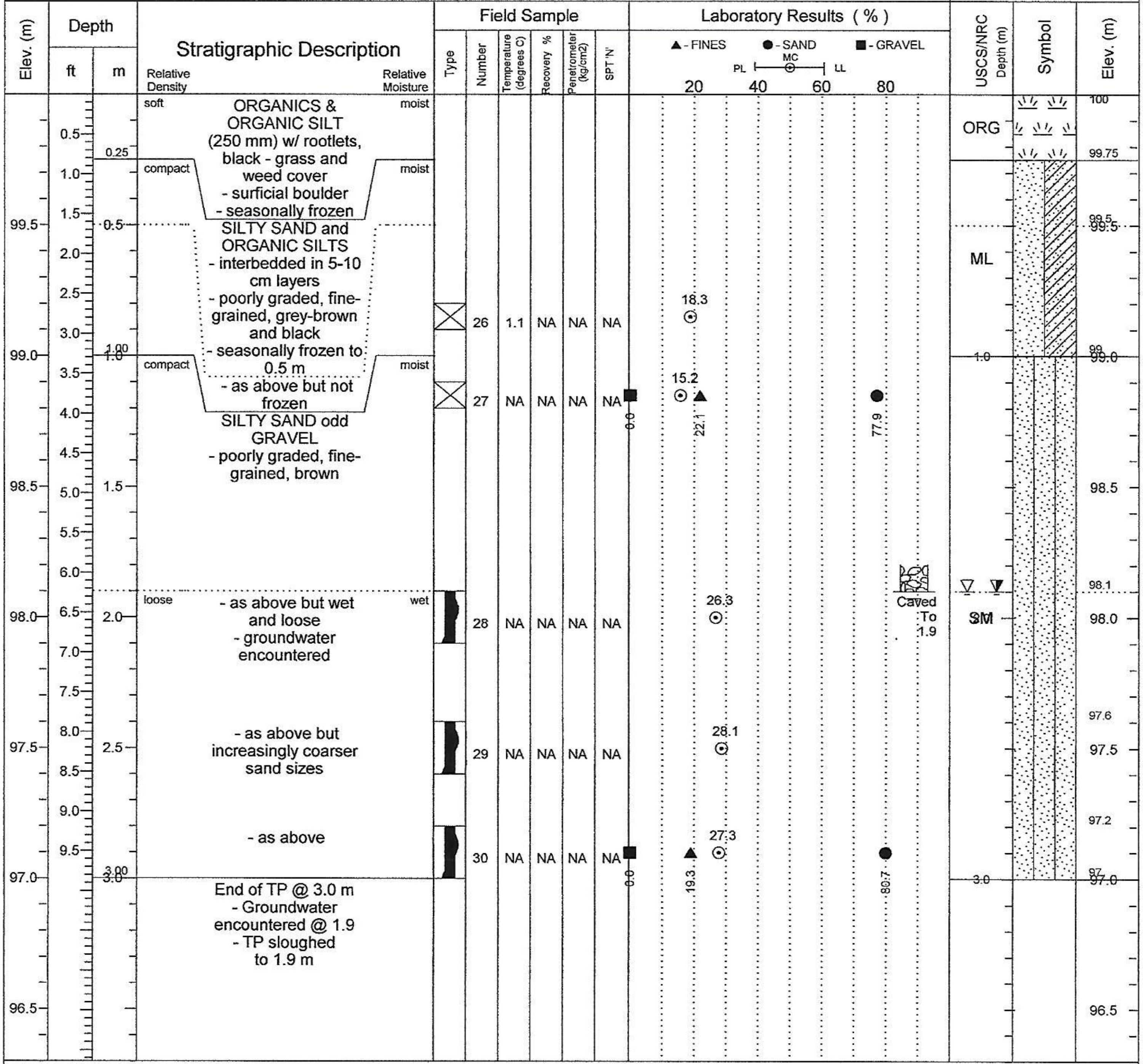
Client : YG - EMR - Lands Branch
Location : Carmacks, Yukon
Project : Geotechnical Evaluation - Joint Development Sub
Date Excavated: June 1, 2018

Elevation : 100.0 meters
TP Termination Depth: 3 meters
Instrumentation: NA
Weather: Partly Cloudy +13 to +17 C

TEST PIT

6-18

Sheet 1 of 1



Depth (m)	Relative Density	Stratigraphic Description	Relative Moisture	Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	MC	FINES	SAND	GRAVEL	USCS/NRC	Elev. (m)
0.25	soft	ORGANICS & ORGANIC SILT (250 mm) w/ rootlets, black - grass and weed cover - surficial boulder - seasonally frozen	moist										ORG	100 – 99.75
1.00	compact	SILTY SAND and ORGANIC SILTS - interbedded in 5-10 cm layers - poorly graded, fine-grained, grey-brown and black - seasonally frozen to 0.5 m	moist	26	1.1	NA	NA	NA	18.3				ML	99.75 – 99
	compact	- as above but not frozen	moist	27	NA	NA	NA	NA	15.2	22.1	77.9	0.0	SM	99
		SILTY SAND odd GRAVEL - poorly graded, fine-grained, brown												
	loose	- as above but wet and loose - groundwater encountered	wet	28	NA	NA	NA	NA	26.3					98.1
		- as above but increasingly coarser sand sizes		29	NA	NA	NA	NA	28.1					97.6
3.00		- as above		30	NA	NA	NA	NA	27.3	19.3	80.7	0.0		97.2 – 97

Caved To 1.9

End of TP @ 3.0 m
- Groundwater encountered @ 1.9
- TP sloughed to 1.9 m

Excavated By : Yellow Truck Excavating Inc. Excavator Type : Bobcat E50 Bucket Type : Digging

Water Level(s)
▽ During Excavation ▼ After Excavation
▼ At End of Excavation

Logged By : G.Keitel
Date : June 1, 2018

Data Entry By : T.Dhara, P.Eng.
Date : June 15-20, 2018

Reviewed By:
Date : June 21, 2018

CHILKOOT GEOLOGICAL ENGINEERS LTD.

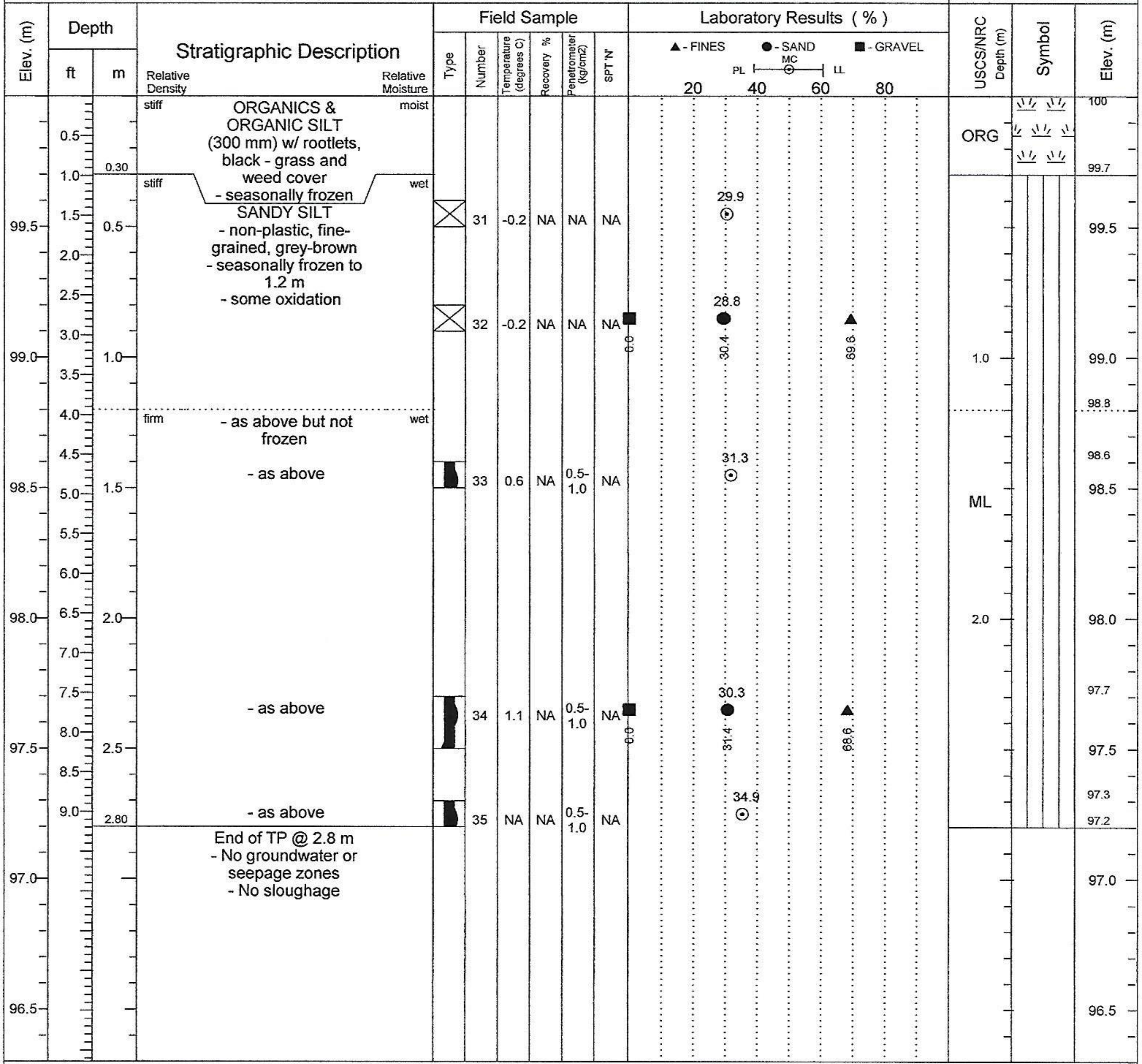
5B Bennett Road, Whitehorse, Yukon
(867) 335-5804 chilkoot.eng@gmail.com

TEST PIT SOIL LOG

Client : YG - EMR - Lands Branch
Location : Carmacks, Yukon
Project : Geotechnical Evaluation - Joint Development Sub
Date Excavated: June 1, 2018

Elevation : 100.0 meters
TP Termination Depth: 2.8 meters
Instrumentation: NA
Weather: Partly Cloudy +13 to +17 C

TEST PIT
7-18
Sheet 1 of 1



Depth (m)	Relative Density	Stratigraphic Description	Relative Moisture	USCS/NRC	Elev. (m)
0 – 0.30	stiff	ORGANICS & ORGANIC SILT (300 mm) w/ rootlets, black - grass and weed cover - seasonally frozen	moist	ORG	100 – 99.7
0.30 – 1.2	stiff	SANDY SILT - non-plastic, fine-grained, grey-brown - seasonally frozen to 1.2 m - some oxidation	wet	ML	99.7 – 98.8
1.2 – 2.80	firm	- as above but not frozen - as above - as above - as above	wet	ML	98.8 – 97.2
		End of TP @ 2.8 m - No groundwater or seepage zones - No sloughage			

Number	Temperature (degrees C)	Recovery %	Penetrometer (kg/cm2)	SPT 'N'	MC (%)	Gravel (%)	Sand (%)	Fines (%)
31	-0.2	NA	NA	NA	29.9			
32	-0.2	NA	NA	NA	28.8	0.0	30.4	69.6
33	0.6	NA	0.5-1.0	NA	31.3			
34	1.1	NA	0.5-1.0	NA	30.3	0.0	31.4	68.6
35	NA	NA	0.5-1.0	NA	34.9			

Excavated By : Yellow Truck Excavating Inc.
Excavator Type : Bobcat E50
Bucket Type : Digging

Water Level(s)
▽ During Excavation ▼ After Excavation
▼ At End of Excavation

Logged By : G.Keitel
Date : June 1, 2018

Data Entry By : T.Dhara, P.Eng.
Date : June 15-20, 2018

Reviewed By:
Date : June 21, 2018

APPENDIX B

Results of Hydrometer and Atterberg Limit Analysis

Golder Associates

LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS

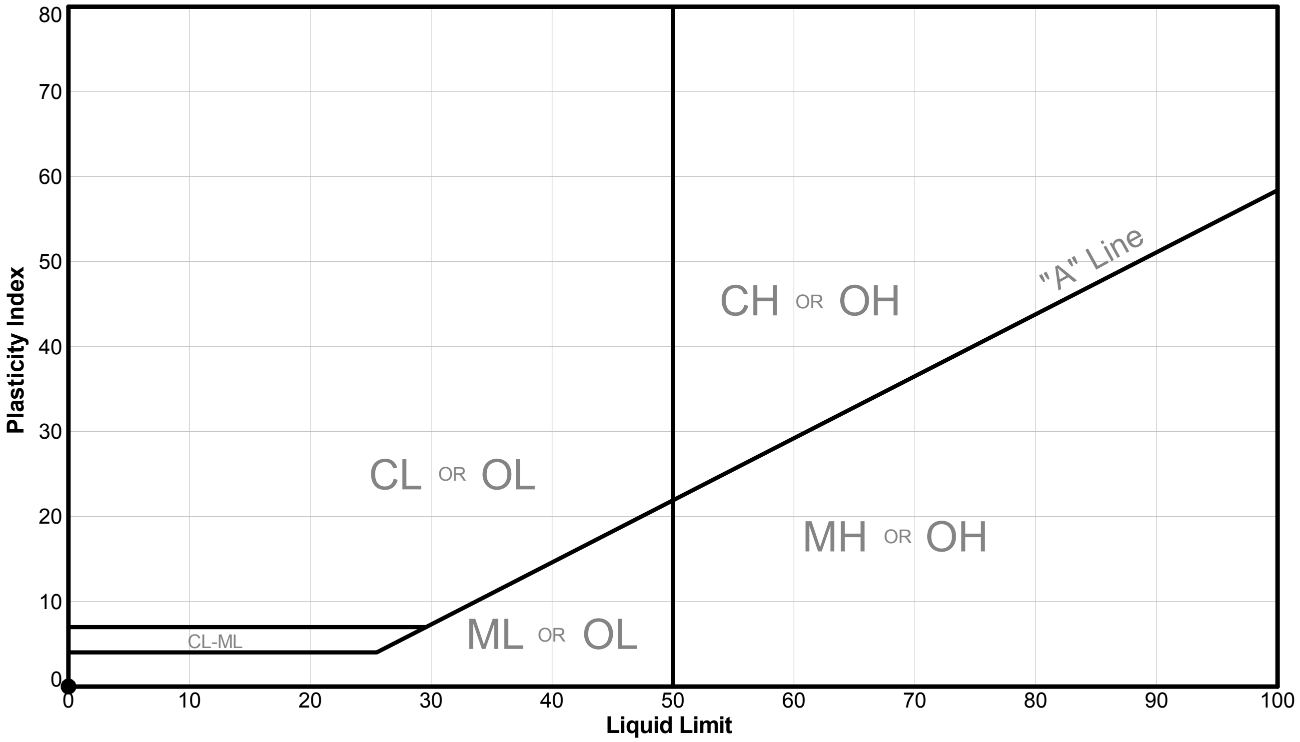
ASTM D 4318-10

Client: Chilkoot Geological Engineers Ltd. **ID: Carmacks Subdivision**
Project: Soil Testing **Sample No.: TP7-18 SA35**
Location: Vancouver, BC **Depth (m):** N/A
Project No.: 1780303 **Phase:** 3000 **Lab Schedule No.:**

Other Remarks: **N/A**

Test Method: A-Multi Point | **Preparation Method: Air Dried**

PLASTICITY CHART



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
●	Carmacks Subdivision	TP7-18 SA35	0.00	0.00	99	NP	NP	NP	0.4	NP

NP - NON-PLASTIC RESULT ND - NOT DETERMINED

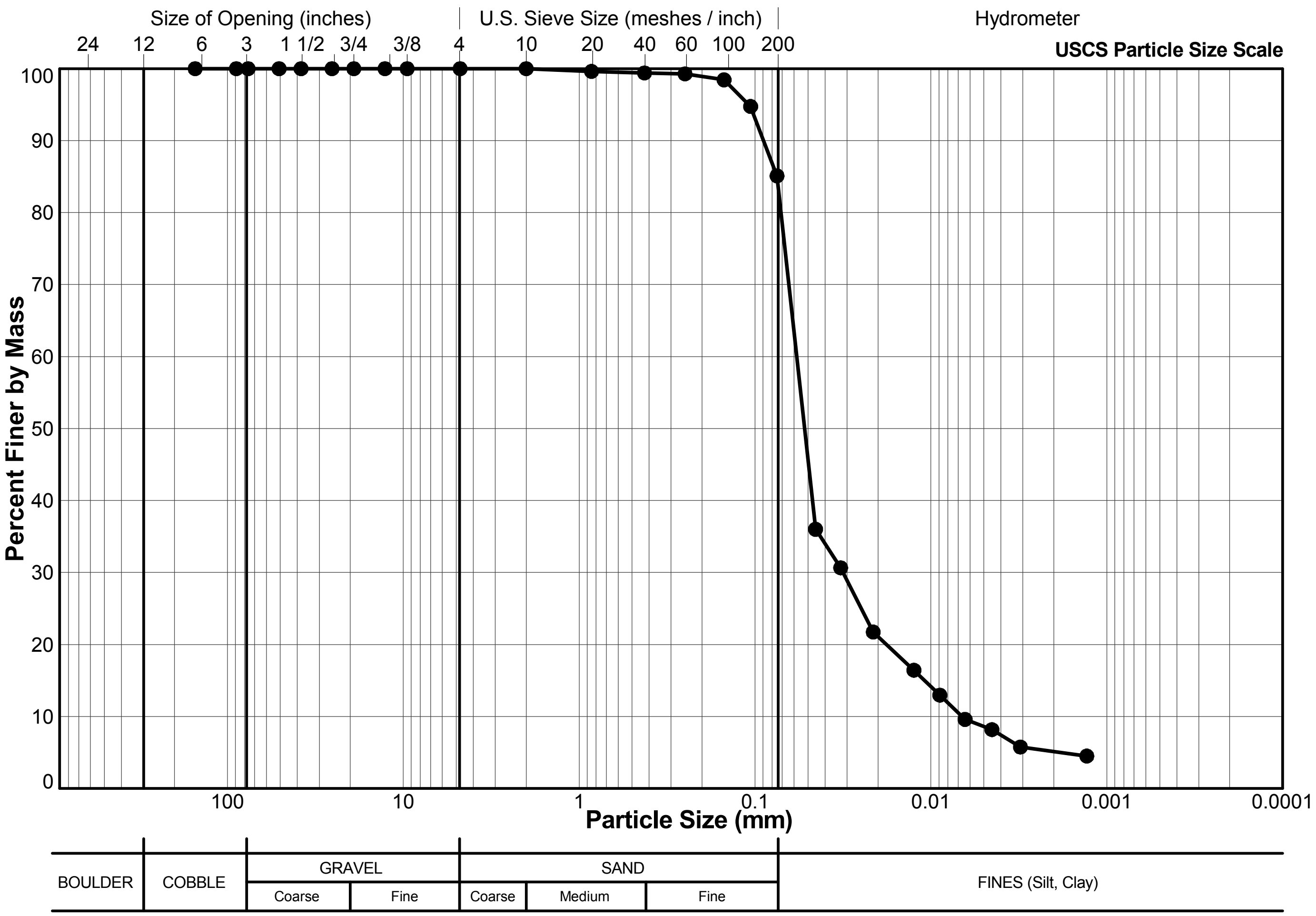
National IM Server:GINT_GAL_NATIONALIM Unique Project ID: Output Form:_LAB ATTERBERG CASAGRANDE (SINGLE) 2018 LHu 4/7/18

RZ	**6/22/2018**	**LH**	**6/29/2018**
Tech	Date	Checked	Date

SUMMARY OF PARTICLE SIZE DISTRIBUTION

ASTM D 422

Client:	Chilkoot Geological Engineers Ltd.	**Sample Location:**	Carmacks Subdivision
Project:	Soil Testing	**Sample No.:**	TP7-18 SA35
Location:	Vancouver, BC	**Depth (m):**	N/A
Project No.:	1780303 **Phase:** 3000	**Lab Schedule No.:**	



Legend

Sieve Size (USS)	Sieve Size (mm)	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		99.6
#40 US MESH	0.425		99.4
#60 US MESH	0.25		99.3
#100 US MESH	0.15		98.4
#140 US MESH	0.106		94.8
#200 US MESH	0.075		85.1
		0.0453	36.0
		0.0326	30.7
		0.0213	21.7
		0.0125	16.4
		0.0089	13.0
		0.0064	9.6
		0.0045	8.2
		0.0031	5.8
		0.0013	4.5

GM	**6/21/2018**	**LH**	**6/29/2018**
Tech	Date	Checked	Date

National IM Server:GINT_GAL_NATIONALIM Unique Project ID:1988 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) 2018 LHu 4/7/18

APPENDIX C

Recommended Grain Size Distribution for Imported Fills

CHILKOOT GEOLOGICAL ENGINEERS LTD.

Appendix C

Recommended Grain Size Distribution for Imported Fills

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